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Methods for Initial Allocation of Points in Flight Prioritization

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Prior research has suggested that the allocation of scarce National Airspace System capacity could be improved if aircraft operators were able to exchange the priority in which their flights will be handled by the air traffic control system to reflect how much they value timeliness for specific aircraft flights. The current priority allocation system is based on a first-come first-served mechanism. FAA and users have made some modifications to first-come first-served to give operators more control over the priority in which their own flights get served through Collaborative Decision-Making. There are also programs which allow a carrier to give up a flight time slot that it will not use without having to go to the "end of the line," which is called slot credit substitution. Significant research has been done into ways to further improve demand-capacity balance in the National Airspace System while taking users' flight priorities into account. Many researchers have proposed market-based allocation systems, which are used when airport slots are bought and sold. Other researchers propose quasi-market systems that could be developed using a points system. This paper illustrates how the initial allocation of priority points among carriers influences how they use these points in establishing the priority for their flights to reduce their delays. The paper then reports the results from the human-in-the-loop simulation of aircraft operators' decisions that show how the delay reduction differences for each operator vary among the different methods used to allocate the points. In general, the paper finds that a system which uses the number of flights in the allocation tends to benefit operators of smaller aircraft, while systems that use passengers and distance in the allocation favor operators of larger aircraft.

I. Introduction

One of the problems facing NextGen planners is that concepts such as trajectory-based operations need a means to determine the priority in which aircraft will be served when there is a conflict in who has priority over the use of national airspace capacity. For example, if two flights are scheduled to arrive at the same point at the same time, which flight takes priority, while the other either waits or takes an alternate path? The Joint Planning and

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Development Office's NextGen Institute conducted a study of flight prioritization in 2011 that examined how this might be accomplished.[1] One concept presented to the Institute's study team was to use a point system where operators could accumulate points and use them to obtain priority for flights that they valued highly.[2] However, there was no consensus on how to make the initial allocation of points to carriers for use in the system.

Prior research has suggested that the allocation of scarce National Airspace System (NAS) capacity could be improved if aircraft operators were able to exchange the priority in which their flights are handled by the air traffic control system to reflect how much they value timeliness for their fleet and specific aircraft operations.[3] The current allocation system is largely based on first-come first-served as a priority mechanism, where aircraft are sequenced by the time they take-off or reach landing queues or as they move into new enroute airspace centers and sectors. During work on the JPDO NextGen Institute's flight prioritization study, carriers made it clear that they did not favor pure market based allocation systems for flights. They believed these would favor the larger and more profitable carriers, which have the resources to outbid smaller competitors for priority in congested airspace. These concerns may be based on their experience with buy-sell systems for airport slots.

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A. Problem Definition

It is not possible for the ATC system managers to know the current status of each flight in advance, such as when it will actually be ready to depart. They also do not know the priorities operators place on the value of specific flights, and how these change over the day and from day to day. Without up-to-the-minute input from operators about their real priorities, the NAS cannot deliver the levels of service they desire for individual flights, therefore likely producing suboptimal results for operators and their customers. The Collaborative Decision Making (CDM) process employed by the Federal Aviation Administration (FAA) and the airspace user community has allowed users to play a larger role in determining the order in which their aircraft are served if required to meet a business or operational necessity, but there is still significant room for automation and improvement.[4] Nonetheless, ATC system managers face the complex tradeoff among basic demand capacity imbalances (which are often exacerbated by weather), the need to treat operators fairly (the concept of equity is important to users) and the need for a decision framework as more automation is introduced.

Procedures that allow one operator to exchange priorities among its own flights have been initiated under the CDM programs conducted between FAA and the aircraft operators. A carrier that is not able to operate a flight under the first-come-first-served (FCFS) priority that it has can exchange places among its own flights or release a specific place in the queue without moving to the end of the line through slot credit substitution. However, this system does not allow the explicit exchange of flight priorities among aircraft operators. For example, a feeder flight into a hub with a large number of international connecting passengers might be valued more by Operator A than a domestic flight by a non-hubbing carrier operating to the same airport (Operator B). Operator B may be willing to help Operator A to move its operation ahead of Operators B's flight, and Operator B may be willing to accept this swapping of flight times. Current CDM procedures do not allow this type of exchange.

B. Research Gaps

Researchers have explored a number of possible priority point allocation systems to more closely align demand and capacity. Most allocation systems were applied at the airport level and employ techniques such as auctions or voting to develop a more efficient and equitable system. Past research has suggested a priority points-based system could improve NAS performance, where operators were awarded points based on their need for or use of NAS services. The points system would be a way for operators to establish priority, while retaining some efficiency aspects of a buy-sell system as well as addressing equity considerations among operators at the same time. If this results in a more efficient and equitable allocation of resources, the question of how to design such a system comes to the fore. Some users have expressed concerns that the operator with the deepest pockets would be able to control the priority system. In a recent study of alternative methods for flight prioritization, operators were concerned that monetary exchanges would not preserve enough capacity for smaller or less financially strong operators.[5] In the absence of a market allocation method, researchers have proposed systems that share some attributes of a market system. One of the more interesting proposals that have emerged in the flight prioritization literature is the use of a point system instead of a pure buy/sell market transaction for flight priorities.[6] A recent paper brings together work on using virtual queues to manage first come first served departure priority, which would reduce airfield congestion and improve performance. Points were awarded to operators who then used and exchanged them to establish take off priority for selected flights.[7] While it is recognized that any system of exchange would allow more efficient outcomes, a major question has been how to allocate the priority points among operators.

This paper reviews alternative allocation methods and shows how each performs in simulated exchanges by individual operators. A system where users could exchange priorities in a market or by other means would generally improve the allocation of resources among all users. Prior research has shown that allowing users to express priority for flights before they depart can reduce system-wide delays.[8] Such a system can also result in a more efficient and equitable distribution of delays among users. This type of system can be operated under a buy/sell concept where users could exchange priorities based on a market transaction among operators. In other words, Operator A would offer to pay Operator B to allow its flight to depart first (assuming B was ahead in the queue based on first come first served). Such a system could also work using surrogates for money. In these mechanisms once an initial distribution of resources is made, operators can exchange these resources among or within themselves to achieve an efficient outcome.

One concern that has emerged about the use of a point system is how the initial allocation of points would be made. In this paper, data on the utilization of NAS resources for individual flights are used to develop point systems that reflect both NAS usage and measures of the value of flights to airlines and consumers. Some researchers suggest that a points system would be perceived as more equitable and would not necessarily allow the financially strongest operator to control the priority system. While it is recognized that any system of exchange would allow more efficient outcomes, the initial allocation of points among operators determines whether most operators view the system as fair or equitable. This paper reviews alternative allocation methods and shows how each performs in simulated exchanges among carriers. Human-in-the-loop (HITL) simulations were run previously, using subject matter experts in the role of dispatchers assigning points among operators. These generally show that a points system can be used and that it would reduce delays and may improve the allocation of NAS priorities in an equitable and acceptable manner.[9] The purpose of this research is to experiment with different systems of awarding priority points, and then simulating the possible outcomes in terms of delay as operators use points to gain priority on air traffic control resources for flights they value highly.

II. Research Approach

This section describes how the data were assembled for the initial awarding of points and for use in the simulations of operator behavior. The days selected for analysis were: 8/24/2005, 8/5/2010, 8/12/2010, 9/16/2010, 10/7/2010, 10/21/2010, 5/13/2011 and 7/7/2011. These reflect dates for which NASA had run simulations for delay computations with flight priorities in the past, allowing this new research to take advantage of data already in hand. Simulations of traffic based on recorded schedules for those eight days was used as the baseline first-come-first-served case.

The simulation is developed for domestic airspace using flights over the Continental United States (CONUS). Airspace is divided into two broad types: Terminal (below a certain altitude within a certain distance in the vicinity of airports) and Enroute. Enroute airspace is further classified by the FAA as follows:

1. Domestic airspace is that over CONUS, plus Alaska and Hawaii.
2. Oceanic airspace are those portions of the Atlantic and Pacific Oceans, plus the Gulf of Mexico, for which the United States provides a reduced set of air traffic control services.
3. Foreign airspace is that for which FAA does not provide air traffic control services.

Figure 1 shows the airspace boundaries of FAA enroute centers. Red lines show the boundaries of Domestic airspace centers. Blue lines show the limits of Oceanic airspace. Areas outside these lines are foreign airspace.

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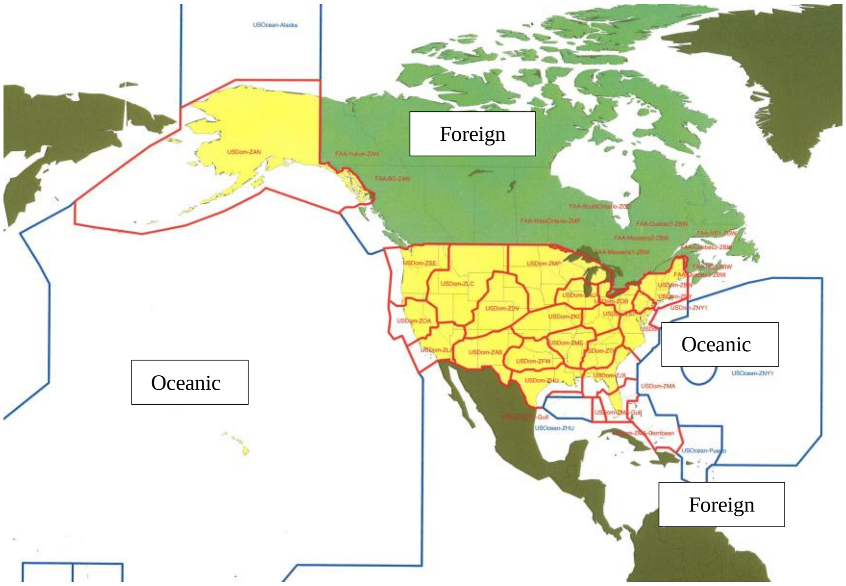

Figure 1. Airspace Boundaries

Flights are assigned to one of four “geographies,” based on origin and destination:

- Domestic—within an area consisting of the Continental United States (CONUS) plus southern Canada and northern Mexico. The domestic zone includes the parts of Canada and Mexico that are within 225 miles of the border with CONUS
- Alaska/Hawaii—flights with one terminus in CONUS (but not the domestic zones of Canada or Mexico) and the other in Alaska or Hawaii.
- International—flights with one terminus in CONUS and one terminus in a foreign country. Fights to Canada or Mexico outside the domestic zone are international, as are flights to U.S. territories.
- Overflight—flights with no terminus in CONUS, but which fly through U.S. airspace.

The assignment of geographies was done in order to eliminate flights which were assumed to not participate in a points-based priority system. Previous work indicates that non-participants in CDM systems are not significantly impacted.[10] Current CDM programs conducted by the FAA are limited to flights by U.S. operators within CONUS. The analysis was therefore restricted to the domestic geography.

III. Data Analysis

A.Selection Process

The data developed for this study are based on flight segment record data from FAA’s Enhanced Traffic Management System (ETMS).[11] The Air Traffic Laboratory (ATA-100) provided boundary crossing file (BCF) records for each flight in the National Airspace System. A flight segment for this purpose is one aircraft traveling through one Air Route Traffic Control Center (ARTCC), so a flight which travels through three ARTCCs would consist of three records (assuming a boundary crossing record for each).

These segment records were assembled into complete flights. The analysis dataset was further refined as follows:

- Flights conducted by military operators are excluded from results.
- Using a database of aircraft characteristics, fields were appended to each record for the number of seats and the payload of the aircraft used for the flight. Seats are based on the most common passenger configuration. Payload is either a known value for that model or calculated as 13.5% of Maximum Take-Off Weight (MTOW), which has been found to be a reasonable estimate.[12]

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Table 1 shows a summary of the four activity measures, by geography, for the eight study days. The table has counts of flights, flight miles, available seat miles (ASMs) and available ton miles (ATMs), plus averages of flight miles, seats, ASMs and ATMs for each flight in domestic airspace.

Table 1. Domestic Airspace Activity

	ACTIVITY IN DOMESTIC AIRSPACE							
	TOTAL				AVERAGE			
GEOGRAPHY	Flights	Flight Miles	Available Seat Miles (000)	Available Ton Miles (000)	Average Miles / Flight	Average Seats / Flight	Average ASMs / Flight	Average ATMs / Flight
Alaska/Hawaii	3,398	2,237,092	537,275	73,628	658	240	158,115	21,668
Domestic	345,293	153,270,056	15,066,501	1,256,231	444	98	43,634	3,638
International	26,156	11,932,205	2,507,849	361,581	456	210	95,880	13,824
All US Terminus	374,847	167,439,354	18,111,624	1,691,440	447	108	48,317	4,512
Overflight	9,928	2,440,549	425,953	47,741	246	175	42,904	4,809
All Flights	384,775	169,879,903	18,537,577	1,739,181	442	109	48,178	4,520

The analysis used eight days of ETMS flight data. The individual days were examined for delay as shown in Table 2 below using data from FAA's Operations Network (OPSNET). The day from 2005 has the highest number of operations (flights), but relatively low total and average delays when compared to the days from 2010. The majority of delays are weather related, and occur during August and September of 2010.

Table 2. Flights by Day and Reported Delay Levels

			Delays by Cause					Delay (minutes)		
Date	Total Operations	Total Delays	Weather	Volume	Equipment	Runway	Other	Average	Total	Delays Per Thousand Operations
August 24, 2005	417,126	957	495	331	1	118	12	34.68	33,188	2.29
August 5, 2010	350,937	2,395	1,918	186	-	70	221	46.16	110,557	6.82
August 12, 2010	353,066	2,153	1,913	146	-	8	86	45.90	98,812	6.10
September 16, 2010	341,164	1,914	1,459	258	-	150	47	50.15	95,990	5.61
October 7, 2010	357,423	541	266	148	-	50	77	35.74	19,334	1.51
October 21, 2010	342,721	985	671	162	-	49	103	39.05	38,462	2.87
May 13, 2011	336,549	1,223	1,103	88	-	-	32	58.66	71,743	3.63
July 7, 2011	345,791	1,446	1,230	197	-	11	8	44.21	63,927	4.18
Total	**2,844,777**	**11,614**	**9,055**	**1,516**	**1**	**456**	**586**	**45.81**	**532,013**	**4.08**

Table 3 shows flight activity for the Air Traffic Services Business Model (ATSBM)[13] operator groups for the eight simulation days. The flights in the ATSBM are assigned to user types at a much greater level of detail than in the basic ETMS flight record or other FAA activity counting systems such as OPSNET or the Air Traffic Activity Data System (ATADS). Although scheduled commercial operators and their regional airline partners conduct a large percentage of the flights in the NAS, there are also many other types of flights. Government agencies operate aircraft, and there are many aircraft used for private purposes (known as general aviation) owned by individuals and organizations. However, only commercial and larger business aircraft operators participate in the CDM programs. Operator groups corresponding to commercial aviation with turbine-engine aircraft are highlighted in green. These represent the portion of air traffic potentially participating in the points-based system. Fortunately, these operators can be individually identified in the flight data with a carrier code field.

Table 3. Total Activity in Domestic Airspace for Eight Study Days

Domestic Geography Flights, Domestic Airspace, 8 Study Days				
Description	Flight Miles	ASMs (000)	ATMs (000)	Flights
US Commercial Carrier Passenger	45,667,273	7,166,730	572,357	57,096
US Low-Cost Carriers Passenger	26,671,181	3,582,336	262,164	41,212
Foreign Carriers	2,605,969	284,420	25,835	4,935
Regional Airline Passenger	35,316,087	1,968,651	140,553	100,407
Charter Flight on US Carrier	480,548	61,408	5,815	1,143
Commercial Passenger Carriers- Piston	8,403	207	19	84
US Commercial Carrier Freight	6,561,151	1,588,164	193,855	10,490
Foreign Carrier Freight	57,380	18,404	3,517	117
Regional Airline Freight	872,522	14,741	1,129	5,044
Commercial Cargo Carriers- Piston	146,581	3,636	367	884
Fractional Ownership Programs	4,000,963	42,121	7,107	9,728
Non-Scheduled Part 135 Passenger	6,399,710	80,720	12,392	17,786
Part 135 Passenger - Piston	760,295	4,787	258	4,881
Non-scheduled Part 135 Freight	889,358	13,619	931	4,727
Part 135 Freight - Piston	498,891	3,399	168	3,504
General Aviation-Turbine	12,910,637	158,099	23,907	34,880
General Aviation-Piston	6,641,344	31,646	1,657	36,385
General Aviation-Rotor	21,504	225	15	234
Government	458,907	19,086	1,420	2,457
Tax Exempt	1,840,668	17,640	1,884	7,354
Not Classified by User Type	460,687	6,461	882	1,945

Operator groups corresponding to domestic commercial aviation with turbine-engine aircraft highlighted

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B.Flights and Point Allocation Parameters

Flights were assigned to six four-hour time blocks, as shown in Table 4, based on UTC time of departure, and points were developed for each measure of activity. The assignment of time blocks was done in order to be able to eliminate flights occurring outside of peak travel times. This allowed confirmation that peaking occurred in the data is as observed in actual traffic. Because congestion is concentrated during these times, analysis was restricted to the hours in time block 6 (in Table 4) since it has greatest competition for NAS resources among users.

A subset of the ATSBM data was used to develop the enhanced dataset relevant to the study. The enhanced dataset was used to develop measures of activity on which a points system could be based. The most straightforward measure of activity is a count of flights. From the perspective of equity, this measure is appealing, since operators are credited the same for every flight conducted, regardless of distance or aircraft size. A second possible measure is miles flown. Points credited increase linearly with the distance between origin and destination. Because the purpose of a flight is to transport passengers and cargo, it can be argued that a flight transporting them over greater distance provides a larger benefit to society/operator than a shorter flight. (Operators of long distance flights could also experience more competition for NAS resources.) From that perspective, it could also be helpful to take aircraft size into account, because a larger aircraft transports more passengers or cargo over any given distance. Measures that incorporate the size of the aircraft are: Available Seat Miles—aircraft seats multiplied by miles flown; and, Available Ton Miles—aircraft payload in tons, multiplied by miles flown.

Table 4. Four-Hour Time Blocks

Time Block	UTC Time Hours
1	0000-0259, 2300-2359
2	0300-0659
3	0700-1059
4	1100-1459
5	1500-1859
6	1900-2259

The aircraft database used for the analysis has both seat counts and payload by aircraft model. Thus, it was possible to calculate both ASM and ATM values for each flight, regardless of whether it was a passenger or all-cargo operation**.** Points were calculated for four measures of activity, by time block, for each en route center. The measures were: flight count, flight miles (great circle distance between center entry and exit points), ASMs and ATMs. In addition, a carrier superset—a list of all those carriers which were in the top 40 (by flight count) in at

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least one center over the eight days studied—was developed. Tables of activity and points (flight count, miles, ATMs) for each center by carrier and time block were produced. Tables of activity and points for the peak travel time block for each of the superset carriers were produced. Values were averages (total for the eight study days, divided by eight), which were used to calculate points for the simulation.

The four measures of activity (flight count, O-D flight miles, ASMs, and ATMs) were summed by carrier, date and flight geography, and were used to develop formulas for assigning points based on activity. The analysis used only flights with "domestic" geography; i.e., those conducted within CONUS plus the exclusion zones in Canada and Mexico.

IV. Calculating Points by Operator

As noted above, this research examined a number of possible ways of calculating and distributing points among carriers using objective measures of NAS usage. A set of related measures were calculated that could be used for flight prioritization based on data from the ATSBM.[14] These start with tabulating the number of flights and assigning points based on the number of flights for each operator. The points to be allocated were calculated based on the distance over which a flight operates, which also represents a measure of the importance of that flight to the operator. A third measure was calculated, ASMs flown. This takes into account that a flight took place, how far it operated, and how many passengers could be carried.[15] The fourth measure, based on ATMs for the aircraft, gave a measure that included cargo. The calculation of points used the following algorithms to produce results of a similar scale:

- Five points per flight
- One point per 100 miles flown
- Five points per 100,000 ASMs
- One point per 1,000 ATMs

The results of the calculations of the four metrics for top domestic operators are shown in Table 5. For each metric, the number of points and the percentage of total points this represents are shown. As can be seen, flights-based measures result in a smaller percentage of points for operators of larger aircraft such as American, Continental, Delta, Northwest, Southwest and United airlines. Once flight distance is used, the largest carriers get a larger share of points, reflecting larger average flight segment lengths. The measures of seat miles and ton-miles result in very similar results and provide the largest share of points to the operators of the largest aircraft. Conversely, operators of smaller aircraft flying shorter distances such as the regional airlines (American Eagle, Expressjet, Mesa, Mesaba, etc.) and business aircraft (Flight Options and NetJets) received a larger share of points when the number of flights is used as the allocation measure. Four metrics were used in the simulations of how allocations would affect operator decisions, and the impacts on the NAS. Ton-miles were also used, even though highly correlated with seat miles for passenger carriers, because doing so provided a metric for cargo aircraft.

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Table 5. Calculated Points for Top Domestic Operators

CARRIER POINTS AWARDED PER DAY FOR DOMESTIC OPERATIONS IN DOMESTIC AIRSPACE, BY ALLOCATION BASIS*										
TOP OPERATORS	FLIGHTS		FLIGHT MILES		AVAILABLE SEAT MILES		AVAILABLE TON MILES		Average Flight Distance
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	
Air Canada	967	0.4%	1,451	0.8%	856	0.9%	1,329	0.8%	750
Air Canada Jazz	884	0.4%	654	0.3%	194	0.2%	270	0.2%	370
Air Wisconsin Airlines	2,413	1.1%	1,376	0.7%	343	0.4%	490	0.3%	285
Airnet Systems; Inc	863	0.4%	367	0.2%	16	0.0%	31	0.0%	212
Airtran Airways	3,353	1.6%	4,237	2.2%	2,623	2.8%	3,712	2.4%	632
Alaska Airlines Inc.	1,703	0.8%	2,577	1.3%	1,921	2.0%	2,825	1.8%	757
American Airlines Inc.	7,594	3.5%	13,302	6.9%	10,339	11.0%	16,457	10.5%	876
AMR American Eagle; Inc	7,334	3.4%	5,681	3.0%	1,407	1.5%	1,968	1.3%	387
Atlantic Southeast Airlines	4,170	1.9%	2,883	1.5%	836	0.9%	1,209	0.8%	346
Britt Airways; Inc.; D/B/A Continental Express	6,444	3.0%	5,848	3.1%	1,458	1.5%	1,927	1.2%	454
Chautauqua Airlines	2,664	1.2%	1,656	0.9%	395	0.4%	540	0.3%	311
Colgan Air	1,693	0.8%	619	0.3%	159	0.2%	176	0.1%	183
Comair; Inc.	2,804	1.3%	2,146	1.1%	618	0.7%	868	0.6%	383
Continental Air Lines Inc.	3,591	1.7%	7,233	3.8%	5,783	6.1%	8,711	5.5%	1,007
Delta Air Lines; Inc.	10,349	4.8%	15,533	8.1%	12,490	13.3%	20,715	13.2%	750
Express Airlines I; Inc. D/B/A Delta Connection	3,943	1.8%	2,744	1.4%	731	0.8%	1,040	0.7%	348
Federal Express Corporation	3,321	1.5%	4,470	2.3%	5,806	6.2%	15,136	9.6%	673
Flight Options	639	0.3%	559	0.3%	33	0.0%	97	0.1%	438
Freedom Airlines; Inc	56	0.0%	35	0.0%	9	0.0%	12	0.0%	314
Frontier Airlines; Inc	1,192	0.6%	1,904	1.0%	1,224	1.3%	1,848	1.2%	799
Gulfstream International Airlines; Inc.	479	0.2%	172	0.1%	17	0.0%	20	0.0%	179
Horizon Airlines; Inc.	1,898	0.9%	1,023	0.5%	355	0.4%	437	0.3%	270
Jetblue Airways Corporation	2,480	1.1%	4,638	2.4%	3,215	3.4%	4,695	3.0%	935
Mesa Aviation Services; Inc.	2,553	1.2%	1,784	0.9%	598	0.6%	850	0.5%	349
Mesaba Aviation	2,408	1.1%	1,701	0.9%	557	0.6%	775	0.5%	353
Netjets Aviation; Inc.	3,105	1.4%	2,722	1.4%	142	0.2%	505	0.3%	438
Northwest Orient Airlines Inc.	831	0.4%	993	0.5%	703	0.7%	1,080	0.7%	597
Piedmont Airlines; Inc. D/B/A USAir Express	1,827	0.8%	563	0.3%	111	0.1%	138	0.1%	154
PSA Airlines	1,736	0.8%	1,078	0.6%	295	0.3%	427	0.3%	311
Republic Airlines; Inc.	2,246	1.0%	2,005	1.0%	785	0.8%	1,284	0.8%	446
Shuttle America Corporation	1,325	0.6%	1,341	0.7%	485	0.5%	831	0.5%	506
Sky West Aviation; Inc.	8,876	4.1%	7,031	3.7%	1,985	2.1%	2,850	1.8%	396
Southwest Airlines Co.	16,385	7.6%	18,299	9.6%	12,324	13.1%	18,148	11.6%	558
Trans States Airlines; Inc. D/B/A Trans World Express	987	0.5%	637	0.3%	157	0.2%	205	0.1%	323
United Air Lines Inc.	5,002	2.3%	9,425	4.9%	7,630	8.1%	13,028	8.3%	942
United Parcel Service Company	1,945	0.9%	2,464	1.3%	2,936	3.1%	6,866	4.4%	633
US Airways**	5,389	2.5%	7,814	4.1%	5,795	6.2%	8,533	5.4%	725
Westjet Airlines Ltd	176	0.1%	344	0.2%	232	0.2%	368	0.2%	980
Total of Top Operators	125,624	58.2%	139,305	72.7%	85,564	90.9%	140,399	89.4%	551
Total	215,808	100.0%	191,588	100.0%	94,166	100.0%	157,029	100.0%	444
Other Operators	90,184	41.8%	52,283	27.3%	8,602	9.1%	16,630	10.6%	292
Top Operators Percent of Total	58.2%		72.7%		90.9%		89.4%		

*Based on an average of 8 days of traffic from FAA Air Traffic Services Business Model

**Includes activity for America West, which merged with US Airways.

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Table 6 summarizes the points calculated under each method for the ATSBM carrier groups. In general, the points for the operators of the largest aircraft over the longest distances increase when using distribution methods that consider aircraft weight and distance flown. This applies to five groups: commercial passenger, commercial cargo, low cost passenger, foreign passenger and foreign freight flights. The other user types, including regional airlines, have a higher share of points when only the count of flights is used in the points allocation.

Table 6. Calculated Points by Operator Group

POINTS AWARDED PER DAY FOR DOMESTIC OPERATIONS IN DOMESTIC AIRSPACE, BY ALLOCATION BASIS									
	FLIGHTS		FLIGHT MILES		AVAILABLE SEAT MILES		AVAILABLE TON MILES		Average Flight
Group	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Distance
US Commercial Carrier Passenger	35,685	16.5%	57,084	29.8%	44,792	47.6%	71,545	45.6%	800
US Low-Cost Carriers Passenger	25,758	11.9%	33,339	17.4%	22,390	23.8%	32,770	20.9%	647
Foreign Carriers	3,084	1.4%	3,257	1.7%	1,778	1.9%	3,229	2.1%	528
Regional Airline Passenger	62,754	29.1%	44,145	23.0%	12,304	13.1%	17,569	11.2%	352
Charter Flight on US Carrier	714	0.3%	601	0.3%	384	0.4%	727	0.5%	420
Commercial Passenger Carriers- Piston	53	0.0%	11	0.0%	1	0.0%	2	0.0%	100
US Commercial Carrier Freight	6,556	3.0%	8,201	4.3%	9,926	10.5%	24,232	15.4%	625
Foreign Carrier Freight	73	0.0%	72	0.0%	115	0.1%	440	0.3%	490
Regional Airline Freight	3,153	1.5%	1,091	0.6%	92	0.1%	141	0.1%	173
Commercial Cargo Carriers- Piston	553	0.3%	183	0.1%	23	0.0%	46	0.0%	166
Fractional Ownership Programs	6,080	2.8%	5,001	2.6%	263	0.3%	888	0.6%	411
Non-Scheduled Part 135 Passenger	11,116	5.2%	8,000	4.2%	504	0.5%	1,549	1.0%	360
Part 135 Passenger - Piston	3,051	1.4%	950	0.5%	30	0.0%	32	0.0%	156
Non-scheduled Part 135 Freight	2,954	1.4%	1,112	0.6%	85	0.1%	116	0.1%	188
Part 135 Freight - Piston	2,190	1.0%	624	0.3%	21	0.0%	21	0.0%	142
General Aviation-Turbine	21,800	10.1%	16,138	8.4%	988	1.0%	2,988	1.9%	370
General Aviation-Piston	22,741	10.5%	8,302	4.3%	198	0.2%	207	0.1%	183
General Aviation-Rotor	146	0.1%	27	0.0%	1	0.0%	2	0.0%	92
Government	1,536	0.7%	574	0.3%	119	0.1%	177	0.1%	187
Tax Exempt	4,596	2.1%	2,301	1.2%	110	0.1%	236	0.2%	250
Not Classified by User Type	1,216	0.6%	576	0.3%	40	0.0%	110	0.1%	237
Total	215,808	100.0%	191,588	100.0%	94,166	100.0%	157,029	100.0%	444

V. Modeling and Simulation

A. Simulation Set Up

1. NAS Simulation Environment

To assess the usefulness of the proposed allocation methods, the Future Air traffic management Concepts Evaluation Tool (FACET)[16] developed at NASA Ames Research Center was used. FACET is a modeling and analysis system developed to explore advanced Air Traffic Management concepts. It handles traffic information at various spatial levels in the NAS, from the ARTCC, the sub-regions called Sectors, to individual aircraft trajectories. FACET can be used as a playback, simulation or real-time data analysis system. The simulation mode allows the user to take traffic initial conditions from a certain time. It evolves the air traffic based on available intent, consisting of flight plans that provide origin, destination, route of flight, aircraft type, cruise speed, cruise altitude and take-off time.

As far as NAS resource capacity constraints are concerned, any sector or airport that was used by any flight in the system was included in the NAS capacity data set. This data set represents all resources whose capacity constraints must be satisfied. For this study, the data set contained 974 sectors, and 905 airports. The FAA's Aviation System Performance Metrics (ASPM) and OPSNET data were used to obtain the maximum departure and arrival values for each of the top 70 airports. Since the airport capacity statistics are available in 15-minute intervals only, and some airports reconfigure their runways to increase their departure or arrival rates, the observed maximum values are an estimate of the operational capacity of the top 70 airports. Airports outside of this set were assumed to have a default value of 13 departures and arrivals every 15 minutes. Similarly, the default sector capacities known as Monitor Alert Parameters (MAP) were taken from ETMS.

2. Simulations

For each traffic dataset, the top 100 users were simulated as participants, and only their flights between the top 70 airports in the United States were used for metric evaluation. All of the other flights were included as background traffic, operating on their nominal flight plans and granted five points. Aircraft were flown along assigned routes and at each minute, capacity violations in the NAS were identified. Whenever a capacity violation arose, flights creating the imbalance were ranked by their points and the flight with the lowest point assignment was selected for rerouting.

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If no optional route was submitted or selection of optional routes caused another capacity violation, a system-imposed departure delay was assigned to the flight. The value of the system-imposed departure delay varied depending on the capacity violation. For sector congestion, a 5-minute ground delay was given, but a lower value may also be specified. For an airport capacity violation, a 15-minute delay or less was assigned. Given that airport capacities are evaluated every fifteen minutes, the assigned delay for an airport capacity violation was the necessary amount to reschedule the flight within the next 15-minute interval. This iterative process continued until no capacity violations occur. Then, the final point values for participant flights are decremented from their total point allocation.

In today's air traffic operations, airport and sector capacity constraints may be violated. In contrast, all resource capacity constraints were strictly satisfied in the simulation. Thus, for each traffic dataset, a simulated baseline case of one filed route and equally prioritized flights, reflecting the current FCFS system, was taken as the representation of the current air traffic operations. This allowed the system to calculate delays with respect to the baseline simulation.

B. Simulation Results

The priority points assigned to operators were used in a human-in-the-loop simulation based on prior work.[17] Three point measures were calculated for each operator: Flights, Flight Miles and Ton Miles. The simulations involved carriers using these priority points to sequence the flights that they wanted to have a priority for service, when the system could not serve all flights at their desired times. For example, a flights-based awarding of points provides relatively more points to those operators with the smallest aircraft. An allocation based on flight miles awards points to those operators with the longest flight segments, and the ton-mile based allocation gives relatively more points to those operators using the largest aircraft over the longest distances.

The results of the simulation by carrier for August 12, 2010 are shown in Table 7. Similar results were observed on other days. As can be seen, the largest operators such as Delta, Southwest and American have longer delays in the flights-based point system because operators with small aircraft have the same priority on a flight basis. WestJet experienced an unusual delay (45 minutes) under the flights-based system, possibly due to a flight arriving at a more-congested time than it did under the other systems. These carriers have fewer delays and shorter average delays when miles and ton-miles, respectively, are used for the initial allocation of points. This illustrates how the initial points allocation method affects an operator's ability to use them to reduce the delays it incurs.

Table 7. Delay Minutes by Operator under Alternative Point Systems

		Ton Miles			Miles			Flights		
OPERATOR	Flights	TOTAL DELAY	MEAN DELAY	MAX DELAY	TOTAL DELAY	MEAN DELAY	MAX DELAY	TOTAL DELAY	MEAN DELAY	MAX DELAY
Delta Air Lines; Inc.	1,279	955	0.7	41	980	0.8	41	1168	0.9	41
Southwest Airlines Co.	1,021	899	0.9	31	919	0.9	31	1152	1.1	44
American Airlines Inc.	949	672	0.7	34	695	0.7	34	729	0.8	39
US Airways	684	537	0.8	21	626	0.9	61	753	1.1	76
United Air Lines Inc.	613	446	0.7	24	489	0.8	26	685	1.1	41
AMR American Eagle; Inc.	568	517	0.9	30	480	0.8	30	446	0.8	16
Sky West Aviation; Inc.	491	568	1.2	65	398	0.8	36	418	0.9	51
Britt Airways; Inc.; D/B/A Continental Express	444	588	1.3	35	515	1.2	20	500	1.1	31
Continental Air Lines Inc.	400	293	0.7	16	302	0.8	16	357	0.9	25
Comair; Inc.	347	382	1.1	20	431	1.2	20	347	1.0	16
Mesa Aviation Services; Inc.	319	284	0.9	35	307	1.0	35	206	0.6	6
Atlantic Southeast Airlines	283	214	0.8	20	196	0.7	4	200	0.7	4
Express Airlines I; Inc. D/B/A Delta Connection	264	230	0.9	18	195	0.7	5	190	0.7	5
Air Canada	264	150	0.6	16	160	0.6	16	160	0.6	16
Netjets Aviation; Inc.	256	293	1.1	27	192	0.8	16	176	0.7	7
Chautauqua Airlines	219	313	1.4	55	289	1.3	25	202	0.9	16
Air Canada Jazz	202	116	0.6	9	116	0.6	9	116	0.6	9
Mesaba Aviation	195	163	0.8	15	163	0.8	15	149	0.8	15
Alaska Airlines Inc.	180	123	0.7	5	123	0.7	5	128	0.7	6
Airtran Airways; Inc.	173	127	0.7	5	152	0.9	25	212	1.2	30
Air Wisconsin Airlines Corporation	162	168	1.0	16	122	0.8	11	108	0.7	4
Horizon Airlines; Inc.	150	152	1.0	25	167	1.1	40	118	0.8	10
Piedmont Airlines; Inc.	148	139	0.9	15	124	0.8	7	124	0.8	7
Trans States Airlines; Inc. D/B/A Trans World Express	140	145	1.0	16	231	1.7	36	129	0.9	13
Federal Express Corporation	133	101	0.8	3	111	0.8	10	111	0.8	10
Flight Options	130	275	2.1	56	266	2.0	71	121	0.9	21
INDEPENDENCE AIR	126	243	1.9	26	302	2.4	62	137	1.1	13
Jetblue Airways Corporation	115	101	0.9	10	101	0.9	10	109	0.9	10
PSA Airlines	111	77	0.7	9	68	0.6	3	68	0.6	3
Westjet Airlines Ltd	107	38	0.4	2	53	0.5	15	83	0.8	45

Restricted to operators with at least 100 flights during the sample day

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The data in Table 8 summarize the delay simulation results by the operator groups. These confirm the results above, in that the groups operating larger aircraft over longer distances (Commercial Carrier Passenger and Low Cost Carriers) use the points in a way to have fewer delays under the systems which award points based on metrics that consider distance and the combination of distance and aircraft size. Conversely, the operators of smaller aircraft flying shorter distances have fewer delays in a system where the initial allocation is made using flights.

Table 8. Delay Minutes by Operator Group under Alternative Point Systems

		Ton Miles			Miles			Flights		
Group	**Flights**	**TOTAL DELAY**	**MEAN DELAY**	**MAX DELAY**	**TOTAL DELAY**	**MEAN DELAY**	**MAX DELAY**	**TOTAL DELAY**	**MEAN DELAY**	**MAX DELAY**
Regional Airline Passenger	4,375	4,617	1.1	65	4,432	1.0	62	3,731	0.9	51
US Commercial Carrier Passenger	4,105	3,026	0.7	41	3,215	0.8	61	3,820	0.9	76
US Low-Cost Carriers Passenger	1,434	1,207	0.8	31	1,252	0.9	31	1,558	1.1	44
Foreign Carriers	797	497	0.6	37	597	0.7	56	492	0.6	45
Fractional Ownership Programs	509	889	1.7	56	688	1.4	71	422	0.8	49
US Commercial Carrier Freight	226	166	0.7	10	191	0.8	16	186	0.8	15
Part 135 Freight - Piston	120	248	2.1	19	243	2.0	19	208	1.7	16
Regional Airline Freight	39	48	1.2	7	48	1.2	7	48	1.2	7
Non-scheduled Part 135 Freight	25	42	1.7	16	42	1.7	16	42	1.7	16
General Aviation-Turbine	16	6	0.4	1	6	0.4	1	6	0.4	1
Commercial Cargo Carriers- Piston	15	7	0.5	1	7	0.5	1	7	0.5	1
General Aviation-Piston	14	12	0.9	2	12	0.9	2	12	0.9	2
Part 135 Passenger - Piston	14	11	0.8	2	11	0.8	2	11	0.8	2
Non-Scheduled Part 135 Passenger	9	2	0.2	1	2	0.2	1	2	0.2	1
All operators	11,698	10,778	0.9	65	10,746	0.9	71	10,545	0.9	76

Figure 2 shows the average delay data by operator group in a visual comparison of the allocation alternatives. It also shows the total number of flights by group. As above, the flights based point allocations favor the regional airlines and operators of small aircraft in that they are able to use the points to get the shortest average delays. The opposite effect is evident for the Commercial passenger carriers and Low Cost carrier groups. User groups with 120 (Part 135 Freight - Piston) or fewer flights do not exhibit any difference in delay among the three metrics. This simply reflects their having few flights, which were subject to little delay and so did not happen to be affected by the flight prioritization system.

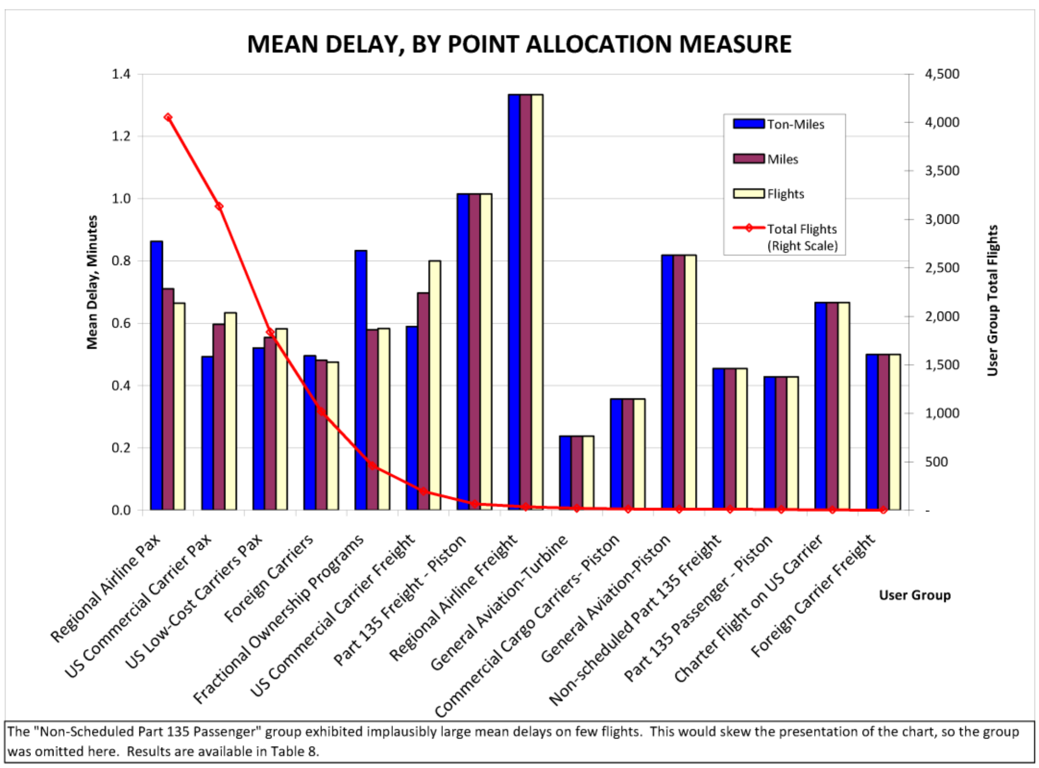

Figure 2. Comparison of Average Delay by Operator Group and Allocation Method

VI. Conclusions

A concept of priority points was introduced in earlier research. In subsequent research, analysis of system delay performance was presented using assignment of points by aircraft operators in the National Airspace System. The aspect of initial allocation of points is presented here. This research shows that it is possible to examine the delay reduction potential of alternative flight prioritization methods using alternative allocation schemes. The research also shows that the initial allocation of points affects the outcomes in terms of how carriers use priority points to reduce delays for the flights they operate. Allocation methods that consider aircraft size and distance flown tend to award proportionally more points to the operators of larger aircraft. This carries through to the outcomes because carriers with more points tend to achieve average flight delay reductions. Systems that consider only the number of flights operated produce more points and greater delay reductions for operators of smaller aircraft.

Future research should determine which allocation method produces the most socially desirable results. An important step would be assigning financial value to delay avoided. This value has two components: reduced aircraft operating cost, and value of passenger time saved. Hourly operating costs for aircraft used in commercial service are well-documented. Valuation of passenger travel time has been addressed in guidance from the Department of Transportation. It should therefore be relatively straightforward to develop reliable estimates of the potential cost savings among methods for awarding carrier points in a flight prioritization system.

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