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Benefit-Cost Analysis of a 2022 Point-To-Point ATM Concept

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In order to significantly improve future National Airspace System (NAS) capacity, we have developed a new NAS operational concept under the auspices of NASA's Virtual Airspace Modeling and Simulation (VAMS) program. The core concept – based on using advanced communication, navigation, surveillance, and Air Traffic Management (ATM) technologies and more Point-to-Point (PTP) flights – enhances the NAS payload capacity and efficiency by both relieving the throughput-limited hub-and-spoke airports and by providing more direct services to the traveler or shipper. The central premise that drives development of this concept is that there is a growing demand for more time-efficient, hassle-free, point-to-point and on-demand air transportation that better serves the traveling public and cargo shippers . Under Concept PTP, this demand is more effectively served by utilizing the existing network of non-hub-and-spoke public airports rather than depending on the the larger airports and the existing hub-and-spoke operational paradigm . In this paper, we describe an effort to quantify the benefits and costs of such a future PTP ATM operational concept. A majority of the work focused on the potential business case for specific improvements to the Chicago metropolitan area in 2022. Future air traffic demand generation and NAS-wide simulation evaluation runs are detailed. The analysis suggests the significant potential for future NAS capacity improvements from implementation of the PTP concept.

I. Introduction

SINCE the passage of the Airline Deregulation Act in 1978, the steady average growth in air transportation operations has very often pushed the aviation system in the United States to the brink of gridlock, most notably at the top 31 busiest air carrier airports and in the airspace directly surrounding them. Although commercial flight operations dropped after the terrorist attack on September 11, 2001, it is believed that domestic Revenue Passenger Miles (RPMs) will return to the pre-September 11 levels by 2005. Commercial traffic overall is expected to increase at an average annual rate of 4.0 percent after 2004 for at least the following 12 years[1]. Hence, delay is again looming as a critical limiting factor to hub-and-spoke based capacity growth in the foreseeable future.

According to the Federal Aviation Administration (FAA) Operational Evolution Plan (OEP)[2], 90% of the delay is experienced at 31 benchmarked hub airports, and demand will grow by 200 million passengers at these airports over the coming decade. Building more runways at these locations to absorb the projected growth in air transportation is politically and economically very difficult and a strategy with diminishing returns given increasing airspace complexity. Squeezing aircraft operations closer together will help but this does not represent a long-term solution.

The Point-to-Point (PTP) concept was developed to address this coming NAS capacity crunch. The central premise of the Point-to-Point (PTP) concept is that the National Airspace System capacity can be increased significantly by facilitating and incorporating massive use of point-to-point and on-demand commercial air transportation from a greater number of public airports than are used in today's hub-and-spoke configurations. This central premise is based upon the facts that there are both (a) an availability of over 5000 under-utilized public airports to choose from; and (b) a growing demand to use these airports for more time-efficient, hassle-free, point-to-point, on-demand air transportation that better serves the traveling public and cargo shippers[3].

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To enable the PTP concept, current ATM and flight operations infrastructure systems, aircraft fleets, and commercial aircraft operations management processes would all need to be augmented and enhanced. The current hub-and-spoke paradigm used by the large air carriers will be less and less capable of providing timely, efficient services as the hub airports reach their throughput limits. Also, the hub-and-spoke system has limits to growth without undergoing the very expensive, politically unattractive process of building more runways at the hub airports.

The PTP concept postulates that NAS flight capacity (defined as the number of passengers and volume of freight served within a normal business day) can be increased by:

1. Complementing the hub-and-spoke (HS) flight schedule from the viewpoint of the customer, with more alternate PTP flights that bypass hub airport congestion;
2. Utilizing more of the smaller public or underutilized military/government operated airports to serve as flight origin or destination points for PTP flights with the additional advantage that these airports could be closer to the intended starting and/or ending points of the trip;
3. Utilizing a greater spectrum of aircraft sizes and types to more economically meet the individual payload capacity (i.e., number of passengers or volume of cargo per flight) demands for the increased number of distributed origin-destination (O-D) airport pairs; and
4. Providing increased on-demand PTP air taxi-like service to complement the scheduled HS and PTP service.

In other words, a larger spectrum of aircraft types using PTP flights to and from the currently underutilized airports can (a) unload the hub airports; (b) provide large numbers of users with more direct flights, leading to shorter travel time to the desired destination; (c) provide more efficient transportation services to the nation's growing, smaller communities and expanding urban areas; and (d) offer on demand service as required to meet specific customer needs. This concept is depicted in Figure 1.

Figure 1. The Point-to-Point Concept

The PTP concept is characterized in a set of six integrated core ideas:

1. Airport Air Traffic Management (ATM). Provide towered and non-towered airports with the ability to handle enhanced low visibility operations via airport ATM automation, airport lighting system automation, precision landing guidance systems, and related infrastructure;
2. Terminal Area ATM. Utilize time-based and integrated ATM-flight management automation to provide even, regulated traffic flows along flexible paths within dense regional terminal areas servicing both large and small public airports in these regions;
3. En Route Airspace ATM. Integrate strategic ATM (traffic density management and flow control) and flight management automation processes within dense en route airspace, and utilize a new airspace design, free flight mechanisms, and communications, navigation, surveillance (CNS) technologies that move away from today's static sector mode of operation;
4. Traffic Flow Management (TFM). Expand the TFM functions to encompass the flow control needs of all providers of air transportation, to assist in optimizing each flight from the providers' business perspectives;
5. Fleet Operations. Integrate all commercial fleet (including air carriers, air taxis, business jet, uninhabited aerial vehicles (UAV) and rotorcraft operations) ground operations and dispatch functions with the ATM/TFM functions encompassed by the first four core ideas; and
6. Flight Deck Management and Avionics. Accommodate a broader aircraft type spectrum with advanced avionics designed to work directly with ATM and Fleet Operator automation tools and advanced ATM and flight operations procedures.

The details of the PTP concept has been previously described[4,5]. Recent work has been completed to produce additional details on the PTP concept[6], technical requirements[7], human performance requirements[8], and related operational scenarios[9]. All of this previous work has primarily been focused on the detailing of the PTP concept and investigations into its technical and operational feasibility.

In addition to these other investigations, a key issue for the PTP concept is whether it is economically feasible. In order to address this question, we conducted an in-depth investigation into the potential benefits and costs of the PTP concept for the 2022 timeframe. This paper is focused on highlighting the details of the approach and key findings of our completed[10] and ongoing PTP concept regional and NAS-wide benefit-cost analysis efforts.

II. Concept PTP Regional Benefit-Cost Assessments

After a review of the Concept PTP Core Ideas from our previous concept development effort[11], we defined a set of potential benefit mechanisms for each Concept PTP Core Idea. For every Core Idea, one or more capabilities were determined. Then, following the approach of Poage[12], we created tables of direct impacts and benefit impacts for each PTP capability as shown in Table II-1. For each capability, one or more direct impacts were defined that illustrated how the capability was expected to impact the relevant operations. Then, for each direct impact, a related metric was defined that could be used to quantitatively measure the direct impact. Also, "benefit" impacts and their metrics were also defined. These differed from the direct impacts in that they were defined to represent some final metrics tied directly or indirectly to expected metrics that would be of value to one or more aviation stakeholders. For instance, an airline is not likely to care so much about the (direct impact) metric of "pilot response time to identify proximate traffic", but is likely to care a lot about the (benefit impact) metric of "accident rate within 5 nm of nontowered airports".

Table II-1. Example Concept PTP Benefit Mechanisms Specification

Capabilities	Direct Impacts	Direct Impact Metrics	Benefit Impacts	Benefit Impact Metrics
• **Surrounding small airport surveillance and air traffic control automation system with new nontowered airport procedures**	• **Pilots not required to follow one-in, one-out IFR procedures** • **Improved pilot awareness of surrounding traffic** • **Reduced level of ATC staffing and equipment to support equivalent IFR ops**	• **Number of simultaneous aircraft within 5 nm of airport** • **Pilot response time to identify proximate traffic** • **Number of ATC Specialists required to support typical IFR traffic levels**	• **Increased airport capacity** • **Increased airport safety** • **Reduced airport ATC costs for a given level of ATC service**	• **Average number of IFR aircraft arrivals per peak hour** • **Average number of arrival delays per peak hour** • **Accident rate within 5 nm of nontowered airports** • **FAA cost savings to support IFR operations**

Once complete, we then generated a number of guidelines for our Concept PTP benefit-cost assessments. These guidelines included:

- use 2002 as our "baseline year" and 2022 as our "baseline NAS problem year" for purposes of defining appropriate demand scenarios and baseline capacity estimates; we aimed to leverage the previous May 17, 2002 demand data used to perform Airspace Concept Evaluation System (ACES) verification and validation[13] and the previous National Aeronautics and Space Administration (NASA) Headquarters (HQ) demand scenario work that targeted the generation of 2022 demand scenarios[14] (note: this work established a rough factor of 2X as the traffic ratio between 2022 and 1997/2002 traffic data);
- if possible use the Virtual Airspace Modeling and Simulation (VAMS) Virtual Airspace Simulation Technologies (VAST) ACES NAS-wide simulation software for the purpose of generating benefits;
- define and conduct an appropriate regional benefits study as well as extend the benefits analysis NAS-wide;
- choose a single day's worth of air traffic before going to a multi-day or year's worth of air traffic data;

- use the endpoint of the Federal Aviation Administration (FAA)'s Operational Evolution Plan (OEP) (currently in v5.0), slated for 2013, as the "baseline" system to measure Concept PTP's additional value against;
- choose a "perfect" day of weather before going to worse weather days; though this may minimize the Concept PTP benefits, we assume that even under perfect weather conditions the anticipated increases in NAS demand by 2022 are likely to outstrip even post-OEP NAS capacity;
- compare Concept PTP's benefits with corresponding concept costs; and
- use suggested FAA economic values for investment decision making[15] in benefit quantification.

We then determined the overall approach to the regional benefits and cost assessment work shown in Figure 2. This approach consisted of three major steps: the benefit analysis, the cost analysis, and the benefit-cost analysis based on the idea of comparing a future Concept PTP case to a "NAS Baseline" OEP case. Our benefit analysis consisted of the separate steps of defining demand, system, and environment inputs into a fast-time operational benefits simulation, and then converting the simulation output into economic benefits. This approach included the decision to use the VAMS ACES software to support the benefits assessment. Our cost analysis consisted of calculating the rough-order-of-magnitude marginal costs required for Concept PTP. Finally, the last step, a benefit-cost analysis consisted of comparing the outputs of the economic benefit and cost analyses in a one-to-one manner.

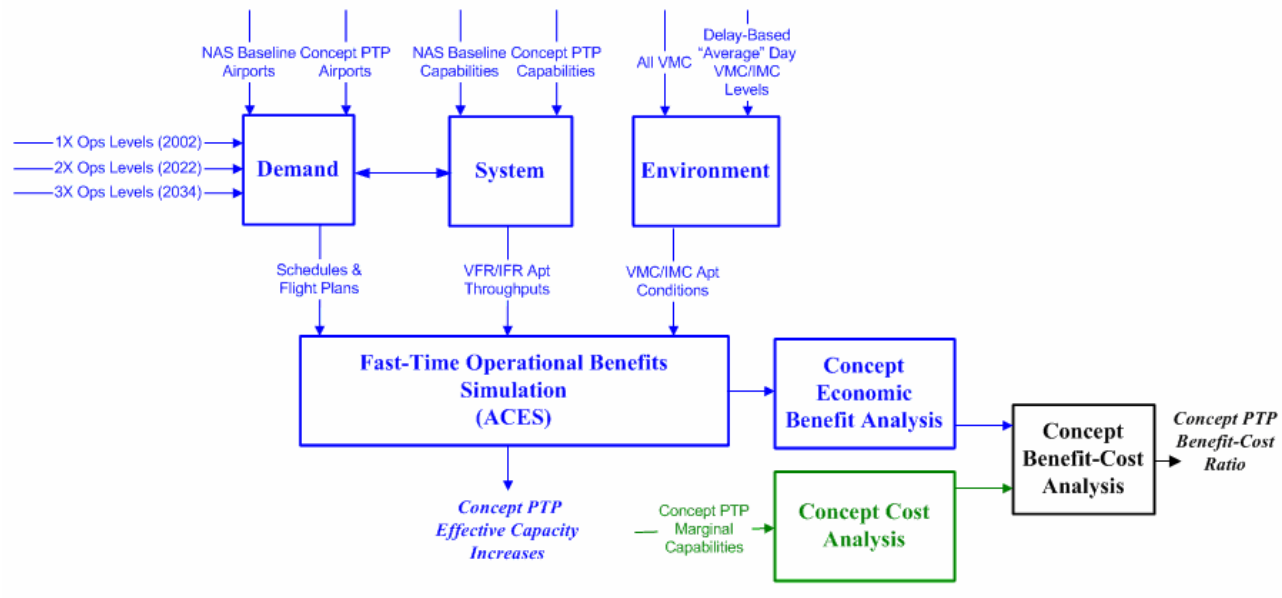

Figure 2. Concept PTP Regional Benefit-Cost Approach

Then we determined the scope of our initial regional benefit-cost assessments. It was our intuition that the Concept PTP core idea with the greatest capacity improvement potential is Core Idea 1: the improvement of nontowered and towered airports with Air Traffic Management (ATM) automation and supporting capabilities. Some modifications including leveraging multilateration surveillance instead of Automated Dependent Surveillance-Broadcast (ADS-B) and removing the smart taxi lighting were made to the supporting airport infrastructure to maximize its benefit-cost. Figure 3 shows the resulting Concept PTP Automated Airport Infrastructure.

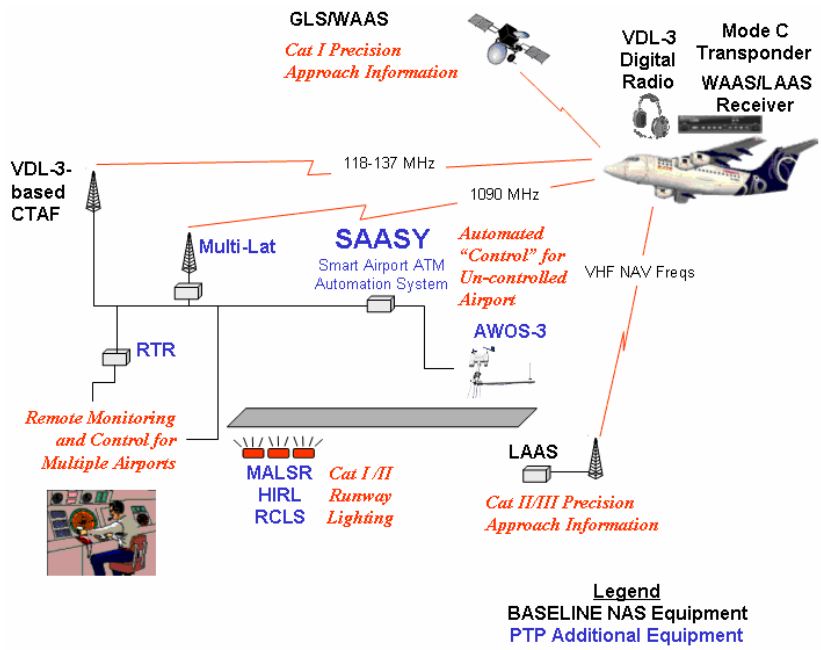

Figure 3. PTP Automated Airport Infrastructure

We chose the Chicago metropolitan area for our regional benefit-cost assessment. Specifically, the 11 public-use airports within 30 nm of Chicago O'Hare International Airport (ORD) were chosen. Currently, only two support commercial services: ORD and Chicago Midway (MDW). The other nine airports, which we referred to as the "PTP auxiliary airports" include four towered airports: Waukeegan Regional (UGN), Palwaukee Muni (PWK), Du Page (DPA), and Aurora Muni (ARR), and five nontowered airports: Campbell (C81), Lake in the Hills (3CK), Schaumberg Regional (06C), Clow International (1C5), and Lewis University (LOT). The relative locations of the focal airports for the study are shown in Figure 4.

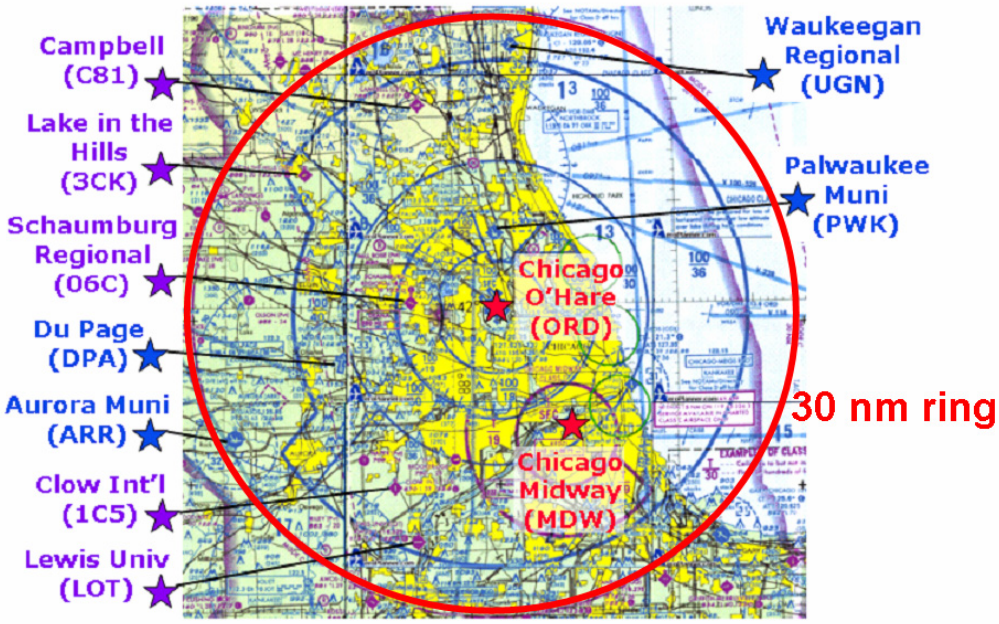

Figure 4. We conducted a regional benefit analysis focused on the public-use airports within 30nm around ORD.

We now discuss the Concept PTP Chicago Metro Area benefits analysis, cost analysis, and benefit-cost analysis in-turn.

A. Benefit Analysis

The first aspect of the benefit analysis we tackled was the demand. First, we took a set of Enhanced Traffic Management System (ETMS) traffic data from May 17, 2002, and parsed it down to just the traffic flying into and out of ORD and MDW (see Figure 5).

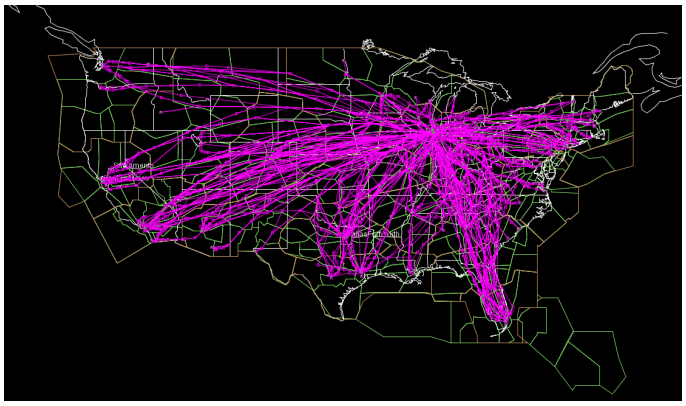

Figure 5. Flight plans for the Chicago Metro Area traffic

Then, we generated seven different demand scenarios for the future Chicago Metro Area. The most appropriate scenarios for our problem year of 2022 are those with a level of twice (2X) the baseline level of traffic. This is because of an analysis commissioned by NASA estimated the amount of traffic level in 2022 to be 1.98 times of the level of 2002 (ref. 28). The dimensions of 1X, 2X, and 3X the baseline traffic demand level and the separate assumptions of: baseline O'Hare (ORD) and Midway (MDW) traffic (1X and 2X), baseline ORD and MDW traffic with time-shifting (1X and 2X), and traffic distributions to the 9 auxiliary public-use airports around ORD and MDW (1X, 2X and 3X) were explored. Figure 6 illustrates the approach used to generate the demand scenarios.

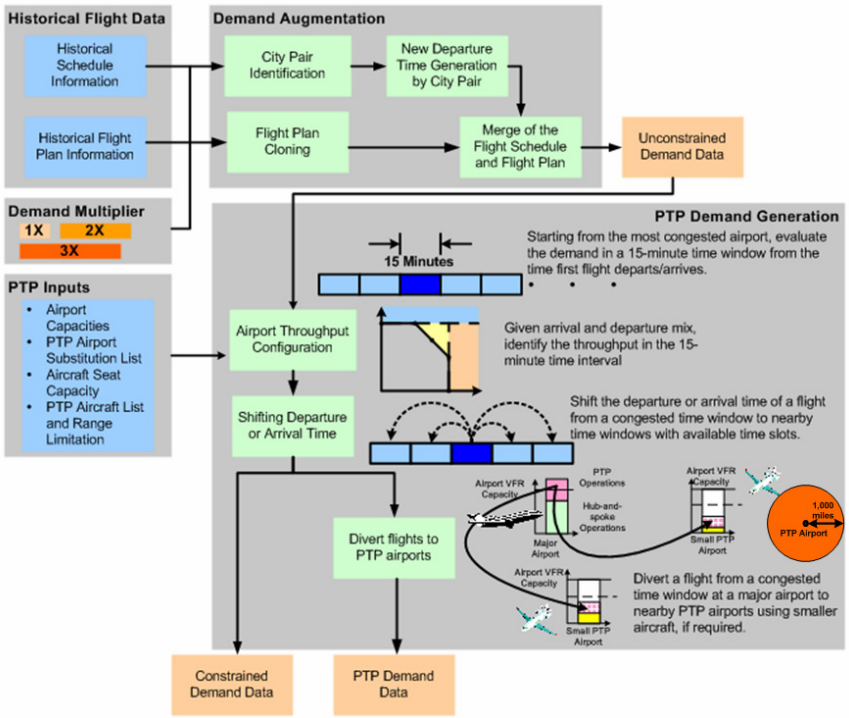

Figure 6. PTP Flight Demand Generation Process

Starting from a given flight demand dataset, which consists of historical flight schedule information and historical flight plan information, a demand augmentation process is used to create the unconstrained demand time. Since this demand does not account for airport capacity, a process to determine excessive demand above an airport's VFR capacity in a time window and time shift these flights to available slots is used to produce the constrained demand sets. After creating the airport capacity-constrained demand, if there remains excessive demand in the hub airports, the PTP demand generation algorithm is used to relieve the congestion at the hub. Each of these demand generation schemes is now described.

Unconstrained Flight Demand

For the generation of unconstrained demand generation, we used a deterministic approach to augment the flight demand data. From the demand dataset, flights from the same airport pairs are grouped together. The flight schedule and flight plan are treated as two different entities. For flight schedule augmentation, for a given origin-destination pair, the first and last flight departure times as well as the total time interval between these two flights are recorded first. Based on the given user-specified demand multiplier, the new number of flights between airport pairs is computed. The first and last departure of the day, in the original demand data, define the departure time window. The new flights are scheduled so the departures are evenly spaced across the departure time window. The original flight plans for the airport pairs are cloned and used in the new flight schedules. The result is a non-airport capacity constrained or "unconstrained" flight demand set.

Airport Capacity Constrained Flight Demand

The unconstrained flight demand set does not take airport capacity into consideration. Therefore, the flight peaking activities can easily exceed the airport capacity for a given time period. On the other hand, there are also times when the airport still has runway slots available for departure and arrival. To take advantage of the available capacity, we used an algorithm to switch flights from excessive demand time windows to the nearby time windows with available runway slots. Starting from the most congested airport, the timeline at each airport is divided into 15-minute intervals. The algorithm starts at the beginning of the day and goes through each time period until the end of the day. The algorithm examines flights in a 15-minute time window and determines the airport departure and arrival throughput using the Pareto capacity envelope. During a 15-minute time window, if there are more departure flights than the arrival flights, then the departure rate is set to the 15-minute maximum departure rate, or the departure capacity. This hourly departure capacity is divided by four. The arrival rate at this 15-minute interval is set to the remaining capacity, which is the difference between the total capacity and the departure capacity. The same logic holds when the arrival flights dominate the traffic. When the number of departure flights equals the arrival flights, both departure and arrival rate are set to half of the total capacity.

Once the rate for both arrival and departure are determined in the 15-minute time window, the amount of excessive departure/arrival flights at this time window can be determined. If there is any excessive demand, the algorithm searches for unused capacity in the hour before and hour after the 15-minute time window under examination (eight 15-minute time windows in all, four before and four after). A flight can be re-assigned only if both the departure and arrival airports have runway slots available at the time to which the flight is intended to be re-assigned. In addition, when deciding which flights to shift to the other time window, flights from an origin-destination airport pair with low daily flight frequency will be given priority. After completing all airports in the demand set, the result is the airport capacity constrained flight demand.

PTP Flight Demand

Sometimes the flight demand is too high for the airport to handle even after fully utilizing the available runway slots and taking advantages of residual airport capacity. In this case, Concept PTP makes use of the small airports around a major commercial airport by allowing the excessive demand at the major airport to land and take off at these small airports. These flights are regarded as PTP flights and the aircraft serving these flights are regarded as PTP aircraft.

In a 15-minute time interval, when there are still excessive demands and no available runway slots nearby, a PTP algorithm is used to divert flights from the major airport to a nearby small airport. Among excessive flights, flights from an origin-destination airport pair with high daily frequency will be given priority in diverting to a small airport. This is because airport pairs with a high frequency of daily flights tend to attract more origin-destination passenger and airport pairs with a low frequency of daily flights usually have more connecting passengers onboard. The purpose of diverting traffic to smaller airports here is to allow passengers who travel non-stop from/to the target airport can avoid congestion at the target airport. Passengers who use the target airport as an intermediate stop will have limited impact on the connecting opportunity because low frequency airport pairs are less likely to be removed from the target airport. In addition, because the runway length at small airports are shorter than the major ones, the

aircraft allowed to serve at these small airports are limited in both the service range and the number of seats. A flight distance limitation is implemented to ensure that flights that are diverted to smaller airports are within the serviceable flight range of these PTP aircraft.

In both the airport capacity constrained flight demand and the PTP flight demand, a target demand-to-capacity constraint ratio is applied to for diverting flights to nearby time-slots as well as nearby PTP airports. This is to reflect that airlines and airports may not want to have flights that are scheduled up to the theoretical capacity limitation. Instead, a lower capacity threshold is used. In the experiment, the target demand-to-capacity constraint ratio is set at 70%.

Also, to ensure that the number of seats provided by the new service is comparable to the number of seats provided by the original flight, the PTP algorithm determines the number of flights and aircraft substituting the original flight. The new flights will have at least the same number of seats as the original flight.

The PTP algorithm is executed from the most congested airports to the least congested airports. Within the airport, the algorithm also starts from the beginning of the day to the end of the day. The flight demand generated from the PTP algorithm is referred to as the PTP flight demand.

One important consideration in the PTP demand generation process is the determination of the fleet mix that is available to use the auxiliary airports. In the case that an auxiliary airport's runways are short, this can become an issue, especially for jet aircraft. The results of an investigation into the relationship of jet aircraft types to their corresponding takeoff field lengths (TOFLs) and number of passengers and to available Chicago area nontowered airport runway lengths is shown in Figure 7[20]. The comparison of aircraft performance to the shorter 3-4,000 ft runway lengths suggest that there is only one type of currently available jet aircraft family that can land at the shorter runway lengths: the Bae 146-100/200; Avro Regional Jet RJ70/85/100. Also, the Avro RJ85 has the capability to carry (a round value of) 100 passengers. For these reasons, the PTP demand scenarios assume that an AvroRJ85 would be the aircraft type for all PTP-distributed flights that operate out of the auxiliary airports. It is likely that assuming the success of the Concept PTP business case, future aircraft manufacturers will likely produce new aircraft types that can fit the PTP market niche.

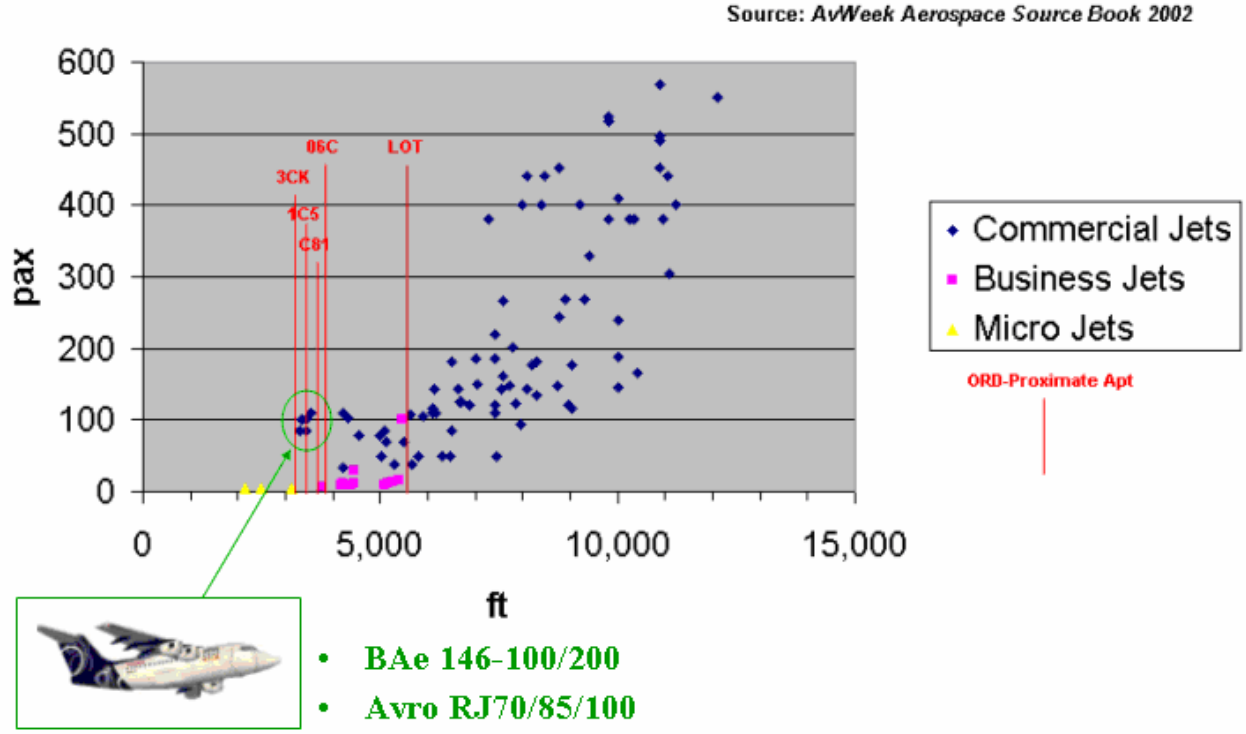

Figure 7. Jet Aircraft Takeoff Field Length vs. Number of Passengers vs. Runway Length

We used the flight demand generation process to create 7 days worth of flights to and from the Chicago Metro Area airports based on May 17, 2002 ETMS data as the baseline demand that was augmented. We created two unconstrained demands: 1X and 2X Demand; two constrained demands: 1X and 2X Time-shift; and three PTP demands: 1X, 2X, and 3X PTP. The unconstrained and constrained demands consisted of only departures and arrivals to and from ORD and MDW. The PTP demands involved distributing excess flights from ORD and MDW

to all of the nine PTP auxiliary airports. In the case of ORD, flights were allowed to be offloaded to MDW. Figure 8 shows the number of flights and how they breakdown between the area airports. The total traffic required to carry the flight demand in the distributed 2X PTP airport scenario was approximately 30% greater than the 2X non-PTP cases.

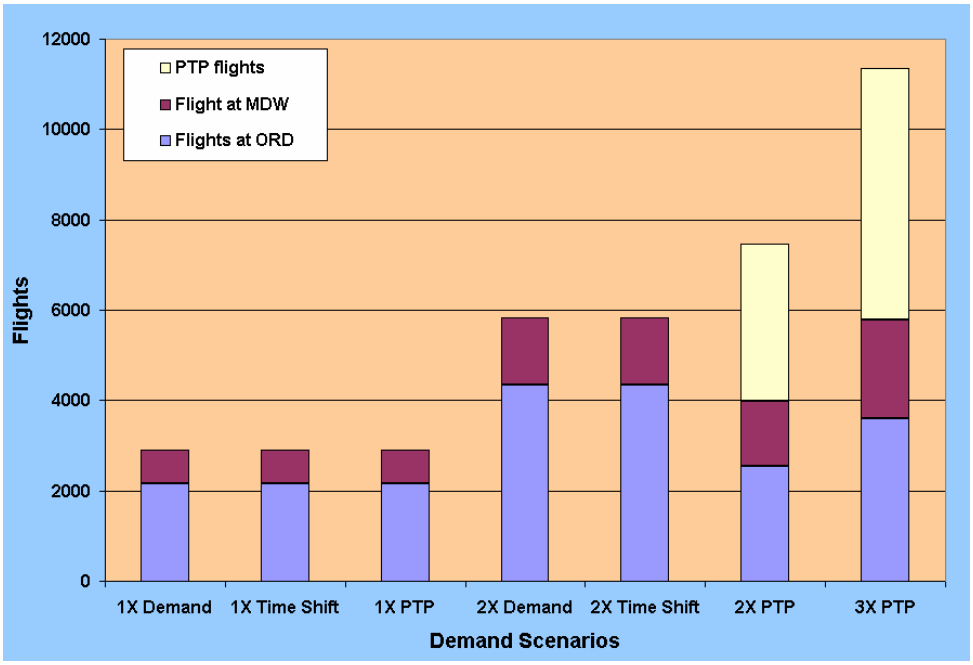

Figure 8. Demand Scenario Number of Flights Comparison

A typical daily traffic loading for the 2X PTP demand scenario is shown for hub airport Chicago O'Hare (ORD) and auxiliary airport Palwaukee (PWK) in Figure 9. The ORD hub airport is "saturated" at a target 70% of capacity criteria, while PWK still has room for additional flight demand.

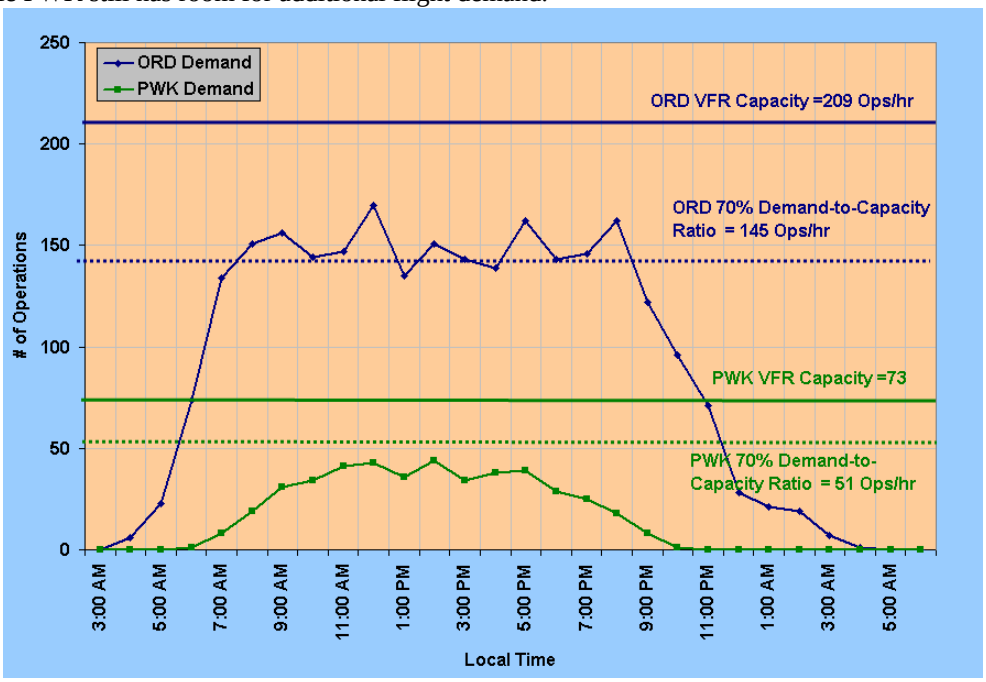

Figure 9. PTP 2X Demand Scenario: ORD and PWK Flight Demand Comparison

On the "System" dimension of the benefits assessment, we analyzed the existing and predicted FAA OEP capacities for ORD and the other Chicago Metro Area airports. In the case of ORD, previous FAA capacity

estimates[16] for 2010 were used; all other airport capacities were estimated using the standard FAA "handbook" approach of Advisory Circular 150/5060-5[17]. Table II-2 shows the final hourly Visual Flight Rules (VFR) and Instrument Flight Rules (IFR) capacities, as well as aggregate itinerant General Aviation (GA) aircraft loadings based on the FAA's Terminal Area Forecast (TAF) data[18]. We assumed that the VFR and IFR capacities for ORD and MDW represent 2013 OEP airport capacities. In fact, they also represent 2022 OEP airport capacities as well since the FAA does not have any clear plan beyond the OEP 2013 timeframe to improve airport capacities beyond that timeframe. The capacities of the other metro area airports are assumed to be those appropriate for future 2022 auxiliary airports that conform to the operational concept and equipment assumed with PTP Core Idea 1.

Also, as Table II-2 shows, a nominal level of general aviation operations was determined for each airport. We wanted to ensure that general aviation itinerant operations would not be impacted adversely by the Concept PTP auxiliary airport demand distribution (this does not include general aviation local operations which typically consist of in-the-pattern flight training). This would not have to be the case in a future NAS and it will limit the potential benefits of Concept PTP auxiliary airport demand distribution. However, since we chose to make this assumption, we calculated the impact of predicted general aviation operations as follows. First, we used the 2000 and 2015 TAF predictions for general aviation itinerant aircraft operations and derived an average annual growth rate that we in turn used to predict 2020 TAF general aviation operations. These total operations were assumed to be uniformly distributed over an assumed 16 hour operational day and a 350 day operational year. This "operational day" assumption was derived from other existing air traffic annualization methods[19].

Table II-2. PTP Core Idea 1 Benefits Study Airport Capacity Assumptions

Airport Designator	Airport Name	Towered, Commercial Status	Nominal VFR Capacity (Ops/Hr)	Nominal IFR Capacity (Ops/Hr)	Nominal Itinerant GA (Ops/Hr)
ORD	Chicago O'Hare International	Towered/ Commercial	213	179	NA (4)
MDW	Chicago Midway	Towered/ Commercial	125	60	NA (9)
PWK	Palwaukee Muni	Towered/ Noncommercial	77	56	26
DPA	Du Page	Towered/ Noncommercial	121	56	28
UGN	Waukegan Regional	Towered/ Noncommercial	77	57	9
ARR	Aurora Muni	Towered/ Noncommercial	77	57	11
C81	Campbell	Nontowered/ Noncommercial	77	56	2
06C	Schaumburg Regional	Nontowered/ Noncommercial	74	57	7
LOT	Lewis University	Nontowered/ Noncommercial	74	57	7
1C5	Clow International	Nontowered/ Noncommercial	63	56	5
3CK	Lake in the Hills	Nontowered/ Noncommercial	63	56	5

On the "Environment" part of the benefits assessment, we identified October 5, 2000, as a typical weather day for ORD (see Figure 10). In the figure based on a plot of FAA Aviation System Performance Metrics (ASPM) data[21] for every day in CY2000, the % of a given day's hours are plotted against the average gate arrival delays per flight. As shown, for the days considered, the average gate arrival delay was 16.9 minutes with a standard deviation of 14.0 minutes and the average % VMC was 85.1% with a standard deviation of 23.7%. One definition of the most typical weather day is the day whose % VMC and average gate arrival delay were closest to the average values. As shown in the figure, this day was October 5, 2000.

Further investigation into its use based on available ASPM data, led to the identification that airport capacity and meteorological conditions were not very well correlated (see Figure 11). Therefore, we chose to be conservative in our benefits assumptions and assume an all Visual Meteorological Conditions (VMC) weather day for the benefits analysis.

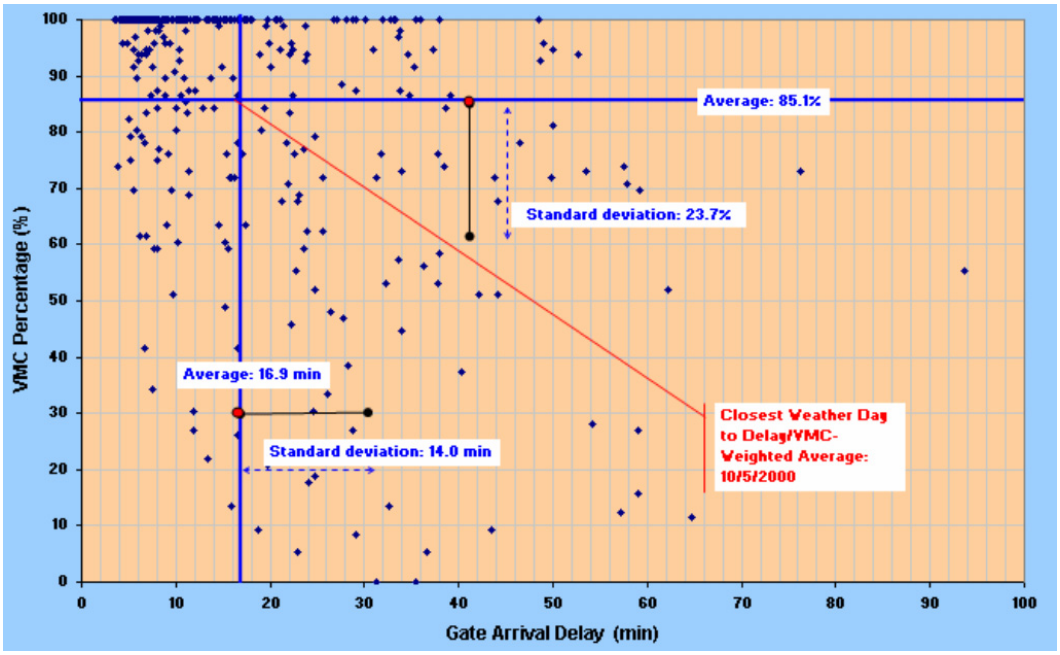

Figure 10. Determination of a Typical ORD Weather Day

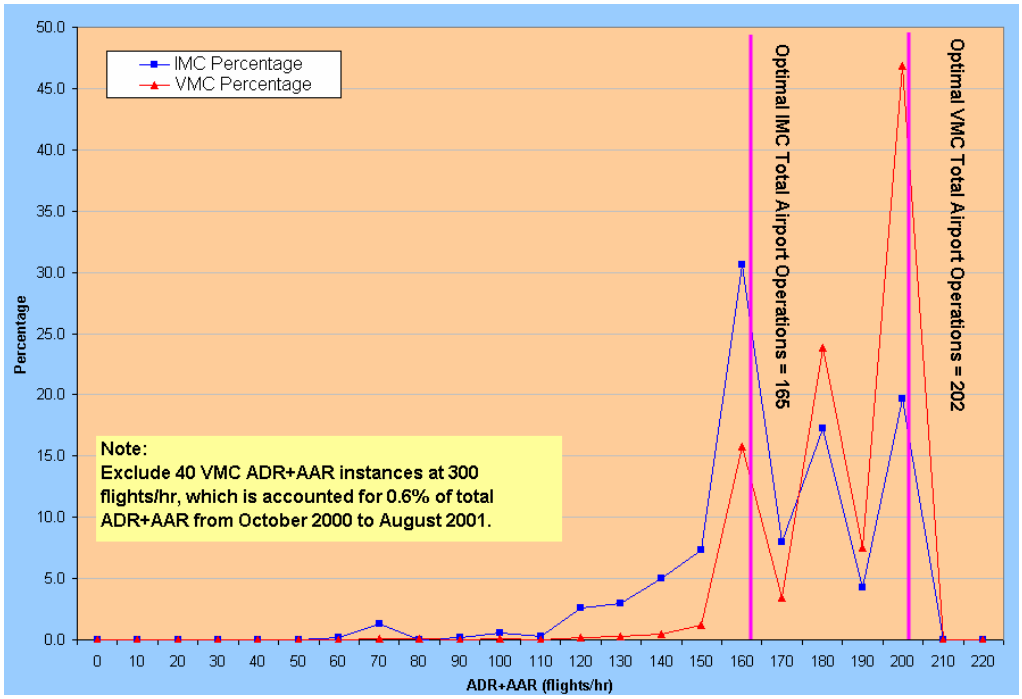

Figure 11. ORD Hourly Airport Arrival Rate + Airport Departure Rate (AAR+ADR) under Visual Meteorological Conditions (VMC) and Instrument Meteorological Conditions (IMC)

Using our assumptions of a Chicago Metro Area analysis using the demand, system, and environment assumptions, we ran the NASA VAMS ACES fast-time, NAS-wide simulation software to generate the demand vs. delay results shown in Figure 12 as a function of flight demand and in Figure 13 as a function of passenger demand.

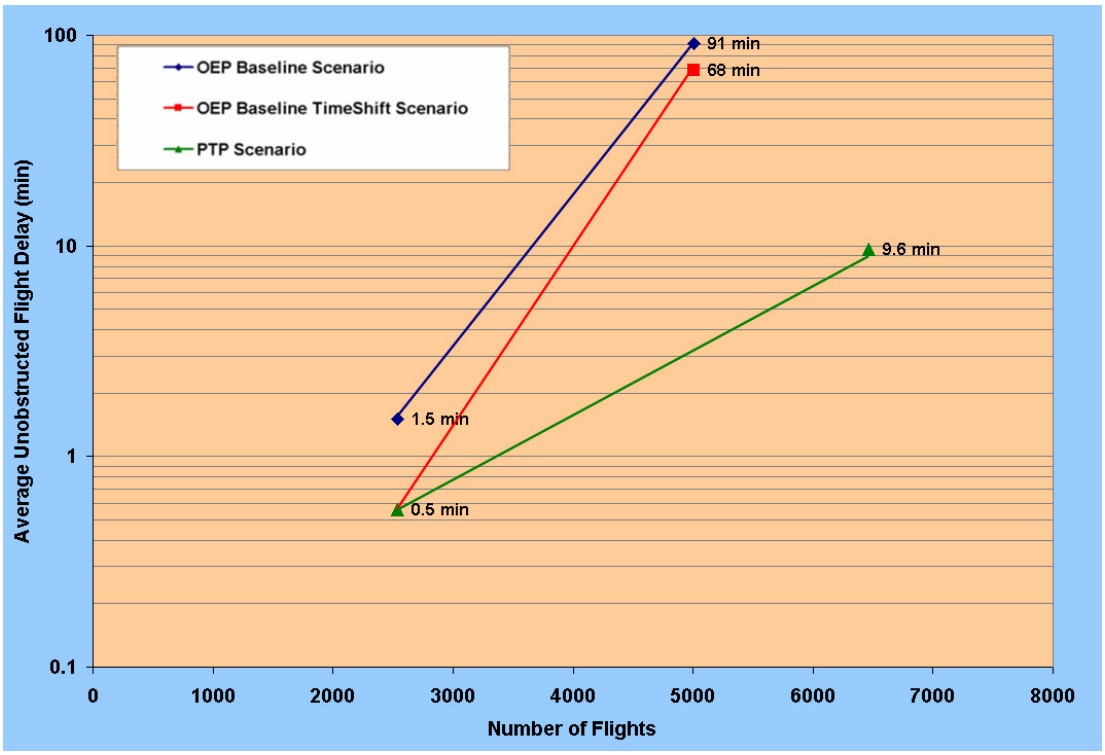

Figure 12. Concept PTP Regional Benefits Assessment *Flight Demand*-Delay Curve based on ACES Chicago Metro Area Traffic Simulation

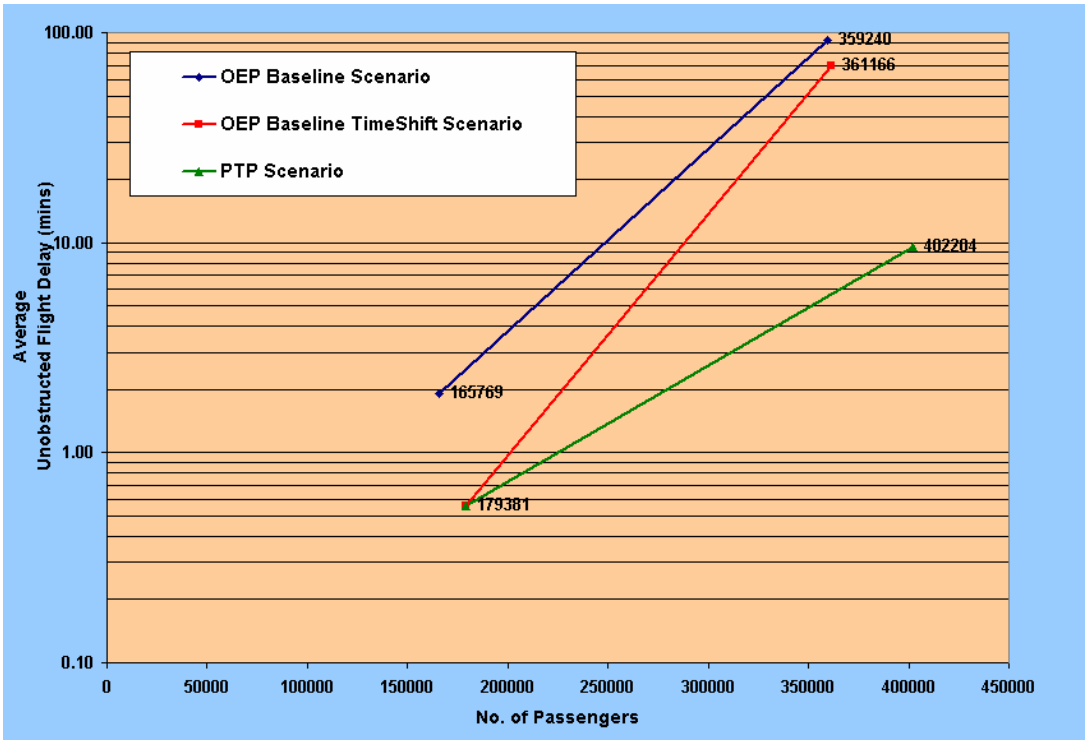

Figure 13. Concept PTP Regional Benefits Assessment *Passenger Demand*-Delay Curve based on ACES Chicago Metro Area Traffic Simulation

For the Chicago Metro Area analysis performed, this led to the following conclusions:

- at a 1X demand level, Concept PTP provides no significant benefits over an OEP baseline with schedule time-shifting,
- at a 2X demand level, that corresponded to a Year 2022 demand prediction, Concept PTP provides significant delay time savings over OEP Baseline cases; instead of an average delay of 68 minutes per flight for the 2X OEP Baseline with Time Shift, the 2X PTP case yields an average delay of 9.6 minutes per flight (despite an increase of 30% more total flights than the 2X OEP Baseline), and
- Concept PTP provides significant effective capacity increases (on the order of 70% or greater for the Chicago Metro Area (see Figure 14).

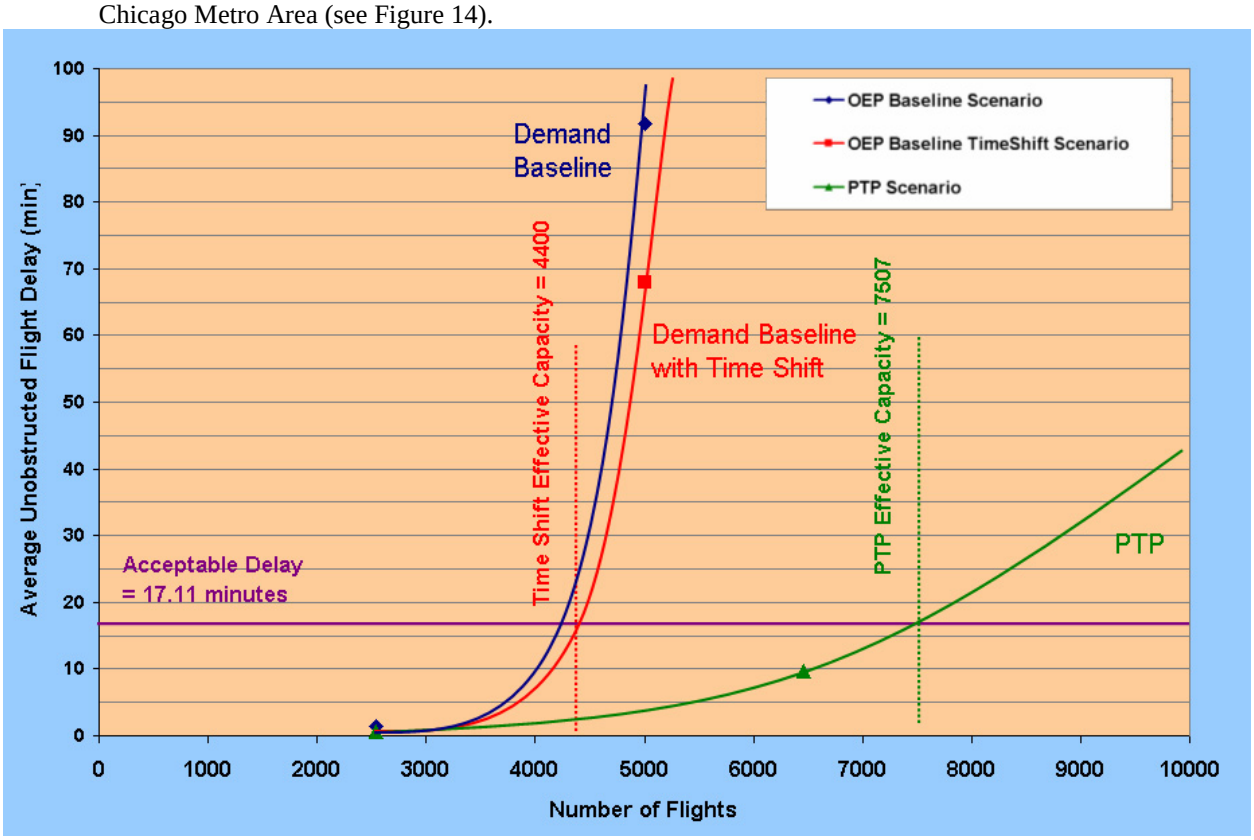

Figure 14. Effective Capacity Estimation Assuming Exponential Demand-Delay Relationship

The curve in Figure 14 is constructed assuming that the delay will grow exponentially. Therefore, we are able to construct each curve with only 2 points. In addition, the delays calculated in our six scenarios are against the unobstructed flight time. The unobstructed flight time of a flight is calculated assuming the flight is the sole flight in the NAS. Thus, the time is the shortest possible time of a flight based on the flight plan, cruise altitude and cruise speed. Therefore, the flight time in the simulation against the unobstructed flight time is defined as the unobstructed flight delay. Acceptable delay, an index to estimate the relative effective capacity for both demand baseline with time-shift and PTP concept, equals to the maximum tolerable delay against flight schedule plus the average airline schedule padding. The Department of Transportation considered a flight is a delayed flight if the flight is delayed for more than 15 minutes against its schedule. Thus, the the maximum tolerable delay against flight schedule is 14 minutes. Also, the average airline padding, 3.11 minutes, is calculated by comparing the unobstructed flight time with the Official Airline Guide (OAG) time. As a result, the acceptable delay is 17.11 minutes.

B. Cost Analysis

In addition to the regional benefits analysis, a regional cost analysis was performed. We first inventoried the existing airport equipage at the Chicago Metro Area airports. Then, using the equipage already planned for the 2013 timeframe, we identified the marginal airport infrastructure required for Concept PTP operations (see Figure 15).

Cost data were collected for the marginal Concept PTP equipment costs and rolled up into life cycle costs for the auxiliary airport equipment using assumptions of a 20 year economic life (see Table II-3). The total Net Present

Value for the marginal Concept PTP airport equipment was a total of $139.7M with the Smart Airport Automation System (SAASY) ATM Automation and Multilateration system costs dominating.

Chicago Metro Area Airports	Commercial		Towered				Non-Towered				
	ORD	MDW	PWK	DPA	UGN	ARR	LOT	06C	1C5	C81	3CK
NAS Equipage											
RCO				X							
RTR	X(5)	X	X(2)	X	X(2)	X	X	X	X	X	X
Multi Lat		X	X	X	X	X	X	X	X	X	X
ATM Automation			X	X	X	X	X	X	X	X	X
MALSR	X	Lights	X	X	X	X	X	X	X	X	X
HIRL	X	X	X	X	X	X	X	X	X	X	X
RCLS	X	X	X	X	X	X	X	X	X	X	X
LAAS	X					X				X	
RVR	X	X		X							
AW/SOS	ASOS	ASOS	ASOS	ASOS	ASOS	ASOS	AWOS-3	AWOS-3	AWOS-3	AWOS-3	AWOS-3
CTAF	UNICOM	UNICOM	CTAF	UNICOM	CTAF/UNI	CTAF/UNI	CTAF/UNI	CTAF	CTAF	CTAF/UNI	CTAF/UNI
VDL-3 CTAF	X	X	X	X	X	X	X	X	X	X	X
GLS/WAAS	X	X	X	X	X	X	X	X	X	X	X
Other											
FireFighting	ARFF/IndE	ARFF/IndD									
Terminal Buildings	X	X									

Aircraft Equipage	
Mode C Transponder	X
VDL-3 Digital Radio	X
GLS/WAAS Nav Radio	X
LAAS Nav Radio	X

Exists X
Forecasted to Exist X
PTP Additional Item X

Figure 15. Chicago Metro Area Airport Equipage Assumptions

Table II-3. Chicago Area Concept PTP Marginal NAS Infrastructure Annualized Life Cycle Cost Estimates

Concept PTP Cost Item	Annualized Life Cycle Costs in 2003$K
IFR Clearance Capable Smart Airport Automation System (SAASY)	$108,780
Small Airport Multilateration Surveillance System	$13,950
Remote Transmitter Receiver (RTR)	$10,850
Medium Intensity Approach Lighting System with Runway indicators (MALSR)	$2,232
Local Area Augmentation System (LAAS)	$1,240
Automated Weather Observing System (AWOS)	$988
Runway Centerline Lighting System (RCLS)	$977
High-Intensity Runway Lights (HIRL)	$698

C. Benefit-Cost Analysis

For the benefit-cost analysis, we desired to compare the benefits of Concept PTP with its costs on a one-to-one basis. We chose to do this comparison on a daily basis. This is due to a number of factors including a) our previous benefits analysis was performed for a single day, and b) the daily benefits are likely to increase significantly forward in time because of the expected nonlinearity of the average delays as a function of increasing demand. We noted that the potential benefits and costs estimations for Concept PTP can be viewed in at least two different ways: the case where air traffic demand is purely inelastic and the case where the air traffic demand is purely elastic. Coming from the field of economics, the elasticity of air traffic demand can be defined as the sensitivity of air traffic demand to the delay level experienced by that demand. If the air traffic demand is purely inelastic, demand for air travel will not be affected by air travel delays. If the air traffic demand is purely elastic, demand for air travel will be heavily affected by air travel delays; in fact, we assume that in this case the air travel demand does not increase above that of a given level of maximum acceptable delay. We assume this maximum acceptable delay level to be that where the average arrival delay is 14 minutes past the scheduled arrival time. Our benefit-cost analysis was developed through

separate investigations of the general benefit-cost analysis, followed by investigation into the inelastic and elastic demand cases.

1. The General Benefit-to-Cost Case for A Given Concept

In order to better understand at least two ways to look at the economic cost-benefits for Concept PTP, let us begin with analysis of the generic benefit-cost problem for any future capacity-increasing ATM concept, Concept X. We assume that Concept X is being quantitatively evaluated against the given Baseline System and both systems consist of different sets of aircraft and NAS infrastructure that support moving a given set of air travel passengers to their desired set of destinations. One way to evaluate the differences between the relative performances of future Concept X and the Baseline System under a future passenger demand is through the modeling and generation of system delay data for each case. In its most generic form, we have two systems that handle a given future passenger regional traffic demand through two sets of different sets of flights and yield two different delay levels, for a given set of weather conditions. These two systems yield different combinations of (flights, delay) that are reflected as point "B" (for the Baseline system) and point "C" (for Concept X) (see Figure 16).

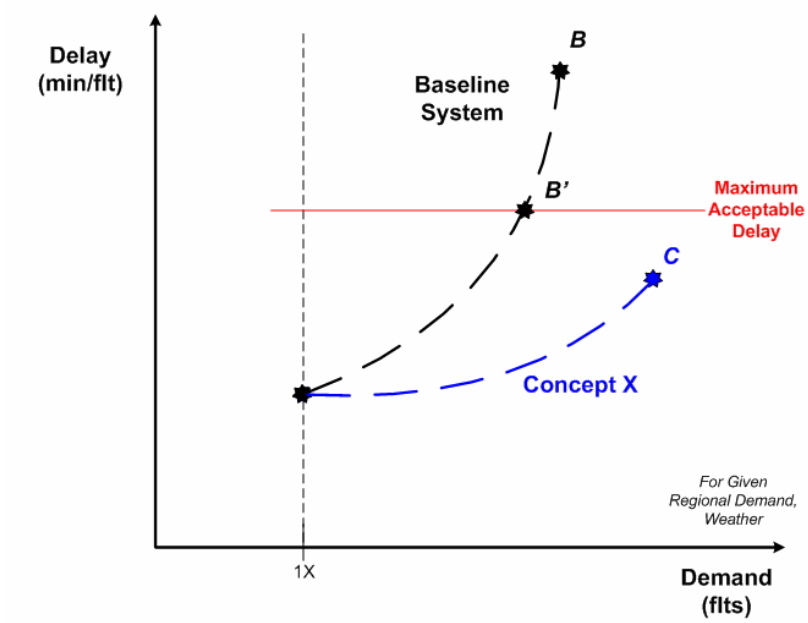

Figure 16. Demand-Delay Results for Concept X and a Baseline System

Now, we want to compare the economics of the Baseline System and Concept X. Therefore, in its most general form, we want to compare the revenue and costs of our two systems. Assuming that we are interested in the calculation of the economic benefits of our Concept X, one may formulate the calculation of these benefits as follows:

$$EconomicBenefits = Revenue_{ConceptX} - Cost_{ConceptX} - (Revenue_{BaseSys} - Cost_{BaseSys}) \quad (1)$$

Furthermore, let's assume that the costs of our two concepts are reflected in both the economic costs of the aircraft that are used to fly the passengers around and the costs of the associated NAS infrastructure required to support the safe and efficient flight of the aircraft. These system costs can be represented as aircraft direct operating costs (DOCs) and NAS infrastructure costs (NASCosts). Therefore,

$$\begin{aligned} EconomicBenefits = {} & Revenue_{ConceptX} - DOC_{ConceptX} - NASCosts_{ConceptX} \\ & - (Revenue_{BaseSys} - DOC_{BaseSys} - NASCosts_{BaseSys}) \end{aligned} \quad (2)$$

Now, the aircraft direct operating costs can be further broken down into those direct operating costs that are sensitive to actual flight times, the so-called Variable Direct Operating Costs (VarDOCs), and those that are fixed costs, the so-called Fixed Direct Operating Costs (FxdDOCs). The VarDOCs consist of crew costs, maintenance costs, and fuel and oil costs that vary based on the amount of time that each aircraft flies, and, thus, when significant delays occur, these VarDOCs increase. The FxdDOCs consist of depreciation, insurance, and acquisition/rental costs that are not sensitive to aircraft flight time, but are fixed for the given economic life of the airframes. These FxdDOCs will not be typically impacted by aircraft delays, but the value of the FxdDOCs in cost per unit flight time will be impacted by the utilization of the airframes. If the airframes are better utilized, the amount of aircraft needed

to fulfill a given level of passenger demand will decrease, and, therefore, the FxdDOCs will decrease. Adding the distinction of the two types of aircraft direct operating costs now yields:

$$EconomicBenefits = Revenue_{ConceptX} - VarDOC_{ConceptX} - FxdDOC_{ConceptX} - NASCosts_{ConceptX} - (Revenue_{BaseSys} - VarDOC_{BaseSys} - FxdDOC_{BaseSys} - NASCosts_{BaseSys}) \quad (3)$$

This Equation (3) represents the economic benefits of Concept X in its most generic form.

Now, focusing on the economic costs of transitioning from the Baseline System to Concept X can be represented as:

$$EconomicCosts = Cost_{ConceptX} - Cost_{BaseSys} \quad (4)$$

Reusing the breakdown of the costs as done in the economic benefits case, the economic costs of Concept X in its most generic form can be represented as:

$$EconomicCosts = VarDOC_{ConceptX} + FxdDOC_{ConceptX} + NASCosts_{ConceptX} - (VarDOC_{BaseSys} + FxdDOC_{BaseSys} + NASCosts_{BaseSys}) \quad (5)$$

2. The Benefit-to-Cost Case Assuming Perfectly Inelastic Demand

Then, focusing on the case where we assume that passenger demand is perfectly inelastic (i.e., the demand for air travel is not diminished by the magnitude of the resulting delays), the appropriate benefits to calculate for Concept X are the differences between our two operating points, "B" for the Baseline System, and "C" for Concept X (previously shown in Figure 16). In this case, we make the following assumption:

- since the number of passengers carried in the two cases is the same, we assume that the average yield per passenger is the same in both cases, and, therefore, $Revenue_{ConceptX} = Revenue_{BaseSys}$.

Furthermore, since the difference in the NAS Infrastructure costs between the Baseline System and the Concept are just the marginal costs required to provide the concept, $MarginalNASCosts_{ConceptX}$, our equation for Concept X economic benefits now simplifies to:

$$EconomicBenefits_{ConceptX} = VarDOC_{BaseSys} + FxdDOC_{BaseSys} - VarDOC_{ConceptX} - FxdDOC_{ConceptX} - MarginalNASCosts_{ConceptX} \quad (6)$$

and the equation for Concept X economic benefit-to-cost ratio is:

$$\frac{EconomicBenefits}{EconomicCosts} = \frac{VarDOC_{BaseSys} + FxdDOC_{BaseSys} - VarDOC_{ConceptX} - FxdDOC_{ConceptX} - M\arg inalNASCosts_{ConceptX}}{M\arg inalNASCosts_{ConceptX}} \quad (7)$$

The different economic benefit and cost components were calculated for the specific case of 2X 5/17/02 passengers for Concept PTP vs. a Baseline OEP with Time-shift case assuming inelastic demand for traffic into and out of the Chicago metropolitan area. For each set of demands, the variable and fixed direct operating cost rates were obtained using FAA suggested values[15] for each aircraft type and the marginal NAS costs were taken from the previously-determined Concept PTP cost analysis. In each case, a daily value of the operating costs was obtained. The variable and fixed direct operating costs were obtained using the output of the NAS-wide simulator as shown:

$$VariableDOC = (SimulatedGateArrivalTime - ScheduledGateDepartureTime) * (Fuel\ \&\ OilCost + MaintenanceCost + CrewCost) \quad (8)$$

$$FixedDOC = (ScheduledGateArrivalTime - ScheduledGateDepartureTime) * (RentalCost + DepreciationCost + InsuranceCost) \quad (9)$$

The daily marginal NAS operating cost was obtained by dividing the 20 year economic life costs by 20 years and 365 days per year.

A summary of the resulting economic values are shown in Table II-4.

Table II-4. Concept PTP Economic Benefit and Cost Values for the Case of Inelastic Demand for 2X Passengers flying into and out of the Chicago Metropolitan Area

Economic Value	Variable Name	Value in 2003$
Baseline System Daily Variable Direct Operating Costs	$VarDOC_{BaseSys}$	$40,978,348
Baseline System Daily Fixed Direct Operating Costs	$FxdDOC_{BaseSys}$	$8,789,611
Concept PTP Daily Variable Direct Operating Costs	$VarDOC_{ConceptPTP}$	$23,103,853
Concept PTP Daily Fixed Direct Operating Costs	$FxdDOC_{ConceptPTP}$	$12,517,665
Concept PTP Daily Marginal NAS Infrastructure Costs	$M\arg inalNASCosts_{ConceptPTP}$	$19,139
Concept PTP Daily Economic Benefits	$EconomicBenefits_{ConceptPTP}$	$14,127,302
Concept PTP Daily Economic Costs	$EconomicCosts_{ConceptPTP}$	$19,139
Concept PTP Daily Economic Benefit-to-Cost Ratio	$\frac{EconomicBenefits_{ConceptPTP}}{EconomicCosts_{ConceptPTP}}$	738

As we see, the economic benefit-to-cost ratio for transitioning to Concept PTP, with the assumption of inelastic demand, is an overwhelming value of 738, suggesting that Concept PTP seems very economically feasible.

3. The Benefit-to-Cost Case Assuming Perfectly Elastic Demand

Having calculated the benefit-to-cost case where demand was perfectly inelastic, we now turn our attention to the opposite case: where the demand is perfectly elastic (i.e., demand will increase up to a limit determined by a maximum acceptable delay threshold). In this case, the appropriate benefits to calculate for Concept X are the differences between our two operating points, " B' " for the Baseline System, and "C" for Concept X (as shown in Figure 16). Point B' is the point on the Baseline System throughput curve that intersects with the maximum acceptable delay line, was found by exponentially interpolating the baseline with time shift scenario curve in Fig. 14. A commonly-accepted interpretation of the demand at Point B' is the so-called "effective capacity" of the Baseline System. Because the maximum potential demand is not realized in the Baseline System case, $\mathrm{Re}venue_{ConceptX} > \mathrm{Re}venue_{BaseSys}$ and the number of flights and passengers are correspondingly reduced in the Baseline System case. Thus, our previous economic benefits equation (3) cannot be simplified beyond:

$$EconomicBenefits_{ConceptX} = \mathrm{Re}venue_{ConceptX} - VarDOC_{ConceptX} - FxdDOC_{ConceptX} - M\arg inalNASCosts_{ConceptX} - (\mathrm{Re}venue_{BaseSys} - VarDOC_{BaseSys} - FxdDOC_{BaseSys}) \quad (10)$$

and the equation for the given Concept's economic benefit-to-cost ratio is:

$$\frac{EconomicBenefits_{ConceptX}}{EconomicCosts_{ConceptX}} = \frac{EconomicBenefits_{ConceptX}}{M\arg inalNASCosts_{ConceptX}} \quad (11)$$

The different economic benefit and cost components were calculated for the specific case of 2X 5/17/02 passengers for Concept PTP vs. a Baseline OEP with Time-shift case assuming elastic demand for traffic into and out of the Chicago metropolitan area. Variable and fixed direct operating costs and marginal Concept PTP NAS infrastructure costs were calculated as previously performed for the inelastic demand case. Revenues were calculated using the following expression:

$$Revenue = Revenue \quad per \quad Passenger \quad Mile * (No.of.Passengers * FlightDistance) \quad (12)$$

The revenue per passenger mile was 11.85 cents[29]. The great circle flight distance was used and the number of passengers was obtained by converting the flight demand into equivalent passenger demand. In the conversion the aircraft data such as the seating capacity was obtained from the FAA aircraft registry[30] and airline loading factor was used.

Table II-5. Concept PTP Economic Benefit and Cost Values for the Case of Elastic Demand for 2X Passengers flying into and out of the Chicago Metropolitan Area

Economic Value	Variable Name	(Inelastic) Value in 2003$	(Elastic) Value in 2003$
Baseline System Daily Revenue	$Revenue_{BaseSys}$		$29,242,125
Baseline System Daily Variable Direct Operating Costs	$VarDOC_{BaseSys}$	$40,978,348	$20,535,794
Baseline System Daily Fixed Direct Operating Costs	$FxdDOC_{BaseSys}$	$8,789,611	$7,553,404
Concept PTP Daily Revenue	$Revenue_{ConceptPTP}$		$36,555,708
Concept PTP Daily Variable Direct Operating Costs	$VarDOC_{ConceptPTP}$	$23,103,853	$23,103,853
Concept PTP Daily Fixed Direct Operating Costs	$FxdDOC_{ConceptPTP}$	$12,517,665	$12,517,665
Concept PTP Daily Marginal NAS Infrastructure Costs	$MarginalNASCosts_{ConceptPTP}$	$19,139	$19,139
Concept PTP Daily Economic Benefits	$EconomicBenefits_{ConceptPTP}$	$14,127,302	-$237,876
Concept PTP Daily Economic Costs	$EconomicCosts_{ConceptPTP}$	$19,139	$19,139
Concept PTP Daily Economic Benefit-to-Cost Ratio	$\frac{EconomicBenefits_{ConceptPTP}}{EconomicCosts_{ConceptPTP}}$	738	-12.4

As we see, the economic benefit-to-cost ratio for transitioning to Concept PTP, with the assumption of elastic demand, is an economically-infeasible value of -12.4. This value occurs because of the high drop-off in variable direct operating costs for a less consequential drop-off in passengers carried and revenue as one drops from the inelastic demand point B to the elastic demand maximum acceptable delay point B'.

However, this negative benefit-cost picture is tied to an assumption that the airlines are incurring the additional costs inherent in the increased fixed direct operating costs associated with the additional airframes required to fly the Concept PTP demand, which is $237,876 for the Concept PTP elastic demand. If we assume that these additional Concept PTP operating costs can be transferred from the airline to the passengers through higher ticket prices, e.g. $1 per passenger, we achieve a benefit-to-cost ratio of 8.6. This value was calculated based on the passenger demand in PTP and revenue per passenger mile in 2003 $.

III. Concept PTP NAS-Wide Benefit Assessments

In addition to the regional Concept PTP benefits analysis conducted, we performed additional NAS-wide capacity benefit analyses focused on the complementary benefit mechanisms of:

- increase of regional airport capacity through enhanced use of local auxiliary airports (PTP-A), and
- reduction in airport demand through offloading of hub airport connecting passenger traffic (PTP-B).

With Concept PTP, these two benefit mechanisms can be thought of conceptually in terms of two ways that NAS flight demand can be altered to relieve the demand-to-capacity crunch at congested airports (see Figure 17).

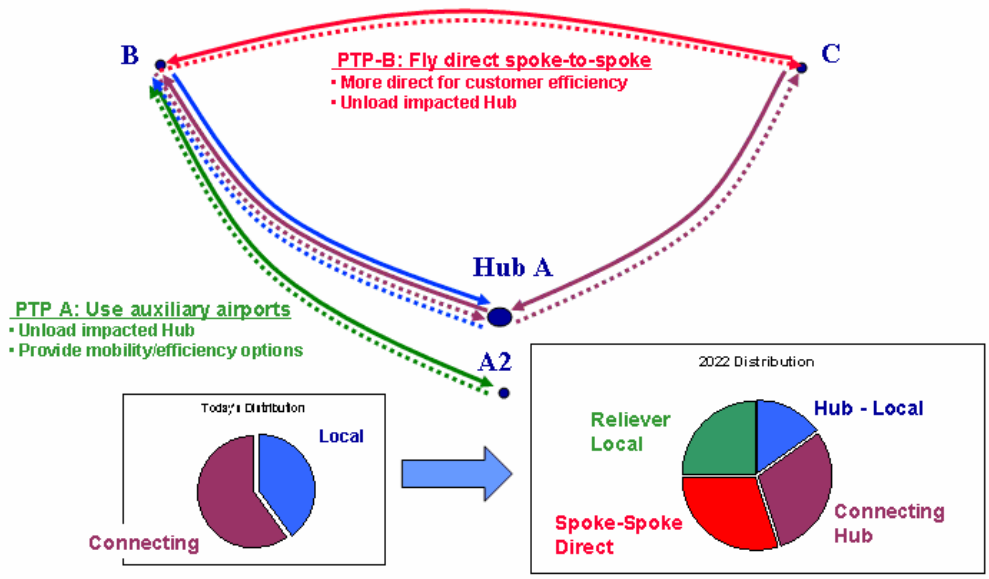

Figure 17. Two NAS-wide Concept PTP Demand-related Benefit Mechanisms

Because of the historically large passenger traffic and delays experienced at the 34 FAA CONUS OEP airports and the importance of current government-sponsored NAS improvement efforts to these airports; we focused our potential NAS-wide improvements around these airports.

The investigations into NAS-wide PTP-A and PTP-B benefits are now described in-turn.

A. PTP Benefits through Auxiliary Airport Use (PTP-A)

The overall approach for conducting the PTP-A benefits analysis is shown in Figure 18. First, we restricted our PTP-A benefits analysis to the 34 CONUS FAA OEP airports and surrounding region. We defined the airport "surrounding region" as an approximate Mode C surveillance veil about the OEP airports. For this purpose, we assumed that the available PTP auxiliary airports were all public-use airports within a 30nm radius around the focus OEP airport. If an airport had some runways in poor condition or were comprised of turf, the uses of these runways were excluded.

We assumed that the identified auxiliary airports did not have radar surveillance coverage down to the runways, and, therefore, operated under non-radar separation rules and provided negligible hourly capacity under the current baseline NAS. The implementation of Concept PTP Core Idea 1 is assumed to provide radar-separation service-enabled capacity levels for each identified auxiliary airport.

Then, a search was performed via aeroplanner.com[22] for the airports within the specified region. Once the qualifying airports were obtained, each airport was checked against the 2001 Airport Capacity Benchmark Study[23] to determine if capacity information already exists. If the airport was in the study, the corresponding VMC and IMC capacity metrics were gathered.

For the Airport Capacity Benchmark Study[23] capacities, we used the maximum 2000 rates for “optimal rate” and “reduced rate” operations corresponding to VMC and IMC, respectively. The “New Runway & New Technology” capacity improvements listed in Airport Capacity Benchmark Study[23] were added to the 2000 rates to determine the OEP capacity for each airport.

If the airport was not in the benchmark study, the capacity was assessed using guidance from the FAA Advisory Circular 150/5060-5(ref. 24). The runway configuration of the airport was determined by maps found at the FAA National Aeronautical Charting Office (NACO)[25] and AirNav[26] with preference given to NACO when available.

Some assumptions were made when assessing the capacity via the Advisory Circular. If the airport had three runways or less, the following assumptions were made:

- Approximately 75% of the airplanes were over 12,500 lb but not over 300,000 lb.
- No airplanes were over 300,000 lb.
- General aviation dominated the airport operations.

If the airport had more than three runways, the following assumptions were made:

- Approximately 75% of the airplanes were over 12,500 lb but not over 300,000 lb.

- Approximately 10% of the airplanes were over 300,000 lb.
- Air carrier operations dominated the airport operations.

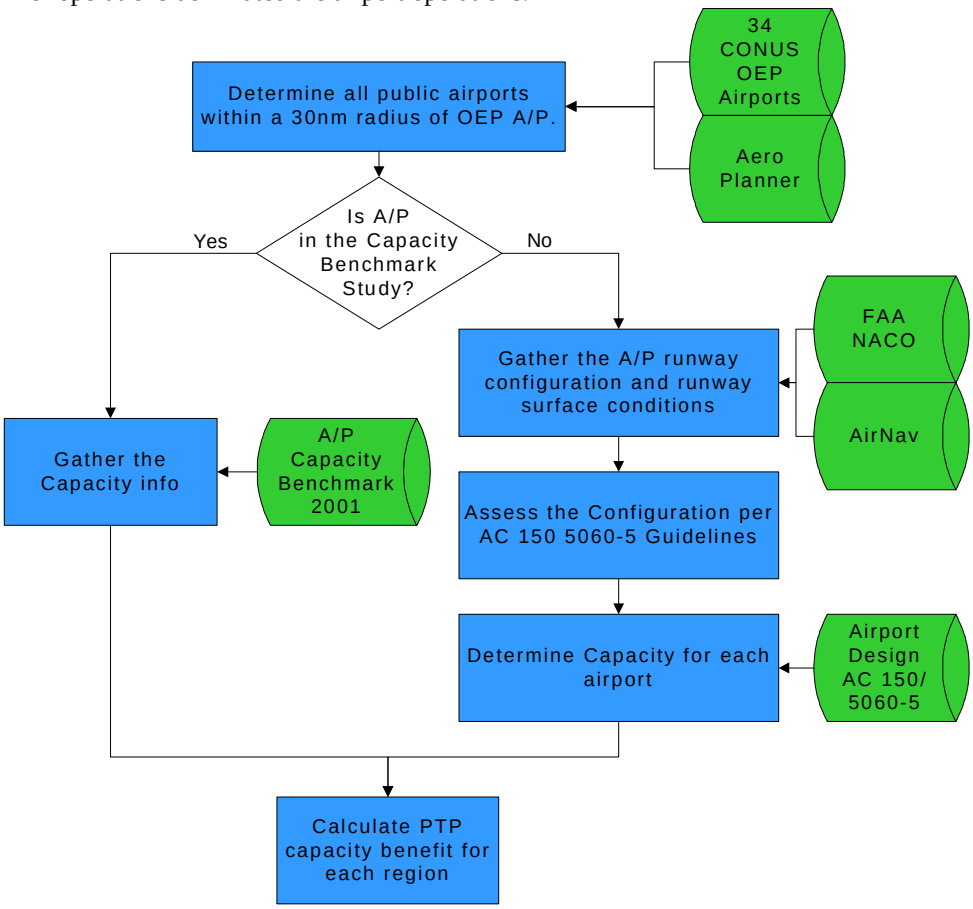

Figure 18. Process for Calculating NAS-wide PTP Auxiliary Airport Capacity Benefits

In order to assess the NAS-wide PTP increase in capacity, a new capacity metric was created using the equation below.

$$PTP\ Increase_{Region} = \frac{\sum_{Airport} All\ Airport\ Capacity_{Region}}{\sum_{Airport} OEP\ Airport\ Capacity_{Region}} \tag{13}$$

To interpret this metric, if there were no PTP airports within the region beyond the OEP airport, the PTP Increase for the region would equal 1. If the PTP Increase metric equals 2, the PTP auxiliary airports doubled the capacity of the region.

The results of the NAS-wide PTP-A analysis of the impact of using auxiliary airports is shown in Figure 19. The areas most impacted by the use of PTP are Seattle in VMC and Cleveland in IMC yielding 9.8X and 13.3X increases, respectively. The region least impacted by PTP-A is Denver. However, Denver still reaps benefits of more than 2.7X under both VMC and IMC. The aggregate CONUS OEP PTP Increase in VMC is 490% and in IMC, 506%.

These results reveal at least two major trends: 1) the potential for NAS-wide capacity improvement due to the increased use of auxiliary public-use airports is significant, and 2) this potential capacity increase is typically higher under IMC than it is for VMC. In the second case, a likely reason for this is the dependent nature of the runways of a large hub airport. The runways of surrounding auxiliary airports (usually single runways) are typically far enough away to handle departure and arrival traffic independent from the hub airport runways and from one another, and, therefore, are more resistant to capacity-reducing impacts of adverse meteorological conditions.

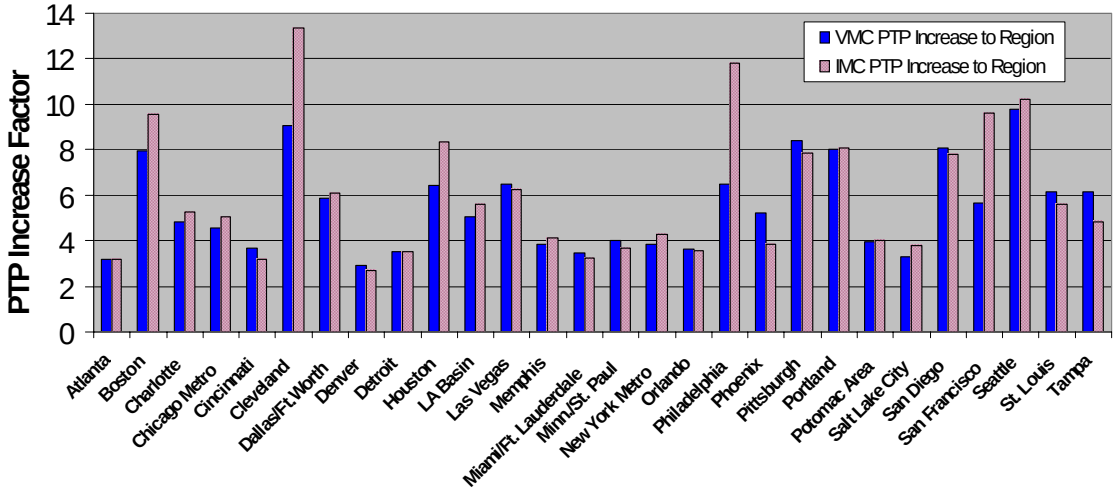

Figure 19. NAS-Wide PTP-A Capacity Increase for CONUS OEP Airports

B. PTP Benefits through Hub Connecting Traffic Offloading (PTP-B)

Our PTP-B benefits analysis evaluated domestic connecting and nonconnecting passenger traffic through the 34 FAA CONUS OEP airports to estimate the maximum amount of passenger traffic that can be reduced because of the PTP-B mechanism of offloading connecting traffic from a congested hub airport. We used two 1999 datasets to estimate the amount of connecting traffic at each airport: Schedules T-100 Air Carrier Data and Department of Transportation Origin-Destination Survey of Airline Passenger Traffic[27]. In the T-100 Air Carrier Data, we obtained the total amount of passenger traffic to and from a specific airport. From the Origin-Destination Survey data, the amount of passengers who initiate or terminate trips at the airport can also be obtained. By comparing these two data, the connecting passengers, those who do not end or start their trips at the airport, can be identified. Due to data restrictions and the issue that connecting international passenger traffic are much less likely to be able to fly direct to their destination, only domestic passengers are accounted in this analysis.

The results of the NAS-wide PTP-B analysis of the impact of off-loading hub airport connecting domestic traffic onto direct, point-to-point flights is shown in Figure 20. These results reveal the potential for significant NAS-wide offloading of hub airport traffic to reduce NAS flight congestion, especially for the hub airports in the middle of the country.

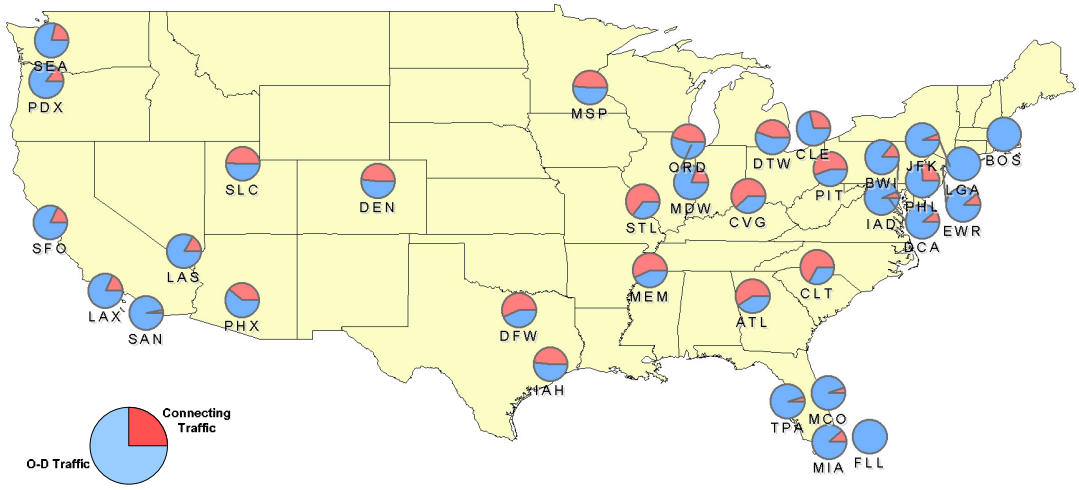

Figure 20. Potential NAS-wide PTP-B Hub Airport Domestic Demand Reductions at the 34 CONUS OEP Airports

A total 779 million passengers used these 34 airports in 1999. Of these passengers, 495 million passengers actually start their trips or terminate their trips at these airports. These passengers account for 63% of the total passenger traffic. This means that there are 284 million passengers, which are equivalent to 36.47% of the total passenger flow, who use these airports as intermediate stops only. Using point-to-point routing for these passengers could reduce congestion at the major hubs and reduce passenger flight time and connections.

As in the case of the PTP-A benefit mechanism, future work is needed to quantify the economic value of this hub offloading and further investigate the detailed economic and operational drivers behind airline decision-making to change their flight schedules.

IV. Conclusions

From the results of our benefits and cost assessments, it is abundantly clear that Concept PTP, even limited to Core Idea 1, has a significant potential for increased NAS capacity benefits over and above that predicted for the FAA's OEP improvements. Also, given the anticipated increases in NAS demand over the next 20 years, the benefits are expected to significantly outweigh the related costs for such a new concept. Our initial regional analysis for Concept PTP suggests that the economics case seems feasible (esp., for Core Idea 1). Some of the dimensions to the economics case that remain to be investigated include:

- the sensitivity of the benefits case relative to more demand scenarios (note: the key issue here is the generation of finer-grained demand scenarios in order to better understand the nonlinear nature of the demand-delay curves and determine a better estimate for effective capacity increases),
- the sensitivity of the benefits case relative to different weather scenarios,
- the extrapolation of the Concept PTP benefits and cost assessments to NAS-wide air traffic scenarios and the already identified benefit mechanisms of small airport demand distribution and hub airport demand off-loading,
- the extension of the economics investigation into the other Concept PTP Core Ideas, and
- the economics of potential alternative solutions such as, in the case of Core Idea 1, the implementation of local radar surveillance system and an Air Traffic Control Tower or building additional hub airport runways.

The economics business case for Concept PTP Core Idea 1 also contains the paradoxical result of increasing capacity and reducing delay while increasing air traffic demand significantly. We expect this increasing flight demand to be a challenge to the technical feasibility of the Concept PTP Core Idea 2 regarding time-based ATM improvements for the Terminal Area. This is a key area for additional study in future Concept PTP evaluation phases.

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