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Effects of Aircraft Technology Improvements on Intercity Energy Use

Final Report

Contract No. NAS 2-6473(Task I)

May 1976

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER
Mountain View, California

ENERGY AND TRANSPORTATION DIVISION
THE AEROSPACE CORPORATION

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INTRODUCTION

Following the fuel embargo in late 1973 and early 1974, Aerospace was asked by the National Aeronautics and Space Administration (NASA) to examine the role advanced aircraft might play in reducing energy consumption in intercity transportation. In another NASA study, Aerospace had examined the viability of STOL transports in commercial service in high-density short-haul arenas. These high-thrust-to-weight ratio aircraft employed high bypass advanced turbofan engines exhibiting low specific fuel consumption. The STOL airline system was assumed to operate from STOL-ports generally providing better access than did the major jetports in a metropolitan region. Modernized air traffic control permitted nearly linear port-to-port routes, further reducing total trip time. Thus, it appeared that STOL systems could require substantially less energy than did the existing conventional takeoff and landing (CTOL) systems.

Rather than reducing energy consumption in the arena, it was found that the STOL system, with favorable economics attributed to STOL aircraft, permitting fares to be set at levels below the Civil Aeronautics Board approved fares required of the CTOL system, attracted not only most CTOL passengers but induced a substantial number of travelers to shift from other modes to the STOL mode. As a result, the total use of energy in the arena increased.

Subsequently, NASA decided to restudy the short-haul market, this time considering the evolution of aircraft technology into the 1980 time period and assuming that no revolutionary changes would occur. The results of this study are included in this report. Aircraft considered in the scenarios analyzed include the Boeing 727-200 and the Douglas DC9 Series 50, a stretched version of the present DC9 Series 30. Because NASA is developing the technology for fuel efficient aircraft, it was decided to also include a near-term fuel-efficient turboprop design, which cruises at jet altitudes and Mach numbers. The Northeast Corridor arena was taken as the setting for the study. A 1976 baseline transportation system was defined, and scenarios devised to study the 1982 timeframe. Improvements in energy consumption exhibited by the evolutionary systems were evaluated by comparison with the 1976 baseline.

PROGRAM OVERVIEW

An examination of the growth or decline in energy consumption in short-haul, high density, intercity transportation is made in relation to changes in aeronautical technology, principally of an evolutionary nature. Improvements or changes in the technology of competitive modes are also included.

In order to limit the size of the study, it was decided to concentrate on a single high-density arena, viz., the Northeast Corridor, and to restrict the study to origin/destination intercity travel in six major city pairs of that Corridor. Near term (here defined as 1976) and intermediate term (defined as 1982) scenarios were designed. The framework of the scenarios permitted the introduction of evolutionary modal changes. Certain improvements in air traffic control procedures were also included to determine their effectiveness in saving energy. To round out the study, a fuel-efficient turboprop short-haul aircraft concept was included and compared with the conventional aircraft otherwise considered.

PROGRAM OVERVIEW

- PURPOSE
  - CONTINUE EXAMINATION OF GROWTH OR DECLINE IN INTERCITY ENERGY USE AS AFFECTED BY AERONAUTICAL TECHNOLOGY ADVANCEMENTS AND COMPETITIVE MODE CHANGES

- SCOPE
  - ANALYZE SHORT-HAUL ORIGIN DESTINATION TRAVEL IN A HIGH-DENSITY ARENA
  - EXAMINE NEAR AND INTERMEDIATE TERM TRAVEL SCENARIOS DESIGNED TO STUDY AERONAUTICAL TECHNOLOGY IMPACTS ON ENERGY CONSUMPTION
  - EMPHASIZE EVOLUTIONARY AERONAUTICAL IMPROVEMENTS AND PLANNED CHANGES IN OTHER MODES
  - CONSIDER IMPLEMENTATION OF FUEL EFFICIENT TURBOPROP AIRCRAFT

APPROACH

To carry out the study, it was necessary to determine the number of vehicles of each mode required to carry the anticipated demand. This required the evaluation of modal patronage and an assumption of vehicle load factors. Patronage of each mode was computed by utilizing separate total demand and modal split forecasting techniques. This was done for each timeframe and each scenario considered. Data on energy consumption characteristics of each of the modes was utilized to determine energy consumed within the framework of typical mission profiles. Computations were performed for six Northeast Corridor city pairs, selected such that they encompassed the great majority of origin/destination travelers in the arena. An algorithm was also developed to permit escalation of the six city pair results to the total arena level. This was one to permit a more balanced analysis of the air modes relative to the other modes in the Northeast Corridor.

APPROACH

- UTILIZE SEPARATE TOTAL DEMAND AND MODAL SPLIT FORECASTING MODELS TO ESTIMATE MODAL DEMAND IN FUTURE TIMEFRAMES.

- ANALYZE IMPACT OF CHANGES IN AERONAUTICAL TECHNOLOGY ON ENERGY CONSUMPTION IN SIX MAJOR NORTHEAST CORRIDOR CITY-PAIRS.

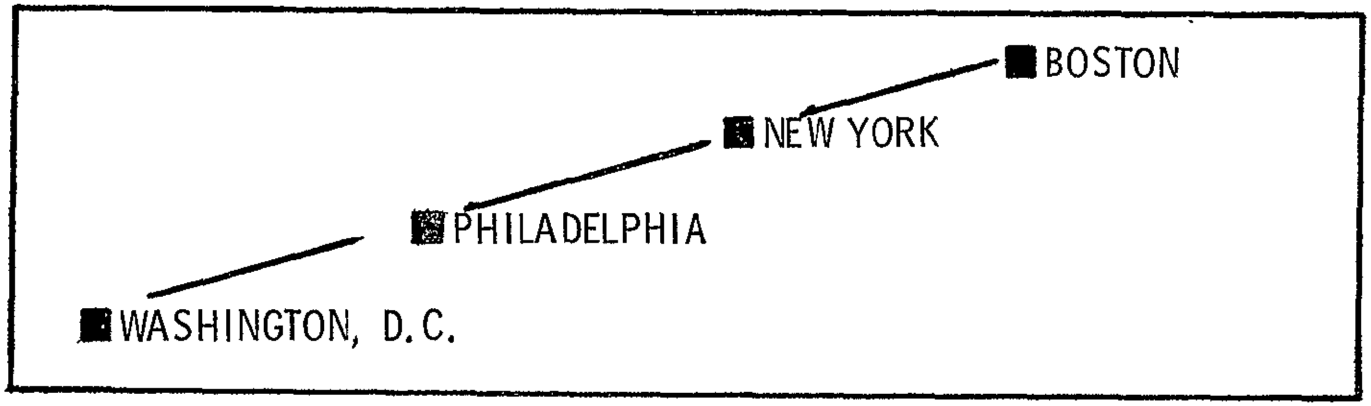
- ESTIMATE ENERGY CONSUMPTION AT TOTAL ARENA LEVEL BY APPLYING SUITABLE EXPANSION FACTORS TO RESULTS AT THE MAJOR CITY-PAIR LEVEL.

SIMULATED PORTION OF NEC

This chart indicates the four metropolitan regions which were modeled for this study. Also shown are the six city pairs for which demand and modal split forecasts were made. If all the cities along the spine of the Northeast Corridor are considered, it is found that the corridor is made up of approximately 55 city pairs. The six modeled city pairs include more than 90% of all origin/destination air traffic in the arena. On an overall Corridor basis, however, the six city pairs account for roughly 50% of total origin/destination traffic. Thus, reliance on data from only the six modeled city pairs results in an over-estimation of the impact of air travel on energy consumption. A more balanced view of energy consumption characteristics in the Corridor may be obtained by escalating the six city pair data to the 55 city-pair level, utilizing an appropriate escalation algorithm developed from available Northeast Corridor data.

SIMULATED PORTION OF NEC

- MODELED NEC CITIES



- MODELED CITY-PAIRS
  - BOSTON-NEW YORK
  - BOSTON-PHILADELPHIA
  - BOSTON-WASHINGTON, D.C.
  - NEW YORK-PHILADELPHIA
  - NEW YORK-WASHINGTON, D.C.
  - PHILADELPHIA-WASHINGTON, D.C.

- TOTAL NEC ARENA
  - INCLUDES 55 CITY-PAIRS
  - APPROXIMATELY 90% OF O/D AIR TRAFFIC IN MODELED CITY-PAIRS
  - APPROXIMATELY 50% OF TOTAL O/D TRAFFIC IN MODELED CITY-PAIRS

SIMULATION APPROACH TO MODAL SPLIT ANALYSIS

The modal splits for the scenarios considered in this study were determined using the Aerospace Transportation System Simulation (TSS) model. In this model, simulated travelers optimize their mode (and path) selection using an "effective perceived cost" algorithm, while facing a specific network of very pricisely described service.

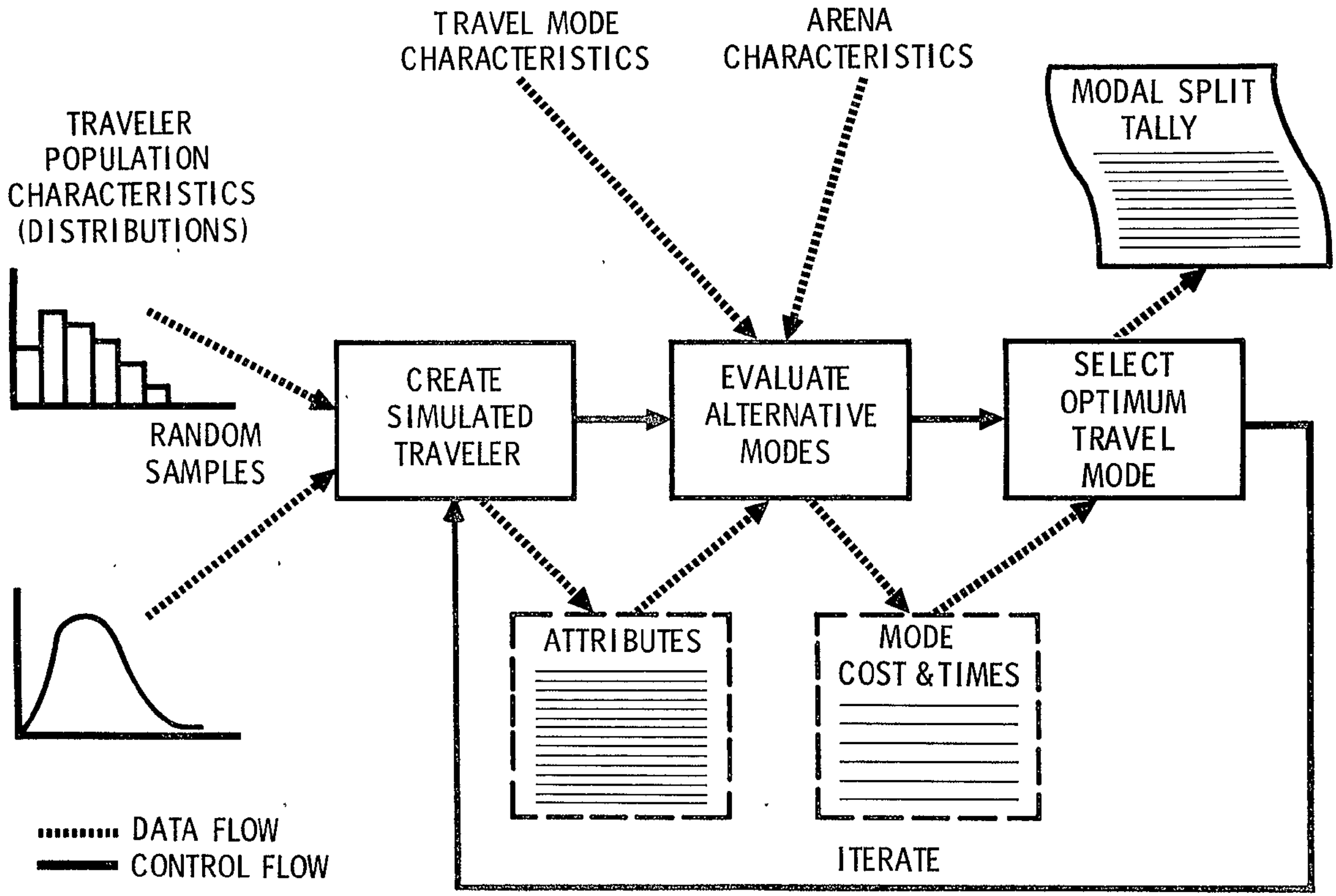
Travelers are individually simulated by means of a Monte Carlo technique which selects their exact origin and destination location within a city or region, their trip purpose, desired departure time, sensitivity to frequency of service, car availability, trip duration, party size, time value, and modal preference factors. The latter account for the nonquantifiable (in terms of time or cost) elements of the modal choice decision process and are used to calibrate the model to known historical travel statistics.

Distributions from which most of the traveler attributes are drawn are derived by utilizing projections of metropolitan area demographic and socioeconomic characteristics on a zonal basis, in combination with regional travel habit patterns extracted from the latest Census of Transportation Public Use Tape (the National Travel Survey). For each simulated traveler, an effective perceived trip cost is computed for all possible combinations of local (door-to-port and port-to-door) and intercity (port-to-port) transportation modes. Effective perceived trip cost reflects total out-of-pocket expenses, door-to-door trip time, modal preferences, and traveler time values.

The traveler is assigned to that combination of local and intercity modes which produces the minimum effective perceived trip cost. The resulting allocation of all simulated travelers to their respective minimum effective-trip-cost modes produces the modal split.

Accuracy of the modal split results is directly related to the degree of realism achieved when characterizing the arena, its travelers, and the transportation system alternatives. Considerable effort was directed toward identifying and quantifying characteristics that will have an impact on a traveler's mode choice. These include port location, port processing time (peak and off-peak), and the intercity travel time, cost, and frequency of service as a function of mode and service path.

SIMULATION APPROACH TO MODAL SPLIT ANALYSIS



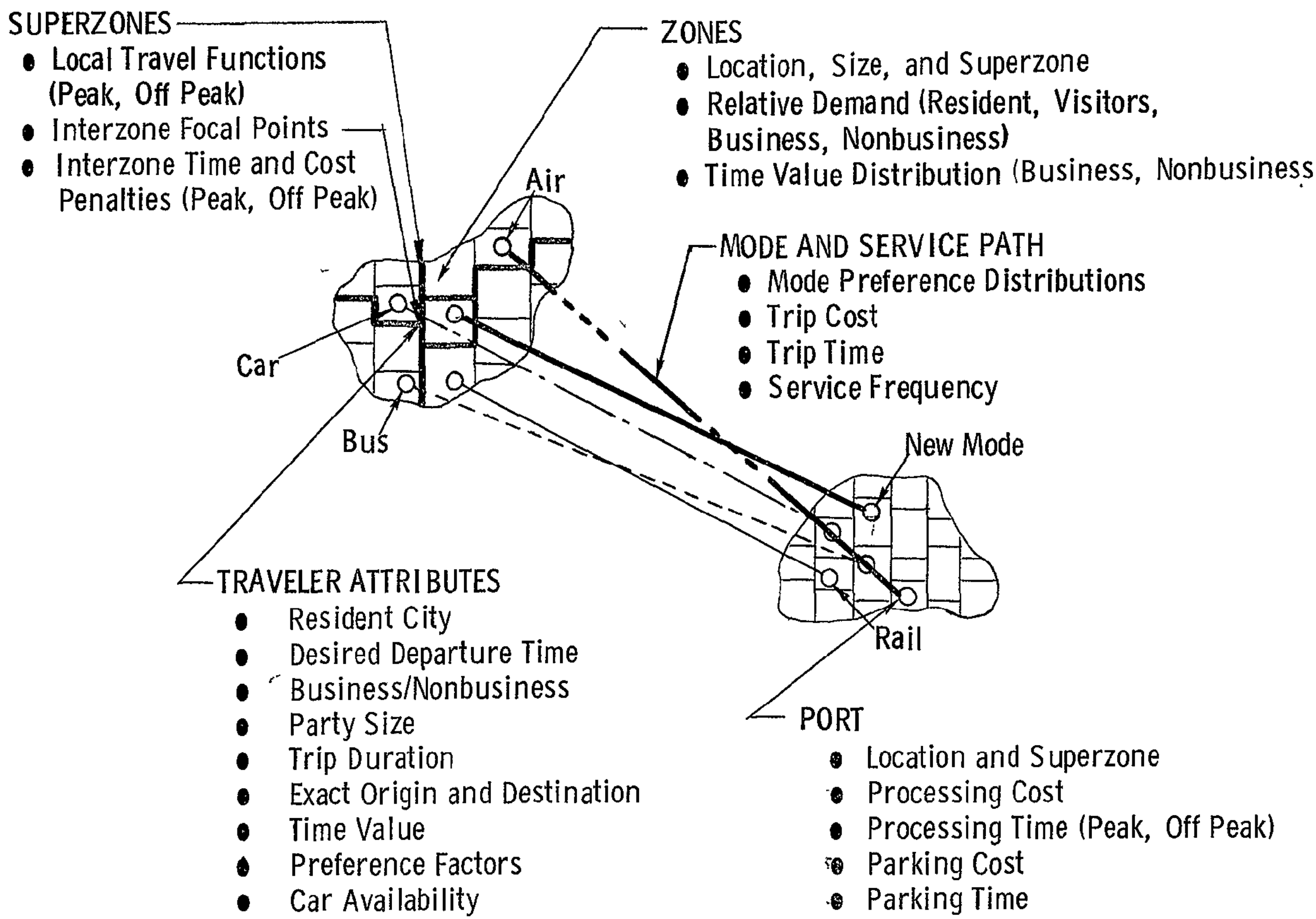
TSS ARENA AND TRANSPORTATION SYSTEM CHARACTERIZATION

This chart depicts a city-pair and shows various service paths between the cities. Each city is divided into as many as 100 separate zones, within which relative demand among four types of travelers (resident business, resident nonbusiness, nonresident business, nonresident nonbusiness) is characterized. The relative distribution of resident and visitor, business and nonbusiness travelers among the zones is derived from a function which accounts for the population density and income distribution of residents of a zone, the employment level in that zone and the number of hotels which exist in that zone relative to others throughout the city. A time value distribution for business and nonbusiness travelers in each zone is also established. The zones are usually characterized on the basis of established zonal systems utilized by planning agencies. In general, it is necessary to modify the data obtained in order to maintain a grid system with 100 zones or less.

In addition to its location, each zone is characterized as being a member of a superzone. This is a set of one or more contiguous zones exhibiting similar local travel conditions. Each superzone has its own set of local travel tables (time and cost vs. distance) for describing car and other available forms of local travel. In addition, the superzone system permits the simulation of interzone time and cost penalties, which model congestion and/or toll points, such as bridges and tunnels. Superzone pairs may optionally have a focal point defined, a technique for forcing all local travel between the superzone pair to be routed through the focal point. This models topographic features such as bridges, tunnels, and mountain passes, where traffic is channeled through a specific point.

In simulating modes and service paths, such variables as trip cost and time, and frequency of service, are included. Preference factor distributions, determined during the calibration process, are provided for each mode, and, where data is available, separately for business and nonbusiness travelers. Every service path associated with each mode can be included in the simulation. Thus,

TSS ARENA & TRANSPORTATION SYSTEM CHARACTERIZATION



if city A has 3 airports and city B has 2 airports, all 6 of the possible service paths would generally be simulated, assuming that each path was indeed served by an airline.

A port is characterized by its location in a common coordinate system with the zones. Each port is assigned to a specific superzone, and has its own processing cost and time, as well as a parking time and parking cost table (as a function of trip duration) for those travelers who choose to access the port by means of drive-and-park.

Traveler attributes are simulated in terms of a large number of factors, each of which is established for a given traveler by means of a draw from a statistical distribution. Included among the traveler attributes are the trip type (whether business or nonbusiness), the traveler's party size, trip duration, the city of residence, his desired departure time, exact origin and destination coordinates, car availability, time value, and his individual preference factors for each mode.

The options open for each traveler, in terms of modes, ports and paths are then described and evaluated. For example, the traveler can drive from door to the port of a line haul carrier, park his car there for the duration of the trip, take that mode to the destination city, and then be driven from that port to his final destination. Alternatively, the traveler can be driven by someone else to a port, or can choose to drive directly from origin to destination. Travelers assess all alternatives and then choose that combination of local transportation (at both ends) and common carrier or private automobile which minimizes costs, including the value of his time. Mode preference factors modify the port-to-port portion of the cost functions of each mode, and permit calibration of predicated modal usage to known historical modal split information.

SELECTED DEMOGRAPHIC AND SOCIO-ECONOMIC DATA

This chart contains population and income forecasts for the four modeled Northeast Corridor regions. The size in square miles of each region is substantially larger than the individual cities comprising the regional hub. The New York region, for example, extends to Bridgeport on the Northeast, to Islip, Long Island, on the East, to all of Westchester County on the North, and to a large portion of northern New Jersey on the West. This very large region is modeled as 91 individual zones, within which it is convenient to establish demographic and socio-economic parameters. The other metropolitan regions are similarly treated.

Basic population and income projections are obtained from area projections made by the Department of Commerce and extending to the year 1990. Population projections are based on Series IIE of the Current Population Survey which essentially amounts to zero population growth by the Year 2000. The so-called OBERS projections of income growth, made in 1972, do not account for the recent recession nor do they account for the anticipated effects of the fuel embargo and the subsequent increase in fuel prices. Thus, the projections forecast sizable and continuing increases in the Gross National Product and associated high rates of income increases. In a recent volume published as part of Project Independence, a revised GNP forecast was produced which accounted for the effects of increased fuel prices. The overall rate of income growth forecast by the OBERS projections amounts to approximately 3.3% annually, but is reduced by the Project Independence data to a level closer to 2% out to 1990. Income growth rates shown on this chart (extending to 1982 only) are somewhat above 2% but substantially below 3.3%. This is due to the fact that income growth rates are anticipated to be higher in the immediate future than they will be toward the end of the forecast period.

Since demand for transportation is a function of both population and income, it is important that these quantities be forecast using the best available data, since all the analytical results to follow will be affected by these forecasts.

SELECTED DEMOGRAPHIC AND SOCIOECONOMIC DATA

Modeled Region	Approx. Size (Sq. Mi.)	Number of Zones	Population[1] (000)			Median Income[2] (73$)		
			1972	1976	1982	1972	1976	1982
Boston	2,513	100	3,724	3,881	4,127	11,644	11,994	14,904
New York	3,138	91	16,937	17,518	18,392	11,634	11,913	14,294
Philadelphia	3,553	85	4,885	5,073	5,356	11,366	11,770	13,744
Washington DC	1,621	89	2,918	3,158	3,575	13,454	13,751	15,672

[1] Department of Commerce Area Projection to 1990

[2] Same source but corrected by Project Independence GNP Forecast

INTERCITY TRAVEL DEMAND FORECASTING

In an earlier study of intercity travel, Aerospace observed that total travel demand in California Corridor city pairs did not behave as forecast by the usual gravity models. Such models generally plot as straight lines on charts such as the one shown here. Aerospace was able to obtain total travel demand data for a number of California Corridor city pairs for the years 1960 and 1967. Connecting the 1960 and 1967 demand points by straight line segments for each city pair, it was found that the slopes of these line segments decreased as the city pair population product increased. This effect was borne out by data from the mid-West triangle (Chicago, Detroit, Cleveland) and has subsequently also been corroborated by data from the Northeast Corridor. When the slopes of the line segments were plotted against population product, it was found that the data fell onto a smooth straight line. This resulted in development of the equation shown on this chart. The equation is for a family of curves whose slope decreases as population product increases. To make use of the demand forecasting technique, it is necessary to have a survey data point for each city pair of interest in a calibration year. This locates the curve in the family which is characteristic of the city pair being analyzed. Moving along that curve to the forecasted population product yields the forecasted total demand.

INTERCITY TRAVEL DEMAND FORECASTING

- UNLIKE GRAVITY MODEL, REQUIRES SINGLE SURVEY DATA POINT FOR EACH CITY-PAIR INVESTIGATED
- ALL NON-POPULATION TRAVEL DEMAND FACTORS ASSUMED TO BE ACCOUNTED FOR IN SURVEY DATA POINT
- SUBSEQUENT CHANGES IN TRAVEL DEMAND, RELATIVE TO SURVEY DATA POINT, RELATED TO POPULATION GROWTH

$$T_1 = \left[C\,(\log\,(PP_1) - \log\,(PP_0)\,) + T_0^{\,K}\right]^{1/K}$$

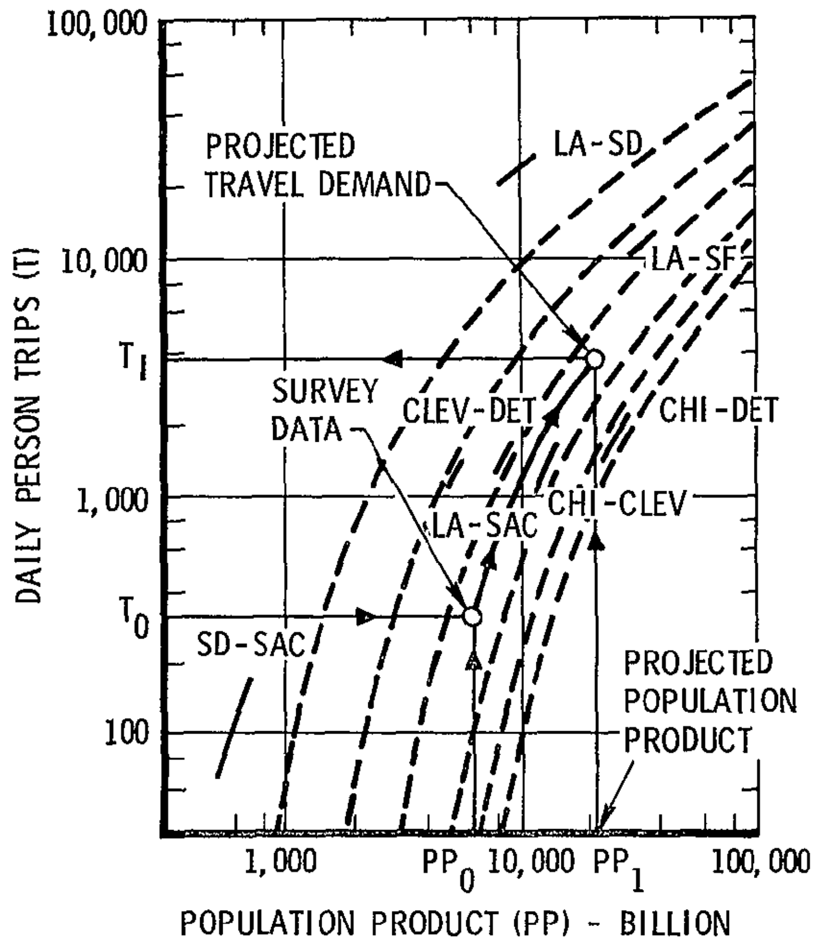
WHERE: THE CALIBRATION CONSTANTS
C = 15.3417 AND K = 0.328

AND PP_0 = SURVEY DATA POINT POPULATION PRODUCT

T_0 = SURVEY DATA POINT DAILY PERSON TRIPS

PP_1 = PROJECTED POPULATION PRODUCT FOR YEAR OF INTEREST

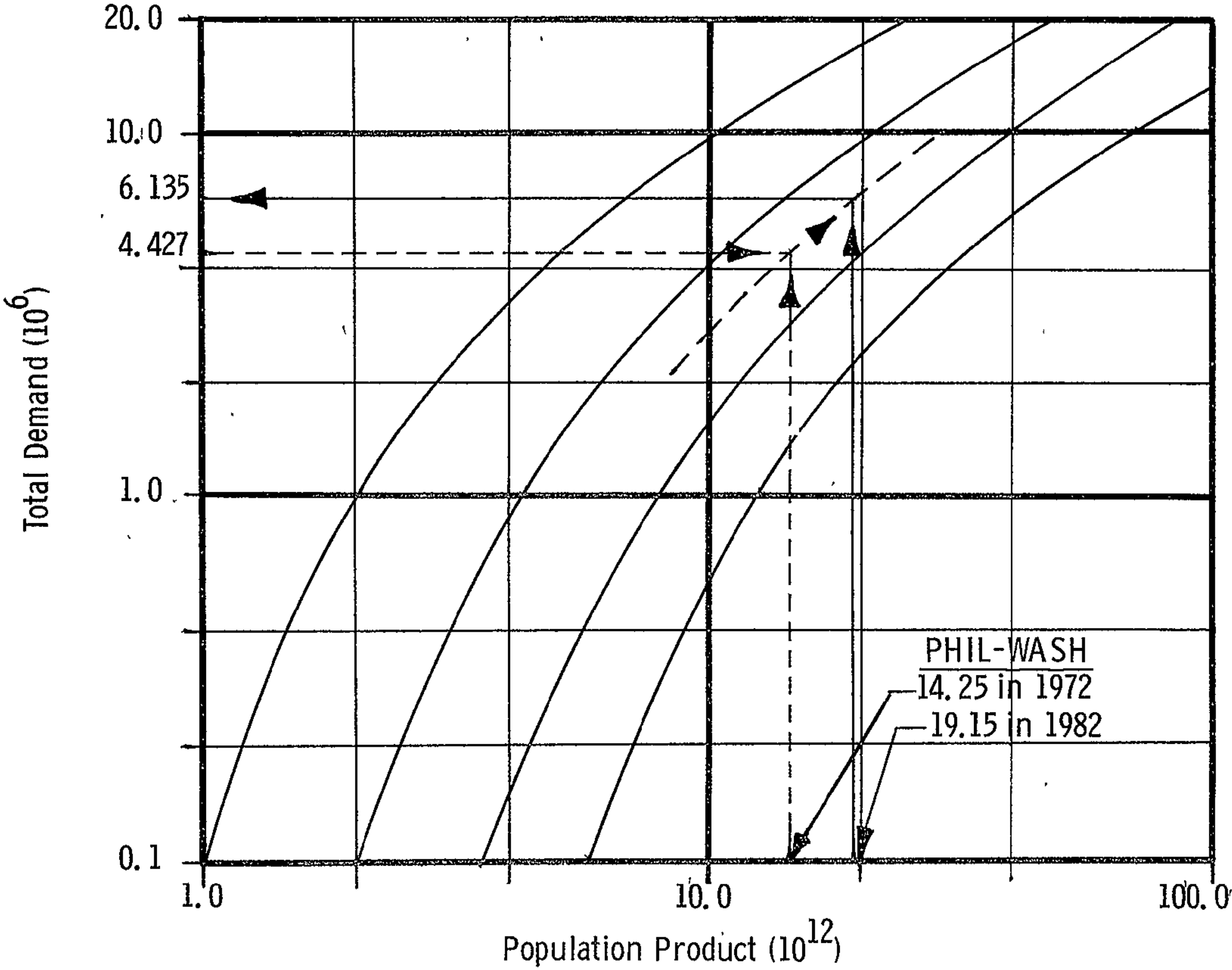
T_1 = DERIVED DAILY PERSON TRIPS FOR YEAR OF INTEREST



TOTAL O&D DEMAND ESTIMATING METHOD

This chart presents an example of the use of the total demand method for the Philadelphia-Washington, D.C., city pair. Using data in the demographic and socioeconomic chart shown earlier, one determines the 1972 population product for the city pair. Data used for calibrating the Transportation System Simulation model is then used to determine 1972 total demand. The intersection of the vertical population product line and the horizontal total demand line locates the curve in the family which is characteristic of Philadelphia-Washington demand. Again using the demographic data shown in an earlier chart for 1982, the forecasted population product is located. Moving along the vertical line for that population product determines the forecasted demand at the intersection with the characteristic curve.

TOTAL O&D DEMAND ESTIMATING METHOD



TRAVEL DEMAND DATA

This chart presents the total demand computed for 1976 and 1982 using the technique illustrated on the previous two charts. 1972 total demand data was developed from a large variety of sources, including auto cordon surveys, planning agency data, CAB data, AMTRAK data, motor bus information, etc. The chart also includes, for reference purposes, the great circle distances beween central business districts for each city pair. In addition, the 1972 air modal split, utilized in calibrating the Transportation System Simulation model, is also given. The estimate of Northeast Corridor total travel shown on the chart was determined using data developed as part of the Department of Transportation's Northeast Corridor Transportation Project and follow-on efforts to that project. This information was helpful in developing the escalation algorithm used in estimating energy consumption on a total corridor basis.

TRAVEL DEMAND DATA

CITY-PAIR	GREAT CIRCLE DISTANCE (SM)	1972 AIR MODAL SPLIT (Percent)	TOTAL DEMAND (10^3 Annual Person-Trips)		
			1972	1976	1982
BOS-NY	198	30.5	7,079	7,624	8,473
BOS-PHIL	273	42.0	928	1,078	1,327
BOS-WASH	400	69.3	815	1,031	1,435
NY-PHIL	76	0.7	15,810	16,695	18,026
NY-WASH	202	25.3	7,215	8,055	9,463
PHIL-WASH	127	2.6	4,427	5,058	6,135
Six-City-Pair TOTAL	-	-	36,274	39,541	44,859
Estimated NEC TOTAL	-	-	77,700	87,900	99,700

TRAVELER CHARACTERISTICS

Inputs to TSS which tend to vary as a function of city pair are as follows:

- Relative fraction of travelers that live in each city.
- Business fraction for travelers from each city.
- Party size distribution for business and nonbusiness.
- Trip duration distribution for business and nonbusiness.

An equal number of travelers were assumed to originate in each of the two cities in every city pair modeled. This assumption, which was confirmed by reducing data on the Census of Transportation data tape, is generally true for most major city pairs in the United States, except those which involve resort cities such as Las Vegas or Miami. The distinction between business and nonbusiness travelers is an important element in the analysis, because many of the attributes directly affecting mode choice are dependent upon trip purpose (such as trip duration and party size). Business fractions were obtained by correcting the business fraction data prepared for the Northeast Corridor transportation project in 1971, using actual 1972 mode demands. Trip-duration distributions, represented in this analysis by two parameters related to the median and standard deviation of a lognormal distribution, affect such costs as parking and the value of a car in the destination city. Party size, categorized as one through six or more travelers, affects certain direct costs (for example, the parking cost at a port) which are shared by the travel party as a whole.

In general, the Census of Transportation data tape does not have enough samples between individual city pairs to allow trip duration or party size distributions to be determined between the SMSAs of the specific city pairs involved. In order to obtain an adequate sample size, all travelers with SMSA origins in appropriate arenas whose trip distance falls within an interval associated with the city pair of interest, are included. The philosophy is that the trip duration and party size in a given arena is most directly influenced by the intercity distance. The appropriate distance interval from the data tape for each city pair is determined by considering both the extent of the metropolitan area being modeled for each city and the minimum and maximum round trip circuitous distance for travelers between the two SMSAs of interest.

TRAVELER CHARACTERISTICS

1972 National Transportation Survey Data Tape

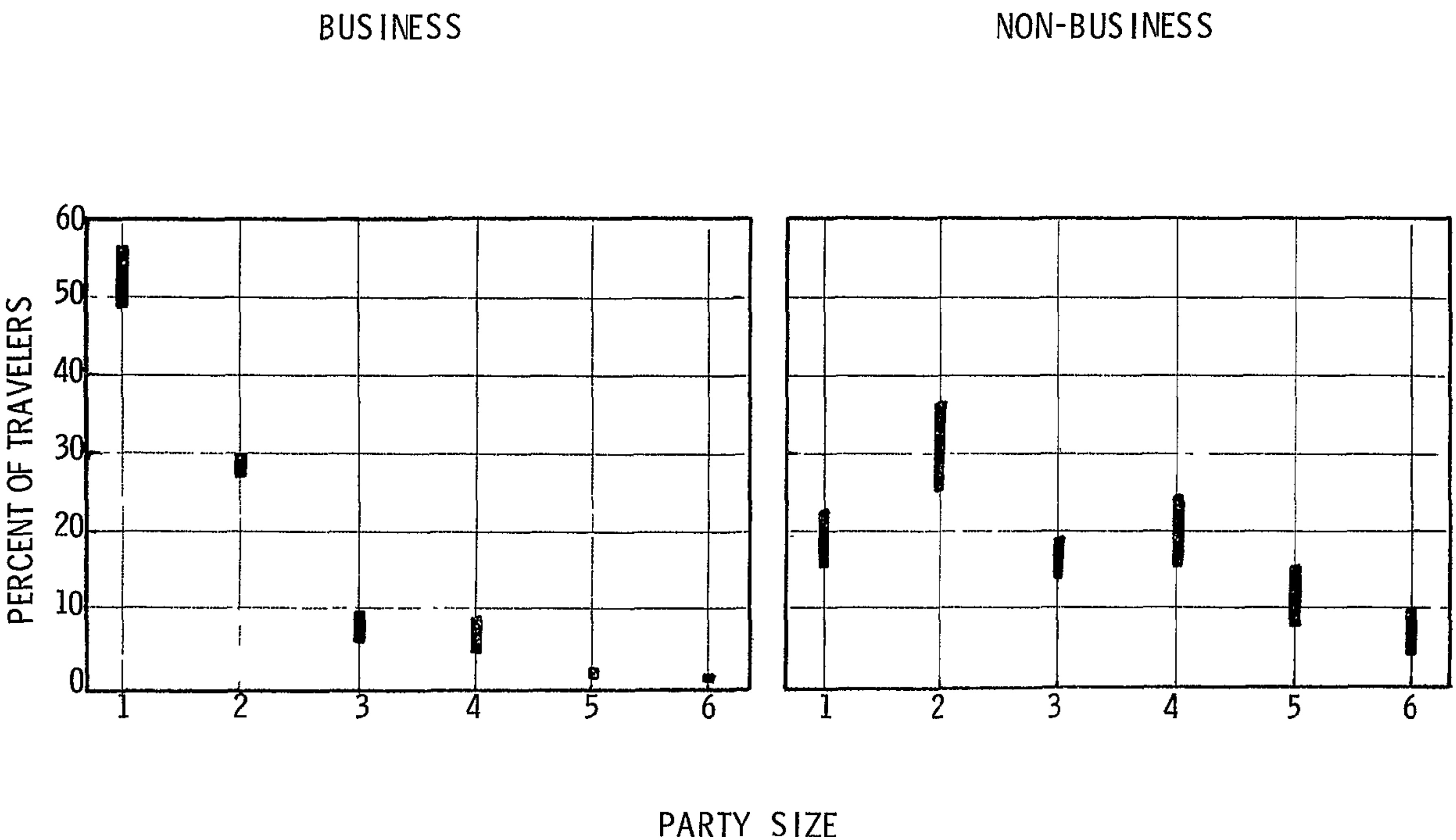
CITY-PAIR	BOS-NY	BOS-PHIL	BOS-WASH	NY-PHIL	NY-WASH	PHIL-WASH
NTS Interval (SM)*	350-610	580-880	880-1250	200-350	430-690	230-440
Business Fraction	0.36	0.41	0.42	0.27	0.39	0.34
Business Duration(Days)						
• Median	1.6	2.1	1.7	0.9	1.6	1.2
• Spread	2.4	2.5	3.1	2.7	2.2	2.6
Non-Business Duration (Days)						
• Median	2.1	2.6	2.8	1.6	2.3	1.7
• Spread	2.1	2.1	2.1	2.3	2.1	2.3

* Round Trip Circuitous Distances

PARTY SIZE DISTRIBUTION

The business and nonbusiness party size distributions were obtained in a manner similar to that used for trip duration. The same distance intervals were used, but no fitting process was required, since these distributions are modeled explicitly in the modal split simulation. Examples of party size distributions are shown on this chart. The only modification to the data as it comes from the data tape is that the business party size distribution is corrected for the failure of the survey data to include business associates in the determination of travel party size. The correction applied is based on travel party data from the Northeast Corridor Transportation Project.

PARTY SIZE DISTRIBUTION



PROPENSITY TO TRAVEL

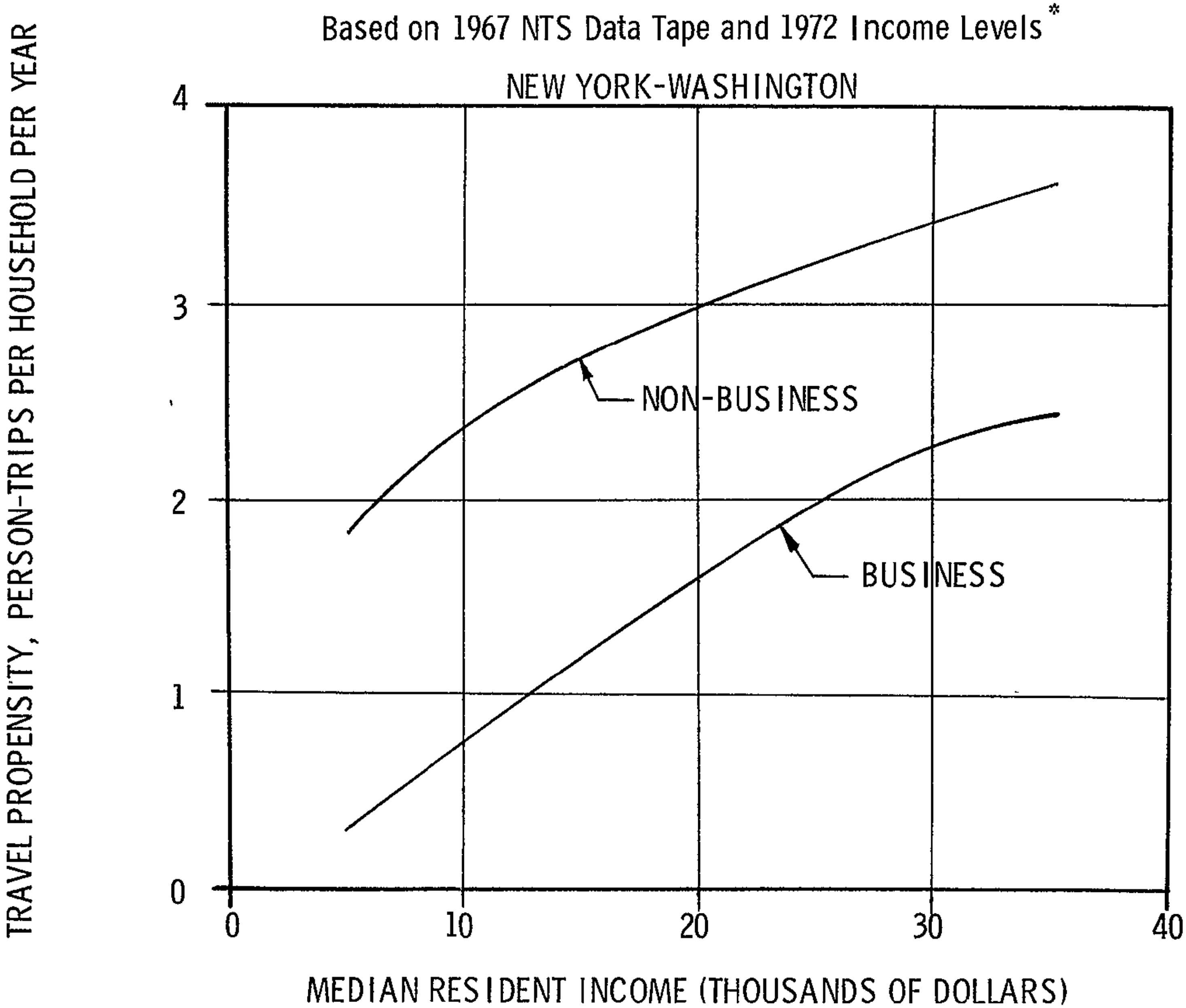
Each zone in a city must be assigned a relative fraction of each of four types of travel demand (business/nonbusiness, resident/nonresident). Resident population, resident income, employment population, and hotel unit data on a zonal basis provide inputs to the determination of these demand distributions. In order to convert the raw socioeconomic data sets on a zonal basis to the four types of demand for each zone, a relationship between population and travel demand must be defined. The propensity to travel (person trips/person/year) as a function of income is the required relationship, and is derived from the Census of Transportation Data Tape as a function of trip purpose (business or non-business), trip distance interval, and region of the country for all trips originating within an SMSA for each household-income interval. The city pairs in each arena are grouped into distance intervals wide enough to include suburban origins and destinations, yet narrow enough to differentiate between close and distant city pairs. Income intervals are chosen consistent with the ten intervals contained on the data tape. The derived propensity polynomials are unique to each arena, trip purpose, and distance interval. Typical examples are shown in the chart.

The relative resident business demand and the relative resident nonbusiness demand in a zone are obtained by multiplying the zonal resident population by the business travel propensity and nonbusiness travel propensity, respectively, associated with the resident income for that zone. The relative non-resident business demand is obtained by multiplying the zonal employment population by business travel propensity associated with the income of the people working in that zone. The conceptual implication is that businessmen travel to zones in proportion to that zone's employment level and that they have incomes similar to the people working in that zone. If income data at the zone of employment is not available then demand is made proportional to employment. Finally, the relative nonresident non-business demand is obtained by augmenting the relative resident nonbusiness demand to account for the hotel/motel units in that zone. This adjustment is based on the ratio of nonbusiness visitors staying in a hotel to those staying in a residence, as determined from the Census of Transportation Data Tape for each city.

PROPENSITY TO TRAVEL

Based on 1967 NTS Data Tape and 1972 Income Levels*

NEW YORK-WASHINGTON



*1967 Income Modified to Account for 20.5% Inflation between 1967 and 1972

1972 BOSTON-NEW YORK COMMON CARRIER SERVICE PATH CHARACTERISTICS

The next three charts indicate the extensiveness of the simulation utilized to study intercity travel. The charts present data for 1972, in which the Aerospace Transportation System Simulation was calibrated. This chart contains common carrier data for the Boston-New York city pair. Multiple service paths are modeled for each mode in terms of ticket costs, block time and frequency of service. The bus service paths, for example, are modeled between downtown Boston and three different locations in the New York metropolitan area, and between the Newton, Massachusetts bus terminal and the same three locations in the New York metropolitan area, resulting in six service paths (not necessarily served by different buses). For the CTOL mode, the two service paths designated by an X are the Northeast Corridor shuttle paths. The remaining paths are generally segments of longer routes served by the same aircraft. In order to improve the fidelity of the simulation, two separate rail modes have been considered, one termed RAIL, and the other termed TMRR. The latter is a higher speed mode served by the Turbotrain. It is also a higher cost mode and is characterized (in this arena) by low frequency of service.

One major advantage of this type of detailed modeling is that traffic can be deployed throughout the day in a manner closely resembling that of the actual schedule. For example, the CTOL mode contains over 50 departures in each direction per day. If these had been modeled uniformly across the day, a traveler would see almost a continuous stream of aircraft, thus effectively reducing his waiting time to essentially zero. Because air traffic in this simulation is broken up into eight service paths, utilizing seven different airports (six in the New York metropolitan area), it is clear that the traveler is presented with quite realistic daily schedules.

1972 BOSTON-NEW YORK COMMON CARRIER SERVICE PATH CHARACTERISTICS

Mode	Service Path	Cost ($)	Time (hr)	Frequency (departures/hr)
BUS	BBOSB - NPAB	9.65	4.50	2.27
	BBOSB - NGWB	9.65	4.08	0.87
	BBOSB - NWPNB	9.65	4.60	0.27
	BNEWTB - NPAB	10.75	4.17	1.93
	BNEWTB - NGWB	10.75	3.75	0.73
	BNEWTB - NWPNB	10.75	4.27	0.27
CTOL	BBOS - NLGA	24.00	0.83	0.73
	BBOS - NEWR	24.00	0.93	0.27
	BBOS - NJFK	24.00	0.95	1.10
	BBOS - NHPN	28.00	1.00	0.07
	BBOS - NISP	25.00	0.93	0.54
	BBOS - NBDP	23.00	0.67	0.13
	BBOSX - NLGAX	24.00	0.83	2.00
	BBOSX - NEWRX	24.00	0.93	2.00
RAIL	BBOSR - NNYCR	9.90	4.46	0.60
	BBOSR - NSTMR	9.90	4.10	0.33
	BBOSR - NEWRR	10.65	5.30	0.57
	BBOSR - NBRPR	9.75	3.54	0.27
	BBOSR - NRYER	9.90	3.89	0.40
	B128R - NNYCR	9.90	4.16	0.60
	B128R - NSTMR	9.90	3.80	0.33
	B128R - NEWRR	10.65	5.00	0.57
	B128R - NBRPR	9.75	3.24	0.27
	B128R - NRYER	9.90	3.69	0.40
TMRR	BBOSR - NNYCR	15.65	3.90	0.10
	B128R - NNYCR	15.65	3.65	0.10

1972 NEW YORK-WASHINGTON COMMON CARRIER SERVICE PATH CHARACTERISTICS

This chart contains service path ticket cost, block time and service frequency data for the New York-Washington, D.C., city pair. Once again, a large number of service paths have been modeled. The X-paths for CTOL designate the shuttle. For this city pair, the TMRR mode represents the Metroliner between New York and Washington. It is seen to be a higher cost, lower block time system offering good frequency of service relative to that of RAIL, and indeed, relative to that of the air and bus modes.

1972 NEW YORK-WASHINGTON COMMON CARRIER SERVICE PATH CHARACTERISTICS

Mode	Service Path	Cost ($)	Time (hr)	Frequency (departures/hr)
BUS	NPAB - VWASB	11.80	4.05	2.33
	NPAB - WLAUB	11.20	4.30	0.93
	NEWRB - WWASB	9.65	3.95	0.53
	NEBRNB - WWASB	9.65	3.60	0.53
CTOL	NLGAX - WDCAX	26.00	1.02	2.00
	NEWRX - WDCAX	26.00	1.00	1.60
	NLGA - WDCA	26.00	1.02	1.00
	NLGA - WIAD	26.00	1.00	0.37
	NEWR - WDCA	26.00	1.00	0.10
	NEWR - WIAD	26.00	1.15	0.37
	NJFK - WDCA	26.00	1.08	0.33
	NJFK - WIAD	26.00	1.25	0.43
	NHPN - WDCA	33.00	0.92	0.20
	NISP - WDCA	29.00	0.95	0.27
RAIL	NNYCR - WWASR	12.12	3.81	0.63
	NNYCR - WBELTR	11.88	3.63	0.13
	NEWRR - WWASR	12.50	3.55	0.53
	NEWRR - WBELTR	11.75	3.37	0.13
	NMETR - WWASR	11.50	3.33	0.13
	NMETR - WBELTR	11.00	3.12	0.07
	NRYER - WWASR	12.12	4.92	0.27
	NSTMR - WWASR	14.95	5.10	0.13
TMRR	NNYCR - WWASR	18.00	3.03	0.89
	NNYCR - WBELTR	17.50	2.84	0.47
	NEWRR - WWASR	17.50	2.74	0.53
	NEWRR - WBELTR	15.75	2.64	0.27
	NRYER - WWASR	15.50	2.66	0.33
	NMWTR - WBELTR	15.00	2.47	0.20
	NRYER - WWASR	18.00	3.68	0.07
	NSTMR - WWASR	19.75	3.92	0.07

1972 NEW YORK-WASHINGTON COMMON CARRIER SERVICE PATH CHARACTERISTICS

This chart contains service path ticket cost, block time and service frequency data for the New York-Washington, D.C., city pair. Once again, a large number of service paths have been modeled. The X-paths for CTOL designate the shuttle. For this city pair, the TMRR mode represents the Metroliner between New York and Washington. It is seen to be a higher cost, lower block time system offering good frequency of service relative to that of RAIL, and indeed, relative to that of the air and bus modes.

1972 AUTO SERVICE PATH CHARACTERISTICS

City Pair	Service Path	Cost ($)	Off-Peak Time (hr)	Peak Time (hr)
BOS-NY	B128A - NMTKA	10.12	2.75	2.95
	B128A - NPTCA	11.78	2.84	3.09
	BSWA - NCONA	9.38	2.46	2.46
	BWA - NMTKA	8.08	2.35	2.55
	BWA - NPTCA	9.74	2.47	2.67
NY-WASH	NGWBA - WMDEA	15.79	3.85	4.05
	NGWBA - WCBDA	16.88	4.25	4.65
	NEZA - WCBDA	15.54	3.85	4.25
	NJMS - WMDEA	13.22	3.05	3.05

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COMPETITIVE TRANSPORTATION MODES

This study projected travel in the Northeast Corridor in the years 1976 and 1982. 1976 was utilized as a baseline, against which conditions in 1982 could be compared. The 1976 transportation system in the Northeast Corridor was taken to be similar to that which existed early in 1975. For the air system, the shuttle paths are served by DC9 Series 30 aircraft. The remaining paths are served by a combination of aircraft, which in this study have been assumed to exhibit characteristics similar to those of the Boeing 727-200. The rail system in the South Corridor consists of Metroliners and conventional trains, both electrically powered. In the North Corridor, the rail system consists mainly of diesel powered conventional trains, with a few Turbotrains interspersed during the day. The bus system was based on standard 46-passenger intercity diesel coaches.

In order to model the automobile, the characteristics of an average car were developed. The technique used projected mixes of cars from sales data, weight trend information, and attrition of the existing fleet. The method is described in detail in Short Haul Airline System impact on inter-city use, Aerospace Report ATR-74(7307)-1, 31 May 1974.

For 1982 the shuttle paths are assumed to be served either by DC9 Series 50 aircraft, which are just now entering revenue service, or by an advanced turboprop aircraft designed to operate at jet Mach numbers but with substantially improved fuel economy. As in 1976, the remaining air paths are modeled as being served by a 727-200 aircraft. The rail mode was assumed to be an improved, all electric, high-speed system known as Corridorrail. The system exhibits improved block times in both the North and South Corridors. The Congress recently passed a bill providing funds for an

COMPETITIVE TRANSPORTATION MODES

MODE	DESCRIPTORS	
	1976	1982
AIR	DC9-30 (SHUTTLE) 727-200 (OTHER)	DC9-50 OR TURBOPROP (SHUTTLE) 727-200 (OTHER)
RAIL	STANDARD (MIXED ELECTRIC AND DIESEL TRAINS)	CORRIDORRAIL (ALL ELECTRIC HIGH SPEED TRAINS)
BUS	46-PASSENGER INTERCITY DIESEL COACH	46-PASSENGER INTERCITY DIESEL COACH
AUTO	AVERAGE (BASED ON PROJECTED MIX FROM SALES, WEIGHT TRENDS, ATTRITION OF FLEET)	AVERAGE (BASED ON PROJECTED MIX AND INCLUDING FUEL ECONOMY IMPROVEMENT ESTIMATE)

improved Northeast Corridor rail system, with characteristics somewhat poorer than those represented by Corridorrail. Thus, the rail system modeled in this study is representative of a more advanced system than that which will actually be in existence along the Northeast Corridor in 1982. The bus system is assumed to use the same vehicles specified for 1976. The average car in 1982 is projected by using the same technique as for the 1976 car. Basically, the 1982 car is found to be somewhat lighter and more fuel efficient. However, because the mix of cars changes more slowly than do the characteristics of new cars being introduced, it is found that the average car improved substantially less than does the 1982 new car.

ON-BOARD AVERAGE LOAD FACTORS

A major element of any study involving energy consumption and, in particular, the relative energy consumed by the various modes, is the specification of the average on-board load factor. Most modes which use uniform daily schedules experience load factor variations throughout the day, with peak periods showing the highest load factors. The average load factor determines the average number of vehicles of that mode required to serve the demand.

In the case of the air mode, there is a complete performance data base available from the Civil Aeronautics Board. In this study, CAB service segment data, available on request from the CAB on a city pair basis, was used to determine average load factors in the six city pairs analyzed, for the years 1972 and 1973. At the time this data was acquired, 1974 data had not yet been made available by the CAB, which does not release data to the public for at least one year after it is collected and processed. It was assumed that average load factors in 1976 and 1982 would be essentially equal to those determined from the 1973 service segment data.

Bus data is not readily available on a city pair basis. Transportation Facts and Trends October 1973 issue published some data on national bus load factors. This data was augmented by discussions with the major carriers in the Northeast Corridor and with the National Association of Motor Bus Operators. The results are shown for 1976 and 1982.

ON-BOARD AVERAGE LOAD FACTORS[5]

CITY-PAIR	AIR				BUS[2]		RAIL[4]	TMRR	
	1972[1]	1973[1]	1976	1982	1976	1982	1976	1976[4]	1982
BOS-NY	51.42	53.70	54.0	54.0	45.0	45.0	50.0	N/A	55.0
BOS-PHIL	46.81	46.12	47.0	47.0	45.0	45.0	-	N/A	-
BOS-WASH	55.43	55.26	55.0	55.0	45.0	45.0	-	N/A	-
NY-PHIL	27.43	25.75	26.0	26.0	55.0[3]	55.0[3]	-	-	-
NY-WASH	50.54	51.68	52.0	52.0	45.0	45.0	50.0	55.0	55.0
PHIL-WASH	40.17	36.98	37.0	37.0	50.0[3]	50.0[3]	-	-	-

1 CAB Service Segment Data

2 Based on data from "Transportation Facts and Trends," October 1973

3 For the non-stop route between CBD terminals. All other service paths are assumed to be 45.0%.

4 BOS-NY and NY-WASH Load Factors based on "Rail Passenger Statistics in NEC - 1973," FRA Document dated January 1974.

5 Average Auto Party Size = 2.6 Travelers

Good quality rail data is available for the Northeast Corridor between Boston and New York and between New York and Washington. The data is published by the Federal Railroad Administration using information obtained from AMTRAK. These load factors were utilized to establish the average consist, or length of train. Since all trains make stops between their terminal points, it is clear that the load factor varies during the trip. For example, while the average New York-Washington load factor is indicated to be 55%, that between New York and Philadelphia could be as high as 80% or more during certain hours of the day. Cross corridor load factors (for example, from Boston to Washington) are not available in the rail data base.

Data collected on the Northeast Corridor indicates that the average auto party size for an intercity trip is 2.6 travelers.* In general, auto business travel comprises less than two travelers per car, whereas non-business travel comprises under three travelers per car.

MODELED AIRCRAFT

It was noted earlier that four aircraft types have been modeled in this study. This chart indicates that two types of paths are modeled for these aircraft; viz., a standard path which contains no allowance for aircraft delays, and a path with a six-minute delay. To simulate peak conditions in the Northeast Corridor, the delays are applied only to the paths serving LaGuardia, Kennedy, and National Airports. The DC9-50 and the advanced turboprop aircraft (termed PTOL in this study) are assumed to be interchangeable in terms of fares, block time and frequency of service. The only difference is in fuel consumption. As was done in previous Aerospace studies for NASA, the paths are modeled as realistically as possible. For example, the highly circuitous route required between LaGuardia Airport in New York and National Airport in Washington has been modeled. This provides a substantial contrast with nearly linear area navigation routes studied in some of the scenarios in this analysis.

MODELED AIRCRAFT

Type	Aircraft	Remarks
1	B727-200	Standard Path (No Delays)[1]
2	B727-200	En Route 0.1 Hr Delay[2]
3	DC9-30	Standard Path (No Delays)[1]
4	DC9-30	En Route 0.1 Hr Delay[2]
5	DC9-50[3]	Standard Path (No Delays)[1]
6	DC9-50	En Route 0.1 Hr Delay[2]
7	PTOL[4]	Standard Path (No Delays)[1]
8	PTOL	En Route 0.1 Hr Delay[2]

[1] All CTOL Service Paths except those involving LGA, JFK, and DCA

[2] All CTOL Service Paths involving LGA, JFK, and DCA

[3] Preliminary Data from Douglas Aircraft Company

[4] Advanced Turboprop Data from T. Galloway, NASA/Ames Research Center

AIRCRAFT FUEL CONSUMPTION CHARACTERISTICS

This chart indicates the fuel consumption characteristics for the four aircraft types of the previous chart, for standard and delay paths. 727-200 and DC9-30 fuel consumption data was taken from the aircraft manufacturers' data books. For the DC9-50, this data was not available at the time of this analysis. Douglas Aircraft Company did, however, provide a relationship between DC9-50 and DC9-30 fuel consumption levels. The DC9-50 results were recently validated through discussions with the DC9-50 project office at Douglas. Indeed, actual revenue service of the DC9-50 has indicated fuel consumption to be approximately 2% better than expected values. Fuel consumption data for the PTOL was obtained from NASA/Ames Research Center.

Using the data on this chart, any desired flight profile may be constructed for any service path distance. (Service path distance and block distance may not be the same because of circuity.) The cruise segment is established by selecting a cruise altitude and determining the distance traversed in the non-cruise portion of flight from the data in the first portion of the chart. Cruise fuel burn is then determined from the second portion of the chart. The third portion provides the non-cruise fuel burn. An allowance has been made of 14 minutes for taxiing, which is somewhat longer than normal, to account for ground delays at the busy Northeast Corridor airports. Maneuver, landing, and takeoff times have also been included in computing the non-cruise fuel burn.

AIRCRAFT FUEL CONSUMPTION CHARACTERISTICS

Altitude (Kft)	AIRCRAFT TYPE							
	727-200	727-200	DC9-30	DC9-30	DC9-50	DC9-50	PTOL	PTOL
DISTANCE FOR TAKEOFF AND INITIAL CLIMB, CLIMB, DESCENT AND LANDING (NM)								
10	50	50	34	34	34	34	61	61
15	84	84	60	60	60	60	81	81
20	123	123	80	80	80	80	103	103
25	154	154	113	113	113	113	128	128
30	187	187	175	175	175	175	163	163
CRUISE FUEL BURN, #/NM								
10	30.3	30.3	20.0	20.0	21.7	21.7	18.7	18.7
15	28.6	28.6	18.2	18.2	19.7	19.7	18.4	18.4
20	25.5	25.5	17.2	17.2	18.6	18.6	17.2	17.2
25	22.2	22.2	15.4	15.4	16.7	16.7	15.2	15.2
30	20.0	20.0	13.9	13.9	15.1	15.1	13.4	13.4
NON-CRUISE FUEL BURN, LB[1]								
10	3780	4630	2330	2685	2555	2910	3097	3548
15	4855	5680	2730	3070	2990	3330	3506	3944
20	5780	6580	2980	3305	3260	3585	3916	4326
25	6680	7480	3330	3630	3635	3935	4409	4778
30	7480	8280	4130	4440	4505	4815	4915	5236

[1] Includes allowances for 14 minutes of taxiing, 6 minutes for manuever and landing, and 1 minute for takeoff.

AIRCRAFT FUEL EFFICIENCY INDEX COMPARISON

This chart indicates a comparison between the three 1982 aircraft types considered in this study. in terms of available seat miles per BTU as a function of block distance. Energy consumption is computed from the data on the previous chart. The number of seats per aircraft was determined for aircraft of similar seating configurations. A one-class cabin was assumed with 34-inch seat pitch. In the case of the 727-200, the configuration involved is that used by Pacific Southwest Airlines in California, whose aircraft contain 158 seats. The 90/10 configuration of the DC9-50 aircraft contains a total of 117 seats, including four rows of four-abreast seats in first class and twenty-one rows of five-abreast seats in coach. An all coach version of this aircraft, therefore, converts to a total of 123 seats. The equivalent PTOL seating, utilizing cabin dimensions provided by NASA, is 156 seats (26 rows of six-abreast seats).

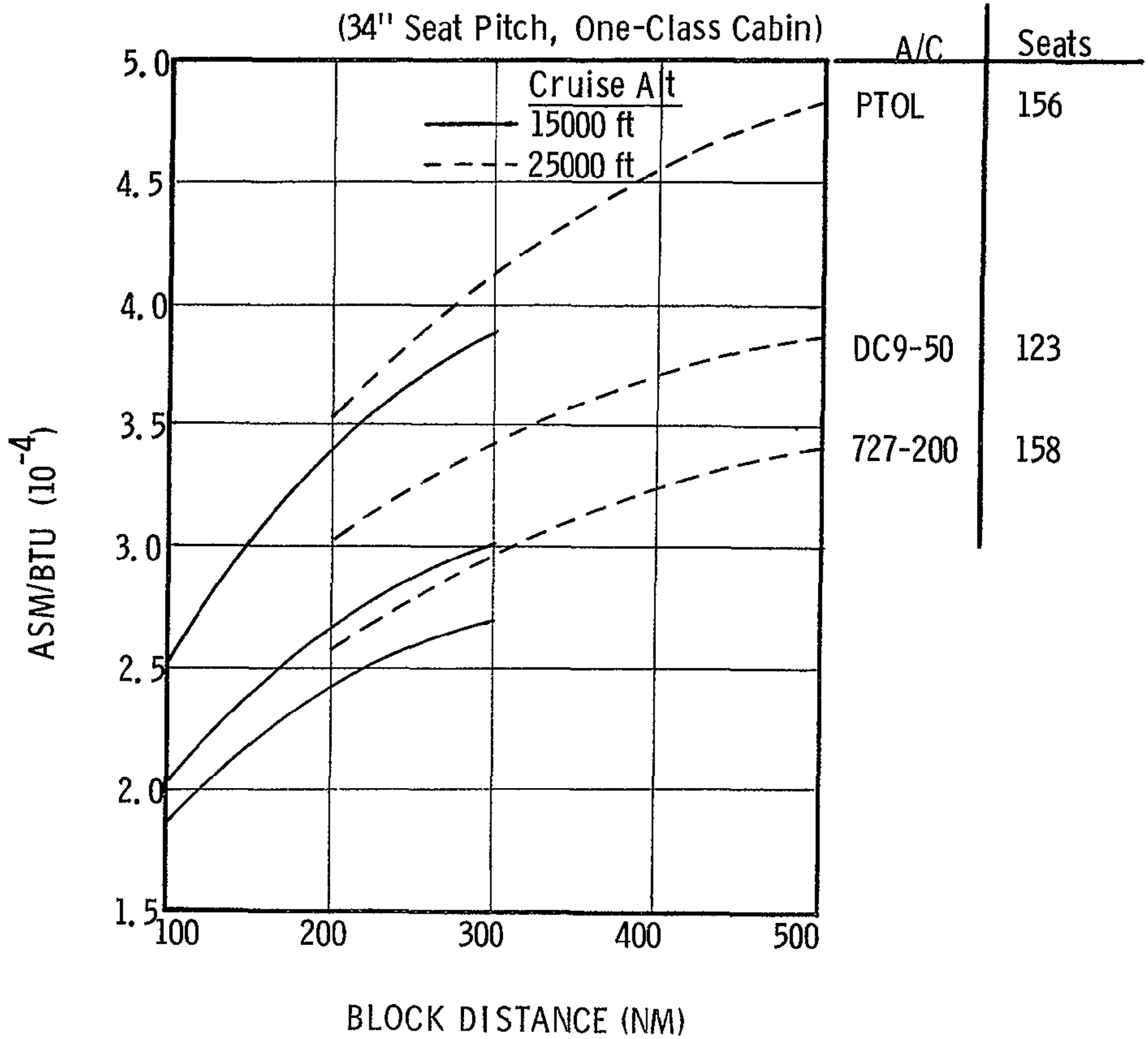
The chart shows that the PTOL is substantially more efficient than either the DC9-50 or the 727-200. For a stage length of 200 miles, characteristic of the Northeast Corridor shuttle paths, it is seen that a PTOL cruising at 15,000 feet is 29% more efficient than the DC9-50 and 41% more efficient than the 727-200. Even at the higher cruise altitude of 25,000 feet, the PTOL still exhibits substantially better fuel efficiency than do the other two aircraft. For example, at 400 miles, representative of the distance from Boston to Washington, the PTOL is 24% more efficient than the DC9-50 and remains 41% more efficient than the 727-200.

Thus, the PTOL concept appears to offer the possibility of very significant fuel savings relative to contemporary aircraft.

AIRCRAFT FUEL EFFICIENCY INDEX COMPARISON

(High Density Configurations)

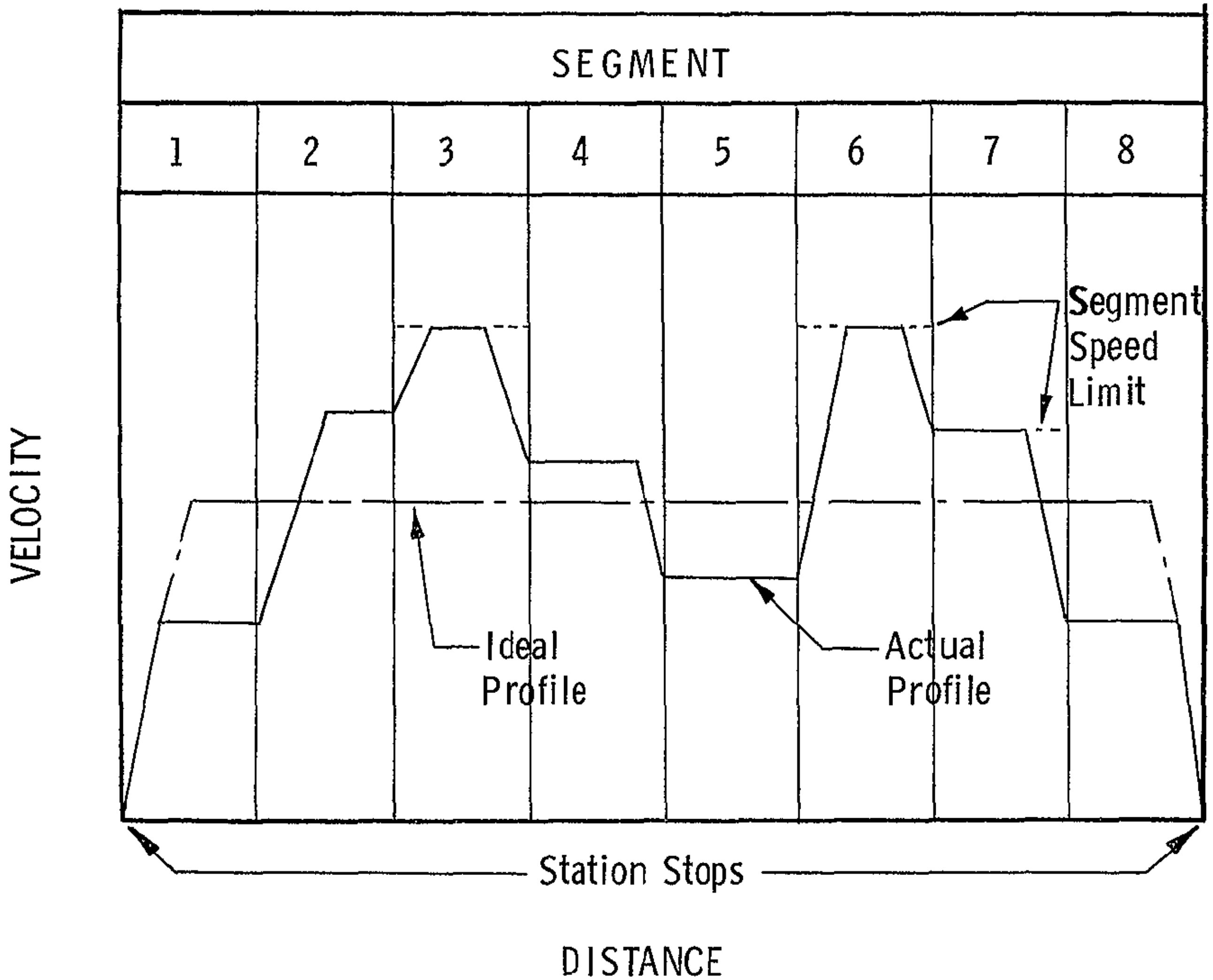
(34" Seat Pitch, One-Class Cabin)



RAIL SYSTEM VELOCITY PROFILE

It is usually assumed that rail systems accelerate to a cruise speed, hold that speed essentially constant until reaching the vicinity of the next station stop, and then decelerate to a stop in the station. This, however, is not how a rail system operates. Curves, grades, grade crossings, speed restrictions due to right-of-way problems, and so on, require the train to continually accelerate and decelerate along its trip. Its peak cruise speed must therefore be higher than the average speed on an ideal profile in order to maintain the same block time. While this chart indicates only eight segments between station stops, in actuality in the Northeast Corridor between Boston and Washington there are some 825 segments along which a change in track characteristics occurs. It is, therefore, a complex undertaking to determine a train's block time, required cruise speed and energy consumption.

RAIL SYSTEM VELOCITY PROFILE*



*Profiles are for same block time.

Aerospace has developed a simulation of a train moving along a right-of-way consisting of a series of segments, each characterized by a length, a speed limit, a grade, and a radius of curvature. The simulation contains models of the mechanical and aerodynamic resistance of a train. Torque and power profiles have been assumed such that torque is held essentially constant during acceleration until power reaches a certain prescribed level at the so-called base speed. At this point, acceleration continues at essentially constant power while torque is reduced. This model permits the construction of acceleration equations. An iterative process is utilized to obtain the required maximum cruise speed. This speed is found when the desired block time has been attained. The associated energy consumption is determined at the same time.

Indicated on the chart is the energy efficiency computed for a Corridorrail train in the South Corridor. Major characteristics of the train assumed are shown. An efficiency of 31% is applied to catenary power to determine the demand from the remote fossil or nuclear fueled power plant. Calculations were made for both the ideal path (accelerations and decelerations associated only with station stops) and a modified (improved) Penn Central right-of-way broken into 375 separate segments. The 10% difference between the energy efficiency numbers shown indicates that the ideal profile for this case is indeed a good representation of the more realistic situation.

RAIL SYSTEM ENERGY CONSUMPTION

- UTILIZE SIMULATION OF TRAIN CONSIST
  - Mechanical and Aerodynamic Resistance
  - Electrical Characteristics
    - Torque and Power Profiles
    - Conversion Efficiency
  - Right-of-Way Characteristics Segmented
    - Length
    - Speed Limit
    - Grade
    - Curvature
  - Iterate on Maximum Speed to Obtain Desired Block Time
  - Find Associated Energy
- APPLY ENERGY DELIVERY SYSTEM EFFICIENCY
- CORRIDORRIAL ENERGY COMPARISON
  - Two Engines, 8250 HP Each, 85% Conversion Efficiency
  - Ten-Passenger Cars, 70 Seats per Car
  - NY-Wash Route, 227 SM
  - 2.5 Hr Block Time with Five Intermediate Station Stops
  - 31% Powerplant and Energy Transmission Efficiency

DESCRIPTORS	Efficiency, BTU per Seat-SM
• Ideal Path	829
• Modified Penn Central Track Profile, 375 Segments	908

AUTO AND BUS ENERGY CONSUMPTION

In order to model the energy consumption of the auto mode, it is necessary to project the characteristics of an "average" automobile on the road in the years of interest. In addition, it is necessary to develop a data base on energy consumption as a function of weight of the vehicle and its cruise speed.

Through its support of the Environmental Protection Agency and the Energy Research and Development Administration, Aerospace has acquired a complete data base on automobile physical and performance characteristics. The automobile fleet is normally divided into five market classes, each of which is characterized by an average loaded weight. From this definition and from historical data on market class sales distributions, it is possible to construct a sales weighted average new car weight for a number of years of interest. Specifically, data has been developed for the years 1973 (representative of conditions just prior to the fuel embargo), 1974 (representative of conditions just after imposition of the fuel embargo), and 1975 (representative of post-embargo conditions and with the economy in a recession). The observed trends in sales distributions permit projections to be made of the sales weighted average weight of 1976 and 1982 new cars.

The next step is to determine the weight of the average car on the highway in 1976 and 1982. To accomplish this, it is necessary to project sales trends, which may be done using historical data dating back to 1958, and vehicle attrition, or the percent of vehicles still in use as a function of automobile age. Putting all this information together produces an estimate of the weight of the average car on the road in 1976 and 1982, as shown in the chart.

Intercity fuel economy is determined by utilizing data developed by the Chrysler Corporation and validated by Aerospace through comparisons with many other data sources. Urban fuel economy is determined by simulating the operation of an automobile in a typical urban environment (the so-called EPA urban driving cycle) on a computer.

A typical intercity bus weighs 19 tons, has a capacity of 46 passengers, and is powered by a Detroit Diesel engine rated at 280 horsepower. This engine (and its derivatives) is used in most intercity buses on American highways. DOT's Transportation Systems Center has conducted test programs on

AUTO AND BUS ENERGY CONSUMPTION*

MODE	DESCRIPTOR	FUEL CONSUMPTION, MPG			
		1976		1982	
		URBAN	INTERCITY	URBAN	INTERCITY
AUTO	Composite Vehicle based on Projected Sales, Weight, Attrition, and Efficiency Characteristics 1976 Weight = 4000 Lb 1982 Weight = 3800 Lb	12.5	17.1	14.9	19.5
BUS	46-Passenger, 19-Ton Vehicle, with 280 HP Diesel	4.2	7.0	4.2	7.0

*Based on Data from "Short-Haul Airline System Impact on Intercity Energy Use" Aerospace Report ATR-74(7307)-1, dated 31 May 1974

Massachusetts highways with the objective of defining fuel economy characteristics of these vehicles. The results are far from definitive, indicating a large scatter of data. Aerospace also acquired interurban fuel economy data from several major motor bus operators, thereby further adding to the scatter. As a result, we obtained performance maps for the specific powerplant involved and performed an analysis of bus fuel economy characteristics. The results essentially provided a lower bound on the data, and thus represented a conservative estimate of interurban bus fuel economy.

Practically no data could be found on urban fuel economy characteristics of interurban buses. We therefore modified the EPA automobile driving cycle computer program to accommodate the significantly different acceleration characteristics of an intercity bus. The urban fuel consumption number shown in the chart was developed using this technique.

SCENARIOS

This chart indicates the scenarios studied in the two timeframes considered. For 1976, the Baseline Scenario utilized modes described on an earlier chart, called Competitive Transportation Modes. The 1976 Fuel Price Increase Scenario assumes that the price of imported oil rises 35% above the January 1975 price level of $12.00/bbl, that old domestic oil rises to the price level of new domestic oil, with new domestic oil remaining at the January 1975 price level ($12.00/bbl), and that the mix is 30% imported oil and 70% domestic oil. This scenario results in a composite price of $13.26/bbl. Only the air and auto modes are assumed to be affected by the fuel price increase, which amounts to approximately a 5% fare increase for air and 7% increase in auto costs (excluding tolls). Bus and rail fares are assumed to be unaffected by petroleum price rises, on the theory that the electrified portion of the rail system receives its power from coal and nuclear plants, and diesel fuel costs associated with the rail diesel-electric system and the diesel motor bus system represent a small fraction of total operating costs.

The 1982 Baseline Scenario also utilized vehicles described in the Competitive Transportation Modes chart. The DC9-30 aircraft flying the Northeast corridor shuttle services in 1976 is assumed to be replaced by the DC9-50 aircraft. The rail system is assumed to be upgraded to the Corridorrail all-electric high-speed system. At the time this analysis was made, the Federal Government was planning to develop such a system, but because of very high projected costs, a decision was recently made to develop a lesser performance all-electric system. Thus, the rail competition assumed in the 1982 scenarios is more formidable than that which will actually exist in 1982. No change was assumed to occur in the bus mode between 1976 and 1982.

SCENARIOS

MODE	1976		1982				
	1	2	1	2	3	4	5
AIR	BASE 76	FPI	BASE 82	FPI	RNAV	PTOL	PTOL + RNAV
RAIL	BASE 76	BASE 76	BASE 82	BASE 82	BASE 82	BASE 82	BASE 82
BUS	BASE 76	BASE 76	BASE 82	BASE 82	BASE 82	BASE 82	BASE 82
AUTO	BASE 76	FPI	BASE 82	FPI	BASE 82	BASE 82	BASE 82

<u>LEGEND</u>

BASE 76 = 1976 Baseline for Particular Mode
BASE 82 = 1982 Baseline for Particular Mode
FPI = Fuel Price Increase
RNAV = Direct Routing (Minimal Circuitry)
PTOL = Hi-Speed Turboprop

The Fuel Price Increase Scenario for 1982 is similar to that assumed for 1976, except for evolutionary modal changes.

The three remaining 1982 scenarios examine improvements in the air system due to better air traffic control and navigation (the use of RNAV), the introduction of a fuel efficient turboprop aircraft (the PTOL) as a replacement for the DC9-50 shuttle, and a combination of the two events. These scenarios are modifications of the 1982 Baseline Scenario and should be compared directly with it. The 1982 Baseline Scenario is, in turn, an evolutionary modification of the 1976 Baseline Scenario. Thus, the structure of the scenario changes assumed is such that continual comparisons can be made to determine the effectiveness of improvements in the air transportation mode as well as the impact of evolutionary modal improvements.

FARE AND COST STRUCTURES

This chart indicates the fares assumed for the common carrier modes and the costs assumed for the auto mode. All computations in this study have been made in 1973 dollars and are therefore entirely internally consistent. 1975 air fares were obtained from a midyear issue of the Official Airline Guide and deflated, using appropriate Department of Commerce data, to 1973 dollars. These fares are assumed to exist in all 1976 and 1982 scenarios except when a fuel price increase occurs. 1975 bus fares were obtained from official carrier schedules. The deflated fares are assumed to remain unchanged in all 1976 and 1982 scenarios. Northeast Corridor rail system fares were obtained from AMTRAK system schedules, and include the fare increase initiated early in the year. These fares have been applied only to the 1976 rail system. A newly developed fare formula has been applied in 1982, and is based on studies made by the Federal Railroad Administration for the upgraded rail system. Neither the 1976 nor 1982 fares are affected by fuel price changes.

Auto costs are developed on the basis of the average cars discussed earlier. It is interesting to note that the average cost per mile decreases substantially between 1976 and 1982, due to the transition to smaller, lighter, more fuel efficient automobiles forecast to be in use in the 1982 time period. The costs shown are those perceived by the driver, but must be augmented by tolls and other charges to compute a driver's total trip cost.

FARE AND COST STRUCTURES

MODE & SCENARIO	FARES AND COSTS
1976 and 1982 Air Systems Fuel Price Increase	1975 Fares Deflated to 1973 $ 5% Fare Increase[1]
1976 Auto 1982 Auto Fuel Price Increase	5.83¢/mi in 1973 $ (Reflects Average 1976 Car and 51.3¢/gal fuel cost)[2] 5.35¢/mi in 1973 $ (Reflects Average 1982 Car and 51.3¢/gal fuel cost)[2] Fuel Cost rises to 59.8¢/gal from 51.3¢/gal (1973 $)
1976 and 1982 Bus Systems Fuel Price Increase	1975 Fares Deflated to 1973 $ Does not Affect Bus Fares
1976 Rail System 1982 Rail System Fuel Price Increase	1975 Fares Deflated to 1973 $ Fare (73 $) = 1.50 + 7.5¢/mi Does not Affect Rail Fares

1 - 39% Jet Fuel Price Increase
2 - Toll Charges Additional

EFFECTS OF CHANGING CONDITIONS ON MODAL SPLIT (BOS-NY CITY PAIR)

The modal split analysis of all seven scenarios has been carried out using the Aerospace Transportation System Simulation for each of the six city pairs considered in this study. This chart includes the results for the major North Corridor city pair of Boston-New York, and clearly indicates that air and auto are the favored modes in this arena. An overall improvement in AIR mode split is seen to occur between 1976 and 1982, at the expense of a degradation in AUTO mode split. This situation cannot be explained by changes in the minority modes, RAIL and BUS, since the former appears to improve at the expense of the latter. In an earlier chart on Selected Demographic and Socioeconomic Data, it was noted that income rises quite significantly between 1976 and 1982, a condition that results in greater preference for faster (and thus more expensive) modes.

It may be seen from this chart that no change occurs in modal split when PTOL is substituted for DC9-50, nor is there a modal split change between the two RNAV scenarios. This is the result of an assumption that no change occurs in AIR block times when the aircraft substitution occurs. On the other hand, a significant block time change occurs with the implementation of RNAV shuttle routes, leading to the higher AIR mode split. Overall, improvements in AIR are at the expense of all the other modes, although the changes in each are relatively small.

The other analyzed city pairs containing Boston as one trip-end are Boston-Philadelphia and Boston-Washington, D. C. These cross-corridor city pairs are characterized by low RAIL and BUS mode splits, due to the high block times of those modes. It was found that BOS-PHIL travel is mainly by AIR and AUTO (47.84% and 48.40%, respectively, for 1982 Baseline), while BOS-WASH travel is mainly by AIR (74.78% for 1982 Baseline).

EFFECTS OF CHANGING CONDITIONS ON MODAL SPLIT

BOS-NY CITY-PAIR*

Scenario	Mode Split, Percent			
	AIR	AUTO	BUS	RAIL
76 Baseline	30.38	56.62	8.24	4.76
76 FPI	29.34	56.28	9.10	5.28
82 Baseline	33.16	52.04	7.76	7.04
82 FPI	32.04	52.20	8.28	7.48
82 RNAV	33.48	51.84	7.74	6.94
82 PTOL	33.16	52.04	7.76	7.04
82 PTOL/RNAV	33.48	51.84	7.74	6.94

*BOS-PHIL travel is mainly by air and auto
BOS-WASH travel is mainly by air

EFFECTS OF CHANGING CONDITIONS ON MODAL SPLIT (NY-WASH CITY PAIR)

This chart contains the same information shown on the previous chart but for the major South Corridor city pair of New York-Washington, D. C. The distribution of results is similar to that on the earlier chart, except that AIR mode split is lower and RAIL mode split is considerably higher (well over twice that for BOS-NY). AUTO and BUS remain substantially the same.

The other analyzed city pairs in the South Corridor are New York-Philadelphia and Philadelphia-Washington, D. C. These are characterized by high AUTO mode splits (78.60% and 82.08%, respectively) for 1982 Baseline. Indeed, AIR is truly the minority mode, showing mode splits of 0.32% and 2.80%, respectively. RAIL mode splits are relatively good in both city pairs, while BUS is relatively poor.

EFFECTS OF CHANGING CONDITIONS ON MODAL SPLIT

NY-WASH CITY-PAIR*

Scenario	Mode Split, Percent			
	AIR	AUTO	BUS	RAIL
76 Baseline	25.00	54.50	7.50	13.00
76 FPI	23.76	54.32	8.04	13.88
82 Baseline	26.46	49.52	7.22	16.80
82 FPI	25.42	49.42	7.70	17.46
82 RNAV	28.02	49.02	7.12	15.84
82 PTOL	26.46	49.52	7.22	16.80
82 PTOL/RNAV	28.02	49.02	7.12	15.84

*NY-PHIL and PHIL-WASH travel is mainly by auto

PORT-TO-PORT ENERGY EFFICIENCY INDEXES BY MAJOR MODE (NY-WASH CITY PAIR)

The energy efficiency index, defined in terms of consumed energy (in Btu) per revenue passenger mile (rpm) is presented in this chart for the five scenarios in which standard fuel pricing was assumed. Except for the AUTO mode, the data is given for the intercity portion of the trip only, i.e., on a port-to-port basis. For AUTO, the port-to-port quantity is not meaningful, since a driver remains in his vehicle from door-to-door and because the auto "ports" are merely convenient locations enabling calculations to be made in the same format used for common carrier modes.

The chart indicates that the AIR mode is the least energy efficient of any mode by a wide margin. This situation is particularly true in this city pair, where the average air trip is on the order of 200 miles, indicating that cruise (the most efficient flight segment in terms of energy consumption) is only a small portion of the total trip. Examining AIR more closely, it is found that the 1982 scenarios indicate a substantial overall improvement in air system efficiency. This is due to the changeover on the shuttle path (which carries some 45% of total Northeast Corridor AIR mode rpm's) to the more efficient DC9-50 or to the very efficient reduced energy advanced turboprop. Indeed, the energy efficiency of the shuttle system by itself is much better than overall air efficiency (which is heavily weighted by relatively inefficient 727-200 aircraft). This observation is particularly true when the shuttle is served by advanced turboprop aircraft. For example, a 26% improvement in efficiency occurs between the 1976 Baseline Scenario shuttle path and the 1982 PTOL Scenario shuttle path.

Of the remaining modes, BUS is seen to be the most efficient, but it also has the highest block times. The improvement in AUTO noted between 1976 and 1982 is due to the presence of lighter, more efficient cars on the highway. The degradation observed in RAIL efficiency between 1976 and 1982 is due to the implementation of Corridorrail, a substantially higher speed, lower block time system.

PORT-TO-PORT ENERGY EFFICIENCY INDICES BY MAJOR MODE

NY-WASH CITY-PAIR

Scenario	Energy Efficiency Index, BTU/RPM			
	AIR	AUTO[1]	BUS	RAIL
76 Baseline	8250 (7950)[2]	2742	977	1232[3]
82 Baseline	7860 (7005)[2]	2500	975	1648[4]
82 RNAV	7550 (6950)[2]			
82 PTOL	6980 (5650)[2]			
82 PTOL/RNAV	6500 (5580)[2]			

1 Door-to-Door (Intercity Portion Approximately 8% better)
2 Shuttle Path (DC9-30, DC9-50, or PTOL)
3 Metroliner (Conventional = 861 Btu/RPM)
4 Corridorrail

MODE RPM AND ENERGY SPLIT SUMMARY (SIX-CITY PAIR ARENA)

This chart includes data on port-to-port mode rpm and door-to-door mode energy consumption aggregated to the six-city pairs studied and presented for each of the seven scenarios. Also included on the chart are mode rpm and energy splits (in percent of total for each scenario). Thus, it is possible to compare the fraction of rpm's served by a given mode with the fraction of energy consumed by that mode. For AIR, it is seen that the mode uses approximately 50% of total energy while carrying only 25% of total rpm's. In contrast, AUTO uses some 40% of total energy while carrying 57% of total rpm's. RAIL and BUS indicate the same trend as AUTO, viz., the energy share is lower than the mode rpm share.

It is noteworthy that over 90% of total energy used in the arena is used by AIR and AUTO, which serve over 80% of total rpm's. It can also be seen that energy and rpm's are both higher in 1982 than in 1976 for all modes except AUTO, which indicates a leveling in energy consumption for this mode in the face of an increase in mode rpm.

MODE RPM AND ENERGY SPLIT SUMMARY

SIX CITY-PAIR ARENA

SCENARIO	Mode RPM (Millions)				Mode Energy (Billions of BTU)**			
	AIR	AUTO	BUS	RAIL	AIR	AUTO	BUS	RAIL
76 BASELINE	1483 (22.7)*	4038 (61.8)	377 (5.8)	635 (9.7)	12797 (47.9)	12253 (45.8)	515 (1.9)	1175 (4.4)
76 FPI	1462 (22.4)	4005 (61.3)	400 (6.1)	666 (10.2)	12552 (47.3)	12137 (45.9)	548 (2.1)	1234 (4.7)
82 BASELINE	1924 (25.4)	4313 (56.9)	406 (5.4)	935 (12.3)	15956 (51.1)	12074 (39.4)	546 (1.8)	2345 (7.7)
82 FPI	1904 (25.1)	4290 (56.6)	424 (5.6)	961 (12.7)	15730 (50.7)	12015 (39.5)	573 (1.9)	2410 (7.9)
82 RNAV	1968 (26.0)	4299 (56.7)	403 (5.3)	912 (12.0)	15376 (50.3)	12032 (40.2)	543 (1.8)	2293 (7.7)
82 PTOL	1924 (25.4)	4313 (56.9)	406 (5.4)	935 (12.3)	14870 (50.2)	12074 (40.2)	546 (1.8)	2345 (7.8)
82 PTOL/RNAV	1968 (26.0)	4299 (56.7)	403 (5.3)	912 (12.0)	14203 (49.2)	12032 (41.1)	543 (1.9)	2293 (7.8)

*Numbers in parentheses are percentages of total.
** Includes Access.

ENERGY EFFICIENCY INDEX (SIX CITY PAIR ARENA)

This chart again demonstrates the energy efficiency index defined on an earlier chart, except that in this case the energy consumed door-to-door to serve mode rpm's is aggregated to form an index for each individual mode. The total arena energy index is formed by aggregating energy consumed and all mode rpm's in the arena. It is, therefore, indicative of overall improvements made.

Also shown on the chart is the ratio of the energy efficiency index in a given scenario to that in the 1976 Baseline Scenario, for the AIR mode and for the total arena. The trends are, of course, identical to those observed on the earlier chart. An overall improvement is found in the AIR mode of more than 16% for the best scenario (the advanced turboprop on the shuttle paths using area navigation). A lesser improvement is seen for the total arena, principally because AIR accounts for only a portion of total energy consumption and because RAIL becomes less efficient.

ENERGY EFFICIENCY INDEX[1]

SIX CITY-PAIR ARENA

SCENARIO	Energy Efficiency, Index, Btu/RPM				
	AIR	AUTO	BUS	RAIL	ARENA
76 BASELINE	8630 (1.000)[2]	3030	1370	1850	4090 (1.000)[2]
76 FPI	8590 (0.995)	3030	1370	1850	4050 (0.990)
82 BASELINE	8300 (0.962)	2800	1350	2510	4080 (0.998)
82 FPI	8260 (0.957)	2800	1350	2510	4050 (0.990)
82 RNAV	7810 (0.905)	2800	1350	2510	3990 (0.976)
82 PTOL	7730 (0.896)	2800	1350	2510	3940 (0.963)
82 PTOL/RNAV	7220 (0.837)	2800	1350	2510	3830 (0.936)

1 Includes Access

2 Efficiency Ratio

COMMON CARRIER PATRONAGE EXPANSION FACTORS

The analysis presented to this point was based on examining six city pairs in the Northeast Corridor. If all major cities along the so-called spinal corridor route from Boston to Washington via New York were considered, then the arena actually is made up of 55 city pairs. The six city pairs studied carry close to 50% of total Northeast Corridor arena rpm's; however, the same six city pairs account for some 90% of AIR rpm's. Thus, any results from a six city pair arena tend to exaggerate the influence of the air system. As a result, it was decided to expand the six city pair results to the total Northeast Corridor arena, by applying appropriate factors to passengers and to rpm's, and recalculating energy consumption using previously computed average values of mode energy use on a Btu per passenger-mile basis.

This chart shows the expansion factors applied in 1976 and 1982 and includes the data sources utilized.

COMMON CARRIER PATRONAGE EXPANSION FACTORS

From 6 City-Pair Subject to 55 City-Pair Arena

MODE	1976		1982[1]	
	Passengers	RPMs	Passengers	RPMs
BUS[2]	2.13	1.88	2.13	1.88
AIR[2]	1.24	1.19	1.24	1.19
RAIL[3, 4]	2.08	2.47	-	-
TMRR[3]	1.44	1.40	1.85	1.53

1 From "Northeast Corridor High Speed Rail System Patronage Analysis," Aerospace Report to FRA, dated 10 April 1974

2 1976 Values Assumed Same as 1982

3 From "Rail Passenger Statistics in NEC-1973," FRA Document, dated June 1974

4 Mode "RAIL" eliminated in 1982 and replaced by Corridorrail, called Mode "TMRR"

MODE RPM AND ENERGY SPLIT SUMMARY (TOTAL NEC ARENA)

This chart contains mode rpm and mode energy consumption data in the format used on an earlier chart for the six city pair arena, except that the results here are aggregated to the total 55 city pair NEC arena. It may be noted that the AIR mode accounts for some 36% of total energy consumption, rather than the 50% seen in the six city pair arena, and for some 16% of mode rpm's, rather than the 25% seen earlier. AUTO on the other hand uses some 54% of total arena energy, rather than the 40% seen in the six city pair arena, while carrying 68% of total rpm's rather than the 57% seen on the earlier chart. BUS and RAIL remain the minority modes, accounting for less than 10% of total energy and about 16% of total rpm's. Again, energy and rpm's are both higher in 1982 than in 1976 for all modes except AUTO.

MODE RPM AND ENERGY SPLIT SUMMARY

TOTAL NEC ARENA

SCENARIO	Mode RPM (Millions)				Mode Energy (Billions of BTU)**			
	AIR	AUTO	BUS	RAIL	AIR	AUTO	BUS	RAIL
76 BASELINE	1765 (14.1)*	9027 (72.4)	708 (5.7)	972 (7.8)	15229 (33.5)	27395 (60.4)	968 (2.1)	1798 (4.0)
76 FPI	1740 (13.9)	8962 (71.9)	751 (6.0)	1019 (8.2)	14937 (33.2)	27161 (60.3)	1031 (2.3)	1888 (4.2)
82 BASELINE	2289 (16.2)	9667 (68.3)	763 (5.4)	1430 (10.1)	18987 (37.5)	27060 (53.3)	1027 (2.1)	3587 (7.1)
82 FPI	2265 (16.0)	9618 (68.0)	797 (5.6)	1471 (10.4)	18719 (37.1)	26939 (53.4)	1078 (2.1)	3689 (7.4)
82 RNAV	2342 (16.5)	9662 (68.2)	759 (5.4)	1396 (9.9)	18298 (36.7)	27043 (54.1)	1021 (2.1)	3510 (7.1)
82 PTOL	2289 (16.2)	9667 (68.3)	763 (5.4)	1430 (10.1)	17696 (35.8)	27060 (54.9)	1027 (2.1)	3587 (7.2)
82 PTOL/RNAV	2342 (16.5)	9662 (68.2)	759 (5.4)	1396 (9.9)	16902 (34.9)	27043 (55.8)	1021 (2.1)	3510 (7.2)

*Numbers in parentheses are percentages of total.

** Includes Access

ARENA ENERGY EFFICIENCY INDEX COMPARISON

The energy efficiency index, in Btu per rpm, has been formed by aggregating door-to-door energy consumed and mode revenue passenger miles, both at the six city pair arena level and the 55 city pair total NEC arena level. The results are shown on this chart for each of the seven scenarios. The differences in results for the two methods of presentation are seen to be quite small, with the total NEC arena exhibiting about a 10% better efficiency index than the six city pair arena. In each case, the total improvement occurring in the best scenario relative to the 1976 Baseline Scenario is only about 6%, despite the much larger improvement in AIR efficiency noted earlier.

ARENA ENERGY EFFICIENCY INDEX COMPARISON

SCENARIO	6 CITY-PAIRS		TOTAL NEC	
	BTU/RPM	EFFICIENCY RATIO	BTU/RPM	EFFICIENCY RATIO
76 BASELINE	4090	1.000	3640	1.000
76 FPI	4050	(0.990)	3610	(0.992)
82 BASELINE	4081	(0.998)	3580	(0.984)
82 FPI	4050	(0.990)	3560	(0.978)
82 RNAV	3990	(0.976)	3520	(0.967)
82 PTOL	3940	(0.963)	3490	(0.959)
82 PTOL/RNAV	3830	(0.936)	3420	(0.940)

PATRONAGE AND ENERGY SUMMARY

This chart summarizes the results of the study in terms of annual passengers (rather than rpm's) and energy consumption, both for the six city pair and total Northeast Corridor arenas and, within each arena, for the AIR mode and for the aggregate of all modes. As noted earlier, the AIR mode consumes a much larger fraction of total energy than the fraction of passengers carried, and this situation is not altered by the air system improvements considered in this analysis. It is also seen that there is a significant growth in passengers between 1976 and 1982, both for AIR and in the total arena, and that this results in a growth in energy consumption. On a total arena basis, however, energy consumption grows only 7% between the best 1982 scenario and the 1976 Baseline Scenario, while a growth of some 13% occurs in travelers. Thus, the improvements in energy efficiency of the AIR and AUTO modes indicate a strong trend toward a leveling in energy consumption.

PATRONAGE AND ENERGY SUMMARY

SCENARIO	PASSENGERS (000)				ENERGY, 10^9 BTU			
	6 City-Pairs		NEC Arena		6 City-Pairs		NEC Arena	
	Air	Total	Air	Total	Air	Total	Air	Total
76 BASELINE	5716 (14.45)*	39541 (100.00)	7087 (8.06)	87900 (100.00)	12797 (47.9)	26740 (100.00)	15229 (33.5	45390 (100.00)
76 FPI	5572 (14.09)		6909 (7.86)		12552 (47.3)	26471 (100.00)	14937 (33.2)	45017 (100.00)
82 BASELINE	7251 (16.16)	44859 (100.00)	8991 (9.02)	99700 (100.00)	15956 (51.6)	30921 (100.00)	18987 (37.5)	50662 (100.00)
82 FPI	7098 (15.82)		8802 (8.83)		15730 (51.2)	30728 (100.00)	18719 (37.1)	50424 (100.00)
82 RNAV	7426 (16.55)		9208 (9.24)		15376 (50.8)	30245 (100.00)	18298 (36.7)	49871 (100.00)
82 PTOL	7251 (16.16)		8991 (9.02)		14870 (49.8)	29836 (100.00)	17696 (35.8)	49371 (100.00)
82 PTOL/RNAV	7426 (16.55)		9208 (9.24)		14203 (48.9)	29072 (100.00)	16902 (34.9)	48475 (100.00)

*Numbers in parentheses are percentages of total.

CONCLUSIONS

This chart provides a summary of the major study results, in terms of population and socio-economic conditions in the arena, improvements in the AIR mode, and for the scenarios considered. It is also noted that further improvements are possible with wider use of the fuel efficient advanced turboprop aircraft which, in this analysis, was assumed only on the air shuttle paths.

CONCLUSIONS

- ARENA
  - 6 CITY PAIR DEMAND GROWS 13% (2% PER YEAR)
  - 4 CITY POPULATION GROWS 6% (1% PER YEAR)
  - 4 CITY INCOME GROWS 20% (CONSTANT DOLLARS, 3% PER YEAR)
- AIRCRAFT (200 NM STAGE LENGTH)
  - DC9-50 IS 18% MORE FUEL EFFICIENT THAN 727-200 (DC9-30)
  - PTOL IS 38% MORE FUEL EFFICIENT THAN 727-200 (DC9-30)
    OR 18% BETTER THAN DC9-50
  - AT 500 NM, PTOL IS 42% BETTER THAN 727-200 (DC9-30)
    AND 27% BETTER THAN DC9-50
- SCENARIOS (6 CITY PAIRS)
  - DC9-50 USE IMPROVES AIR SYSTEM EFFICIENCY 5%
    - 8% IMPROVEMENT WITH RNAV
  - PTOL USE IMPROVES AIR SYSTEM EFFICIENCY 15%
    - 21% IMPROVEMENT WITH RNAV
  - ENERGY CONSUMPTION FOR AIR SYSTEM AND ARENA GROWS 25%
    AND 16%, RESPECTIVELY, FOR DC9-50
    - 16% AND 12% WITH PTOL
    - 11% AND 9% WITH PTOL/RNAV
  - FURTHER IMPROVEMENTS POSSIBLE WITH WIDER USE OF FUEL-EFFICIENT AIRCRAFT,
    OR MORE ADVANCED FUEL-EFFICIENT AIRCRAFT

APPENDIX

This appendix contains computer printouts of the results from each of the seven scenarios studied in this program. For each scenario the printouts amount to four pages. The first page contains demand data, in terms of annual passengers, for each of the six city pairs, and aggregated both to the six city pair and the 55 city pair Northeast Corridor arenas. The term "Subset" on these charts denotes the six city pair arena. The second page provides the revenue passenger miles on a mode basis for each of the six city pairs. Subset and 55 city pair arena totals are also given. The third page is a summary of results for the six city pair arena, while the fourth page is a similar summary for the total 55 city pair Northeast Corridor. It should be observed that energy efficiency is given on these charts in terms of great circle distance (GCD). The circuitry factor is also provided, so that the results can be converted to whatever format is desired.

1976 *BASELINE SCENARIO*

DEMAND - PASSENGERS (×1000)

MODES→	*BUS*	*CAR*	*CTOL*	*RAIL1*	*TMRR*	*TOTALS*
BOS-NY	628	4317	2316	363	0	7624
BOS-PHIL	26	564	473	15	0	1078
BOS-WASH	35	259	720	17	0	1031
NY-PHIL	471	13657	60	2104	404	16695
NY-WASH	604	4390	2014	437	611	8055
PHIL-WASH	123	4284	133	180	338	5058
SUBSET TOTAL	1887	27470	5716	3115	1352	39541
ARENA TOTAL	4020	68209	7087	6636	1948	87900
SUBSET PERCENTAGE	4.77	69.47	14.45	7.88	3.42	100.0
ARENA PERCENTAGE	4.57	77.60	8.06	7.55	2.22	100.0

1976 *BASELINE SCENARIO*

MODE REVENUE PASSENGER MILES (×10*6)

MODES→	*BUS*	*CAR*	*CTOL*	*RAIL1*	*TMRR*	*TOTALS*
BOS-NY	148.9	936.7	458.6	84.2	.0	1628.4
BOS-PHIL	8.6	170.3	144.7	4.9	.0	328.5
BOS-WASH	16.3	113.9	325.6	7.9	.0	463.5
NY-PHIL	43.8	1229.1	5.9	193.5	37.2	1509.5
NY-WASH	141.4	987.7	527.6	99.1	138.6	1894.4
PHIL-WASH	17.6	599.8	20.4	24.3	45.6	707.8
SUBSET TOTAL	376.6	4037.5	1482.7	413.9	221.4	6532.1
ARENA TOTAL	707.9	9027.0	1764.5	662.2	309.9	12471.6
SUBSET PERCENTAGE	5.76	61.81	22.70	6.34	3.39	100.0
ARENA PERCENTAGE	5.68	72.38	14.15	5.31	2.49	100.0

1976 *BASELINE SCENARIO*

ARENA SUBSET SUMMARY

MODES→	*BUS*	*CAR*	*CTOL*	*RAIL1*	*TMRR*	*TOTALS*	
PASSENGERS(×1000)	1887	27470	5716	3115	1352	39541	
MODE REV PASS MILES (×10*6)	376.6	4037.5	1482.7	413.9	221.4	6532.1	
ENERGY (*BTU*×10*9)	515	12253	12797	279*	142*	25987	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.17	1.12	1.15	(1)
PERCENT - PASSENGERS	4.77	69.47	14.45	7.88	3.42	100.0	
PERCENT - REV PASS MILES	5.76	61.81	22.70	6.34	3.39	100.0	
PERCENT - ENERGY	1.98	47.15	49.25	1.07	.55	100.0	
EN. EFF.(*BTU/GCD RPM*)	1614	3422	9814	1913	2035	3760	(2)

(1)*COMPOSITE SUBSET CIRCUITY FACTOR*

(2)*COMPOSITE SUBSET ENG. EFF.*

* ACCESS ONLY

1976 BASELINE SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
PASSENGERS(×1000)	4020	68209	7087	6636	1948	87900
MODE REV PASS MILES(×10*6)	707.9	9027.0	1764.5	662.2	309.9	12471.6
ENERGY (BTU×10*9)	968	27395	15229	1231	567	45390
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.17	1.12	1.15 (1)
PERCENT - PASSENGERS	4.57	77.60	8.06	7.55	2.22	100.0
PERCENT - REV PASS MILES	5.68	72.38	14.15	5.31	2.49	100.0
PERCENT - ENERGY	2.13	60.36	33.55	2.71	1.25	100.0
EN. EFF.(BTU/GCD RPM)	1614	3422	9814	2174	2056	4127 (2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.

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1976 FUEL PRICE INCREASE SCENARIO

DEMAND - PASSENGERS (×1000)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	694	4291	2237	403	0	7624
BOS-PHIL	28	570	463	17	0	1078
BOS-WASH	26	214	778	13	0	1031
NY-PHIL	471	13610	60	2147	407	16695
NY-WASH	648	4375	1914	462	656	8055
PHIL-WASH	127	4271	120	184	355	5058
SUBSET TOTAL	1994	27331	5572	3226	1418	39541
ARENA TOTAL	4247	67830	6909	6871	2042	87900
SUBSET PERCENTAGE	5.04	69.12	14.09	8.16	3.59	100.0
ARENA PERCENTAGE	4.83	77.17	7.86	7.82	2.32	100.0

1976 FUEL PRICE INCREASE SCENARIO

MODE REVENUE PASSENGER MILES (x10*6)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	164.4	931.1	442.9	93.4	.0	1631.8
BOS-PHIL	9.2	172.2	141.6	5.5	.0	328.6
BOS-WASH	12.3	94.1	351.7	5.9	.0	463.9
NY-PHIL	43.8	1224.9	5.9	197.5	37.5	1509.6
NY-WASH	151.5	984.5	501.4	105.0	148.8	1891.3
PHIL-WASH	18.2	597.9	18.5	24.9	47.9	707.5
SUBSET TOTAL	399.6	4004.7	1462.0	432.1	234.3	6532.6
ARENA TOTAL	751.2	8962.3	1739.8	691.4	328.0	12472.6
SUBSET PERCENTAGE	6.12	61.30	22.38	6.61	3.59	100.0
ARENA PERCENTAGE	6.02	71.86	13.95	5.54	2.63	100.0

1976 FUEL PRICE INCREASE SCENARIO

ARENA SUBSET SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
PASSENGERS(×1000)	1994	27331	5572	3226	1418	39541
MODE REV PASS MILES (×10*6)	399.6	4004.7	1462.0	432.1	234.3	6532.6
ENERGY (BTU×10*9)	548	12137	12552	293*	150*	25681
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.17	1.12	1.15 (1)
PERCENT - PASSENGERS	5.04	69.12	14.09	8.16	3.59	100.0
PERCENT - REV PASS MILES	6.12	61.30	22.38	6.61	3.59	100.0
PERCENT - ENERGY	2.14	47.26	48.88	1.14	.58	100.0
EN. EFF.(BTU/GCD RPM)	1621	3417	9754	1917	2032	3748 (2)

(1)COMPOSITE SUBSET CIRCUITY FACTOR

(2)COMPOSITE SUBSET ENG. EFF.

* ACCESS ONLY

1976 FUEL PRICE INCREASE SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS	
PASSENGERS(×1000)	4247	67830	6909	6871	2042	87900	
MODE REV PASS MILES(×10*6)	751.2	8962.3	1739.8	691.4	328.0	12472.6	
ENERGY (BTU×10*9)	1031	27161	14937	1289	599	45017	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.17	1.12	1.15	(1)
PERCENT - PASSENGERS	4.83	77.17	7.86	7.82	2.32	100.0	
PERCENT - REV PASS MILES	6.02	71.86	13.95	5.54	2.63	100.0	
PERCENT - ENERGY	2.29	60.33	33.18	2.86	1.33	100.0	
EN. EFF.(BTU/GCD RPM)	1621	3417	9754	2180	2053	4093	(2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.

1982 BASELINE SCENARIO

DEMAND - PASSENGERS (×1000)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	658	4409	2810	0	596	8473
BOS-PHIL	24	642	635	0	26	1327
BOS-WASH	39	291	1073	0	32	1435
NY-PHIL	418	14168	58	0	3382	18026
NY-WASH	683	4686	2504	0	1590	9463
PHIL-WASH	177	5036	172	0	751	6135
SUBSET TOTAL	1999	29233	7251	0	6376	44859
ARENA TOTAL	4257	74655	8991	0	11796	99700
SUBSET PERCENTAGE	4.46	65.17	16.16	.00	14.21	100.0
ARENA PERCENTAGE	4.27	74.88	9.02	.00	11.83	100.0

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1982 BASELINE SCENARIO

MODE REVENUE PASSENGER MILES (×10*6)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	155.8	956.8	556.3	.0	138.4	1807.4
BOS-PHIL	8.0	194.0	194.3	.0	8.3	404.5
BOS-WASH	18.2	128.0	485.0	.0	14.6	645.9
NY-PHIL	38.9	1275.2	5.7	.0	311.1	1630.8
NY-WASH	159.9	1054.4	656.0	.0	360.9	2231.1
PHIL-WASH	25.3	705.0	26.5	.0	101.4	858.1
SUBSET TOTAL	406.1	4313.4	1923.7	.0	934.7	7577.9
ARENA TOTAL	763.4	9666.9	2289.3	.0	1430.1	14149.7
SUBSET PERCENTAGE	5.36	56.92	25.39	.00	12.33	100.0
ARENA PERCENTAGE	5.40	68.32	16.18	.00	10.11	100.0

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1982 BASELINE SCENARIO

ARENA SUBSET SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
PASSENGERS(×1000)	1999	29233	7251	0	6376	44859
MODE REV PASS MILES (×10*6)	406.1	4313.4	1923.7	.0	934.7	7577.9
ENERGY (BTU×10*9)	546	12074	15956	0	639*	29215
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12 (1)
PERCENT - PASSENGERS	4.46	65.17	16.16	.00	14.21	100.0
PERCENT - REV PASS MILES	5.36	56.92	25.39	.00	12.33	100.0
PERCENT - ENERGY	1.87	41.33	54.61	.00	2.19	100.0
EN. EFF.(BTU/GCD RPM)	1585	3154	9437	1	2725	3380 (2)

(1)COMPOSITE SUBSET CIRCUITY FACTOR

(2)COMPOSITE SUBSET ENG. EFF.

* ACCESS ONLY

1982 BASELINE SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS	
PASSENGERS(×1000)	4257	74655	8991	0	11796	99700	
MODE REV PASS MILES(×10*6)	763.4	9666.9	2289.3	.0	1430.1	14149.7	
ENERGY (BTU×10*9)	1027	27060	18987	0	3587	50662	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.27	74.88	9.02	.00	11.83	100.0	
PERCENT - REV PASS MILES	5.40	68.32	16.18	.00	10.11	100.0	
PERCENT - ENERGY	2.03	53.41	37.48	.00	7.08	100.0	
EN. EFF.(BTU/GCD RPM)	1585	3154	9437	1	2890	4030	(2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.

1982 FUEL PRICE INCREASE SCENARIO

DEMAND - PASSENGERS (×1000)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	702	4423	2715	0	634	8473
BOS-PHIL	27	653	618	0	29	1327
BOS-WASH	28	243	1143	0	22	1435
NY-PHIL	425	14122	58	0	3421	18026
NY-WASH	729	4677	2405	0	1652	9463
PHIL-WASH	178	5018	160	0	779	6135
SUBSET TOTAL	2088	29136	7096	0	6537	44859
ARENA TOTAL	4448	74357	8802	0	12093	99700
SUBSET PERCENTAGE	4.66	64.95	15.82	.00	14.57	100.0
ARENA PERCENTAGE	4.46	74.58	8.83	.00	12.13	100.0

1982 FUEL PRICE INCREASE SCENARIO

MODE REVENUE PASSENGER MILES (×10*6)

MODES→	BUS	CAR	CTOL	RAIL1	TMKR	TOTALS
BOS-NY	166.3	959.6	537.5	.0	147.0	1810.6
BOS-PHIL	9.0	197.1	189.2	.0	9.3	404.6
BOS-WASH	12.9	107.1	516.4	.0	9.9	646.3
NY-PHIL	39.6	1270.9	5.7	.0	314.8	1630.9
NY-WASH	170.5	1052.2	630.2	.0	375.1	2228.0
PHIL-WASH	25.4	702.6	24.6	.0	105.2	857.8
SUBSET TOTAL	423.7	4289.7	1903.6	.0	961.2	7578.2
ARENA TOTAL	796.5	9617.8	2265.3	.0	1470.7	14150.3
SUBSET PERCENTAGE	5.59	56.61	25.12	.00	12.68	100.0
ARENA PERCENTAGE	5.63	67.97	16.01	.00	10.39	100.0

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1982 *FUEL PRICE INCREASE SCENARIO*

ARENA SUBSET SUMMARY

MODES→	*BUS*	*CAR*	*CTOL*	*RAIL1*	*TMRR*	*TOTALS*	
PASSENGERS(×1000)	2088	29136	7098	0	6537	44859	
MODE REV PASS MILES (×10*6)	423.7	4289.7	1903.6	.0	961.2	7578.2	
ENERGY (*BTU*×10*9)	573	12015	15730	0	657*	28975	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.66	64.95	15.82	.00	14.57	100.0	
PERCENT - REV PASS MILES	5.59	56.61	25.12	.00	12.68	100.0	
PERCENT - ENERGY	1.98	41.47	54.28	.00	2.27	100.0	
EN. EFF.(*BTU/GCD RPM*)	1595	3156	9398	1	2724	3374	(2)

(1)*COMPOSITE SUBSET CIRCUITY FACTOR*

(2)*COMPOSITE SUBSET ENG. EFF.*

* ACCESS ONLY

1982 FUEL PRICE INCREASE SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TNRK	TOTALS	
PASSENGERS(×1000)	4448	74357	8802	0	12093	99700	
MODE REV PASS MILES(×10*6)	796.5	9617.8	2265.3	.0	1470.7	14150.3	
ENERGY (BTU×10*9)	1078	26939	18719	0	3689	50424	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.46	74.58	8.83	.00	12.13	100.0	
PERCENT - REV PASS MILES	5.63	67.97	16.01	.00	10.39	100.0	
PERCENT - ENERGY	2.14	53.42	37.12	.00	7.32	100.0	
EN. EFF.(BTU/GCD RPM)	1595	3156	9398	1	2889	4041	(2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.

1982 BASELINE RNAV SCENARIO

DEMAND - PASSENGERS (×1000)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	656	4392	2837	0	588	8473
BOS-PHIL	24	642	635	0	26	1327
BOS-WASH	39	291	1073	0	32	1435
NY-PHIL	418	14168	58	0	3382	18026
NY-WASH	674	4639	2652	0	1499	9463
PHIL-WASH	177	5036	172	0	751	6135
SUBSET TOTAL	1988	29168	7426	0	6277	44859
ARENA TOTAL	4234	74646	9208	0	11613	99700
SUBSET PERCENTAGE	4.43	65.02	16.55	.00	13.99	100.0
ARENA PERCENTAGE	4.25	74.87	9.24	.00	11.65	100.0

1982 BASELINE RNAV SCENARIO

MODE REVENUE PASSENGER MILES (×10*6)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	155.4	953.2	561.7	.0	136.4	1806.7
BOS-PHIL	8.0	194.0	194.3	.0	8.3	404.5
BOS-WASH	18.2	128.0	485.0	.0	14.6	645.9
NY-PHIL	38.9	1275.2	5.7	.0	311.1	1630.8
NY-WASH	157.7	1043.7	694.7	.0	340.3	2236.3
PHIL-WASH	25.3	705.0	26.5	.0	101.4	858.1
SUBSET TOTAL	403.4	4299.0	1967.8	.0	912.1	7582.4
ARENA TOTAL	758.5	9662.4	2341.7	.0	1395.6	14158.1
SUBSET PERCENTAGE	5.32	56.70	25.95	.00	12.03	100.0
ARENA PERCENTAGE	5.36	68.25	16.54	.00	9.86	100.0

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1982 BASELINE RNAV SCENARIO

ARENA SUBSET SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS	
PASSENGERS(×1000)	1988	29168	7426	0	6277	44859	
MODE REV PASS MILES (×10*6)	403.4	4299.0	1967.8	.0	912.1	7582.4	
ENERGY (BTU×10*9)	543	12032	15376	0	628 *	28580	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.43	65.02	16.55	.00	13.99	100.0	
PERCENT - REV PASS MILES	5.32	56.70	25.95	.00	12.03	100.0	
PERCENT - ENERGY	1.90	42.10	53.8	.00	2.20	100.0	
EN. EFF.(BTU/GCD RPM)	1586	3154	8908	1	2733	3276	(2)

(1)COMPOSITE SUBSET CIRCUITY FACTOR

(2)COMPOSITE SUBSET ENG. EFF.

* ACCESS ONLY

1982 BASELINE RNAV SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TNKR	TOTALS	
PASSENGERS(×1000)	4234	74646	9208	0	11613	99700	
MODE REV PASS MILES(×10*6)	758.5	9662.4	2341.7	.0	1395.6	14158.1	
ENERGY (BTU×10*9)	1021	27043	18298	0	3510	49871	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.25	74.87	9.24	.00	11.65	100.0	
PERCENT - REV PASS MILES	5.36	68.25	16.54	.00	9.86	100.0	
PERCENT - ENERGY	2.05	54.23	36.68	.00	7.04	100.0	
EN. EFF.(BTU/GCD RPM)	1586	3154	8908	1	2899	3995	(2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.

1982 BASELINE PTOL SCENARIO

DEMAND - PASSENGERS (×1000)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	658	4409	2810	0	596	8473
BOS-PHIL	24	642	635	0	26	1327
BOS-WASH	39	291	1073	0	32	1435
NY-PHIL	418	14168	58	0	3382	18026
NY-WASH	683	4686	2504	0	1590	9463
PHIL-WASH	177	5036	172	0	751	6135
SUBSET TOTAL	1999	29233	7251	0	6376	44859
ARENA TOTAL	4257	74655	8991	0	11796	99700
SUBSET PERCENTAGE	4.46	65.17	16.16	.00	14.21	100.0
ARENA PERCENTAGE	4.27	74.88	9.02	.00	11.83	100.0

1982 BASELINE PTOL SCENARIO

MODE REVENUE PASSENGER MILES (×10*6)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	155.8	956.8	556.3	.0	138.4	1807.4
BOS-PHIL	8.0	194.0	194.3	.0	8.3	404.5
BOS-WASH	18.2	128.0	485.0	.0	14.6	645.9
NY-PHIL	38.9	1275.2	5.7	.0	311.1	1630.8
NY-WASH	159.9	1054.4	656.0	.0	360.9	2231.1
PHIL-WASH	25.3	705.0	26.5	.0	101.4	858.1
SUBSET TOTAL	406.1	4313.4	1923.7	.0	934.7	7577.9
ARENA TOTAL	763.4	9666.9	2289.3	.0	1430.1	14149.7
SUBSET PERCENTAGE	5.36	56.92	25.39	.00	12.33	100.0
ARENA PERCENTAGE	5.40	68.32	16.18	.00	10.11	100.0

1982 BASELINE PTOL SCENARIO

ARENA SUBSET SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS	
PASSENGERS(×1000)	1999	29233	7251	0	6376	44859	
MODE REV PASS MILES (×10*6)	406.1	4313.4	1923.7	.0	934.7	7577.9	
ENERGY (BTU×10*9)	546	12074	14870	0	639*	28130	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.46	65.17	16.16	.00	14.21	100.0	
PERCENT - REV PASS MILES	5.36	56.92	25.39	.00	12.33	100.0	
PERCENT - ENERGY	1.94	42.92	52.87	.00	2.27	100.0	
EN. EFF.(BTU/GCD RPM)	1585	3154	8795	1	2725	3253	(2)

(1)COMPOSITE SUBSET CIRCUITY FACTOR

(2)COMPOSITE SUBSET ENG. EFF.

* ACCESS ONLY

1982 BASELINE PTOL SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS	
PASSENGERS(×1000)	4257	74655	8991	0	11796	99700	
MODE REV PASS MILES(×10*6)	763.4	9666.9	2289.3	.0	1430.1	14149.7	
ENERGY (BTU×10*9)	1027	27060	17696	0	3587	49371	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.27	74.88	9.02	.00	11.83	100.0	
PERCENT - REV PASS MILES	5.40	68.32	16.18	.00	10.11	100.0	
PERCENT - ENERGY	2.08	54.81	35.84	.00	7.27	100.0	
EN. EFF.(BTU/GCD RPM)	1585	3154	8795	1	2890	3956	(2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.

1982 BASELINE RNAV PTOL SCENARIO

DEMAND - PASSENGERS (×1000)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	656	4392	2837	0	588	8473
BOS-PHIL	24	642	635	0	26	1327
BOS-WASH	39	291	1073	0	32	1435
NY-PHIL	418	14168	58	0	3382	18026
NY-WASH	674	4639	2652	0	1499	9463
PHIL-WASH	177	5036	172	0	751	6135
SUBSET TOTAL	1988	29168	7426	0	6277	44859
ARENA TOTAL	4234	74646	9208	0	11613	99700
SUBSET PERCENTAGE	4.43	65.02	16.55	.00	13.99	100.0
ARENA PERCENTAGE	4.25	74.87	9.24	.00	11.65	100.0

1982 BASELINE RNAV PTOL SCENARIO

MODE REVENUE PASSENGER MILES (×10*6)

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS
BOS-NY	155.4	953.2	561.7	.0	136.4	1806.7
BOS-PHIL	8.0	194.0	194.3	.0	8.3	404.5
BOS-WASH	18.2	128.0	485.0	.0	14.6	645.9
NY-PHIL	38.9	1275.2	5.7	.0	311.1	1630.8
NY-WASH	157.7	1043.7	694.7	.0	340.3	2236.3
PHIL-WASH	25.3	705.0	26.5	.0	101.4	858.1
SUBSET TOTAL	403.4	4299.0	1967.8	.0	912.1	7582.4
ARENA TOTAL	758.5	9662.4	2341.7	.0	1395.6	14158.1
SUBSET PERCENTAGE	5.32	56.70	25.95	.00	12.03	100.0
ARENA PERCENTAGE	5.36	68.25	16.54	.00	9.86	100.0

1982 BASELINE RNAV PTOL SCENARIO

ARENA SUBSET SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	TMRR	TOTALS	
PASSENGERS(×1000)	1988	29168	7426	0	6277	44859	
MODE REV PASS MILES (×10*6)	403.4	4299.0	1967.8	.0	912.1	7582.4	
ENERGY (BTU×10*9)	543	12032	14203	0	628*	27407	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.43	65.02	16.55	.00	13.99	100.0	
PERCENT - REV PASS MILES	5.32	56.70	25.95	.00	12.03	100.0	
PERCENT - ENERGY	1.98	43.90	51.83	.00	2.29	100.0	
EN. EFF.(BTU/GCD RPM)	1586	3154	8229	1	2733	3141	(2)

(1)COMPOSITE SUBSET CIRCUITY FACTOR

(2)COMPOSITE SUBSET ENG. EFF.

* ACCESS ONLY

1982 BASELINE NNAV PTOL SCENARIO

TOTAL ARENA SUMMARY

MODES→	BUS	CAR	CTOL	RAIL1	THRR	TOTALS	
PASSENGERS(×1000)	4234	74646	9208	0	11613	99700	
MODE REV PASS MILES(×10*6)	758.5	9662.4	2341.7	.0	1395.6	14158.1	
ENERGY (BTU×10*9)	1021	27043	16902	0	3510	48475	
AVG. CIRCUITY FACTOR	1.18	1.13	1.14	1.00	1.15	1.12	(1)
PERCENT - PASSENGERS	4.25	74.87	9.24	.00	11.65	100.0	
PERCENT - REV PASS MILES	5.36	68.25	16.54	.00	9.86	100.0	
PERCENT - ENERGY	2.11	55.79	34.86	.00	7.24	100.0	
EN. EFF.(BTU/GCD RPM)	1586	3154	8229	1	2899	3884	(2)

(1)COMPOSITE ARENA CIRCUITY FACTOR

(2)COMPOSITE ARENA EN. EFF.