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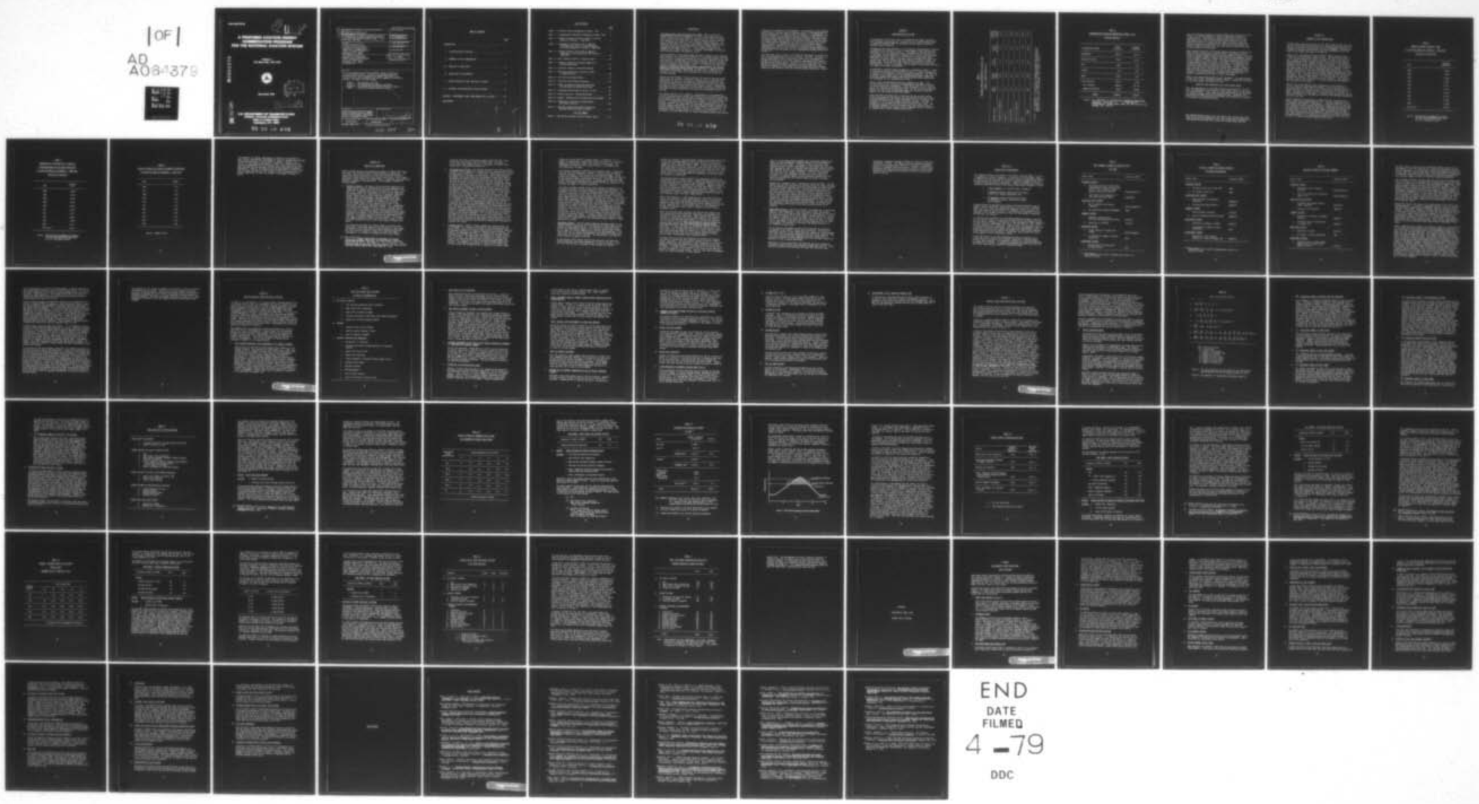

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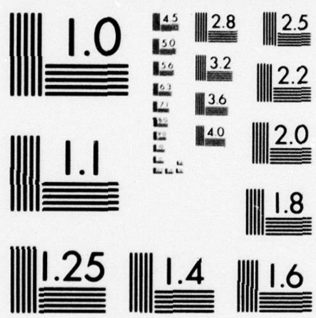


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# A PROPOSED AVIATION ENERGY CONSERVATION PROGRAM FOR THE NATIONAL AVIATION SYSTEM

AD A064379

Volume I

The Short Run, 1977-1978

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16. Abstract


This study presents an overview of potential options for improving aviation energy efficiency. Included in the proposed program are alternatives that could be pursued by the Federal Government as well as options that could be adopted by the various segments of the aviation industry. The report is in four volumes:

Volume I - The Short Run, 1977-1978;
Volume II - The Intermediate and Long Run, 1979-1990;
Volume III- The Proposed Aviation Energy Conservation Program; and
Summary - Overview of preceding technical volumes.

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# INTRODUCTION

The Energy Policy and Conservation Act (EPCA), Public Law 94-163, signed by the President on December 22, 1975, established major new policy directions for both American industry and all levels of Government concerning the conservation of domestic energy supplies and the more efficient utilization of scarce national energy resources. In a February 1976 report to Congress, the Federal Aviation Administration (FAA) described the energy conservation actions already taken or promoted by the agency since 1973. These actions by the aviation community had already resulted in a 16 percent improvement in aviation fuel efficiency before the EPCA was signed.

Section 382(a)(2) of the EPCA charged the FAA to "report to the Congress with respect to the content and feasibility of proposed programs for additional savings in energy consumption by the persons regulated by (the FAA) which have as a minimum goal a 10 percent reduction, within 12 months of the institution of such programs, in energy consumption from the amount of energy consumed during calendar 1972 . . ." On April 20, 1976, the Report to Congress by the Federal Aviation Administration on Proposed Programs for Aviation Energy Savings was submitted in response to the requirement noted above. An earlier version of this volume served as the basis for that report which analyzed only short-term energy conservation options.

Despite the improvements already achieved, the need for aviation energy conservation is as great, or greater, today as it was a few years ago. Recognizing the need for an exhaustive, comprehensive program of aviation energy conservation, the FAA initiated this follow-on study which presents an aviation energy conservation program of short, intermediate, and long-term options consistent with the need to maximize aviation fuel efficiency, without compromising the safety and environmental goals of the FAA.

This volume consists of six chapters, corresponding to the methodology utilized in examining the content and feasibility of the short run options to be proposed as a part of the Aviation Energy Conservation Program. The policy option generation methodology is as follows: (1) Clarification of the Goal - an examination of the meaning of energy conservation in the aviation industry, the development of the proper quantitative measure for aviation energy conservation, and the establishment of what an energy conservation program should achieve; (2) Progress in Fuel Conservation - an evaluation of the current situation; (3) Analysis of Conditions - an investigation into the determinants of energy consumption within the aviation

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industry; (4) Projection of Developments - an evaluation of the probable realization of the goal based on expected trends of the determinants of energy consumption; (5) Identification of Options - a comprehensive listing of all policy and operational options available to the FAA and the aviation industry which enhance those factors having a favorable effect and repress those factors having a deleterious effect on the efficiency of aviation energy consumption; and finally, (6) Synthesis and Evaluation of Options - a quantitative analysis of option effectiveness combined with a feasibility evaluation of these options to produce a challenging but realistic set of short run aviation energy conservation options which serve as inputs into the comprehensive program analysis of Volume III.

The time frame for the study is 1977-1990 with the short run analysis of this volume encompassing the first two years, 1977-1978. The short run options described in this volume have not been fully implemented as assumed for purposes of this study, however, implementation of many of the options has already begun. Volume II of this study analyzes intermediate and long-term energy conservation options separately, and Volume III combines all the options for the program derivation methodology and final synthesis into the Aviation Energy Conservation Program.

# CHAPTER I

## CLARIFICATION OF THE GOAL

The objective of this first step is to determine the proper interpretation of energy conservation as it pertains to the aviation industry and to establish precisely what any proposed aviation energy conservation program should accomplish.

The *EPCA* provides some guidance as to the general interpretation of energy conservation for aviation in that it placed emphasis upon improving the efficiency of use of energy resources. Responding to Section 382(a)(3) of the *EPCA*, the FAA submitted in December 1976 a report regarding agency regulations and their effect on the efficient use of aviation energy. Efficiency of energy usage is the major thrust throughout the *EPCA*, suggesting that rates of energy usage are preferred to absolute levels of energy usage. Given the fact that aviation is playing an increasingly important role in the U.S. economy, rate of usage is clearly more realistic as a measure of energy conservation.

An overview of national energy consumption is provided in Table 1. While transportation accounts for 26 percent of total U.S. energy consumption, it accounts for 54 percent of total petroleum consumption. The fact that 97 percent of the energy used in the transportation sector comes from petroleum suggests that energy conservation and petroleum conservation are synonymous for the transportation sector.

Table 2 shows transportation petroleum consumption by mode. Civil aviation accounts for 8 percent of transportation petroleum (4 percent of national petroleum consumption). Since 96 percent of civil aviation energy is accounted for by petroleum fuels, and air carriers account for most of the civil aviation petroleum usage, air carriers provide the emphasis for FAA energy conservation efforts.

Since efficiency of energy use is the focus for the aviation energy conservation program, and aviation fuel, particularly air carrier fuel, is the predominant form of energy consumption for civil aviation, the efficiency of aviation fuel usage is the goal variable. The goal, therefore, is to increase the efficiency of aviation fuel usage. The conventional measure of this efficiency within the aviation industry is "Revenue Ton-Miles Per Gallon," where a Revenue Ton-Mile is one ton of revenue (paid) traffic transported one mile.

TABLE 1

NATIONAL ENERGY CONSUMPTION BY SECTOR, 1976

(Quads = Quadrillion BTU's)

| National Sector | Total Energy | Percent Total Energy | Total Petroleum | Percent Total Petroleum | Percent Petroleum of Total Energy |
|---|---|---|---|---|---|
| Household and Commercial | 14.7 | 19.8% | 6.3 | 18.1% | 42.9% |
| Industrial | 18.4 | 24.9% | 6.2 | 17.7% | 33.7% |
| Transportation | 19.3 | 26.1% | 18.7 | 53.6% | 96.9% |
| Electricity Generation | 21.4 | 28.9% | 3.5 | 10.0% | 16.4% |
| Other | 0.2 | 0.3% | 0.2 | 0.6% | 100.0% |
| TOTAL | 74.0 | 100.0% | 34.9 | 100.0% | 47.2% |

Source: U.S. Department of Transportation, National Transportation Statistics. Washington, D.C.: U.S. Department of Transportation, Systems Center, Report No. DOT-TSC-OST-77-68, November 1977, Tables 17 and 27.

TABLE 2

TRANSPORTATION PETROLEUM CONSUMPTION BY MODE, 1975

(Million Barrels)

| Transportation Mode | Total Petroleum | Percent Petroleum |
|---|---|---|
| Automobile | 1,820.4 | 59.1% |
| Buses and Trucks | 774.5 | 25.1% |
| Rail | 89.0 | 2.9% |
| Transit | 8.9 | 0.3% |
| Water | 140.2 | 4.6% |
| Civil Aviation | 247.0 | 8.0% |
| (Air Carrier) | (226.4) | (91.7%) |
| (General Aviation) | (20.6) | (8.3%) |
| TOTAL | 3,080.0 | 100.0% |

Source: U.S. Department of Transportation, National Transportation Statistics. Washington, D.C.: U.S. Department of Transportation, Systems Center, Report No. DOT-TSC-OST-77-68, November 1977, Table 20.

The use of Revenue Ton-Miles Per Gallon (RTM/G) for aviation fuel efficiency is an accurate measure in that an improvement in RTM/G is accomplished by: flying heavier loads on existing routes with the same number of gallons, flying existing loads further on the same number of gallons, or flying existing loads on existing routes and using fewer gallons of aviation fuel. While the latter reduces the absolute number of gallons used, the first two also require that each gallon be used more efficiently.

Other potential measures for aviation energy efficiency are inferior to RTM/G in that they may not accurately reflect conservation efforts. Measuring energy consumption by the absolute number of gallons is biased in that a smaller number of gallons could result from exogenous changes, like an economic recession, rather than from a dedicated effort by the aviation industry to conserve fuel. "Available ton-miles per gallon" is unacceptable because it ignores load factors; only passengers and freight for which fares are paid are of interest. An empty seat or cargo hold hardly provides efficient energy usage. Finally, measures like "cost per mile" or "revenue per gallon" are inappropriate since they are financial measures and, as such, subject to distortion from inflation. The measure must be a technical or operational one to properly evaluate the efficiency of actual fuel usage.

RTM/G is the appropriate measure of goal attainment. The specification of the level of goal attainment remains, however. Rather than selecting an arbitrary number, the goal will be to:

MAXIMIZE RTM/G CONSISTENT WITH OTHER AGENCY GOALS.

Thus, the program goal is clarified without being specified. The FAA will not compromise aircraft safety or other agency goals in the process of increasing RTM/G. Thus, there are some constraints on the form that the aviation energy conservation program can take. Otherwise, the maximization of RTM/G during the 1977-1990* time frame will be accepted as the goal of the proposed program.

*The analysis was performed using 1977-1990 as the relevant time frame. Many of the options proposed for 1977 have already been implemented to some degree and attendant fuel savings are already being realized.

## CHAPTER II

## PROGRESS IN FUEL CONSERVATION

Previous fuel conservation efforts by the FAA illustrate that the possibility of long-range fuel shortages was a recognized problem within the FAA and the aviation industry prior to the 1973 embargo. Consequently, programs to improve fuel efficiency have been implemented by the FAA prior to the program developed in Volume III.

Table 3 lists the Domestic Revenue Ton-Miles (RTMs) flown by certificated air carriers between 1966 and 1976. The focus of the study is on air carriers because air carriers account for most of the aviation fuel consumed and RTMs for general aviation are difficult to measure. General aviation is not ignored, however, and several of the options developed later pertain primarily to general aviation. The 112 percent increase in air carrier RTMs in the ten-year period 1966-1975 reflects the rapid growth of the airline industry during that period. It is, however, pertinent to note that while RTMs grew by more than 72 percent between 1966 and 1970, the rate of increase dropped significantly in the seventies. The 1.7 percent increase between 1973 and 1974 illustrates the dramatic impact of the embargo. It is interesting to note that between 1971 and 1975, RTMs rose by only 20.7 percent. This growth in the first half of the seventies is in sharp contrast to the growth in the last half of the sixties.

Table 4 lists total domestic fuel consumption by certificated air carriers during the same 1966-1976 period. The ten-year period was characterized by a rapid drop in the relative use of aviation gasoline versus jet fuel (12.1 percent gasoline in 1966 versus 5.8 percent in 1976). Aviation fuel usage rose 71.7 percent during the ten-year period 1966-1975; however, the consumption of aviation fuel has been essentially constant since 1970.

Table 5 presents the performance of RTM/G over this ten-year period. RTM/G varied little between 1966 and 1971. However, beginning in 1972, a remarkable improvement in RTM/G began. It was March of 1972 when the FAA's National Aviation System (NAS) Policy Summary warned of the potential problems of long-range fuel shortages. Following the embargo, the FAA Seven-Point Jet Fuel Conservation Program, designed to save 300 million gallons per year, was implemented. Several follow-on alternatives were investigated and the FAA is continuing its efforts regarding fuel conservation. It is interesting to point out that the 1976 level of RTM/G is already 22 percent above the 1972 level.

TABLE 3

DOMESTIC REVENUE TON-MILES FLOWN

BY CERTIFIED ROUTE AIR CARRIERS -- 1966-1976

(Millions of Ton-Miles)

| Year | Domestic Operations |
|---|---|
| 1966 | 8,054 |
| 1967 | 9,982 |
| 1968 | 11,462 |
| 1969 | 13,943 |
| 1970 | 13,877 |
| 1971 | 14,142 |
| 1972 | 15,585 |
| 1973 | 16,707 |
| 1974 | 16,999 |
| 1975 | 17,069 |
| 1976 (Est.) | 18,802 |

Source: FAA Statistical Handbook of Aviation CY-1975, and unpublished data from the Civil Aeronautics Board.

TABLE 4

CONSUMPTION OF AVIATION FUEL IN DOMESTIC PASSENGER/CARGO AND AIR CARGO OPERATIONS BY CERTIFIED ROUTE AIR CARRIERS -- 1966-1976

(Millions of Gallons)

| Year | Aviation Fuel |
|---|---|
| 1966 | 4,506 |
| 1967 | 5,789 |
| 1968 | 6,832 |
| 1969 | 8,234 |
| 1970 | 8,085 |
| 1971 | 8,039 |
| 1972 | 8,197 |
| 1973 | 8,538 |
| 1974 | 7,688 |
| 1975 | 7,757 |
| 1976 (Est.) | 8,104 |

Source: FAA Statistical Handbook of Aviation CY-1975, and unpublished data from the Civil Aeronautics Board.

TABLE 5

REVENUE TON-MILES PER GALLON IN DOMESTIC OPERATIONS

BY CERTIFIED ROUTE AIR CARRIERS -- 1966-1976

| Year | RTM/G |
|---|---|
| 1966 | 1.79 |
| 1967 | 1.72 |
| 1968 | 1.68 |
| 1969 | 1.69 |
| 1970 | 1.72 |
| 1971 | 1.76 |
| 1972 | 1.90 |
| 1973 | 1.96 |
| 1974 | 2.21 |
| 1975 | 2.20 |
| 1976 | 2.32 |

Source: Tables 2 and 3

The potential for further improvements is difficult to determine in that, while a considerable improvement in RTM/G has already been attained, the maximum achievable value for RTM/G is unknown. Whether a ten, thirty, or fifty percent improvement in RTM/G can be expected by 1990 cannot be established until all possible fuel conservation options have been evaluated and the proposed aviation energy conservation program determined. Likewise, the maximum expected improvement in RTM/G during 1977 and 1978, the focus of this volume, cannot be estimated until an optimal combination of short run options is developed in Chapter VI below.

## CHAPTER III

## ANALYSIS OF CONDITIONS

Before evaluating policy and operational options to improve fuel usage efficiency, the factors directly affecting RTM/G are identified. In some cases, policy options do not affect fuel efficiency directly; rather, the options may affect other factors which have a direct impact upon RTM/G. These factors are categorized as: technical, socio-political, economic, regulatory, and operational. Each category of factors is discussed below.

A. Technical Factors - The type of aircraft and the modal mix with respect to all types of transportation are both dependent upon technological considerations which are difficult to alter in the short-run. Generally, the types of aircraft in use today were not designed with fuel conservation as an important constraint. Rather, factors such as noise reduction, passenger comfort, safety, speed (time advantage), and development costs have traditionally had the greatest influence on aircraft design. The next generation of commercial aircraft will no doubt utilize higher aspect ratios, supercritical airfoils, new power plants, and/or new structures concepts (e.g., composites) to produce a more energy efficient aircraft. The next generation aircraft is examined in Volume II and ultimately plays a crucial role in the aviation energy conservation program. Other technological advances, from advanced jet engines to performance computers, will become available during the intermediate and long runs, suggesting numerous technical options. In the short run, however, technical factors are essentially fixed, so that the other categorical factors exert the primary influence upon RTM/G.

The transportation modal mix affects RTM/G in that the stage length has a significant impact on the efficiency of fuel usage. For example, a DC-9 requires nearly three times the energy per mile for a 50-mile stage as it does for a 500-mile stage. [1/] Consequently, an increase in average aviation stage lengths,

1/ Hirst, Eric, Energy Intensiveness of Passenger and Freight Transportation Modes, 1950-1970, Oak Ridge National Laboratory Report ORNL NSF-EF-44. Oak Ridge, TN: 1973, and David P. Pilati, Airplane Energy Use and Conservation Strategies, Oak Ridge National Laboratory Report ORNL-EP-69. Oak Ridge, TN: 1974.

resulting from other transportation modes increasing their share of the short haul market, would increase RTM/G. Of course, factors other than energy use (e.g., regulatory influences) have traditionally determined the modal mix.

B. Socio-Political Factors - The primary socio-political factors affecting RTM/G are the constraints imposed by other, sometimes conflicting, national policy objectives. In particular, safety objectives cannot be compromised to increase fuel efficiency. While many operating procedures serve both energy and environmental objectives, some of the methods of reducing aircraft engine noise at the source reduce the fuel efficiency of the engine by increasing its weight. Constraints on energy conservation efforts may well become more severe in the next few years, diminishing the effect of efforts by the FAA and the aviation industry to improve the efficiency of fuel usage. The Department of Transportation (DOT)/FAA noise reduction policy, announced in November 1976, is certainly indicative of this trend. It required a reduction in noise within four years. To the extent that the policy is complied with by muffling existing jets, fuel efficiency would decline. Other socio-political factors include the importance of the domestic airlines and general aviation to the U.S. economy, the contribution of aircraft and avionics industries to the Nation's balance of international payments, the role of innovation and research and development within the aviation industry, the foreign policy relationships with both petroleum-exporting and other net importing countries, intensification in the search for and discovery of new petroleum sources, and the success in our national efforts to develop nonpetroleum sources of energy (e.g., the breeder reactor, solar energy, hydrogen). All of these influences affect the need for and the availability and cost of aviation fuel. Socio-political factors are, for the most part, beyond the control of the FAA, but must be considered as they impact the availability of aviation fuel and can constrain the efforts to improve the efficiency of aviation fuel usage.

C. Economic Factors - RTM/G is greatly affected by factors within the U.S. economy. An increase in load factors (the percentage of passengers and/or cargo carried per flight relative to aircraft capacity) has enormous potential as a means of improving fuel efficiency. For example, the passenger load factor in recent years has been around 50 percent and the RTM load factor (passengers plus cargo) has been about 45 percent. The additional fuel required for a load factor increase is relatively small because the weight of passengers and cargo is only 30 percent or less of the gross takeoff weight of an aircraft. For example, an increase in load for a B727-200 of one ton only raises fuel consumption by 2.1 percent on a typical stage length, but raises RTMs by a greater amount. Furthermore, an increase in load factors in some cases could also result in a decreased number of flights with little or no traveler inconvenience. The improvement in RTM/G for 1976, shown in Table 5, is primarily due to a load factor increase.

Load factors are greatly affected by the business cycle. A recession, like the 1974-1975 experience, results in fewer airline and general aviation passengers traveling and less cargo being shipped. Unless flights are reduced as the airlines did in 1974-1975, RTM/G will decline as the absolute number of passengers decreases. Conversely, an expansionary phase of the business cycle, as experienced in 1976-1977, will result in increased load factors providing that the air carriers do not increase the number of flights excessively.

Inflation is another economic factor which affects the demand for air transportation with a resulting impact on load factors and RTM/G. An increase in the rate of inflation produces higher operational costs for aviation system users via the cost of materials (e.g., aviation fuel), labor costs (especially those tied to the cost-of-living), and capital costs (both the cost of new airplanes and financing costs). This usually means higher passenger fares and higher charges for air cargo, with the result that load factors will decline. For general aviation, this means increased costs of doing business and restricted mobility. Furthermore, large rates of general inflation (like the 12.2 percent rise in the Consumer Price Index in CY-1974) may reduce real disposable personal income for some groups more than others, with disproportionate impacts on mobility. As a result of such influences, both the allocation of load factors within the existing airline route structure and general aviation use patterns change. If longer flights, with the more fuel-efficient longer stage lengths, are reduced relative to shorter stage length traffic, then RTM/G will decline because stage length is a major determinant of RTM/G.

D. <u>Regulatory Factors</u> - The two primary agencies regulating users of the national aviation system are the Civil Aeronautics Board (CAB) and the Federal Aviation Administration. The majority of regulations which delimit the operational aspects of air carriers have as their primary basis either air carrier competitive or service considerations, in the case of the CAB, or safety, environmental, and system efficiency considerations, in the case of the FAA. The regulations of the FAA also impact directly on general aviation.

By specifying airline routes and the rate structure, the CAB effectively determines load factor potentials for the air carriers. Also, the fact that service is provided to many economically marginal markets as a matter of national policy, tends to be energy inefficient. It has been estimated that by shifting one-half of all airline passengers on trips under 200 miles to buses, airline fuel efficiency would rise by 6.1 percent (Pilati, 1974). To the extent that the CAB subsidizes domestic airline operations, some short-haul airline flights are representing regulations serving other socio-political objectives rather than purely economic regulatory interests. The rise in recent years in small air taxi operations has decreased the relative impact of subsidies to some extent.

The existing route structure reflects the constraints of historical evolution as well as current needs. Present day operational objectives of more efficient use of aircraft and increased city-pair service are primary determinants of present route structures. Apparent anomalies do occur, however, as exemplified by the fact that about 50 percent of the airline passengers into Chicago are connecting flights, rather than originating initially from or destined to that location. A restructuring of routes to remove remaining demand condition anomalies could improve energy efficiency significantly.

While route approval is a CAB responsibility, some restructuring of routes, particularly in cases where airports are near or exceeding capacity, could affect the energy efficiency of both airline and general aviation operations by reducing airside congestion and delays, an FAA responsibility. An additional factor is the frequency of flights over approved routes, which in general is an air carrier management option.

Given the existing route structure, the FAA has some control over fuel conservation and has modified regulations and procedures for improving aviation fuel efficiency. These modifications by which the FAA, in conjunction with the aviation industry, has affected significant and immediate improvements in aviation fuel conservation are detailed in the <u>Report to Congress on Energy Conservation Policies and Practices by the Federal Aviation Administration</u>, dated February 1976. The areas of fundamental concern to the FAA have been: (1) reducing delays within the existing national aviation system, and (2) adopting effective air traffic control regulations and procedures which can impact the en route efficiency of the existing aviation fleet (e.g., assigning optimum altitudes, direct routes, and optimum climb and descent paths).

A primary area of current investigation for further fuel conservation efforts concerns the flow control process of FAA air traffic control procedures. The objective of such procedures is to minimize engine running time when destination airport capacities have been exceeded. If airport capacity is insufficient to satisfy the existing traffic, aircraft can be delayed on the ground at the departure airport to economize on fuel usage. Specific flow control recommendations are listed in Chapter V of this volume.

There is no one generalized statement that can be made regarding the impact of FAA/Environmental Protection Agency (EPA) environmental regulations on fuel usage. In general, a noise regulation that requires acoustic retrofit adds weight to the aircraft and increases fuel consumption, but it is possible that technology could be applied that improves specific fuel consumption offsetting the increase in fuel flow due to an increase in weight. Similarly, operational procedures for noise abatement and emissions control may have a positive or a negative impact on fuel consumption depending on the specific procedure and its related effects on thrust, altitude, and performance.

Regulations, therefore, have a considerable impact on RTM/G. The CAB affects airline fuel efficiency by setting air carrier routes and rates. The FAA establishes airspace utilization procedures and safety regulations which affect RTM/G directly. By reducing delays within the national aviation system, by assisting aircraft in operating in the most efficient manner, and by reducing circuitous routings to the extent consistent with underlying safety or environmental purposes, the FAA will continue to promote aviation fuel conservation. In the longer term, the FAA could promote the development of fuel-efficient aircraft technologies and airport configurations. By thus improving the components of the airspace system with respect to energy usage, long-term energy efficiency of the total aviation system can be enhanced.

E. Operational Factors - The way an aircraft is operated has a significant impact on fuel consumption. The cruise speed, climb, and descent profiles, cruise altitude and fuel ferrying or tankering are all operating decisions made by users of the system. Ground operations, such as the number of engines in use while either idle or taxiing, are another area of fuel conservation under the direct control of users. A reduction in the number of engines used in ground operations has the additional benefit of reducing air pollution from engine emissions in the immediate airport areas.

The air carriers and general aviation have performed outstandingly in response to the need to improve fuel efficiency. In the area of operational factors, cruise speeds have been lowered to a near-optimum level and climb and descent procedures have been vastly improved. FAA air traffic controllers have cooperated with the system users in assigning requested altitudes whenever practical and fewer engines are generally in use in ground operations.

Additional savings are possible from improved operating procedures, although the major benefits have probably already been derived. Since operating procedures and practices are under FAA influence, they constitute a potential leverage variable for directly effecting an improvement in RTM/G. New energy conserving operating procedures could be investigated by the FAA and, if practical, implemented directly or promoted among system users. Chapter V of this report enumerates FAA short-run policy options which can further enhance the operating procedures and practices of both air carriers and general aviation.

## CHAPTER IV

## PROJECTION OF DEVELOPMENTS

This chapter estimates the trends of the factors affecting RTM/G. As such, it represents an a priori forecast: an evaluation of the probable impact on RTM/G if the FAA and industry institute no new fuel conservation programs. By determining that scenario, the areas of greatest leverage for FAA and industry program options are delineated. Tables 6-8 present three possible, internally consistent trends of the factors identified in Chapter III above:

- o A Most Probable, or "surprise free," scenario;
- o A Potential scenario within which the energy crisis is of reduced importance; and
- o An Uncertain scenario within which another oil embargo or similar constraint on availability appears.

Program options are selected on the basis of the Most Probable scenario; however, several additional program options are put forth as "insurance" should the less likely, but potentially damaging, results of one of the other two scenarios actually occur. The scenarios are presented for the remainder of the decade, although only the 1977-1978 period is necessary for the short run analysis.

A "surprise free" projection for 1977-1980 essentially assumes a continuation of current trends. No substantially new aircraft are planned for the next few years, although a continuation of the retirement of older commercial aircraft and their replacement with larger aircraft (DC-10, L-1011, B-747 and their derivatives) is expected. Similar trends are foreseen in the area of general aviation aircraft except that results of developmental efforts toward more fuel-efficient engines and designs will begin to be evidenced in new derivatives over the period. On balance, these trends will have a mildly negative initial influence on RTM/G.

A very small shift to railroad transportation might be expected if the current measures to improve the railroads, especially in the Northeast Corridor, are successful. Environmental standards are currently scheduled to become more stringent. As engines are adjusted for lower emissions and less noise, there may be a negative influence on RTM/G.

TABLE 6

MOST PROBABLE SCENARIO ("SURPRISE-FREE")

1977-1980

| Factor Trend | Effect on RTM/G |
|---|---|
| TECHNICAL FACTORS | |
| 1. No new aircraft until after 1979; replacement of older aircraft with B-747, L-1011, and DC-10; some general aviation derivatives | Mildly Negative |
| 2. Small modal shift toward rail and other short-haul modes | Negligible |
| SOCIO-POLITICAL FACTORS | |
| 1. More stringent environmental standards | Mildly Negative* |
| 2. No significant energy developments | None |
| ECONOMIC FACTORS | |
| 1. Economic recovery during 1977-1978 and expansion thereafter | Positive |
| 2. Reduction in inflation | Positive |
| REGULATORY FACTORS | |
| 1. Slight increase in routes and flights | Mildly Negative |
| 2. No substantial changes in safety regulations | None |
| OPERATIONAL FACTORS | |
| 1. Continuation of existing fuel economy measures | None |

*Some changes in air traffic procedures may result in a "positive" effect.

TABLE 7

POTENTIAL SCENARIO OF REDUCED EMPHASIS

ON ENERGY CONSERVATION

| Factor Trend | Effect on RTM/G |
|---|---|
| TECHNICAL FACTORS | |
| 1. No new aircraft until after 1978 | None |
| 2. No change in modal mix | None |
| SOCIO-POLITICAL FACTORS | |
| 1. More stringent environmental standards | Negative* |
| 2. Increased petroleum supplies | Negative |
| ECONOMIC FACTORS | |
| 1. Strong economic recovery | Positive |
| 2. Rise in inflation during 1977-1978 | Negative |
| REGULATORY FACTORS | |
| 1. Substantial increase in routes | Negative |
| 2. No substantial change in safety regulations | None |
| OPERATIONAL FACTORS | |
| 1. Relaxation in fuel economy programs as a result of ample fuel | Negative |

*Some changes in air traffic procedures may result in a "positive" effect.

TABLE 8

UNCERTAIN SCENARIO OF NEW OPEC EMBARGO

| Factor Trend | Effect on RTM/G |
|---|---|
| TECHNICAL FACTORS | |
| 1. Grounding of fuel-intensive aircraft | Mildly Positive |
| 2. Shift from alternative short-haul modes to air | Mildly Negative |
| SOCIO-POLITICAL FACTORS | |
| 1. Relaxation of planned environmental standards | Negligible |
| 2. Embargo, fuel rationing | Negative |
| ECONOMIC FACTORS | |
| 1. Reduction or reversal of economic recovery | Negative |
| 2. Increased rate of inflation due to energy costs | Negative |
| REGULATORY FACTORS | |
| 1. Reduction in routes | Positive |
| 2. No change in safety regulations | None |
| OPERATIONAL FACTORS | |
| 1. Intensification of fuel economy measures by air carriers and general aviation | Positive |

The most probable scenario has no significant energy supply or price developments in the 1977-1980 period. Portions of the Alaska pipeline will be completed, but the pipeline and other developments are expected to have their main impact after 1978. The current state of Organization of Petroleum Exporting Countries (OPEC) and relatively reduced Middle East tensions suggest no major disruptions in petroleum supplies.

The strongest influences over the next four years will be economic ones. The U.S. economy is in a recovery phase of the business cycle and large increases in the rate of inflation have diminished to some extent. Both point to higher load factors and a positive effect on RTM/G. If the Administration's proposal on regulatory reform is adopted, eventual increases in aviation fuel efficiency are projected. If the proposal is not adopted, regulatory factors will have almost negligible additional impact on fuel efficiency. In the latter case, the CAB and air carriers can be expected to reinstate some of the routes and flights that were cut in the past few years in the interest of fuel conservation. This additional service, absent compensating increased demand, can have a mildly negative impact.

Operational factors will consist of a continuation of the current fuel economy programs. It should be remembered, however, that this surprise free projection assumes no new initiatives from the FAA and aviation industry. Essentially, RTM/G is evaluated under the assumption that the current state of affairs continues, so that the current state can serve as a baseline against which proposed programs can be evaluated. An examination of Table 6 indicates that, all things considered, RTM/G would remain essentially constant at its current level if the FAA and industry did not institute new programs. Thus, further improvements in RTM/G will be due to the additional program options developed in this study.

Table 7 represents the unlikely, but potential, event of an amelioration of the energy situation, possibly by an unanticipated discovery of a major new source of petroleum supply or by considerable concessions from some or all of the OPEC countries. The technical factors would stay about the same, although the small shift toward alternative short-haul modes anticipated might not occur. The primary socio-political factor would, of course, be the increased availability of petroleum. An influx of petroleum would enhance the economic factors by accelerating the recovery in the general economy, although the economy would have a greater tendency to overheat, causing a recurrence of inflation in 1978-1979. As a result, the economic factors would be positive but weaker than in the surprise free scenario. With a slackening of petroleum costs and increased supply availability, the air carrier and general aviation growth would tend to be higher than recent historical growth rates. An increase in air carrier routes would have a negative impact on RTM/G. As system users respond more to economic stimuli, fuel efficiency would tend to decline somewhat.

Should the potential scenario of reduced emphasis on energy conservation occur, RTM/G would likely fall back in the direction of the 1.7 level of the 1960's, depending on the relative balance between energy and economic objectives of the operators. The success of FAA efforts to induce an increase in RTM/G would likely be constrained by the adverse trend of factors beyond the control of the FAA.

Finally, Table 8 presents the uncertain scenario of the imposition of a partial or complete OPEC oil embargo or other action with similar effect. The United States is more dependent on imported petroleum today than it was before the 1973 embargo. As a result, most factors would respond as they did to the first embargo. The aircraft fleet mix would shift toward the smaller, less fuel-intensive aircraft. There would probably be a renewed shift toward local service air carriers and general aviation from alternative short-haul transportation modes. Technical factors would have a mildly positive effect on RTM/G. As in 1973, planned environmental standards could be relaxed, although they would remain more stringent than the current standards. The existence of rationing would increase fuel ferrying to insure an adequate supply of fuel.

Economic factors would decrease load factors. As for regulatory factors, a positive effect would be experienced as air carrier routes were reduced. Finally, air carriers and general aviation would intensify fuel conservation measures. On balance, the overall effect on RTM/G of a new embargo would be essentially neutral. This is as would be expected due to the coincidence of energy and cost objectives of aviation system users. In addition, the current state of the aviation system reflects the impact of the first embargo, with most adjustments already made. Consequently, RTM/G is at a level representing costly fuel and uncertain supply. In summary, under this scenario, further energy efficiency improvements would require new programs.

An evaluation of the most probable, potential, and uncertain scenarios of the next four years implies that RTM/G will, at best, stay essentially the same unless new fuel efficiency programs are instituted. This volume and the next consider the range of potential FAA policy options to achieve the goal of raising RTM/G to the maximum level possible. In Volume III, an Aviation Energy Conservation Program is proposed based on the short-run policy options identified herein and the intermediate and long-run options detailed in Volume II. Some of the options listed initially are impractical, technically infeasible in the time frame under consideration, or contrary to other national policy goals (e.g., environmental). The options selected and formulated into the proposed Aviation Energy Conservation Program represent the optimal approach to achieving the goal of maximizing aviation energy efficiency given the expected developments of the next few years as discussed above.

The remainder of this volume is devoted to an analysis of short-run energy conservation policy options. Specifically, the next chapter identifies the array of possible short-run energy conservation options and Chapter VI evaluates and synthesizes this list into a coherent short-run energy conservation program. The short-run program identified in Chapter VI is then integrated in Volume III into the proposed Aviation Energy Conservation Program.

## CHAPTER V

## IDENTIFICATION OF SHORT RUN POLICY OPTIONS

The goal of raising domestic civil aviation RTM/G a maximum amount from its current level of 2.32 is a formidable task and will require the combined efforts of the FAA, the air carriers, general aviation, and other parties engaged in aeronautical research and development activities. The options for this study are divided into short term (1977-1978), intermediate term (1979-1981), and long term (1982-1990). The selection of the breakdown as to short, intermediate, and long run was somewhat arbitrary, reflecting time periods within which primarily operational, airport capacity, and technological options could be implemented, respectively. The focus of this volume is on short-term options; consequently, this chapter enumerates the array of policy options available to the FAA and the aviation industry during 1977-1978. Intermediate and long-term options are deferred to Volume II.

The eighteen short run energy policy options evaluated are listed in Table 9 by area of responsibility. A much larger list of candidate options was initially considered; however, many of the options were excluded as being impolitic, unattainable, or otherwise unworthy of further consideration. Those options excluded from the analysis are listed in the Appendix. Each of the 18 short run options to be evaluated in Chapter VI is presented below:

### 1. FUEL ADVISORY DEPARTURE (FAD) PROCEDURES AT 16 LARGEST AIRPORTS

Delays within the National Aviation System occur primarily at the largest airports. By concentrating flow control (i.e., FAD), procedures at the 16 largest airports, much of the system delay could be absorbed on the ground at a lower rate of fuel consumption. The Air Traffic Control Systems Command Center (ATCSCC) in Washington, D.C. would constantly monitor capacity conditions at these airports and institute FAD whenever delays exceed a predetermined level. Central to the FAD system is the concept of taking delays on the ground by holding at the gate until arrival at the destination airport can be handled by ATC. FAD has been implemented at Chicago's O'Hare International Airport and will be expanded to include other major airports when the Central Flow Control Function (CFCF) is automated. Central Flow Control automation is expected to be completed by December 1978.

## TABLE 9

## SHORT RUN ENERGY POLICY OPTIONS

## BY AREA OF RESPONSIBILITY

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A. AIR TRAFFIC CONTROL

- Fuel Advisory Departure (FAD) Procedures
- Wake Vortex Class Sequencing
- Wake Vortex Avoidance Systems
- Decrease Instrument Flight Rules (IFR) Spacing Standards
- Expand Use of Area Navigation (RNAV)

B. AIRPORTS

- Temporary Construction Runways
- General Aviation Runways at Hubs
- Snow-Ice Removal Equipment

C. AIRCRAFT OPERATORS AND MANAGEMENT

- Maximum Use of Simulators
- Increase Load Factor Through Restraint in Available Capacity
- Reseat Existing Aircraft
- Reduce Fuel Tankering
- Climb Procedures in Terminal Control Areas (TCA's)
- Optimum Cruise Speed
- Optimum Altitude
- Optimum Descent
- Taxi on Fewer Engines
- Load to Aft Center of Gravity (CG)

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2. WAKE VORTEX CLASS SEQUENCING

Wake turbulence basically involves wing tip vortices. Larger and heavier aircraft create more turbulence, and air traffic control spaces aircraft during takeoff and departure based on wake turbulence potential and the size of the aircraft next in the queue. By proper sequencing of aircraft in the queue, wake turbulence spacing can be diminished. This option may need to be coupled with airport specialization or split queues.

3. WAKE VORTEX AVOIDANCE SYSTEMS AT MAJOR AIRPORTS

Current separation standards limit capacity and increase delay at airports. One consideration in the setting of separation standards is the existence of wake vortices. Unfortunately, the position of vortices is indeterminate at most airports, and separation standards are set with considerable allowances for error. A Wake Vortex Avoidance System (WVAS) at an airport subject to delays would permit a tightening of separation standards without an adverse effect on safety. An FAA study analyzed a predictive WVAS based on factors such as aircraft type, wind direction, and wind speed. The data was collected at JFK-New York. In the Spring of 1976, this predictive model was tested at Chicago O'Hare. The Vortex Advisory System (VAS), a precursor to WVAS, was installed at O'Hare in May 1978, and will be used to adjust traffic spacing beginning in the Fall of 1978. The WVAS is expected to replace the VAS and provide better information based on real-time data.

4. DECREASE INSTRUMENT FLIGHT RULES (IFR) SPACING SEPARATION STANDARDS AT LOCATIONS WITH PARALLEL RUNWAYS

During IFR conditions, independent air traffic control operations can now be conducted at locations served by runways not less than 4,300 feet apart. At locations not meeting this criterion it may be possible to safely conduct simultaneous approaches to both runways by staggering arrivals, thereby increasing airport capacity. The FAA currently has a project to develop a standard criterion for proposed staggered approaches. This option may be limited by the wake vortex problem.

5. EXPAND USE OF AREA NAVIGATION (RNAV)

Ideally, aircraft should be able to fly unimpeded from takeoff to touchdown along the most efficient trajectory. The existing structure of airways consists of radial segments defined by the VORTAC network. This limitation to radials imposes additional mileage between terminals. Area Navigation permits direct routing and optimal climb profiles to be followed. Properly equipped and certificated aircraft can use published RNAV routes or request direct point-to-point flight, however, only a small number of users are currently using RNAV routes.

6. SHORT, TEMPORARY PARALLEL RUNWAYS DURING AIRPORT CONSTRUCTION AND RECONSTRUCTION

Airport and/or runway closures reduce aviation system capacity and produce delay. In 1977, 3.1 percent of the air traffic delays 30 minutes or longer were due to such capacity reductions. By installing a short, parallel runway to the runway being resurfaced or constructed, the capacity loss is reduced since small aircraft could use the short runway. It is further assumed that the runway would be built sufficiently permanent to serve thereafter for either general aviation (GA) or short takeoff and landing (STOL) traffic.

7. SHORT, GENERAL AVIATION RUNWAYS AT LARGE HUB AIRPORTS

Delays at primary air carrier airports in the 25 large hubs could be reduced by the provision of short, general aviation runways at such airports. The increased availability of such runways could permit the specialization of runways by type of aircraft, permitting an increase in the acceptance rate on the longer runways as the separation distances are less for large aircraft than for mixed classes of aircraft. This is due to the fact that large, heavy aircraft used primarily by air carriers create wake vortices which require greater separations to ensure that following smaller aircraft will not encounter wake turbulence. Furthermore, the new runway would itself increase airport capacity. Adding GA runways in the short run would also anticipate the needs of STOL/VTOL aircraft in the next decade.

8. SNOW-ICE REMOVAL EQUIPMENT

The time required to open runways after snow falls is highly variable, depending upon the intensity of the snowfall and the availability of snow-ice removal equipment. In 1977, 14.6 percent of NASCOM delays were due to snow and ice problems. The proposed provision of Airport and Airway Development Aid Program (ADAP) funds for additional snow-ice removal equipment may assist in reducing delays due to snow and ice problems.

9. MAXIMUM USE OF AIRCRAFT SIMULATORS IN LIEU OF ACTUAL TRAINING FLIGHTS

Simulators are already widely used in airline training. However, for many airlines, it does not pay to buy a $5 or $10 million simulator. Reexamination of simulator economics, including the possibility of renting time on others' simulators, if the cockpits are similar enough, can enhance the use of simulators. Pilot schools and fixedbase operators should make maximum use of ground trainers to the extent permitted by Federal Aviation Regulations. Manufacturers of flight training equipment should continue to improve the quality of simulators so as to permit reductions in aircraft flying hours for flight training. It is also recommended that planning for future military training take full advantage of existing ground and in-flight simulation techniques to minimize the fuel used without sacrificing training quality.

10. INCREASE LOAD FACTOR THROUGH RESTRAINT IN AVAILABLE CAPACITY (NUMBER OF FLIGHTS)

The greatest potential for decreasing fuel consumption on a revenue ton mile basis or an equivalent technical factor is to increase the load factor (ratio of tonnage transported to capacity). Air carrier capacity can be restrained by limitations in the number of flights or by changing the fleet mix.

11. RESEAT EXISTING AIRCRAFT

Increasing the number of seats in existing air carrier aircraft raises the potential passenger load. Increases in passenger demand can, therefore, be handled without moving to a larger aircraft which would consume more fuel. Reducing first class seats and providing smaller seats in coach have been the general approaches (the 11 major carriers have added 17,200 coach seats and dropped 7,600 first class seats since 1973 to existing aircraft). The CAB has increased the price differential (from 25 to 60 percent) between first class and coach seats to encourage reseating, among other reasons.

12. REDUCE FUEL TANKERING

Because of differing prices and availability of fuel at various airports, air carriers try to minimize fuel cost by buying excess fuel at low price stations. Carrying excess fuel to arbitrage fuel prices increases the fuel burned on the tankering stages. Tighter control over fuel reserves would help reduce the level of tankering.

13. CLIMB PROCEDURES IN TERMINAL CONTROL AREAS (TCA's)

Climb and descent profiles should be close to optimum for maximum trip fuel economy. To permit optimum climbs, departures should be allowed to exceed the 250-knot speed limit below 10,000 feet in certain TCA's. The recommended climb speed (according to Braniff International) for a Boeing 727-200, for example, is 320-knots. Safety considerations and noise abatement procedures may limit full use of optimum climb rates.

14. OPTIMUM CRUISE SPEED

Present airline practice is to fix cruise Mach numbers for each type of aircraft. The Mach number chosen is the one the airline believes will result in minimum costs (not minimum fuel use). A policy for minimum fuel use could be considered, but may require an attendant adjustment in passenger fares to compensate for more costly operation.

15. OPTIMUM ALTITUDE

In general, fuel consumption can be reduced by flying at higher altitudes. There is an optimum altitude (for minimum fuel use) for each airplane's cruise weight and speed. Whenever possible, flights are cleared by air traffic control to fly at requested altitudes. As the aircraft burns fuel and decreases in weight, the optimum altitude increases. By properly increasing cruise altitude during a flight (cruise climb), fuel use is less than at fixed altitude cruise.

16. OPTIMUM DESCENT

The idle-thrust descent and/or NASA landing approach (reduced flap, decelerating) procedures are generally agreed to be the most fuel efficient. Maximum possible use of these procedures should be encouraged. To the extent possible, descent should be uninterrupted versus the present step down techniques employed. Further, maintaining a clean configuration in descent and using the lowest practical certified flap settings for landing will lower fuel consumption with the additional benefit of a reduction in noise on the ground along the approach path.

Optimum descent profiles have been developed for 105 major airports including Dallas/Forth Worth, Regional Kansas City International, Atlanta, Chicago O'Hare, Denver, and St. Louis Airports. There are, however, safety-related problems which must be resolved before full use of optimum descent profiles can proceed.

17. TAXI ON FEWER ENGINES

Aircraft operating on the ground do not need to use all of the engines on the aircraft. Considerable fuel can be saved by shutdown of one or more engines for taxiing. This option is currently employed by all users to some extent, but its use could be increased for additional fuel savings.

## 18. LOAD AIRCRAFT TO AFT CENTER OF GRAVITY (CG)

Aircraft drag is minimized when the aircraft center of gravity is at the aft limit specified as safe for aerodynamic stability. All operators should review the potential for the consequent fuel savings which can be achieved by loading aircraft so as to keep their CG's close to this aft limit.

## CHAPTER VI

## SYNTHESIS AND EVALUATION OF POLICY OPTIONS

This chapter analyzes the policy options generated by the previous section and synthesizes them into coherent programs for achieving the goal of maximizing RTM/G during the short run. The options comprising the proposed programs were structured into relevant categories by area of responsibility (e.g., FAA, airports, etc.) in Table 9 of the preceding chapter.

In Part A, a program evaluation model is constructed for assessing the quantitative impact on RTM/G of program options. Each option is evaluated as if it alone were implemented. The fact that options interact as to their effectiveness is considered in Part B of this chapter and in the program derivation process of Volume III.

In Part B, the expected effectiveness of each potential policy set is evaluated, where a policy set is a combination of some or all of the options. Contrary to the individual effectiveness of policy options estimated in Part B, the effectiveness of each potential policy set as a whole is evaluated. A crucial point of this analysis is that policy options, each of which might raise RTM/G by 5 percent due to reducing congestion at airports, will not raise RTM/G by 10 percent if used together. However, both might be a part of the program to insure that congestion is reduced. The individual options might, for example, refer to different areas of responsibility (e.g., ATC and airports). Nonadditivity must be considered when evaluating each program; hence, a new quantification of the effects of the potential program in its complete form is necessary. Additionally, many individual options are indivisible. An option like optimal cruise control is divisible in that a fractional completion of the program provides a fractional benefit. If 0.8 Mach is determined as the optimal cruise speed for a B-727 and average cruise speeds have been 0.85 Mach, then reducing cruise speed from .85M to .8M will provide substantial fuel savings (Braniff International, Flight Operational Fuel Management Program 1976). But, reducing cruise speed to .83M provides some benefits. On the other hand, advanced onboard avionics are either used or not. Putting such avionics on a few airplanes is meaningless; system-wide implementation is required for policy implementation. Fortunately, all of the short run options are divisible and most are additive. In the intermediate and long run analysis, however, this will tend to be less true.

Having evaluated the effectiveness of each potential policy set, Part C brings together and evaluates the implications and side effects of the potential program as a part of the overall program for goal achievement. Option interactions, if any, are identified and synthesized by adjusting one of the two conflicting policy options on the basis of relative effectiveness. The interdependencies of potential short run programs with respect to other major policy objectives, like air safety, are evaluated and options compromising other policy objectives are either removed or reconfigured. Reevaluation of program effectiveness is necessary as options are altered to satisfy nonenergy policy constraints. When all interpolicy conflicts are resolved, the potential programs are reevaluated as to effectiveness.

Finally, a proposed short run program is derived and RTM/G is projected on the assumption that this proposed short run program was implemented during 1977. The purpose of the projection is to illustrate the limited improvement in RTM/G available in the short run, leading to the necessity for the intermediate and long run analysis of Volume II.

## A. POLICY EVALUATION MODEL

The objective of the policy evaluation model (Table 10) developed below is to help structure those technology and operational variables which have an impact on RTM/G. The basic approach involves a series of tautologies incorporating widely used industry measures of decision variables.

Under a strict assumption of independence, the model equations are combined into expressions of percentage change. This permits evaluation of the impact of policy options through the variable(s) upon which the policy will bring about change to the ultimate target: RTM/G.

Conceptually, the model is system-wide with no distinctions between commercial and general aviation; however, it can be used to evaluate particular segments. This would permit the evaluation of general aviation options where corresponding data collection techniques might not be presently available. The system-wide impact can then be estimated by weighting the GA impact by the percentage of GA to total system. Equation 7 of the model is the one used to evaluate impacts.

The Policy Evaluation Model expresses the percentage change in RTM/G as a function of additive percentage changes in eight different factors or components. The various policy options presented in Chapter V will have their effect on RTM/G through one or more of the eight explanatory variables. The following is a discussion of the model components and a description of how external factors may affect each component.

## TABLE 10

## THE POLICY EVALUATION MODEL

1. $RTM = \frac{RT}{P} \cdot \frac{P}{S} \cdot \frac{S}{A} \cdot A \cdot M$

2. $\delta RTM = \delta\frac{RT}{P} + \delta\frac{P}{S} + \delta\frac{S}{A} + \delta A + \delta M$ (See Note 1)

3. $G = \frac{G}{H} \cdot \frac{H}{M} \cdot \frac{M}{D} \cdot \frac{D}{A} \cdot A$

4. $\delta G = \delta\frac{G}{H} + \delta\frac{H}{M} + \delta\frac{M}{D} + \delta\frac{D}{A} + \delta A$ (See Note 1)

5. $\delta\frac{RTM}{G} = \delta RTM - \delta G$ (See Note 1)

6. $\delta\frac{RTM}{G} = \delta\frac{RT}{P} + \delta\frac{P}{S} + \delta\frac{S}{A} + \delta A + \delta M - \delta\frac{G}{H} - \delta\frac{H}{M} - \delta\frac{M}{D} \; \delta\frac{D}{A} - \delta A$ (See Note 1)

7. $\delta\frac{RTM}{G} = \delta\frac{RT}{P} + \delta\frac{P}{S} + \delta\frac{S}{A} + \delta M - \delta\frac{G}{H} + \delta\frac{M}{H} - \delta\frac{M}{D} - \delta\frac{D}{A}$ (See Note 1)

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RTM = Revenue Ton Miles
RT = Revenue Tons
P = Number of Passengers
S = Number of Passenger Seats
A = Number of Aircraft
M = Number of Miles Flown
G = Gallons of Fuel Burned
H = Number of Hours Flown
D = Number of Departures

**Note 1: The above equations are not exact but are satisfactory approximations when the percentage changes are small.**

**Note 2: The operator "δ" represents "percentage change in."**

1. $\delta \frac{RT}{P}$, PERCENTAGE CHANGE IN REVENUE TONS PER PASSENGER

This component is a measure of payload weight on a per passenger basis. Increases in payload weight on a per passenger basis produce increases in RTM/G. Payload weight basically consists of the weight of the passenger and the passengers' proportionate share of cargo. Present reporting techniques use standard weights for passengers rather than actual weights. Therefore, carrying heavier passengers is not a viable method for increasing RTM. However, the cargo weight per passenger is controllable. By increasing cargo carried per flight, RTM can be increased. The fact that the cargo load factor has been less than the passenger load factor for years suggests that RT/P is capable of being increased. The shift to wide-bodied aircraft has permitted a substantial increase in lower hold cargo capacity. For example, available tons of lower hold cargo capacity per available seat is about .035 for the B-727 and 0.6 for the B-747.

2. $\delta \frac{P}{S}$, PERCENTAGE CHANGE IN LOAD FACTOR

The proportion of seats which are occupied is the single most critical element in RTM calculations. The number of passengers enplaned per flight is the result of both supply and demand decisions. Demand is heavily influenced by both fares and schedules. Indeed, lowering fares and shifting existing flights to more desirable time slots can both increase the average load factor. Supply constraints can also raise load factors.

3. $\delta \frac{S}{A}$, PERCENTAGE CHANGE IN SEATS PER AIRCRAFT

This component measures aircraft passenger capacity. Increases in seating capacity lead to increases in RTM if the average load factor remains constant. Policy options which directly impact S/A include changing the fleet mix and the reseating of existing aircraft.

4. $\delta M$, PERCENTAGE CHANGE IN MILES FLOWN

The greater the number of miles that a given payload is flown, the greater the RTMs. Generally, increases in miles flown could derive from longer average stage lengths or increased departures. An increase in stage length increases both RTMs and gallons burned, but raises the former more than the latter. Increased departures result in more miles, but may reduce average load factors if the increase in available seats exceeds the number of increased enplanements.

5. $\delta\frac{G}{H}$, PERCENTAGE CHANGE IN GALLONS BURNED PER HOUR

In terms of policy options, the major share of proposed options operate directly on G/H and, through its reduction, to increases in RTM/G. One of the most important factors in gallons burned per hour in the short run is delay. Many of the policy options are designed to lower the amount of delay in the system. The adoption of FAD and gate hold procedures permits delay to be taken on the ground. Installation of Wake Vortex Avoidance Systems and the associated reduction in separations increase airport capacity and thereby decrease delay. Greater availability of both permanent and temporary runways to handle traffic during permanent runway downtime (construction) reduces delay. Certain flight and ground operations directly affect fuel burn. Reduced fuel tankering, more frequent trim readjustment, loading to move the center of gravity to the aft limit, and taxiing on fewer engines all lower hourly fuel burn and increase RTM/G. In the intermediate and long run, more fuel-efficient aircraft will be available; however, in the short run, operational options are available which can improve the efficiency of fuel usage.

6. $\delta\frac{M}{H}$, PERCENTAGE CHANGE IN MILES PER HOUR

A straightforward interpretation of this component would be to go faster and reduce gallons consumed. This can only be meaningful to the extent that going faster exceeds an increase in fuel burn per hour. Unfortunately, minimum fuel burn speeds and minimum aircraft direct operating costs (DOC) speeds differ. A faster flight lowers crew costs but raises fuel costs, and vice versa. The solution is a speed selection which neither minimizes crew costs nor fuel burn but minimizes their sum. Consequently, if flight at .82 Mach would optimize crew costs while flight at .78 Mach would optimize fuel efficiency, the economic solution might be flight at .80 Mach which may minimize the sum of the costs. There are a number of policy options which impact speed and fuel burn. Revised climb procedures in TCA's to permit higher speeds improve fuel burn because the speed limits are currently too low. Optimal aircraft descent procedures incorporate speed reductions and uninterrupted descent for fuel savings. Optimum cruise speed and optimum altitude decisions require speed and fuel burn tradeoffs.

7. $\delta\frac{M}{D}$, PERCENTAGE CHANGE IN STAGE LENGTH

An increase in the average stage length results in more miles flown and more gallons of fuel being burned. The fuel burn on short stage lengths is more heavily weighted by the higher takeoff and climb fuel burn. The impact of longer stages on fuel burn is partially offset by the lowered burn per hour in cruise. The net effect is more fuel burned on longer stages; however, the increase in revenue ton miles is greater relative to the increase in fuel burned so that longer stages raise RTM/G.

8. $\delta\frac{D}{A}$, PERCENTAGE CHANGE IN DEPARTURES PER AIRCRAFT

More flights mean increased fuel burn. Decreasing system capacity through curtailed flights at higher payloads has been a key solution to improved airline performance in the face of fuel shortages and higher fuel prices. Improved training techniques making greater use of simulators have also helped reduce the number of flights and thereby lower fuel burn. Reduced ferry flights for maintenance and schedule protection also improves RTM/G. Changing certification requirements and grounding select flights during peak congestion can reduce fuel burn. The primary effects of a change in departures per aircraft is on the effective fleet mix (percent of RTMs versus percent of fleet by aircraft type) and on the average load factor. Excessive aircraft utilization can also lead to engine deterioration and increased fuel inefficiency.

## B. EVALUATION OF SHORT RUN POLICY OPTIONS

The Policy Evaluation Model is used to evaluate proposed programs by determining which variables of the model are affected by the specified options within each program being evaluated. To relate the options to the appropriate variables within the model, the following approach is used: the method of increase in RTM/G is based on the variables of the model. The options are then listed that primarily impact on the method variable under consideration. By analyzing the options in this manner, areas of responsibility for the options, as discussed previously, are often mixed. For the most part, however, options fall neatly within the same area of responsibility. For example, both "Optimum Altitude" and "Optimum Speed" affect aircraft miles per gallon and both are controlled by aircraft operators and management. However, these options require an air traffic control environment that will allow their execution.

The method of RTM/G (via the model), the options under that method, and the quantitative impact analysis are presented according to the outline in Table 11.

TABLE 11

SHORT RUN POLICY OPTION GROUPINGS

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RAISE SEATS PER AIRCRAFT

- o Increase Load Factor Through Capacity Restraint
- o Reseat Existing Aircraft

REDUCE GALLONS PER HOUR BY REDUCING DELAY

- o FAD
- o Wake Vortex Class Sequencing
- o Wake Vortex Avoidance Systems at Major Airports
- o Decrease IFR Spacing
- o Short, Temporary Parallel Runways During Airport Construction and Reconstruction
- o Snow-Ice Removal Equipment
- o Short, GA Runways at Large Hub Airports

REDUCE GALLONS PER HOUR BY AIR/GROUND OPERATIONS

- o Load to Aft Center of Gravity (CG)
- o Reduce Fuel Tankering
- o Taxi on Fewer Engines

REDUCE GALLONS PER HOUR AND MILES PER HOUR

- o Climb Procedures in TCA's
- o Optimum Descent
- o Optimum Cruise Speeds
- o Optimum Altitude

REDUCE MILES AND STAGE LENGTH

- o Expand Use of RNAV
- o Maximum Use of Simulators

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The eighteen short run options are evaluated under each of the methods. By evaluating individual options by method, the non-additive options are explicated. For example, "Wake Vortex Class Sequencing" and "Wake Vortex Avoidance Systems at Major Airports" are both evaluated under the method "Reduce Gallons Per Hour By Reducing Delay." They are clearly nonadditive: the wake vortex problem is solved only once. However, "Taxi on Fewer Engines," which is evaluated under a different method, would be additive to either of the wake vortex options.

Many of the options required an evaluation using the civil aviation fleet mix. The January 1, 1975, fleet mix for U.S. air carriers was: 199 Twin-engine Truboprop, 523 Twin-engine Turbojet, 923 Three-engine Turbojet, 67 Four-engine Turboprop, and 632 Four-engine Turbojet. The B727 Three-engine is both the average and most frequently used airplane in the fleet. For many computations, the B727 was used as the "typical" plane. If the effect of fleet mix is believed to be negligible, then B727 figures are used. Of course, if fleet mix is necessary to the analysis, an airplane-by-airplane approach is used. After much of the analysis was completed, the January 1, 1976, civil aviation fleet statistics became available. The 1976 fleet statistics were not very different from those of the 1975 fleet, with the total fleet size changing by less than one-tenth of one percent (from 2,472 to 2,495 aircraft). Thus, the analysis would have changed very little. Indeed, the use of the B727 as the typical aircraft was further justified, since the B727 represented 32 percent of the 1976 fleet versus 30 percent of the 1975 fleet. 2/

1. METHOD: RAISE SEATS PER AIRCRAFT

OPTIONS:
- o Reseat Existing Aircraft
- o Increase Load Factor Through Capacity Restraint

Raised seats/plane and/or increased load factors through capacity restraint can improve RTM/G. In terms of current aircraft, this can be accomplished by raising the number of seats per aircraft (reseating) assuming there is sufficient demand to maintain a constant load factor, or by raising load factors with a no more than an offsetting decline in seats per plane due to a reduction in aircraft capacity (changing the fleet mix towards the use of smaller planes). This latter approach works because flying the same number

2/ Federal Aviation Administration, Census of U.S. Civil Aircraft Calendar Year 1975. Springfield, Virginia: National Technical Information Service, 1976.

of RTM on a smaller airplane uses fewer gallons of fuel. The reseating of smaller aircraft (e.g., B727-200) offers the dual opportunity of raised load factors (via substitution) and more seats per airplane.

An increase of one ton of weight in a B727-200 increases gallons used by 12.9 percent (120 pounds) for a typical stage length (6 percent added weight). A seat and passenger weighs about 200 pounds. Using a base aircraft of 120 seats, a flight time of 50 minutes, a fuel burn rate of 17.3 gallons per minute, and a 50 percent load factor, then a 10 percent increase in seats (12) adds 1.5 percent to fuel burn for a net 6.6 percent gain in RTM/G (10 percent increase in seats is 8.1 percent increase in RTMs minus 1.5 percent increase in gallons used).

An increase in average load factor by capacity restraint increases RTM/G by reducing the number of gallons used via fleet mix changes. The average load factor for many years has been around 53 percent. The option of eliminating a number of flights (reduce capacity) in order to raise load factors has not been implemented. The reduction in the number of flights following the 1973 OPEC embargo was more in response to the induced recession than to any desire to raise load factors. The fundamental resistance to capacity reduction has been the fact that passenger rejection rates rise with load factors.

The substitution of a smaller aircraft for a larger one on some flights is an alternative to reducing the total number of flights; however, only some fleet mix substitutions are fuel efficient. A 50 percent load factor on a DC-8 would be a 70 percent load factor on a B727-200 and the B727 would burn 0.48 fewer gallons per aircraft mile. However, a 45 percent load factor on a B747 would be a 62 percent load factor on two B727's and the two B727's would burn .56 more gallons per aircraft mile. The primary substitution within the fleet is B727's for DC-8s. A total substitution would affect 8.3 percent of the 1974 fleet and 7.8 percent of the 1975 fleet. Aircraft economics, however, prevents total substitution.

Each aircraft in the fleet flies about half a million miles per year. Substituting a B727 for a DC-8 would, therefore, save 240,000 gallons per year. Total substitution within the 1975 fleet would save 42.5 million gallons per year for a maximum increase in RTM/G of 0.6 percent. The average load factor would rise to 54 percent for B727's, or 51 percent for the fleet (assuming an initial load factor of 50 percent). Table 12 presents the effects of reseating and/or capacity reduction. The effects are additive.

## TABLE 12

## EFFECT ON RTM/G OF INCREASED SEATS/PLANE

## WITH MINIMUM 50 PERCENT LOAD FACTOR

| Load Factor From Substitution | Percent Reseating of Aircraft | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 2 | 4 | 6 | 8 | 10 |
| 50 | 0 | 1.3 | 2.6 | 4.0 | 5.3 | 6.6 |
| 50.2 | .1 | 1.4 | 2.7 | 4.1 | 5.4 | 6.7 |
| 50.4 | .2 | 1.5 | 2.8 | 4.2 | 5.5 | 6.8 |
| 50.6 | .4 | 1.7 | 3.0 | 4.4 | 5.7 | 7.0 |
| 50.8 | .5 | 1.8 | 3.1 | 4.5 | 5.8 | 7.1 |
| 51 | .6 | 1.9 | 3.2 | 4.6 | 5.9 | 7.2 |

Percent Increase in RTM/G

Some of the benefits from reseating and capacity changes have already been realized by the air carriers. In particular, reseating has been extensive since 1973. An additional one percent in reseating and sufficient capacity changes to raise the overall load factor by 0.6 percent is reasonable within the next two years. The time frame for the effect on RTM/G is shown below:

TIME FRAME: RAISE SEATS PER AIRCRAFT OPTIONS

| Cumulative Effect on RTM/G | 1977 | 1978 |
|---|---|---|
| Reseating/Capacity Restraint | 0.5 | 1.1 |

2. METHOD: REDUCE GALLONS PER HOUR BY REDUCING DELAY

OPTIONS:
- o Fuel Advisory Departure Procedures
- o Wake Vortex Class Sequencing
- o Wake Vortex Avoidance Systems at Major Airports
- o Decrease IFR Spacing (Parallel Runways)
- o Short, Temporary Parallel Runways During Airport Construction and Reconstrunction
- o Short, GA Runways at Large Hub Airports

Certainly, one of the primary causes of fuel inefficiency in the National Airspace System is delay. Table 13 is based upon measured delay data for CY-1975.

The seven options listed above are all aimed at reducing delay within the NAS. A delay reduction reduces gallons used for the same Revenue Ton-Miles; hence, the percentage reduction in gallons is identical to the percentage increase in RTM/G. The eight options divide logically into three groups:

(1) FAD

(2) Wake Vortex Class Sequencing
Wake Vortex Avoidance Systems at Major Airports

(3) Decrease IFR Spacing
Short, Temporary Parallel Runways During Airport Construction and Reconstruction
Snow-Ice Removal Equipment
Short, GA Runways at Large Hub Airports

TABLE 13

ESTIMATED SYSTEM DELAY BY SOURCE

CY-1975 1/

| Source | | Number of Minutes (Thousands) | Percent |
|---|---|---|---|
| Taxi-Out | | 11,829.7 | |
| Taxi-In | | 3,247.8 | |
| | GROUND DELAY | 15,077.5 | 49.7 |
| Airborne | | 14,225.1 | |
| | AIRBORNE DELAY | 14,225.1 | 46.9 |
| Awaiting ATC Clearance | | 138.0 | |
| Weather 2/ | | 775.8 | |
| Ramp Taxiway Congestion | | 101.4 | |
| | GATE DELAY 3/ | 1,015.2 | 3.4 |
| TOTAL | | 30,317.8 | 100.0 |

1/ Source: Estimated from "Airline Delay Data 1970-1974," DOT, FAA, Air Traffic Service Executive Staff, Washington, D.C., February 1975, and reported data for 1975 (unpublished) provided to the FAA by Eastern Airlines.

2/ Refers only to delays at the gate attributed to local weather, not total delays which occur as a result of weather.

3/ Causes not related to air carrier operating procedures.

FAD attacks delay directly, the second group increases effective airport capacity by increasing the number of operations per hour through closer spacing of operations, and the third group increases actual airport capacity. The three groups have considerably different impacts on RTM/G.

By encouraging ground delays instead of airborne delays, FAD will alter the rate of fuel usage (a B727 uses 19 gallons per minute in cruise, 8.3 gallons per minute on the ground, and 1.7 gallons per minute at the gate). Furthermore, FAD tends to spread delays throughout the system with the effect that the "peaking" problem is smoothed over several hours.

Figure 1 below illustrates how FAD and the capacity procedures reduce delay. With a capacity limit of C' operations per hour, delay occurs when the curve F (actual operations per hour) crosses C. The shaded area above C represents delays. FAD alters the actual operations per hour line from F to F' and does not affect C; that is, until the limit C is approached, nothing happens and near C flights are spread over more hours. The other procedures increase the number of operations per hour that can be handled at the airport

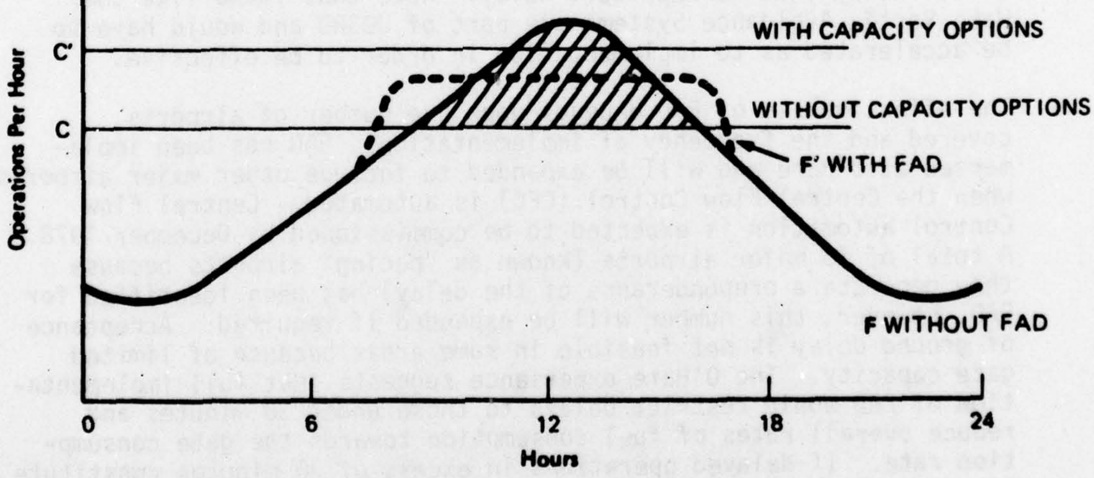


**Figure 1: How FAD and Capacity Options Transfer Delay.**

from C to C' without affecting the curve F. Both approaches reduce delays. In the example, the combination of approaches totally eliminated delay (F' is below C'). FAD is additive as an option to the other six; whereas, most of the other six are not pair-wise additive.

It should be noted that FAD works by spreading the peak area in the diagram. To the extent that capacity is exceeded over several consecutive hours, the effectiveness of FAD diminishes. Tests of FAD at Chicago O'Hare have indicated that significant savings are possible with FAD procedures.

Similarly, the other six options depend upon the kurtosis (peakedness) of the curve in that a very peaked curve will be less affected by changes in capacity than will a flatter curve. Table 13 presents the effects on capacity of the options excluding FAD.

In Table 14, the first three items are essentially nonadditive. The last three are not perfectly additive, but are nearly so. The first three options are specifically designed for departure (ground) or arrival (airborne) delays. The last three affect all delays. If there were no interdependencies, all six options were implemented, and maximum delay reductions were obtained, then delay would be reduced by 34.4 percent. This impact is arrived at by assuming that each one percent increase in capacity reduces delay by 2.5 percent. The percentage delay reductions are then adjusted by the 58 percent of all delay that is arrival delay and/or the 39 percent of all delay that is departure delay. Note that items like the Wake Vortex Avoidance Systems are part of UG3RD and would have to be accelerated as to implementation in order to be effective.

The effectiveness of FAD depends upon the number of airports covered and the frequency of implementation. FAD has been implemented at O'Hare and will be expanded to include other major airports when the Central Flow Control (CFC) is automated. Central Flow Control automation is expected to be commissioned by December 1978. A total of 16 major airports (known as "pacing" airports because they generate a preponderance of the delay) has been identified for FAD, however, this number will be expanded if required. Acceptance of ground delay is not feasible in some areas because of limited gate capacity. The O'Hare experience suggests that full implementation of FAD would restrict delays to those under 30 minutes and reduce overall rates of fuel consumption towards the gate consumption rate. If delayed operations in excess of 30 minutes constitute 25 percent of all delays, then 7.6 million minutes (25 percent of 30.3 million minutes of Table 13) could be saved by FAD. This would reduce gallons used by 131.5 million gallons (using 17.3 gallons per minute net savings). Table 4 showed 7,738 million gallons used in 1975. Thus, FAD could decrease fuel usage a maximum of 1.7 percent.

TABLE 14

AIRPORT CAPACITY-INCREASING OPTIONS

| Option | Maximum Increase In Capacity | Maximum Delay Reduction |
|---|---|---|
| Wake Vortex Class Sequencing | 4.0% | 5.8% A |
| Wake Vortex Avoidance Systems at Major Airports | 2.0% | 2.9% A |
| Decrease IFR Spacing | 0.5% | 0.7% A |
| Short, Temporary Parallel Runways During Airport Construction and Reconstruction | 1.8% | 4.4% B |
| Snow-Ice Removal Equipment | 0.8% | 1.9% B |
| Short, GA Runways at Large Hub Airports | 6.5% | 15.8% B |

A = Arrival Delay Only

B = Both Departure and Arrival Delay

As stated previously, several of the options are interdependent. However, gross impacts are shown below. The interdependencies are accounted for in the cross impact analysis of Volume III. A forecast is provided at the end of this chapter which also utilizes cross impact analysis restricted to the short run options alone.

The impact on RTM/G of each of these options is due to reduced gallons alone. To derive the impact, each of the maximum delay reduction figures of Table 14 is applied to the total system delay minutes of Table 13, multiplied by 17.3 gallons per minute net savings, then divided by the CY-1975 gallonage of 7,738 million gallons.

The time frame of the options presumes half of the gain in 1977 and the remainder in 1978.

TIME FRAME: DELAY REDUCING OPTIONS

| Cumulative Effect on RTM/G | 1977 | 1978 |
|---|---|---|
| Option | | |
| FAD | .85 | 1.70 |
| Wake Vortex Class Sequencing | .20 | .40 |
| Wake Vortex Avoidance Systems | .10 | .20 |
| Decrease IFR Spacing | .02 | .05 |
| Short, Temporary Runways | .15 | .30 |
| Snow-Ice Removal Equipment | .06 | .13 |
| Short, GA Runways | .54 | 1.07 |

3. METHOD: REDUCE GALLONS PER HOUR BY IMPROVING AIR/GROUND OPERATIONS

OPTIONS:
- o Reduce Fuel Tankering
- o Taxi on Fewer Engines
- o Load to Aft Center of Gravity

Fuel tankering produces reductions in RTM/G by its upward impact on gallons. Tankering increases fuel burn per flight because the aircraft burns more fuel to carry the added weight of the tankering fuel. Braniff estimates that 2,000 pounds of tankered fuel requires an additional 120 pounds in fuel burn. For a typical stage, this can increase gallons (G) by as much as one percent for a Boeing 727. Since tankering is economically desirable from the low cost station to a high cost station, a maximum of half of all flights would be between equal price stations. On balance, it is estimated that the maximum percentage decrease in G from elimination of tankering would, therefore, be 0.3 percent.

By taxiing to and from the gate on fewer engines, the fuel burned per flight is lowered. The three-engine Boeing 727 can taxi on two engines, for example. Many air carriers have adopted this practice following the fuel price increases of the early seventies as the resulting dollar savings have risen. It has been estimated that fuel savings of .8 percent can be obtained if all flights would taxi on fewer engines. 3/ However, much of the potential gain from this practice has already been realized. Further, many aircraft cannot feasibly taxi on fewer engines (two-engine and four-engine aircraft present special problems). Given these qualifications, it is estimated that no more than one-half of all flights are amenable to reduced engine taxi and that one-half of these flights are already using the technique. This means potential future savings from reduced engine taxi equals .2 percent. The realistic potential increase in RTM/G from taxiing on fewer engines equals .2 percent.

The location of the center of gravity affects the rate of fuel burn in flight. Given the present aircraft fleet, an aft movement of the CG would produce fuel savings. Lockheed has estimated that a one percent aft CG movement would lower fuel burn by .2 percent. 4/ The benefits of such a movement are relatively uniform over aircraft type. The potential increase in RTM/G is .2 percent.

Assuming maximum yield from these three options is achieved in the short run and that the yield is completed equally in both years, the time frame below summarizes the cumulative effect of the implementation of these options.

3/ Pilati, David, "Energy Use and Conservation Alternatives for Airplanes," Transportation Research, 8 ( ), p. 439.

4/ Lockheed-California Company, Cost/Benefit Tradeoffs for Reducing the Energy Consumption of the Commercial Air Transportation Center, Final Oral Presentation, April 7, 1976, p. 17.

TIME FRAME: AIR/GROUND OPERATIONS OPTIONS

| Cumulative Effect on RTM/G | 1977 | 1978 |
|---|---|---|
| Option | | |
| Reduce Fuel Tankering | .15 | .30 |
| Taxi on Fewer Engines | .10 | .20 |
| Load to Aft CG | .10 | .20 |

4. METHOD: REDUCE GALLONS PER HOUR AND MILES PER HOUR

OPTIONS:
- o Climb Procedures in TCA's
- o Optimum Descent
- o Optimum Cruise Speeds
- o Optimum Altitude

The way an aircraft is operated affects the rate of fuel usage in transporting the same quantity of RTMs. These four options are concerned with the climb, descent, and cruise (altitude and speed) procedures. The B727 is used to evaluate the impact of these options.

The cruise options are easier to implement; indeed, the airlines have begun to institute them to a degree. Unfortunately, cruise speed reductions have been based on minimizing total costs rather than fuel consumption. At 31,000 feet, a reduction in cruise speed from .82M to .8M reduces fuel usage by 1.3 percent; however, a further reduction to .78M reduces fuel usage an additional 1.7 percent. 5/

For a given aircraft weight and speed, there is an optimum altitude with respect to fuel usage. An increase in cruise altitude reduces fuel usage. For example, flying at FL 350 (35,000 feet), instead of at FL 310 reduces fuel consumption by 2.6 percent. 5/ Cruise speed reduction to .78M would require FAA encouragement to the air carriers (or higher fuel prices), but higher altitude assignments

5/ United Technologies Research Center, Cost/Benefit Tradeoffs for Reducing the Energy Consumption of Commercial Air Transportation, East Hartford, Connecticut: Final Report No. R76-912036-16, June 1976.

fall completely within the area of control of the FAA. Table 15 presents a summary of the cruise speed and altitude results. The effects of cruise altitude and cruise speed are approximately additive.

The "Climb Procedure in TCA's" and "Optimum Descent" options are severely constrained by ATC procedures. The primary climb procedure problem is the maximum speed permitted in TCA's of 250 knots below 10,000 feet. The recommended climb speed for minimum fuel burn is 320 knots for a Boeing 727-200. It has been estimated that use of the optimal climb procedure would save slightly less than 100 pounds as the benchmark 6/ and extrapolating through the airline industry, the decrease in G is .16 percent and the increase in RTM/G would be the same. The speed limit is also a constraint on descent procedures in the TCA's.

Conventional descent procedures evolved under an ATC system designed to maximize airport capacity and aircraft safety. The challenge today is to control traffic on the basis of those two criteria while permitting aircraft to fly minimum fuel profiles. Conventional step descent profiles require additional fuel usage to maintain a given assigned altitude. The resulting low speeds of the conventional descent profile induce drag and result in a non-clean configuration early in the descent. By using an idle thrust optimal descent for a B727-200, the fuel savings have been estimated as 1.5 percent on an average stage length. 7/ The descent would begin at over 87 nautical miles from the destination, however, producing an increased FAA en route control problem. NASA has analyzed specific landing approach profiles and found the reduced flap, delayed flap, and decelerating approaches to produce significant fuel savings. The approach profile can be considered a part of the idle descent procedure, however, and the analysis of the NASA procedures produces results compatible with those previously obtained. Safety-related problems will have to be resolved before full implementation of profile descent procedures can proceed.

A 90 day test at Kansas City International indicated a fuel savings greater than those estimated by Boeing and by NASA. Before this greater fuel savings can be realized, however, MLS facilities will be necessary. It is felt that 0.6 of the optimal descent impact can be gained prior to MLS with the remaining 2.0 percent impact MLS-dependent.

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6/ Braniff International, Braniff International Flight Operations Fuel Management Program, January 19, 1976.

7/ Erwin, Ralph and Alan Yarrington, "Fuel Conservation Arrival Control," Paper presented at Air Traffic Control Association 21st Annual Meeting, September 30, 1976, Miami Beach, Florida.

TABLE 15

METHOD: OPTIMUM CRUISE ALTITUDE AND CRUISE SPEED

(ASSUMES B727 AT .82M ON FL 310)

| Cruise Altitude (FL) | Cruise Speed (M) .82 | .81 | .80 | .79 | .78 |
|---|---|---|---|---|---|
| 310 | 0 | .60 | 1.30 | 2.10 | 3.00 |
| 320 | .65 | 1.25 | 1.95 | 2.75 | 3.65 |
| 330 | 1.30 | 1.90 | 2.60 | 3.40 | 4.30 |
| 340 | 1.95 | 2.55 | 3.25 | 4.05 | 4.95 |
| 350 | 2.60 | 3.20 | 3.90 | 4.70 | 5.60 |

Decrease in Fuel Consumption (Percent)

The maximum effects obtainable from the four options in the short run are: 0.7 percent for cruise speed (.81M to .80 M), 0.65 percent for altitude (1,000 feet), 0.60 for optimum descent, and .16 for climb procedures for TCA's.

The benefits are presumed to be captured equally in the two periods with the resultant time frame of benefits shown below.

TIME FRAME: AIRCRAFT OPERATIONS OPTIONS

| Cumulative Effect on RTM/G | 1977 | 1978 |
|---|---|---|
| Option | | |
| Climb Procedures in TCA's | .08 | .16 |
| Optimum Descent | .30 | .60 |
| Optimum Cruise Speeds | .35 | .70 |
| Optimum Altitude | .32 | .65 |

5. METHOD: REDUCE GALLONS BY MINIMIZING DISTANCE TRAVELED

OPTIONS:
- o Expand Use of RNAV
- o Maximum Use of Simulators

The optimum flight distance for minimal fuel consumption per flight between two airports is the straight line distance. The RNAV system moves flight paths closer to this ideal by diminishing the flights "to a VOR." Thus, gallons used will decrease absolutely with RNAV. Full implementation of RNAV would decrease distance flown by about 2 percent. Since the CAB calculates Revenue Ton-Miles on the basis of standardized mileage, the fuel savings would translate directly into an increase in RTM/G. Unfortunately, it is highly unlikely that RNAV can be effectively implemented before 1978 even on an accelerated program basis. Even then, the 2 percent goal will only gradually be attained as the RNAV network is extended. With a concerted effort to implement RNAV as quickly and efficiently as possible, the time frame below gives maximum expected results. Further benefits are obtained in the intermediate and long run.

The increased use of simulators will raise RTM/G by lowering the amount of fuel burned. Training flights do not contribute significantly to RTM but do produce substantial fuel burn. To the extent that the use of simulators reduces fuel consumption, it will increase RTM/G.

The FAA has provided the means through the regulatory process for maximum utilization of aircraft simulators for training and checking of flight crewmembers commensurate with the state of the art of simulation. The FAA encourages operators to acquire simulators and visual attachments so they may make more effective use of this fuel-conserving practice. The rapid improvements in simulator technology of the past few years has also led to increased simulator usage.

The savings to be realized by additional use of simulators varies by the type of aircraft for which simulator training is being received. The fuel savings from the maximum use of simulators by type of aircraft is given by:

| Type of Aircraft | Savings Per Aircraft/Year |
|---|---|
| B-747 | 25,000 gallons |
| DC-10 | 18,480 gallons |
| B-707 | 25,000 gallons |
| B-727 | 8,000 gallons |
| L-1011 | 27,600 gallons |

Of the major types of aircraft used by air carriers, the one not included in the table is the DC-8. For purposes of calculating impacts it is assumed to be similar to B-707 and to, therefore, yield similar savings from simulator utilization.

Based on the 1975 fleet mix for domestic air carriers, the potential fuel savings from simulator usage equals 24.6 million gallons annually or .3 percent of fleet fuel. This converts directly into a .3 percent potential gain in RTM/G.

The near-term impact of simulators on RTM/G depends upon the percentage substitution by airlines of simulator training for flight training. Present indicators are that between 20 and 40 percent of the maximum potential gains from use of simulators is near term. Therefore, it is expected that greater use of this training device will contribute .1 percent to the increase in RTM/G.

A second factor in the consumption of fuel due to training is the changing composition of the fleet mix. By acquiring wide-body aircraft, the airlines have also purchased high-cost aircraft for training pilots both in terms of dollars and of gallons of fuel. The present shift in fleet mix toward the Boeing 727 will bring about supplemental fuel savings in training so long as the aircraft tradeoff is one-for-one. The time frame is shown below for the expected savings from the increased use of simulators.

TIME FRAME: DISTANCE REDUCING OPTIONS

| Cumulative Effect on RTM/G | 1977 | 1978 |
|---|---|---|
| Options | | |
| o Expand Use of RNAV | 0 | .2 |
| o Maximize Use of Simulators | .1 | .1 |

## C. SYNTHESIS OF SHORT RUN POLICY OPTIONS

The policy options evaluated in Part B were treated as being independent. Raising seats/plane, reducing delay, utilizing fuel-saving ground/air operations, using fuel-optimal operating procedures, and expanding the use of RNAV and simulators were analyzed as if they could be implemented simultaneously with no pairwise reduction in effectiveness. This assumption is clearly invalid and is dealt with below. First, however, another problem in the analysis is addressed.

A crucial problem in the derivation of an Aviation Energy Conservation Program is a consideration of the effect of the programs on safety and/or environmental policies. Table 16 places the options by area of responsibility once again and evaluates the effect of these options upon other policy concerns. Some of the inter-policy effects are beneficial. For example, Wake Vortex Avoidance Systems and Snow-Ice Removal Equipment increase safety levels. Noise levels depend upon frequency and type of operations per airport. Decreased IFR spacing would increase overall traffic levels (reducing safety by reducing separations) and increase noise; FAD and most of the

TABLE 16

INTERACTION OF SHORT RUN ENERGY OPTIONS

WITH OTHER POLICIES

| Programs | Safety | Noise | Emissions |
|---|---|---|---|
| A. AIR TRAFFIC CONTROL | | | |
| 1. FAD | + | + | 0 |
| 2. Wake Vortex Class Sequencing | 0* | 0 | 0 |
| 3. Wake Vortex Avoidance Systems | +* | 0 | 0 |
| 4. Decrease IFR Spacing | - | 0 | 0 |
| 5. Expand Use of RNAV | + | 0 | 0 |
| B. AIRPORT PROGRAM | | | |
| 1. Temporary Construction Runways | 0 | 0 | 0 |
| 2. GA Runways at Hubs | 0 | 0 | 0 |
| 3. Snow-Ice Removal Equipment | + | 0 | 0 |
| C. AIRCRAFT OPERATORS AND MANAGEMENT PROGRAM | | | |
| 1. Simulators | 0 | + | + |
| 2. Capacity Restraint | 0 | + | + |
| 3. Reseat Existing Aircraft | 0 | + | + |
| 4. Reduce Tankering | 0 | + | + |
| 5. Climb Procedures | 0* | + | 0 |
| 6. Optimum Descent | 0* | + | + |
| 7. Optimum Cruise | 0 | 0 | 0 |
| 8. Optimum Altitude | 0 | 0 | 0 |
| 9. Taxi on Fewer Engines | 0 | + | + |
| 10. Load to Aft CG | 0 | 0 | 0 |

\+ = Beneficial Effect
\- = Potential Deleterious Effect
0 = Neutral Net Effect
* = Needs Test to Ensure That Safety is Not Adversely Affected

Aircraft Operators and Management Program options reduce noise. None of the options increase engine emissions and many of the Aircraft Operators and Management Program options reduce emissions.

On the basis of the analysis of Table 16, "Decrease IFR Spacing" is dropped as a short run policy option. Table 17 lists the final short run set of policy options which serve as inputs into the analysis of Volume III. The total figures of 3.90 percent in 1977 and 8.01 percent in 1978 are biased upward because the nonadditivity of options has not been evaluated. Nevertheless, it is clear that the gains from short term energy options alone are limited.

The desired maximum increase in RTM/G will require intermediate and long run solutions. These solutions are essentially technological in nature and are capable of significant increases in aviation fuel efficiency. Of course, the desired improvement in RTM/G could be obtained by simply raising the average load factor on existing flights to the range of 60 to 70 percent. Such an increase in load factor would be uncharacteristic of the existing aviation transportation marketplace, however. The advent of regulatory reform, if and when it occurs, could fundamentally alter the behavior of the airlines. There is no assurance, however, that the airlines would desire to increase load factors above their current levels. Rather than depending upon the uncertain possibility of load factor increases, for whatever reason, to improve RTM/G, it is in the best interests of all concerned to aggressively pursue concrete solutions to the energy conservation problem. The seventeen short run options listed in Table 17 are combined with the intermediate and long run options of Volume II.

A forecast of RTM/G for 1977 and 1978 is calculated under the assumption that the above options are implemented. Option interactions (essentially, nonadditivity) had to be taken into account to perform the forecast. Options 2, "Wake Vortex Class Sequencing," and 5, "Temporary Construction Runways" were deleted; the former because of longer run considerations and the latter because of dominance by option 6. The improvement in RTM/G based upon Table 17 is then seen to be 3.55 percent in 1977 and 7.31 percent (cumulatively) for 1978.

The 1976 value of RTM/G adjusted for the load factor increase experienced between 1975 and 1976 (54.8 percent versus 55.8 percent) is 2.25. Thus, a .06 rise in RTM/G was due strictly to the load factor increase, and subsequently, results in a 1977 RTM/G value of 2.41. While this provides a clear improvement over current RTM/G levels, the goal of maximizing RTM/G has not been met

TABLE 1/

SHORT RUN ENERGY CONSERVATION OPTION SET:

MAXIMUM CUMULATIVE IMPACT ON RTM/G

| | 1977 | 1978 |
|---|---|---|
| A. AIR TRAFFIC CONTROL | | |
| 1. FAD | .85% | 1.70% |
| 2. Wake Vortex Class Sequencing | .20 | .40 |
| 3. Wake Vortex Avoidance Systems | .10 | .20 |
| 4. Expand Use of RNAV | 0 | .20 |
| B. AIRPORT OPTIONS | | |
| 1. Temporary Construnction Runways | .15 | .30 |
| 2. GA Runways at Hubs | .54 | 1.07 |
| 3. Snow-Ice Removal Equipment | .06 | .13 |
| C. AIRCRAFT OPERATORS AND MANAGEMENT OPTIONS | | |
| 1. Simulators | .10 | .10 |
| 2. Capacity Restraint | .35 | .70 |
| 3. Reseat Existing Aircraft | .20 | .40 |
| 4. Reduce Tankering | .15 | .30 |
| 5. Climb Procedures | .08 | .16 |
| 6. Optimum Descent | .30 | .60 |
| 7. Optimum Cruise | .35 | .70 |
| 8. Optimum Altitude | .32 | .65 |
| 9. Taxi on Fewer Engines | .10 | .20 |
| 10. Load to Aft CG | .10 | .20 |
| TOTAL | 3.90% | 8.01% |

**NOTE: These options are not independent. The total, therefore, considerably overstates the achievable result from 1979-1981 and is provided as an upper bound only. This problem is addressed in Volume III of this report.**

beyond 1978. The intermediate and long run options evaluated in Volume II must be an integral part of The Aviation Energy Conservation Program. By integrating options from the short, intermediate, and long run, an Aviation Energy Conservation Program is proposed in Volume III. This proposed program maximizes RTM/G for the 1977-1990 period, consistent with other policies.

APPENDIX

SUPPLEMENTAL SHORT TERM

ENERGY POLICY OPTIONS

## APPENDIX

## SUPPLEMENTAL SHORT TERM ENERGY

## POLICY OPTIONS

There were several energy options studied during the early stages of this project which were filtered for a number of reasons and excluded from the presentation in Chapter V. Some options have already been implemented, others are more specifically related to Federal agencies other than the FAA, still others were felt to have negligible effects on RTM/G, the basic thrust of this report.

Although many options were identified and deleted in the first screening stage, it is highly likely that one or more of these options could reappear as a significant energy conservation measure and for this reason they are listed below.

1. QUOTA FLOW CONTROL AT TCA-I's

   Quota flow control assigns airport arrival quotas based on capacity. When capacity is reached, departures in adjacent centers are assigned ground delay and long distance flights will be delayed en route. The Air Traffic Control Systems Command Center (ATCSCC) in Washington, D.C., will determine when quotas are to be imposed, generally when delays exceed 30 minutes.

2. PASSENGER WEIGHT

   The commercial airlines figure passenger weight by use of weight standards for weight and balance purposes. The standard used is 160 pounds per passenger in summer and 165 pounds in winter. No weight distinction is made by sex. This proposal is to lower the standard weight for women by 20 pounds in both the summer and winter categories. There are several different impacts associated with this change. By lowering calculated passenger weight, smaller fuel requirements are legally needed. By lowering calculated passenger weights, the aircraft can take on additional fuel and possibly eliminate a fuel inefficient intermediate stop. In addition, the current emphasis on reseating aircraft to increase capacity may encounter the weight problems associated with too high a standard for women.

3. PEAK HOUR CONGESTION LANDING FEES

   At present, those landing fees in existence in the U.S. are designed more to generate revenue than to control the flow of aviation at



[redacted]

the airfield. Present fees tend to be fixed per landing with little variation except as to aircraft size. There is no incentive to avoid peak-time airport use. The proposal is to use landing fees as a control device for adjusting traffic flow. Higher landing fees for peak hours will drive marginal flights to alternative time periods, thus spreading the load. Those hurt most by high landing fees will be general aviation and commuter airlines. General aviation is a large part of the problem of congestion and the value judgment to restrict their access to specific airports appears economically desirable. Commuter airlines can be offered partial exemption from landing fees, or CAB subsidies can be used to finance the fees, should it be socially and economically desirable for them to fly in peak time.

4. ADMINISTRATIVE QUOTAS

Twice annually, the capacity limitations of the airport(s) could be evaluated and limitations set in terms of hourly runway capacity, hourly passenger flow capacities of terminal buildings, and availability of aircraft stands. The airlines would make bids against these declared capacities, in the form of proposed schedules, and an airline committee would adjust these proposed schedules to bring them within the declared capacities. These adjustments also seek to smooth out any short transitory peaks that might cause congestion, even though the total demand for the hour as a whole is within the declared capacity.

5. BID QUOTAS

The identification of aircraft by a fuel usage category or codes could be used by ATC to adjust traffic flow. Verbal communication of aircraft type to ATC now gives the controller a general feel for the fuel burn level of the aircraft (controllers know the difference between a Boeing 747 and a Cessna 150). However, added precision in such distinctions could be gained by a classification scheme for arrival and departure priorities based on fuel burn per minute. Such a code could conceivably be included in the transponder code and displayed on radar along with position and altitude.

6. TAXIWAY ADDITIONS AND MODIFICATIONS

Generally, there is only one taxiway which leads to the takeoff area of the runway in use. It is generally not feasible for one aircraft to pass another aircraft in the queue, i.e., large aircraft cannot pass small aircraft and move forward in departure queue. One proposal is to redesign airfields so that two or more queues feed the staging area. Thus, separation is possible and priority departures become a feasible flow control device on the ground. A variation of this option is to use more runways, especially short runways where light aircraft can be diverted for departure. Further inefficient taxiway systems on many of today's airports can be improved by relatively simple taxiway additions wherever single taxiways or parallel taxiways exist. Additional runway turnoffs could reduce taxi distances.

7. CREW/EQUIPMENT QUALIFICATIONS

The air traffic flow control system should consider qualifications of equipment and crews when approving departures to airports experiencing delay problems. Certain aircraft can land while others must hold. As a means of allowing the ATC system to distinguish added capacity, airspace users should be encouraged to report their capability data (Category II or Category III equipment) as part of the flight plan.

8. FUEL DUMPING

The requirement for a pilot to exercise his emergency authority in the event of an overweight landing often results in unnecessary fuel dumping. A review, and possible amendment, of the regulations pertaining to fuel dumping and overweight landing might be in order.

9. RECLEARANCE

Greater use of in-flight reclearance flight planning techniques should be considered for certain long range flights to reduce the dispatch fuel requirements and thereby reduce excessive fuel consumption.

10. ADDITIONAL ALTERNATE AIRPORTS

All operators should examine and certify additional alternate airports, where feasible, to reduce the number of times when distant alternates, and therefore, higher diversion fuel requirements must be planned.

11. NO ALTERNATE AIRPORT

Regulatory changes permitting wider use of the no alternate option for commercial flights should be studied and promulgated. Lower diversion fuel requirements would result.

12. REVIEW STANDARD FLIGHT PLANS

Some operators use standard flight plans for many short to medium range segments. These plans often incorporate significant reserve margins and redundant fuel requirements. Such operators should review the potential for converting the use of standard flight plan segments to computational methods optimized for maximum fuel economy.

13. PREFILED BULK STORED FLIGHT PLAN PROGRAMS

Increased use of the prefiled bulk stored flight plan programs should be encouraged for short to medium range flights as a means of providing FAA flow control system earlier knowledge of demand on airports and also to increase the probability of obtaining desired clearance.

14. COMPUTERIZED FLIGHT PLANNING

A great many factors affect the fuel consumption of aircraft besides speed. The air temperature, altitude, load, the aircraft's balance, route chosen (because of winds), and other factors are involved. Air West pioneered flight profile optimization and developed a program which, given a modest amount of forecast meterological data plus the aircraft type, expected load and the desired flight time, will compute the optimum altitude, speed, and fuel load for the flight plus some alternatives in the event that air traffic control is unable to offer the preferred altitude.

15. PASSENGER FARES HIGHER FOR PEAK-HOUR TRAVEL

The demand for airline flights at peak hours is derived from customer time-oriented flight desires. If the desires of customers for peak-hour flight can be reduced, then the derived demand for flights will also fall. The economic solution is to adjust passenger fare upward for a regulated industry such as commercial aviation. The passenger then evaluates the personnel utility of the flight time relative to its cost and many can be expected to shift his time period demand. This proposal would be ineffective in controlling general aviation.

16. OFF-PEAK AIR FARES

One method for shifting airport use to slack periods would be selective changes in airline ticket prices. This method has been used extensively by Eastern and Delta for night coach flights. The combination of high peak-hour prices and special off-peak air fares would tend to spread the demand of passengers for air travel and relieve congestion.

17. DECREASE SERVICE TO SMALL TOWNS AND RURAL AREAS

To date, the CAB has required trunk lines and commuter lines to continue service to small towns and rural areas even when economically unsound. The subsidy program compensates for the losses incurred. Reduction of such service may be desirable both from economic and energy conservation viewpoints.

18. REMOVE OR REDUCE SUBSIDIES TO ALL DOMESTIC AIRLINE OPERATIONS BY THE CAB

In 1971, one-fourth of all domestic airline operations were subsidized by the CAB. Only local carriers are eligible for subsidies and, therefore, only short flights are affected. For example, 65 percent of the flights under 100 miles and 40 percent of those between 100 and 200 miles were Federally subsidized in 1971. These subsidized operations should be reexamined in light of their inefficient fuel use.

19. SPECIALIZATION OF AIRPORTS BY TYPE OF USER

Historically, U.S. airports have been open to all aircraft on a first come first served basis. No priorities, by type of aircraft or aircraft operator, have been instigated until recently. By designating TCA's, the FAA is moving toward airport specialization by type of user. Commercial aviation and general aviation need to be separated. Separate airports can better meet their divergent needs and requirements.

20. SHUTDOWN AUXILARY POWER UNIT (APU) IN FLIGHT

For the year 1971, it was estimated that the APU's were used on 60 percent of flights, consuming 6.5 pounds of fuel per minute while operating for one-half hour per flight. This places APU consumption of airplane fuel at 1.8 to 3.0 percent of fleet fuel. This option would entail a reduction of the time the APU is used en route. Shutdown at the earliest possible point in a flight coupled with delay in turn-on would consume less fuel.

21. TRIM READJUSTMENT

The pilot would periodically disengage the autopilot, adjust the aircraft trim to minimize trim drag, then reengage the autopilot. By reducing drag, fewer gallons would be needed to overcome aerodynamic friction.

22. RETURN TO FIXED TIME OVERHAUL INTERVALS

Newer aircraft and those more evenly employed year round are often maintained by means of the performance of nightly modules of work, each taking about ten hours, which over the years, accomplish everything which needs to be done. This requires the plane to be where maintenance is possible and reduces the ability to keep aircraft overnight at out stations. This tends to result in a pseudo-ferry late night return flight to bring the aircraft to maintenance. This is fuel inefficient. By resorting to older maintenance practices (fixed interval complete overhaul), such fuel inefficiencies could be reduced.

23. ALTER USE OF SCHEDULE-PROTECTION AIRCRAFT

In practice, carriers do not like to cancel flights due to disturbances to the normal routine (aircraft breakdown, weather, etc.) and will ferry an aircraft to pick up a load rather than cancel the flight. Almost all carriers keep one or more aircraft at key points in their system ready for schedule-protection use. More such aircraft would lower the fuel costs of ferrying through shorter stages to point of need. On the other hand, positioning these additional aircraft in the system will increase fuel consumption for operating costs and aircraft investment. What is needed is a balancing of schedule-protection aircraft and outright cancellations to conserve fuel.

24. TRAINING EMPHASIS ON FUEL CONSERVATION

In the past, training has not emphasized fuel conservation in ground and flight operations to the extent that is warranted today. By teaching fuel conservation techniques and by evaluation performance from a fuel usage standpoint, consumption can be lowered both in the commercial and general aviation categories.

25. CIVILIAN AIR TRAFFIC AT JOINT MILITARY AIRPORTS

Delays at commercial airports could be reduced if air traffic could be diverted to joint civilian/military airports within the metropolitan areas of the top 25 commercial airports. In particular, Atlanta, San Francisco, Los Angeles, Houston, and Boston have convenient military airports which could be so utilized.

26. DUAL VASI

Pilot training for avoiding wake vortices involves the principles of landing long and taking off short of vortex-creating heavier aircraft. At present, these principles are followed without the assistance of lighting aids. This proposal involves the installation of a second VASI system which would be positioned so as to guide the pilot who is landing long to the appropriate runway touchdown point. In order to avoid VASI confusion, different light colors might be used.

27. SHARE GATES

Terminal space, and therefore, energy requirements, is in large part a function of the number of gates available in the terminal. Present practice is to have dedicated gates by airline. An alternative would be to share gates thereby reducing the large present gate requirement. This arrangement requires a portability of ground operations which has not been satisfactorily developed to date.

28. OPTIMUM FLIGHT PROFILE ASSISTANCE

At present, FAA supplies pilots through Flight Service Stations (FSS) with information about weather and other factors which affect a flight profile. However, FAA does not provide recommended profiles. As FSS operations become more centralized and automated, the possibility for role expansion to include recommended profiles becomes operational. Many pilots, especially those in GA, would benefit from having FSS supply airline carrier-type flight profiles to nonairline carrier flights. In this manner, FAA can provide the most modern tools of flight planning to the noncommercial pilot. The potential for fuel savings in the GA area is sizeable.

29. DIRECT EXCLUSION OF SELECT OPERATIONS CATEGORIES DURING PEAK HOURS

Presently, student pilots are prohibited from takeoff and departure flights in TCA-I's. This proposal is to extend this concept beyond the cited flight category. General aviation flights for leisure and pleasure may be prohibited during peak hours. Alternatively, slow flying GA aircraft might be prohibited during peak hours. Flight instruction also could be prohibited in the air traffic pattern during congested times.

30. PILOT CERTIFICATION

Reevaluate FAR Part 61 - pilot certification requirements - to permit greater use of simulators and to generally lower flight time required for obtaining certification. Further, broader and fewer certification classes would reduce the number of hours flown strictly for certification purposes. For example, allowing one type certification in certain jet aircraft to serve for all models in that general class would reduce fuel consumption.

31. ENGINE/AIRCRAFT CERTIFICATION

The process of factory testing and certification of new production engines and aircraft should be reevaluated for possible fuel savings. In addition, flight hours required for certification flight testing of experimental and home-built aircraft should be studied. If safety standards can be maintained through a lower certification requirement, then fuel savings will be realized.

32. VISUAL FLIGHT RULE (VFR) TRAFFIC IN TCA

Increased concern in TCA's for direct routing of VFR traffic either through the TCA or to a secondary airport within the TCA will minimize the fuel consumption due to circuitous routing. A strict vector-around policy should be avoided.

33. OPTIMUM HOLDING SPEEDS, ALTITUDES, AND PATTERNS

The air traffic control system should be modified to allow the use of optimum holding speeds for each aircraft type. No matter how efficient the system for air traffic flow becomes, some delays will still be taken in the air and when this is the case, the holding speed and altitude should be selected so as to minimize fuel burn. Also involved is the configuration of the holding pattern by aircraft type and the vertical spacing in the stack.

34. GATE HOLD PROCEDURES

Hold aircraft at gate when ground departure delays are excessive. The FAD system involves gate hold procedures when congestion exists at a destination airport and also involves gate holds at the TCA's where FAD would be installed. This proposal is to use gate hold procedures at non-FAD airports during departure congestion periods in order to cut fuel burn. The gate hold principle is thus being extended to all controlled airports.

35. SEQUENCING (INTERLEAVING) ARRIVALS AND DEPARTURES

Priority is currently given to arrivals by ATC procedures with departures being inserted when gaps occur in the arrival stream. As arrivals increase, departures experience delay. The interval between arrivals is too small to permit a departure; however, by modestly increasing the arrival interval, a departure can be inserted between arrival pairs.

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