AN ANALYSIS OF RNP APPROACH AT MIDWAY INTERNATIONAL AIRPORT

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ABSTRACT

Adoption of Required Navigation Performance (RNP) approach capability (a key enabler of NextGen) by U.S. airlines has been slow and haphazard creating a modernization stalemate. This paper presents an analysis of the benefits of RNP approaches at Midway airport (MDW) with the objective of determining its return on investment (ROI) for an individual airline. A holistic methodology is presented that leverages high fidelity surveillance track data and thrust specific fuel burn models to quantify the benefits of existing and hypothesized RNP flows at MDW. The results show that under the appropriate meteorological conditions when RNP approaches are used instead of the less efficient conventional approaches, there is the potential of saving an average of 0.81 million gallons per year for all arrivals at MDW. The analysis also evaluates an advanced runway configuration model that selects runway configuration based on forecast flows and fuel burn, as well as wind magnitude and direction. Along with RNP approaches this has the potential of improving the fuel savings by 4.5% at MDW. The results of the analysis are used to estimate the ROI of investing in RNP approach for a major air carrier at MDW. The results show the major carrier at MDW cannot break even at MDW in 10 year. For the investment to break-even the carrier would have to perform at least 0.5 million RNP approaches per year throughout its network. The implication of these results and incentives/strategies that exists to achieve airline equipage have also been discussed.

Keywords: RNP equipage, Airline benefit/cost analysis, Terminal airspace flow analysis, Trajectory based thrust specific fuel burn.

INTRODUCTION

Airspace navigation enabled by a combination of ground-based navigation systems, inertial referencing systems and satellite based navigation systems, has evolved from the conventional ground-based point-to-point navigation to area navigation (RNAV) (FIGURE 1). Further, the advancements in the on board monitoring and altering systems have provided the aircraft the capability to maintain a high level of navigation performance through all phases of the flight. These navigational advancements collectively referred to as Performance Based Navigation (PBN), have enabled the implementation of advanced procedures which are expected to transform the National Airspace System (NAS) by making it more efficient and reliable*(1, 2)*.

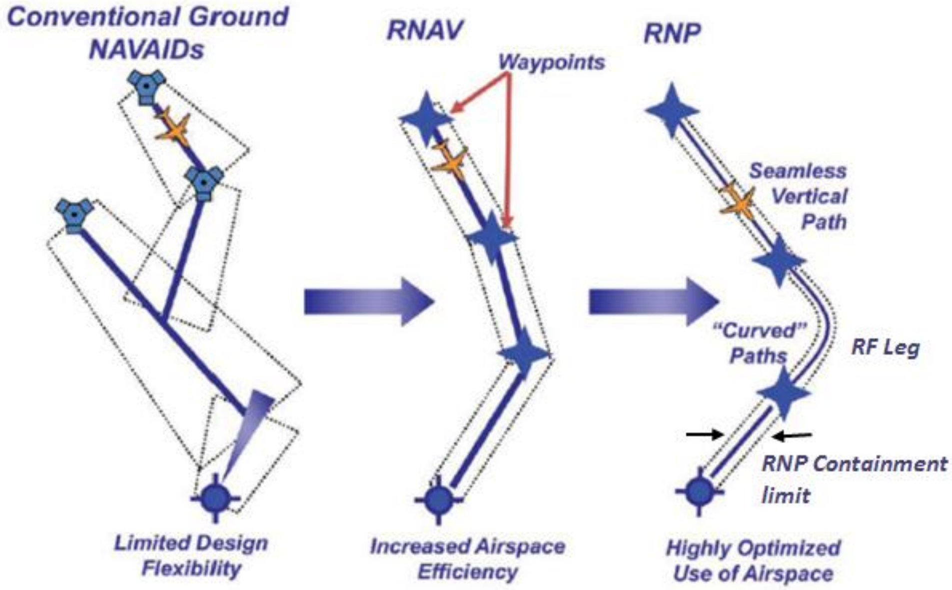

FIGURE 1 A depiction of evolution of navigation performance (source: Ray (2013))

In the terminal airspace PBN has enabled the implementation of precise curved path approach procedure called Required Navigation Performance (RNP) 0.3 approach with Radius to Fix (RF) leg, where “RNP 0.3” is the level of performance required for the approach (i.e., the aircraft are required to laterally maintain the defined path of the procedure within 0.3 nautical miles (NM) 95 percent of the time and twice the RNP value (i.e., 0.6 NM) 99.999 percent of the time) and the RF leg refers to the curved path between two fixes.

The precise curved path RNP approach can improve flight efficiency in the terminal airspace and allow safe navigation near high terrain obstacles and airspace occupied by other flows of air traffic *(3)(4)*. However, the successful adoption and utilization of RNP approach relies on airlines investing in the equipage, crew training and certification to fly the procedure. This has been slow primarily due issues with accurately estimating the Return-on-Investment (ROI). Other factors (not the focus of this paper) include timely design and deployment of RNP approaches by the air navigation service providers (ANSPs), training of air traffic controllers, and the “free rider” issue, i.e., the allocation of benefits to parties that choose not to equip but gain benefits when their competition equips. Together these issues have created a “modernization stalemate.”

The recent availability of high fidelity surveillance track data (which includes actual flights tracks of RNP approaches) coupled with aerodynamic fuel burn models and weather data have created an opportunity to perform a detailed analysis of terminal airspace flows to accurately determine the savings (compared to conventional approaches) and the ROI of RNP approaches.

This paper presents a methodology and results of an analysis of RNP approach at Midway International Airport (MDW) with the objective of answering the following fundamental research questions related to the RNP approach equipage and the associated challenges:

1. Does airline investment in RNP approach capability yield an acceptable Return on Investment (ROI)?
2. Are there opportunities to improve ROI?
3. What portfolio of incentives/strategies exists to achieve airline equipage?

This paper extends a previous analysis which identified 16 unique arrival flows to the four major runways (31C, 4R, 22L and 13C) at MDW. The flows included ILS and Visual approaches to runways 31C, 13C and 4R, visual approaches to runway 22L and RNP approaches to runway 13C at MDW from two cardinal directions (East and West) (see section **Overview of the arrival flow analysis at MDW** for details) *(4)*.

This analysis evaluates the annualized benefits of RNP approaches to all the runways at MDW which includes:

1. Developing RNP flows to all the other major runways (31C, 4R, and 22L) at MDW. The new RNP flows are developed using existing RNP flows and a “reflect and rotate” algorithm.
2. Estimating fuel burn for the new hypothesized RNP flows using the thrust specific fuel burn model.
3. Estimating the annual fuel burn in the terminal airspace for arrivals at MDW by combining the Aviation System Performance Metrics (ASPM) operational data and weighted average fuel burn for each runway and approach type.

The results indicate that the use of RNP approach instead of the less efficient conventional approaches has the potential of saving on average 0.81 million gallons per year for all arrivals and 0.7 million gallons per year for arrivals by the major carrier at MDW. The corresponding savings in terms of airline direct operating cost (ADOC) are $5 million per year for all arrivals and $4.2 million per year for the major carrier.

The analysis also evaluates a method for selecting runway configuration using flow rates and estimated fuel burn, as well as wind direction and magnitude (see section **Optimal Runway Configuration** for details) to explore the potential for improving the ROI of RNP approaches. This has the potential of saving on average 0.85 (+4.5% improvement) million gallons per year for all arrivals and 0.72 (+4.1% improvement) million gallons per year for the major carrier at MDW. The corresponding savings in terms of airline direct operating cost (ADOC) are $5.2 million per year for all arrivals and $4.4 million per year for the major carrier.

A net present value analysis is conducted to determine the ROI for the major carrier’s $175M *(5)* investment for equipping with RNP approach capability. The result shows at $4.4 million savings a year and 7% discount rate *(6)* the major carrier at MDW cannot break even at MDW in 10 year. However, the carrier can break even in 5 years and have a ROI of $127M in 10 years by performing at least 0.5 million RNP approaches per year throughout its network. This is provided the RNP approaches save at least 33 kg of fuel per approach on average compared to the conventional ILS or Visual approaches.

This paper is organized as follows: A background which includes a literature review describing the gaps in the existing literature and an overview of the arrival flow analysis previously performed at MDW is presented in the next section, followed by the methodology which includes development of new RNP approach flows using the “reflect and rotate” algorithm, fuel optimal runway configuration model and estimation of annualized fuel burn for airport arrivals, followed by results of the analysis, and finally the Conclusions and discussion on portfolio of incentives/strategies that exists to achieve airline equipage.

BACKGROUND

Enhancing Existing Analysis Methods

A review of the existing literature identified opportunities to enhance the type of analysis and the underlying methodology related to RNP approaches and their benefits to individual airlines. The benefits/cost analysis of RNP approach capability have been performed from a system-wide perspective *(7, 8)* and not from an individual airlines perspective. As airlines make the investment based on their benefits, taking into consideration the airline network and operations is important. Previous studies estimate fuel burn saving from potential use of PBN procedures by using a time-in-mode method, which assumes constant fuel burn rate for a given mode (e.g., descent, climb, and cruise) *(7)*. The main benefits of RNP approach to individual airlines are in terms of fuel burn savings from shorter and more efficient trajectories in the terminal airspace. Hence, it is important to compute fuel burn savings of RNP approach by taking into consideration the actual trajectories (i.e. level segments vs idle descent segments) of aircraft in the terminal airspace. Also, the existing analyses are based on simulated de-coupled route structure *(7)* or delay analysis of operational data such as ASPM*(8)*. These do not capture the actual real-world complexities of traffic flows and aircraft trajectories in the terminal airspace. Studies that use high fidelity track data are limited to prescribing methodologies to cluster track data, identifying variation in flows and detecting anomalies *(9–12)*. The methodology used for this analysis addresses all of these issues and provides a systematic methodology that uses terminal airspace flow characterization for the purpose of differentiating and comparing actual performance and benefits associated with new terminal airspace PBN procedures.

Overview Of The Arrival Flow Analysis At MDW

At Midway International Airport (MDW) the RNP approach to runway 13C was implemented in 2011 to make the arrivals to the runway independent of operations at the neighboring Chicago O'Hare International Airport (ORD) during Instrument Meteorological Conditions (IMC) *(13)*. An arrival flow analysis was previously performed that used 43 days of National Offload Program (NOP) radar track data (post implementation data which included actual flights tracks of RNP approaches) to identify and compare RNP approaches to conventional approaches *(4)*. The analysis established the presence of 16 unique terminal airspace arrival flows to the four major runways (31C, 4R, 22L and 13C) at MDW*(4)*. The flows were defined as aircraft trajectory clusters/grouping from the final waypoint in the Standard Terminal Arrival Route (STAR) to the runway threshold via an approach type (i.e., ILS, Visual or RNP). The flows included ILS and Visual approaches to runways 31C, 13C and 4R, visual approaches to runway 22L and RNP approaches to runway 13C from the east and the west (FIGURE 2 and FIGURE 3).

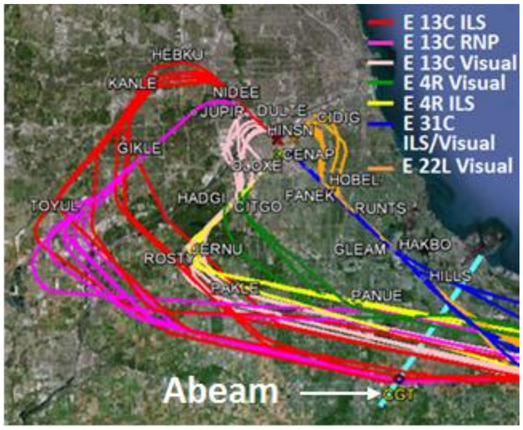

FIGURE 2 Sample of the eight major flows from the east at MDW

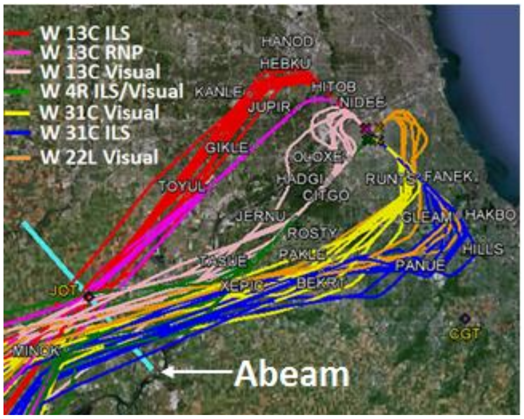

FIGURE 3 Sample of the eight major flows from the west at MDW

The fuel burn performance of these flows was also previously estimated using actual trajectory of the aircraft and a thrust specific fuel burn model that took in to consideration the energy state (kinetic – true air speed and potential – altitude) of the aircraft at discrete intervals along the flight trajectory *(14)*. The fuel burn statistics for these 16 flows and hypothesized 4 flows (RNP flows to runways 31C, 4R and 22L) developed as a part of this analysis have been discussed in the results section.

METHODOLOGY

This section describes the methodology used for this analysis, which includes: (1) Development of RNP approaches, (2) Optimal Runway Configuration, and (3) Estimation of Annualized Fuel Burn

Developing Hypothesized PBN Flows

The precise curved path RNP approach procedures are designed to eliminate trombone vectors in the base leg of the approach and make the approach from the final waypoint on STAR to runway threshold shorter compared to conventional approach procedures. Therefore the benefits of these procedure are just not limited to runways that have procedural conflicts with neighboring airports (as in case of MDW and ORD), but also to all other runways at an airport.

The approach described in this section to develop new RNP approach flows relies on the availability of existing RNP flows and are suitable only for airports that have bisecting runway (like the ones at MDW). The new flows are generated either by rotation or reflection and rotation, depending on the location of the arrival fix (final waypoint on STAR) with respect to the runway (FIGURE 4).

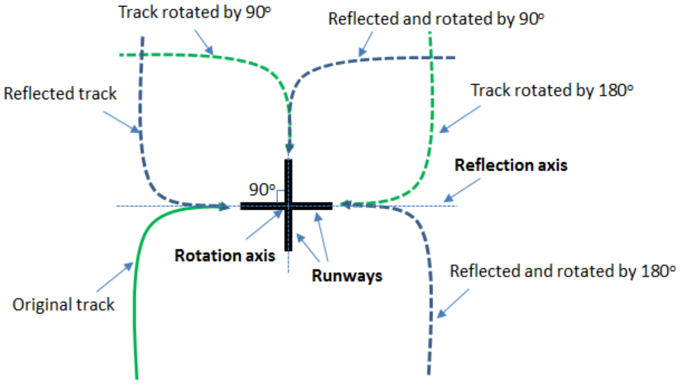

FIGURE 4 Rotation and Reflection of existing flight tracks to engineer new flows

The equation for reflecting and rotating flight vectors are shown in equation (1) and (2) respectively:

$$Ref_l(v) = 2 * \frac{v.l}{l.l} * l - v \qquad (1)$$

Where,

$Ref_l(v)$ is the vector representing the reflected flight track coordinate

v is the flight track co-ordinate vector that needs to be reflected.

l is the vector representing the center line of the runway about which the flight track co-ordinate is reflected.

$v.l$ and $l.l$ are the dot product of the respective vectors.

$$\begin{bmatrix} x' \\ y' \end{bmatrix} = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} \qquad (2)$$

Where,

x, y are the flight track co-ordinate vectors with respect the to axis about which the vectors need to be rotated

x', y' are the rotated flight track co-ordinate vectors

θ is the angle of rotation (i.e., angular difference between the runways).

Optimal Runway Configuration

Runway configurations are set at the airport based mostly on the wind direction and other operational constraints such as procedural conflicts with the neighboring airports. An alternate approach (to leverage the efficiency of RNP approaches) is to select the most fuel optimal runway configuration based on the weighted average fuel burn of flows to the runways.

The algorithm for determining the optimal runway configuration is as follows:

1. Use the wind magnitude and direction information (from the ASPM airport table) to compute the cross wind and head wind component for each runway using the following equation:

$$CW = sin(A) * WS \qquad (3)$$

$$HW = cos(A) * WS \qquad (4)$$

Where,

WS is the magnitude of the wind in knots

CW is the magnitude of the crosswind in knots

HW is the magnitude of the headwind in knots
A is the difference in wind and runway bearing in radian.

2. Select all feasible runways or runway configurations based on the cross wind (CW) and headwind (HW) thresholds and the meteorological conditions (VMC or IMC). A runway is considered feasible if the cross wind component is not be greater than 20 knots and the headwind component is not be less than zero (negative headwind component indicate the presence of tailwind). Also, for Instrument Meteorological Conditions (IMC) only runway configurations and associated approach types that support precision or precision-like approaches are taken into consideration.
3. Compute the weighted average fuel burn per flight for the feasible set of runway configurations and the associated approach type based on ratio of arrivals from each direction to the airport.

$$f_{y',t} = \sum_t W_{y,t} * f_y \qquad (5)$$

Where,
$f_{y',t}$ is the average fuel burn per flight for a given runway configuration and approach type.
$W_{y,t}$ is the percentage of aircraft arriving from each cardinal direction to the airport at time period t (i.e., hour of the day) and $\sum_{y,t} W_{y,t} = 1$. These are determined by counting the number of flights in each flow for each time bin (i.e., hour of the day) by analyzing the flight tracks by hour of the day.
f_y is the average fuel per aircraft for flow y in kg/min.

4. Rank the set of feasible runway configurations based on the fuel burn performance.
5. Select the runway configuration with lowest weighted average fuel burn as the optimal runway configuration.

Estimation Of Annualized Fuel Burn For Airport Arrivals

The annual terminal airspace fuel burn is estimated by combining the ASPM operational data and weighted average fuel burn for each runway and approach type. The total fuel burn is estimated by summing up the fuel burn for each time bin in the ASPM table using the following equation:

$$F = \sum_d \sum_t A_{t,d} * f_{y',t} \qquad (6)$$

Where,
F is the total annual fuel burn for aircraft in the terminal airspace in kg
d is the number of days in the year.
t is the number of time bins in a day (i.e., 96 for 15 min time bins and 24 for 1 hour time bins).
$A_{t,d}$ is the total number of arrivals for given day d and time period/bin t. This is computed from the ASPM flight table by counting the number of arrivals in each time bin for a given day.
$f_{y',t}$ is the average fuel burn per flight for a given runway configuration and approach types (computed using Equation 5).

The total fuel burn is converted to airline direct operating cost (ADOC) using the following equation:

$$ADOC = F * \left(\frac{.26}{.81}\right) * c * \left(\frac{1}{.44}\right) \qquad (6)$$

Where,
$\left(\frac{.26}{.81}\right)$ is the conversion factor from kg to gallons.

c is the cost of jet fuel = 2.69 \$/gallon *(15)*.

$\left(\frac{1}{.44}\right)$ is the conversion factor to convert fuel cost to airline direct operating cost (ADOC). The fuel costs are 44% of the total ADOC *(15)*.

RESULTS

The results of the analysis are provides as follows: (1) fuel burn performance for RNP flows for all runways at MDW;(2) benefits of a runway configuring tool that uses flows, fuel burn, and wind magnitude/direction, (3) annualized benefits of RNP approaches at MDW, and (4) the business case for RNP Approach for the major carrier at MDW.

Fuel Burn Performance For RNP Flows For All Runways At MDW

The existing RNP tracks to runway 13C are reflected and rotated to construct RNP flows to other major runway (22L, 31C and 4R) at MDW (FIGURE 5). For instance, Runway 22L is 90^o north of runway 13C. Therefore, the RNP flow to runway 22L from the east is obtained by reflecting the west RNP flow to runway 13C about the runway's (13C) axis and rotating clockwise by 90^o, and the RNP flow to runway 22L from the west is obtained by reflecting the RNP flow to runway 13C from the east about the runway's (13C) axis and rotating clockwise by 90^o. Similarly, the RNP flows to 4R from the east and 31C from the west are also obtained. The west flows to runway 4R and east flows to runway 31C are aligned with the runway and do not need a RF leg. It is assumed that RNP flows these runways have the same performance as the corresponding ILS approach in terms of fuel burn.

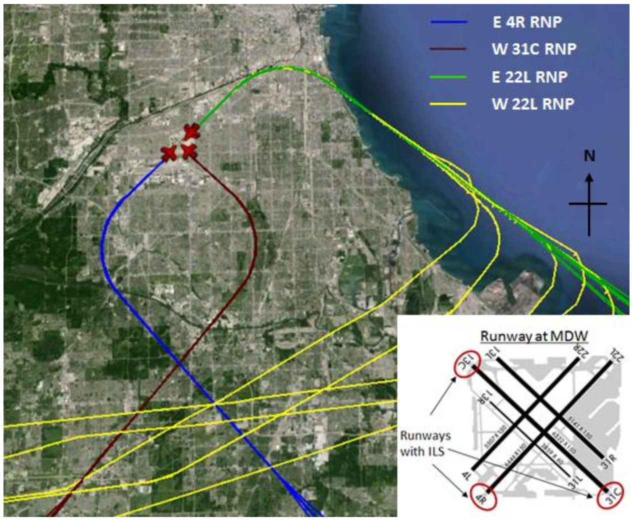

FIGURE 5 Sample of RNP approach flows to runways 4R, 31C, and 22L.

The fuel burn performance (i.e., fuel burn per flight) of these 4 hypothesized flows are computed using the thrust specific fuel burn model *(14)* and included with performance statistics of the previously identified 16 flows (FIGURE 6). The 4-D tracks of the existing RNP approach flows consist only of Boeing 737 (B73) aircraft type, all of which belong to the major air carrier at MDW and constitutes 72% of the fleet mix at MDW for all operations except general aviation. The estimates for the RNP flow's average fuel burn per flight for the complete fleet mix at MDW are obtained by multiplying a factor of 0.84 to the fuel burn estimates of B73's. This factor is determined by analyzing ILS and visual approach flow at MDW that have the complete fleet mix at MDW.

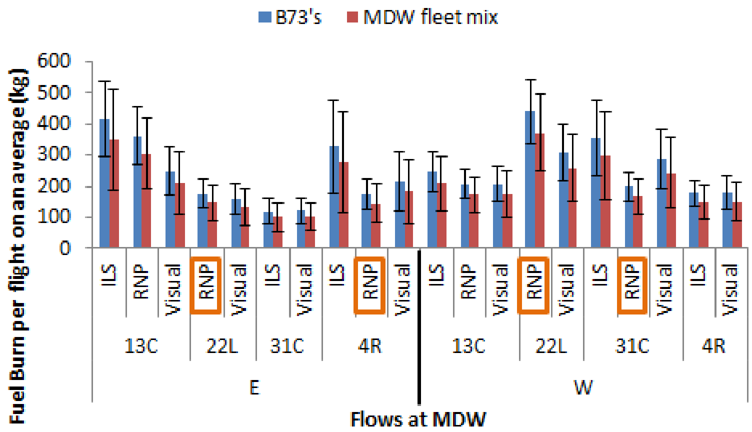

FIGURE 6 Fuel burn performance (mean and standard deviation) of existing 16 flows and hypothesized 4 flows at MDW, for B737's and the fleet mix at MDW

The fuel burn for the RNP approaches to 22L from the east and the west are higher than the corresponding visual approaches (higher by on average +10.5% for the east flow and + 43.5% for the west flow). Therefore, an airline would prefer using the visual approaches to 22L over the RNP approaches during VMC and would use RNP to 22L only during IMC as 22L does not have a published ILS approach.

The fuel burn performances of the RNP approach to runway 4R from the east and the hypothesized RNP approach to runway 31C from the west are lower than the corresponding ILS and visual approach on average by -47% and -20% for 4R and -44% and -30% for 31C. These RNP approaches eliminate the trombone vectors on the base leg that are present in the corresponding ILS and visual approaches to runways 4R and 31C. Therefore, an airline would prefer the RNP approaches to 4R and 31C over the corresponding visual and ILS approach both in VMC and IMC.

The analysis shows that fuel burn for RNP flows is always better than ILS flows and sometimes better than Visual flows depending on the relative position of the runway with respect of the approach direction and the type of approach.

Runway Configuration Based on Fuel Burn and Cardinal Direction Flow Rates

The fuel burn statistics for each flow is averaged based on ratio of arrivals from the east and the west to estimate the average fuel burn for each runway and approach type (FIGURE 7). The weighted average fuel burn for RNP approaches are shown in solid line, visual approaches are shown in dashes lines and ILS approaches are shown in dash-dotted line. The legend shows the ranking of the runway by available approach type for the runway. For example, runway 31C at MDW has the best fuel burn performance for RNP approaches followed by visual approaches and ILS approaches. The "zero" on the x-axis corresponds to the mean fuel burn of the flow from the west and the "one" corresponds to mean fuel burn of the flow from the east. Each line is the average fuel burn per flight for various levels of traffic volume from the east and the west which varies throughout the day. An Analysis of the track data shows that at MDW the traffic is predominantly from the east except for 1PM, 4PM, 7PM and 10PM when traffic volumes are higher from the west. From 6AM to 10 PM the fraction of traffic volume from the east at MDW ranges from 0.46 to 0.69 (highlighted in FIGURE 7).

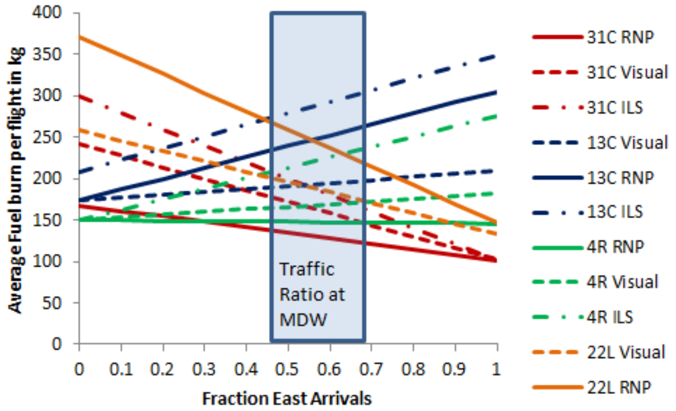

FIGURE 7 Runway ranking based on traffic volume ratio for all flows at MDW

At MDW, irrespective of the traffic volume from the east and the west, the RNP approach to runway 31C has the lowest (best) fuel burn performance followed by the RNP approach to runway 4R. The ILS approach to runway 13C has the highest fuel burn performance. All other approaches show trade-offs based on the level of traffic from the east and west. For visual approaches, performance of runway 4R is better than 31C as long as traffic from the east is 54% or less of the total traffic volume. When the traffic from the east is greater than 54% of the total traffic runway 31C has better fuel burn performance. A similar tradeoff occurs between runways 13C and 22L, when the traffic from the east is 55% or less of the total traffic runway 13C is more favorable than runway 22L in terms of fuel burn per flight in the terminal airspace.
These results demonstrate that benefits can be accrued by assigning runway configuration based on flow rates, fuel burn, and wind magnitude/direction.

Annualized Benefits Of RNP Approaches At MDW

The weighted average fuel burn for each runway and approach type is combined with the ASPM arrival and meteorological data using the methodology described in the earlier section to estimate the annual fuel burn for the baseline scenario, alternate scenario A1 (i.e., RNP at all MDW Runways) and alternate scenario A2 (i.e., RNP Producers at all MDW Runways + Fuel Optimal Runway Configuration).

The baseline scenario estimates the annual fuel burn at MDW using the historic ASPM runway configuration and the associated conventional flows fuel burn statistics (i.e. visual approach flows during VMC and ILS approach flows during VMC). The alternate scenario A1 estimates annual fuel burn using ASPM runway configuration and the associated RNP approach fuel burn statistics. The RNP approach fuel burn statistics are used instead of the visual approaches only in cases when RNP approach is more efficient than the corresponding visual approach (e.g., for runways 31C and 4R). The alternate scenario A2 differs from A1 in that it estimates annual fuel burn using the fuel optimal runway configuration instead of the historic ASPM runway configuration.

The analysis of ASPM data for year 2007 to 2012 shows that runways 31C, 4R, 22L and 13C are used for arrivals on average 44%, 33%, 20% and 3% of the time respectively.

The modelled fuel optimal runway configurations based on the 16 major flows, 4 hypothesized RNP flows and historic wind information show an increase in usage of runways 13C (9%) and 31C (51%) and decrease in the usage of runways 22L(15%) and 4R (24%). This is because 13C is more favorable than 22L in presence of south east winds and heavier traffic from the west (more than 43% of the total traffic), however the RNP approach to 22L has better fuel burn performance than RNP approach to 13C in IMC when traffic volumes from the east are higher than 57% of the total traffic. Also, the RNP approach to 31C is always (irrespective of the traffic volumes from the east and the west) more efficient than any of the flows to 4R; therefore, for prevailing winds from the north 31C is always more favorable than 4R.

The annual savings or benefits of RNP approaches at MDW are estimated by comparing the annual fuel burn for the baseline scenario and alternate scenario (A1). The results indicate (TABLE 1) that the use of RNP approach instead of the less efficient conventional approaches has the potential of saving on average 0.81 million gallons per year for all arrivals and 0.7 million gallons per year for the major air carrier (which constitutes 72% of all operations) at MDW. The corresponding savings in terms of airline direct operating cost (ADOC) are $5 million per year for all arrivals and $4.2 million per year for major carrier at MDW.

The baseline scenario is also compared to an alternate scenario (A2) with the objective of estimating the benefits of implementing operational improvements such as the use of fuel optimal runway configuration. This has the potential of saving on average 0.85 (+4.5% improvement) million gallons per year for all arrivals and 0.72 (+4.1% improvement) million gallons per year for the major carrier at MDW. The corresponding savings in terms of airline direct operating cost (ADOC) are $5.2 million per year for all arrivals and $4.4 million per year for Major carrier at MDW.

TABLE 1 Total fuel burn per year on average for the baseline and the two alternatives and their associated benefits/savings at MDW.

Arrival Flows	Runway Config	Average Annual Fuel Burn (millions of gallons)						Average Annual Savings			
		Visual Conditions		Instrument Conditions		Total		Fuel (millions of gallons)		ADOC ($ in millions)	
		All Arrivals	South west Arrivals	All Arrivals	South west Arrivals	All Arrivals	South west Arrivals	All Arrivals	South west Arrivals	All Arrivals	South west Arrivals
13C (Visual, ILS) 31C(Visual, ILS) 4R(Visual, ILS) 22L(Visual)	ASPM **(Baseline)**	4.76	4.09	0.79	0.67	5.55	4.76	—	—	—	—
13C (Visual, ILS,**RNP**) 31C(Visual, ILS,**RNP**) 4R(Visual, ILS,**RNP**) 22L(Visual,**RNP**)	ASPM **(A1)**	4.18	3.59	0.56	0.48	4.74	4.06	0.81	0.70	$5.0	$4.2
	Optimal **(A2)**	4.13	3.55	0.57	0.49	4.70	4.03	0.85	0.72	$5.2	$4.4

Business Case For RNP Approach and Major Carrier At MDW

The major air carrier at MDW has invested $175M in equipping with RNP approach capability *(5)*. The two financial parameters of interest to an airline are the Net Present Value (NPV) of the investment and the time it takes to obtain a positive ROI or Break Even Time (BET). The NPV analysis done to estimate these two parameters has the following assumptions:

1. Benefits are accrued only after 100% of fleet is equipped
2. Cash outflow = Initial Cost of Equipage, when time t=0
3. Cash outflow =0 for t>0
4. Cash Inflow = Benefits from RNP use per year

5. The NPV is computed for N=10 years
6. Discount rate is assumed to be 7% *(15)*.

The result shows at $4.4 million savings a year (TABLE 1) and 7% discount rate *(6)* the major carrier at MDW cannot break even at MDW in 10 years. The carrier will need at least 10 more airports like MDW to break even.

The major carrier at MDW can break even based on the total number of RNP approach operation it carries out throughout its network - a total of 1.1 million arrival operations per year on average. Break-even in 5 years with an ROI of $127M in 10 years can be achieved by performing at least 0.5 million RNP approaches per year throughout its network. This is provided the RNP approaches save at least 33 kg of fuel per approach on average compared to the conventional ILS or Visual approaches.

CONCLUSION

From an airline perspective equipping with RNP approach capability for a single airport use (e.g. MDW) does not yield a positive ROI. However, network-wide use of RNP procedures provides a break-even point in 5 years.

Using market based approaches to incentivize airlines to equip relies on the inherent benefits of a technology to sell itself onto the aircraft with a positive ROI. Operational improvements like use of fuel optimal runway configuration can improve the benefits associated with RNP approaches, but these are not enough to offset the high cost of equipage *(2)*.

One of the equipage challenges in the “free-rider issue”. It is possible that airlines that do not invest will still benefit from system-wide improvements by the airlines that do equip. Operational incentives can be provided to early adopters of the technology to overcome the free-rider issue, however these have limited scope. For instance, as a part of the FAA’s Best Equipped Best Served (BEBS) program, a proposal to provide operational incentives in the form of priority arrival slots to equipped operators during traffic flow management initiatives (TMIs) like ground delay program (GDP) was investigated *(16, 17)*. Implementation of such TMIs will need new decision support tools and the associated training for the controllers to manage the duration of the program and allocation of slots based on the level of equipage. Also, the priority system will create equity issues for non-equipped operators resulting from excess delay allocation and will increase overall NAS delays due to network wide delay propagation (as a result of large delays for some flights). For example, 15 minutes for four flights can be more easily absorbed by the network than 1 hour delay for a single flight.

In the case of RNP, the operational changes have greater benefits for the system as a whole than for the operator required to invest in the equipage. In such cases financial incentives can be provided to defray the cost of avionics *(18)*. The financial incentives can be use of public funds, or creation of a tax pool that would tax every stakeholder proportional to the benefits accrued from the operational change. This will require accurate estimates of benefits to individual stakeholders, which can be done using this methodology.

Finally, the last option in the interest of modernization is to mandate the equipage. A federal mandate will ensure modernization of NAS required to meet the future demand (necessary for the growth of the nation). However, a mandate is not economically feasible as the overall cost associated with the equipage is much higher than the potential benefits. This analysis shows the total potential benefits of RNP approach to Major carrier at MDW at MDW is $4.4M, whereas the cost to airlines to equip with RNP approach capability is in the hundreds of million ($175M by the major carrier at MDW). Also the lack of published RNP approaches and the associated training will restrict its use and potential benefits. Therefore, before a mandate to equip for RNP approaches is made, the following key issues need to be addressed:

1. The air navigation service providers (ANSPs) must design and approve RNP approaches to all possible runways at all major airports for airlines to use.
2. The ANSPs must train air traffic controllers to smoothly merge and space aircraft at the start of the RNP approach *(4)*.

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