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IMPACT OF AIR TRAFFIC MANAGEMENT ON AIRSPACE USER ECONOMIC PERFORMANCE

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Abstract

This paper focuses on the relationship between Air Traffic Management (ATM) actions and airline decisions and economic performance. Important air carrier costs that can be impacted by ATM actions in the long-term and the short-term are identified. An estimate of system-wide excess cost is presented and includes excess cost during ground turn around, taxi out, airborne and taxi in phases. A method of analysis to assess the impact of ATM improvements on air carrier performance, with a special emphasis on the impact of ATM actions on fleet utilization, is presented. Finally, this paper describes the avenues of possible ATM impact on decision making related to airline product planning.

INTRODUCTION

The MITRE Corporation's Center for Advanced Aviation Systems Development (CAASD) has worked with the FAA since 1958 providing system research and development expertise. Federal Aviation Administration (FAA)-sponsored CAASD programs and projects serve to foster collaboration between government and industry regarding communication, navigation, and surveillance technology and in understanding and improving the design and operation of the Air Traffic Management (ATM) system to meet user needs. The FAA and CAASD have worked together to develop new concepts and prototypes for industry to produce and deliver to the aviation community.

The FAA has made great progress in the last several years to understand user concerns and their relationship to ATM performance. The FAA has developed and applied metrics to assess ATM performance and manage ATM system evolution. The next logical step is to understand the impact of ATM on air carrier economic performance. This paper reports the work CAASD has done with the active participation of the FAAís Office of System Capacity. This body of work addresses the issue of what changes in ATM performance would generate value for users and how should proposed ATM changes be prioritized.

One goal of this CAASD research is to increase FAA effectiveness by understanding what performance really means to users and aid in identifying, developing and prioritizing ATM improvements. Research reported in this paper does not seek to replace operational ATM metrics nor to determine for users what their needs should be. Rather, this work explores the relationship between ATM actions and user decisions, especially those of air carriers. Key relationships are shown in Figure 1. Solid lines indicate reasonably well understood relationships; shaded lines indicate areas where some relationships are understood, but there is much to learn; the dashed lines indicate poorly understood relationships.

This paper summarizes recent CAASD research into the relationship between ATM actions and airline decisions and economic performance. There are broader concerns involved in deciding appropriate future ATM changes than is involved in this research. The purpose of this body of work is to illuminate important relationships between ATM and air carriers so that both FAA and airlines better understand the impact on the other of what they do.

AIRLINE COST DRIVERS AND ATM ACTIONS

CAASD has examined the available public airline costs reporting systems, corporate annual reports and Department of Transportation (DOT) airline financial data. Each of these sources was developed for other purposes. CAASD developed a cost structure tailored to illuminate our understanding of cost impacts of ATM decisions and actions. This new structure is appropriate for understanding the effects of ATM actions on airline costs (defined by functional activity and category) and places all operating costs in a consistent context that mitigate differences between direct and indirect operating costs.

Using these cost categories, industry-wide cost drivers were identified. Costs included under the functional activity **Flying Operations** encompass 36 percent of total airline operating costs (Table 2). The largest costs in this category are pilots' salary and benefits, fuel, and passenger service expenses. **Prepare to Fly** costs are 17 percent of total operating costs. This category includes expenses for servicing the aircraft and handling baggage and passengers prior to flight. **Marketing/Scheduling** costs constitute 17 percent of total operating costs.

Capital Assets and **Direct Maintenance** costs represent 11 percent and 9 percent of total operating costs, respectively.

Airlines can be categorized by the type of service offered, routes served (short or long-haul including international flights), hubbing activity and fleet mix and cost differences can be identified for different types of airlines. A low-cost carrier that provides mainly point-to-point service is likely to spend a higher proportion of its total operating expenses on aircraft, maintenance and fuel than the industry-wide average—a reflection of shorter stage length and an emphasis on greater aircraft utilization. Its expenditures, as

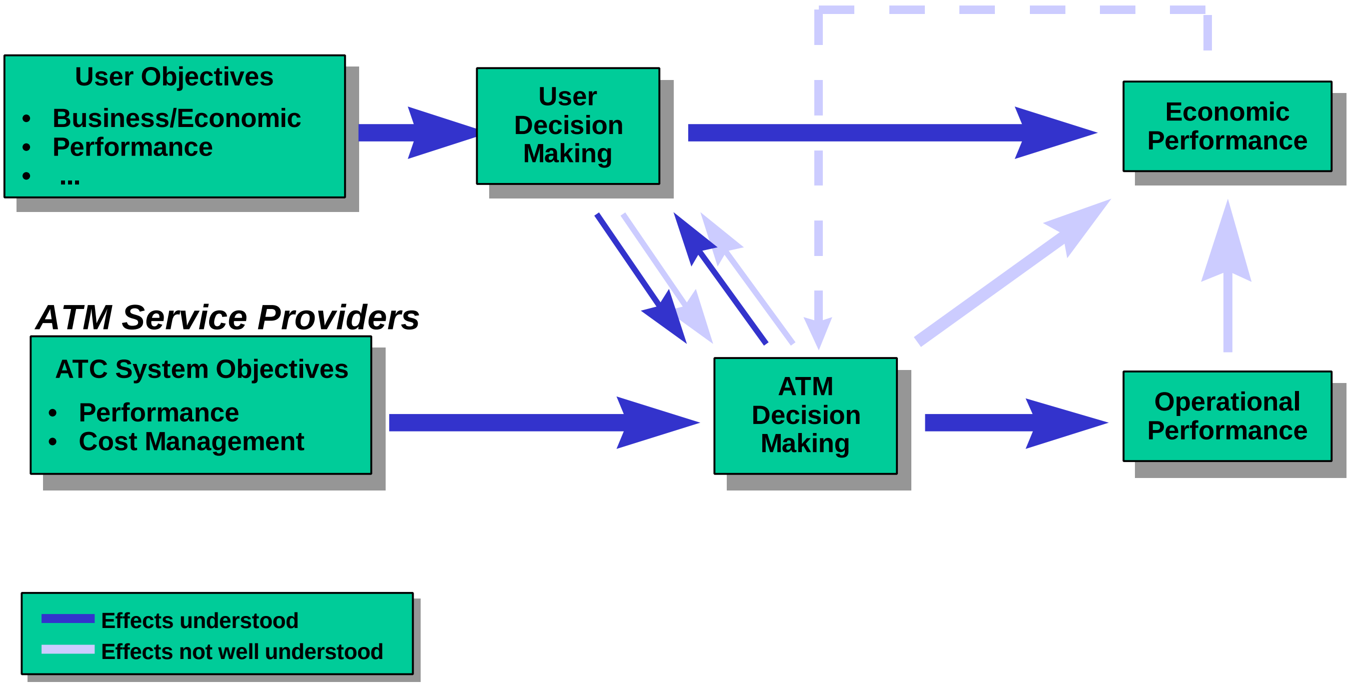

Figure 1: ATM Performance: Operational and Economic Perspectives

a percent of total operating costs, on ground activities and passenger service costs are necessarily lower than the industry-wide average. Major international hubbing airlines spend a higher portion of operating costs on passenger service than the industry-wide average. Cash-strapped airlines spend a smaller portion of its operating costs on crew salaries and benefits than the industry-wide average.

The costs that are related to ATM action were evaluated by dividing costs into fixed and variable components. Whether a cost is constant (fixed) or variable depends on the time horizon. In the short-term, most costs are fixed. In the long-term *all* costs are considered variable. Airline operations were partitioned into short-, medium-, and long-term decisions. In the short run, airlines are focused on flight operations and costs incurred in flight. Only a few costs are variable; therefore only a limited number of cost categories can change in the short run. In the medium-term, an airline has more time to modify schedules, assess routes, and mitigate persistent disruptions to their networks. In the long-term, an airline has the flexibility to respond to ATM system performance changes by changing its fleet mix or moving a hub.

This analysis is to judge the impact of ATM system performance on fuel cost, crew cost, reserve crew requirements, passenger ill-will, crew utilization, aircraft utilization, hub scheduling, route selection, and block times, among other things. The key question is how does ATM performance affect airline cost and service? An airline's schedule is driven by revenue concerns. Fulfilling the schedule involves costs. Increasing ATM efficiency allows shorter scheduled block and ground turn times leading to increased aircraft productivity. Improved aircraft utilization and productivity translates into fewer aircraft or reduced costs to fly a given set of routes or could, of course, lead to additional flights per aircraft and increased revenue.

Recommended improvements to the ATM system have focused on adding capacity, flexibility and access to reduce system-wide delay and to increase schedule predictability. Based upon statements by carriers, their major problem with ATM is *unpredictable* delay.

ESTIMATES OF SYSTEM-WIDE EXCESS COST TO AIRLINES

Estimates of system-wide excess costs were made for both short- and long-term costs. The former reflect excess operating costs for fuel and crew. The latter include all excess operating costs. Excess costs come from increased operating costs due to operational delay—the difference between actual time and a feasible minimum time.

Table 1: CAASD Functional Cost Categories for Selected Air Carriers (1996 data)

COST CATEGORIES	PERCENT OF TOTAL OPERATING EXPENSES
Flying Operations (Pilot and Copilot Salary and Benefits, Fuel, Passenger Service)	36%
Prepare to Fly (Traffic and Aircraft Servicing)	17%
Direct Maintenance (Flight Equipment Maintenance)	9%
Capital Assets Flight Equipment Depreciation, Aircraft Rentals)	11%
Marketing & Scheduling (Reservations and Sales, Advertising and Promotions)	17%
Other (G&A, Ground Property and Equipment Maintenance, Transport Related Expenses)	8%

Operational delay was measured in different flight phases: ground turn-around, taxi-out, airborne and taxi-in. Airborne and ground turn operational delay was calculated from samples, extrapolated to all flights. Actual times for each flight phase were found in the DOT Airline Service Quality Performance (ASQP) database. The ASQP database contains all the domestic flights of the ten largest United States (U.S.) air carriers. The ASQP carriers are Alaska, America West, American, Continental, Delta, Northwest, Southwest, TWA, United and US Airways.

Table 2 shows operational delay in millions of minutes per year by phase of flight. It contains the estimate bounded by lows and highs that capture most of the variation in annual delay due to sampling error. Table 2 also shows extrapolated values of operational delay for non-ASQP air carriers. Non-ASQP carriers are assumed to have the same distribution of delay in the sampled phases as ASQP carriers. Together, operational delay for non-ASQP and ASQP carrierís domestic flights comprise NAS-wide operational delay in this paper.

Table 3 shows operational delay per flight for the roughly 8.4 million domestic flights in 1997. Over all phases, the estimate is 32.0 minutes per flight. The airborne phase is estimated to have 8.2 minutes of operational delay per flight, or 25 percent of the total. The taxi phases combined have 16 percent of operational delay. Almost 60 percent or 18.9 minutes per flight of operational delay occurred at ground turn.

Table 2: Operational Delay By Phase of Flight for ASQP and Non-ASQP Carriers in Millions of Minutes Per Year
(*Lower Bound*, Estimate, *Upper Bound*)

Phase of Flight / Air Carrier	ASQP	Non-ASQP	Total*
Ground Turn	*98*/**100**/*102*	*60*/**61**/*63*	*158*/**162**/*165*
Taxi Out	**20.2**	**12.3**	**32.5**
Airborne	*34*/**44**/*53*	*18*/**25**/*32*	*52*/**69**/*85*
Taxi In	**6.5**	**4**	**10.5**
Total*	*95*/**103**/*111*	*159*/**170**/*182*	*254*/**273**/*293*

*Discrepancies are due to rounding.

Table 3: Operational Delay Per Flight by Phase of Flight for All Carriers in Minutes Per Flight (*Lower Bound*, Estimate, *Upper Bound*)

Phase of Flight / Air Carrier	All Carriers
Ground Turn	*18.5*/**18.9**/*19.3*
Taxi Out	**3.9**
Airborne	*6.2*/**8.2**/*10.1*
Taxi In	**1.3**
Total	*29.7*/**32.0**/*34.3*

Each phase of flight has different direct operating costs with a short- and long-term aspect. The short-term is a period when most costs are fixed by prior decisions, such as the number and mix of aircraft, routes flown, gates available, maintenance schedules, etc. In the short-term, decisions made by airlines concern how to fly given routes and whether certain flights should be canceled because of weather problems or schedule integrity issues. These decisions have impact only on a limited number of cost categories. Operational delay in the short-term causes extra expenditures for fuel and crew above what could potentially be attained if scheduled block time were at a feasible minimum.

Table 4 shows the short-term weighted averages of operating cost per minute for all carriers. The data comes from 1997 financial filings from all commercial air carriers to the DOT in what is called the ìForm 41î database. Non-ASQP carriers (cargo, regional, commuters, air taxi, and charter) employ a wide variety of aircraft as do ASQP carriers. However, on average, non-ASQP carriers utilize aircraft that have lower fuel and crew costs during each flight phase in the short-term and lower indirect costs in the long-term (see Table 6 for long-term operating costs). Although non-ASQP carriers are assumed to have the same distribution of delay per flight as ASQP carriers, unit costs are quite different.

The method of analysis to determine excess cost is to multiply annual operational delay for each phase of flight by the cost per unit of time for that phase and carrier type. For short-term excess cost, this method yielded the results in Table 5. Table 5 shows that the estimate of excess airline operating cost in the short-term is $2.3 billion or roughly 10 percent of total fuel and crew expenses for all carriers. The estimate is derived, in part, from samples in the ground turn and airborne phases. Ranges depicting 95 percent confidence intervals for each sample are reported beginning in Table 2. Based on an extrapolation to non-ASQP carriers from ASQP airborne and turn time samples, it is estimated that short-term excess costs are in the range of $1.8 billion to $2.7 billion.

Table 4: Short-Term Unit Cost by Phase of Flight for ASQP and Non-ASQP Air Carriers ($ Per Minute)

Phase of Flight / Air Carrier	ASQP	Non-ASQP
Ground Turn	$14.28	$7.55
Taxi Out	$16.29	$8.87
Airborne	$26.34	$15.47
Taxi In	$16.29	$8.87

In Table 5, note that the highest excess cost (about two-thirds of the total) occurs during the airborne phase. Airborne operational delay amounts to 8.2 minutes per flight and it costs over $26 per minute for ASQP carriers and over $15 per minute for non-ASQP carriers (as shown in Table 3). Excess cost for turn time is quite low. The reason is that short-term ground turn unit costs are, for all practical purposes, zero for all minutes up to scheduled departure time. The cost per minute accrues only when the flight pushes back late. The study estimated that just 9.3 percent of the operational delay minutes at ground turn occurred beyond scheduled departure time.

In the long-term, all operating costs are variable. Given sufficient time, airlines can alter their schedules, change routes, consolidate gate operations and alter their fleet mix. Long-term airline operating cost per minute estimates require careful judgments. For example, some costs are closely related to phases of flight. During airborne time, fuel is being burned rapidly, about six times faster than on the ground during taxi. Maintenance costs are heavily influenced by time spent airborne. Taxi times have a different fuel burn rate, but the same crew costs as in the air.

Table 5: Short-Term System-Wide Excess Airline Operating Costs by Phase of Flight for ASQP and Non-ASQP Carriers in Billions of Dollars (*Lower Bound*, Estimate, *Upper Bound*)

Phase of Flight / Air Carrier	ASQP	Non-ASQP	Total
Ground Turn	*0.13*/**0.13**/*0.14*	*0.04*/**0.04**/*0.04*	*0.2*/**0.2**/*0.2*
Taxi Out	**0.3**	**0.1**	**0.4**
Airborne	*0.9*/**1.1**/*1.4*	*0.3*/**0.4**/*0.5*	*1.2*/**1.5**/*1.9*
Taxi In	**0.1**	**0.03**	**0.1**
Total	*1.5*/**1.7**/*2.0*	*0.5*/**0.6**/*0.7*	*1.9*/**2.3**/*2.7*

Turn time costs involve crew expenses only when the aircraft stays at gate beyond its scheduled departure time. In addition, there are some airline cost categories that support all phases of flight, called "indirect" operating expenses. Indirect costs are apportioned to each phase of flight proportionate to the actual amount of time spent in each phase. Cost per minute in the long-term (Table 6) is consequently higher than short-term cost per minute because more categories of operating costs are included.

Long-term excess costs are estimated to be $12.4 billion as shown in Table 7, or approximately 15 percent of all carriers' operating costs. Based on extrapolation from a sampling of ASQP carriers to non-ASQP carriers and 95 percent confidence intervals for airborne and turn samples, long-term excess costs are estimated to be in the range of $11.3 billion to $13.6 billion.

The airborne phase (Table 7) does not contribute the most to excess costs even though the largest portion of indirect costs are placed in the airborne phase (because it typically entails more time than other phases). In the long-term, excess cost during the turn phase is greater than for the airborne phase because operational delay minutes are the highest for the turn phase (more than twice the amount of operational delay during the airborne phase) as shown in Table 2 and indirect costs are applied to all those minutes.

The airborne origin-destination (OD) sample was stratified by length of flight and flight frequency. Sample results show that the longer the flight, the greater the airborne delay and, hence, the higher the excess cost. This suggests that there is some operational delay experienced in the en route portion of the airborne phase. The airborne sample was also stratified by frequency of OD routes—low (below 722 flights per year), medium (between 722 and 1730 flights per year), and high (over 1730 flights per year). None of these strata exhibited operational delay per flight averages significantly different than the average for all flights. That is, interestingly, there is no difference in airborne delay and excess cost per flight between less and more frequently traveled routes.

Table 6: Long-Term Unit Cost by Phase of Flight for ASQP and Non-ASQP Air Carriers ($ Per Minute)

Phase of Flight / Air Carrier	ASQP	Non-ASQP
Ground Turn	$59.30	$25.67
Taxi Out	$61.42	$26.99
Airborne	$78.17	$45.20
Taxi In	$61.42	$26.99

Table 7: Long-Term System-Wide Excess Airline Operating Costs by Phase of Flight for ASQP and Non-ASQP Carriers in Billions of Dollars (*Lower Bound*, **Estimate**, *Upper Bound*)

Phase of Flight / Air Carrier	ASQP	Non-ASQP	Total
Ground Turn	*4.6*/**4.6**/*4.7*	*1.1*/**1.2**/*1.2*	*5.7*/**5.8**/*5.9*
Taxi Out	**1.3**	**0.3**	**1.6**
Airborne	*2.7*/**3.4**/*4.1*	*0.8*/**1.1**/*1.5*	*3.5*/**4.5**/*5.6*
Taxi In	**0.4**	**0.1**	**0.5**
Total	*8.9*/**9.7**/*10.5*	*2.4*/**2.7**/*3.1*	*11.3*/**12.4**/*13.6*

EXAMPLE OF THE IMPACT OF ATM IMPROVEMENTS ON LONG-TERM AIRLINE COSTS: FLEET UTILIZATION AND ATM IMPROVEMENTS

The magnitude of airline fleet capital costs makes fleet impacts a key category when evaluating the economic impact of ATM initiatives. The CAASD fleet requirements model estimates fleet requirements among scheduled passenger airlines, establishing a chain of causality from ATM improvements to financial performance, as shown in Figure 2. The chain begins in Phase I with a change in ATM performance. Performance changes typically stem from an initiative like Free Flight Phase One, a new tool like passive FAST, or a new procedure like closely-spaced parallel approaches. Phase I quantifies the improvement using ATM performance measures, whether in terms of increased maximum airport arrival rates, reduced taxi delays, etc.

Phase II translates ATM impacts to airline operating measures such as flight times. In Phase III operating efficiency improvements drive changes in scheduled activity times such as scheduled airborne time and scheduled ground turn time. Because most of an airlineís assets, including the fleet, are allocated to produce the schedule, scheduled times provide a better basis for estimating fleet requirements than daily operating times. A particular benefit of using scheduled times is that they reflect not just average operating times but also variation in times, establishing a tie to operational predictability.

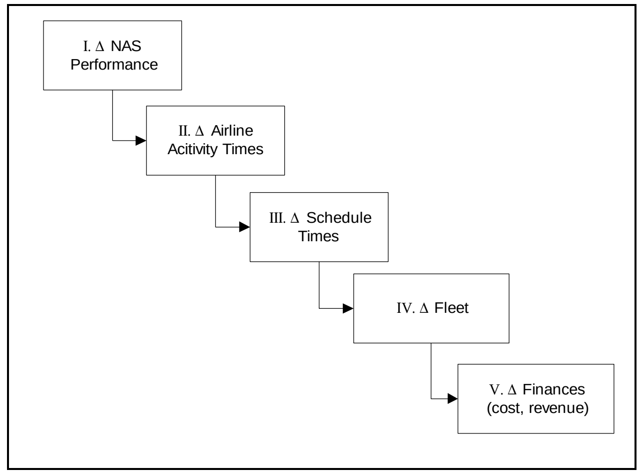

Figure 2: Chain of Impact (Phases) from ATM Change to Fleet Finances

In Phase IV airlines re-allocate their fleets to exploit time savings by saving aircraft. This is an exceedingly complicated process because many airline ìschedulesî must mesh together. Crew, aircraft, ground resources and maintenance schedules must all be carefully managed. Even with careful management, there is likely to be considerable slack in any schedule. Some slack (in aircraft and crew utilization and maintenance deadlines) is useful to respond to schedule disruptions. Phase IV estimates potential aircraft saving assuming that some slack is useful and that crew and maintenance schedules can adapt to new fleet assignments. Any redundant aircraft identified in Phase IV can be removed from service or re-deployed onto new flights. Phase V converts these potential fleet changes into financial measures like cost and revenue.

Suppose all excess airborne time related to ATM performance is eliminated. Assume that this reduction amounts to 1.0 percent of actual airborne time. The CAASD fleet utilization model initially assumes that airlines adjust their fleets but maintain their existing network structure. In that case, how much of their current fleet could be saved?

Table 8 summarizes the results of the analysis conducted to answer this question. Estimated fleet savings are 19 of the 4,429 aircraft in the airlinesí 1997 domestic fleet, or 0.5 percent of the total. If airlines eliminate the excess aircraft, the one-time replacement value of the 19 aircraft is approximately $1.1 billion. Alternatively, airlines could use the extra aircraft to add new service. The estimated increase in passenger revenue is about 0.5 percent of base revenue.

ATM improvements in the airborne phase can occur in the terminal area or in the en route portion of flight. The distribution of Phase IV and V benefits among airlines depends whether time savings accrue in the terminal-area (affecting arrival and departure airspace) or whether they occur en-route. Table 8 illustrates the estimated percentage fleet reduction by airline for the two cases. We assume that terminal area time savings tend to save a fixed length of time per flight. Airlines whose aircraft operate many flights per day benefit most from terminal area savings (Figure 3a).

Table 8: Estimated Fleet Impact from Eliminating Excess Airborne Time

Fleet size	Base Fleet	**4,429 aircraft**
Phase II	Reduction in Airborne Time	**1.0%**
Phase IV	Estimated Reduction in Fleet	**19 aircraft**
Phase IV	Percentage Reduction in Fleet	**0.5%**
Phase V	Approximate One-Time Value (Replacement)	**$1.1 billion**
Phase V	Estimated Revenue Increase	**0.5%**
U.S. Scheduled Passenger Airlines, domestic service, 1997		

We assume that en route time savings are approximately proportional to the average flight duration. Airlines whose aircraft spend the most time per day airborne benefit most from en route savings (Figure 3b). A comparison of Figures 3a and 3b shows that percentage decreases in airborne times produce a more even distribution of benefits than fixed time reductions, which vary widely among airlines.

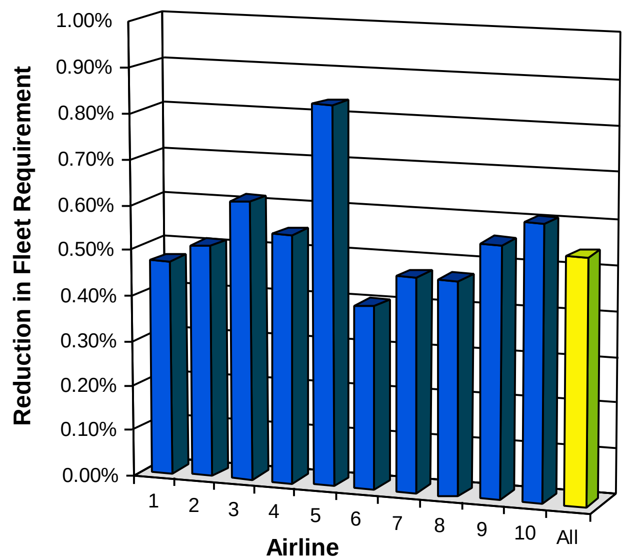

Figure 3a: Reduction: 1.2 Minutes/Departure

THE LARGER PICTURE: THE INFLUENCE OF ATM ON DEMAND-RELATED AIRLINE DECISIONS

ATM improvements can definitely save short-term excess costs of fuel and crew and probably provide aircraft fleet savings in the long-term. The next question is what impact might ATM improvements have on airline strategic planning? Airline planning for routes determines what aircraft airlines need and their potential revenue. To secure the revenue, airlines invest in aircraft, ground equipment, hubs (if necessary) and reservation or ticketing systems. ATM through the services it provides, the restrictions it imposes, and its role in congestion could influence scheduling, route planning or development, and fleet planning. To the extent that ATM impacts these decisions, ATM can indirectly influence decisions on ground equipment investments, hub development and reservation systems. The issue is the extent to which ATM affects airline product decisions with respect to both the importance to any one decision and the prevalance throughout decision-making.

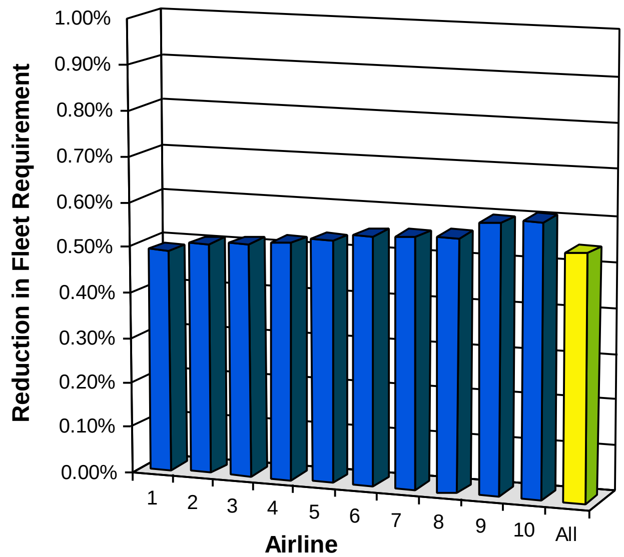

Figure 3b: Reduction: 1.0 Percent of Airborne Time

An air carrier's chief business interest is revenue generation. Key decisions involve route development, scheduling and fleet planning. As Figure 4 indicates, decision-making starts with strategic planning. Route planning and selection lead to fleet requirements. As specific schedules are made regarding city-pair routes, the chosen fleet can be assigned an itinerary. Operational activities provide feedback that may serve to alter a schedule.

Scheduling relies heavily on historical operational data, especially block times. Block times can be influenced by ATM and airlines are sensitive to changes in block times. ATM affects block times through the direct services it offers, with ATM restrictions and in the role ATM plays in contributing to congestion. To obtain their desired on-time performance, airlines will add padding into a schedule to reflect an amount above expected block times to allow for delay and seasonally experienced variation in block times.

Revenue is the main driver of route development decisions although congested routes are sometimes a concern. The issue is the extent to which ATM influences are recognized by airlines at this stage. Logically, if ATM improvements can lead to more economical routes, it can add to revenue and return to investors.

The ATM impact on fleet planning is mostly indirect. ATM can impact block times and block times can affect fleet assignment and fleet utilization. ATM can also influence congestion. Congestion indirectly impacts fleet planning by raising concerns about aircraft size. Thus, ATM influences on airline costs and revenues may be significant. Longer-term consequences of ATM changes and their influence on airline planning must be more clearly understood in order to assess more fully the benefits of ATM improvements.

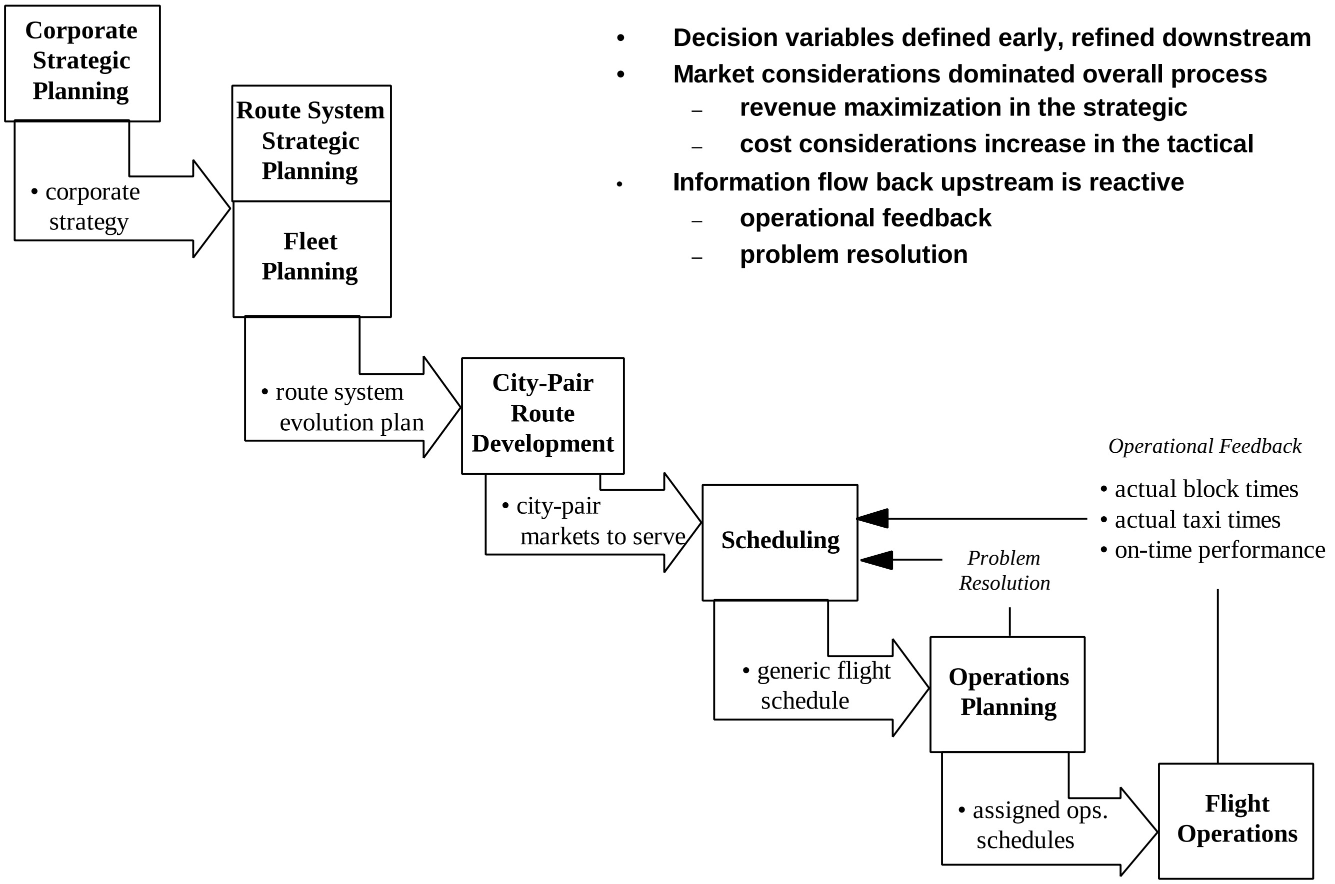

Figure 4: Airline Demand-Related Decision-Making Processes