Measuring Flight Efficiency in the National Airspace System

James DeArmon, Wayne Cooper, Tudor Masek, Alex Tien
MITRE CAASD

Steve McMahon
Federal Aviation Administration

Abstract

Measuring and monitoring resources in the National Airspace System (NAS) is a key activity of Federal Aviation Administration (FAA) operational managers. Airports and associated terminal areas are complex systems and require a number of metrics to properly characterize performance. In this document, 13 performance measures are described, in three different categories: (1) flow efficiency, for both taxiing and airborne flights, (2) runway utilization, for both arrivals and departures, and (3) rate of flights not cancelled or diverted, for both arrivals and departures. These 13 metrics capture performance in the different stages of flight from push-back to gate arrival. Sample calculations and use cases are presented, using Chicago O'Hare International Airport (ORD) as a subject airport. The multiple measures may be combined for an omnibus metric, for quick assessment of performance at that airport, in a next-day review context.

Introduction

There is an adage "for a system to be managed, it must be measured." Measurement of the performance of the National Airspace System (NAS) allows the Federal Aviation Administration (FAA) to adjust policies and procedures, pursuant to improving safety and efficiency of air traffic movement. In this document we propose multiple metrics to characterize the efficiency of airport and terminal area operations. Chicago O'Hare International Airport (the designator is "ORD") is used as an example, for the period of Calendar Year 2014 (CY14)[1], plus other dates.

Motivation

The FAA's currently available metrics for assessing airport efficiency are: the Terminal Arrival Efficiency Rate (TAER), the System Departure Efficiency Rate (DER), and the System Arrival Efficiency Rate (AER). These three efficiency metrics measure how well the declared runway capacity is being utilized in a given time period, up to the expected number of flights which should be able to use the runway capacity in that time period (the estimated demand).

Hourly TAER is the percentage of arrival demand which would be "available to land" in an hour at a specific airport which actually does land in that hour, up to the stated arrival capacity at the airport for that hour (known as the Airport Acceptance Rate [AAR]). The TAER arrival demand which is "available to land" in an hour is the sum of the flights which have actually crossed the 100 nautical mile (NM) radius from the arrival airport which either: (1) have actually landed in the hour, or (2) had "adequate time" from their 100 NM radius crossing to the end of the hour to have landed. The "adequate time" must be greater than or equal to the unimpeded transit time for

[1] References to 2014 in the remainder of the report refer to Calendar Year (CY), unless otherwise stated.

that flight, estimated from the 100 NM radius crossing point to the runway. The FAA has described how this unimpeded time is calculated for TAER in (Wine, 2005).

Similarly, the DER is the percentage of departure demand which would be "available to take-off" in an hour, limited by the Airport Departure Rate (ADR), which actually does take-off in that hour.

The AER is the percentage of arrival demand which would be "available to land" in an hour, limited to the AAR, which actually does land in that hour.

The DER and the AER are usually reported in a combined metric known as the System Airport Efficiency Rate (SAER), which is the demand-weighted average of the DER and AER.

The values of these efficiency metrics can vary if:

- The actual airport runway capacity for the hour is different than the called AAR or ADR
- The actual unimpeded time for a flight is different than the estimated unimpeded time, or
- Flights are delayed beyond their unimpeded time, thus landing in a later hour than the time period in which they should have landed, based on their estimated unimpeded time

Estimating airport departure or arrival capacity for short time periods is difficult, as it can vary with a large number of factors, such as the mix of flights by weight class, the precise weather conditions, and on other factors harder to estimate, such as compression (i.e., progressive reduction) of flight spacing on final approach. The runway capacity also needs to be adjusted during periods when convective weather is affecting the flow of flights to or from the airport.

Likewise, the true unimpeded time for an arrival is difficult to precisely estimate, as it can be affected by the winds aloft in the terminal area, and by the use of specific approach procedures which may change the length of the arrival flight path from the one used to estimate the unimpeded time. Unimpeded times for departures from the airport terminal gate to the departure runway threshold may vary given the precise departure gate and runway being used.

Proposed Metrics

The proposed set of complementary metrics fall into three categories:

1. Flow/taxi efficiency – comparing an observed flight movement time to a nominal or unimpeded time
2. Runways utilization – measuring how many of available runway arrival or departure "slots" are actually used for arrivals and departures
3. Rate of flights not cancelled or diverted – the percentage of scheduled flights to or from an airport which are not cancellations, "taxi-backs" (flight returns to terminal after a push-back and incomplete taxi-out), or diversions.

The proposed metrics are defined as follows (an asterisk denotes that a version of the metric is already part of FAA performance analysis reporting):

- Departure Efficiency Metrics
    - Departure Taxi Efficiency (DTE)
    - Departure Runway Utilization (DRU)*
    - Departure Flow Efficiency, 40 NM (DFE40)
    - Departure Flow Efficiency, 175 NM (DFE175)
    - Departures' Rate of Flights not Cancelled or Diverted (CompleD)*

- Arrival Efficiency Metrics
  - Upstream Flow Efficiency (UFE)
  - Arrival Flow Efficiency, 175 NM (AFE175)
  - Arrival Flow Efficiency, 40 NM (AFE40)
  - Terminal Arrival Runway Utilization (TARU)*
  - System Arrival Runway Utilization (SARU)*
  - Arrival Taxi Efficiency (ATE)
  - Arrivals' Rate of Flights not Cancelled or Diverted (CompleA)*

In addition, a 13th metric is computed as a combination of DTE and ATE: the Total Taxi Efficiency (TTE).

Figure CHART1 depicts the portion of a flight's progress from OUT (gate departure event) to IN (gate arrival event) which is covered by each metric. The taxi-out, departure, and climb phases are denoted in green, and the descent, arrival, and cruise phases in purple. Metrics which would normally be calculated for departure airports are also indicated in green, while those which would normally be calculated for arrivals are indicated in purple.

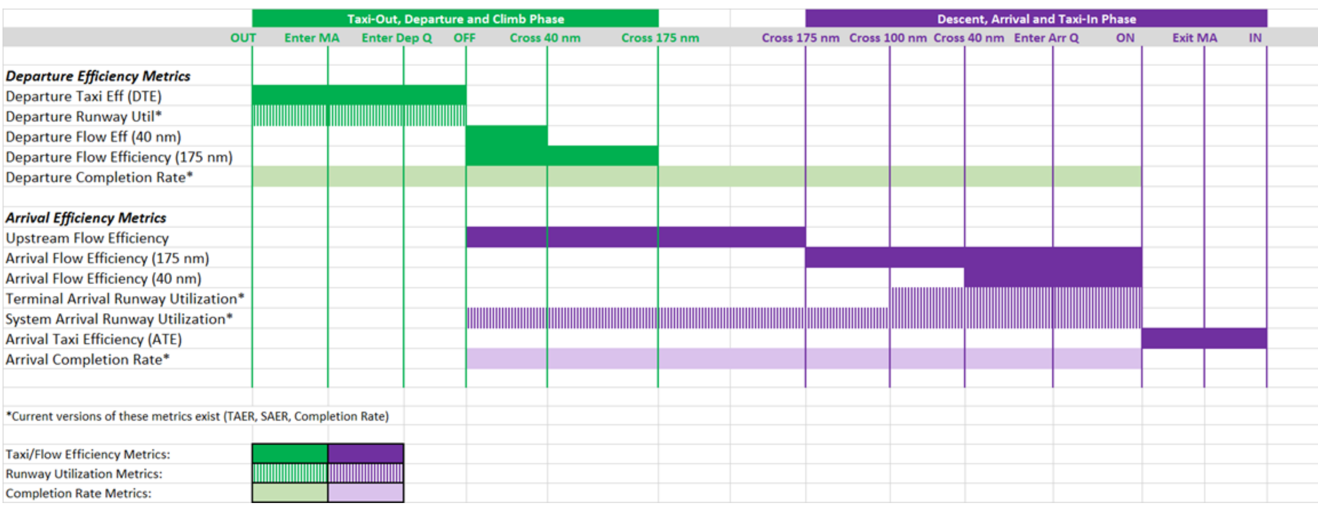


Figure CHART1. Flight Phases Associated with Each Proposed Metric

Rate of Flights not Cancelled or Diverted measure the proportion of scheduled flights which complete their entire transit through gate arrival without being cancelled, or being substantially perturbed from normal operation by a taxi-back or diversion. As such, they can be changed by events along a larger portion of the total flight. This rate for arrivals applies to all arrivals to an airport in a time period, and similarly the rate for departures applies all departures from an airport in a time period.

The events noted in Figure CHART1 are:

1. OUT: gate departure time
2. Enter MA: Time entering FAA movement area from ramp area
3. Enter Dep Q(ueue): Time when a flight joins the end of the queue of flights waiting to use the active departure runway
4. OFF: Take-off or wheels-up time

5. Cross 40 NM (from the origin): Time flight crosses 40 NM radius from the origin airport. This corresponds to the distance from the airport which is typical for a Terminal Radar Approach Control (TRACON) boundary, although by this point most departures would have climbed into en route airspace
6. Cross 175 NM (from the origin): Time flight crosses 175 NM radius from the origin airport. This corresponds to the point at which close to 100% of flights have reached their cruise altitude, based on previous analysis results
7. Cross 175 NM (from the destination): Time flight crosses 175 NM radius from the destination. For consistency, this distance was chosen to mirror the crossing point in the departure phase
8. Cross 100 NM (from the destination): Time flight crosses 100 NM radius from the destination. This distance was chosen as the area in which merging and spacing of flights going to that destination would typically commence
9. Cross 40 NM (from the destination): Time flight crosses 40 NM radius from the destination. This corresponds to the distance from the airport which is typical for a TRACON boundary
10. Enter Arr Q(ueue): Time at which a flight would be expected to land, if its departure time and actual time en route conformed to the flight crew's original intent. As such, it is an imaginary or "virtual queue," not a physical queue like that for flights waiting for a departure runway
11. ON: Landing or wheels-on time
12. Exit MA: Time exiting FAA movement area to ramp area
13. IN: gate arrival

The next sections describe the computations for each of these metrics in detail.

Departure/Arrival Flow Efficiency

For a major metropolitan airport, DFE and AFE consider flight times for departure or arrival flights in certain airspace regions. For departures, flights times are measured from take-off until crossing a 40 or 175 NM radius around the airport. For arrivals, the same measurements are taken for inbound flights: from the 175 or 40 NM radius until landing. As part of the computation of the metric, the flight population is stratified by aircraft performance, runway, and azimuth of a flight's radius crossing (i.e., the measure of the angle, from zero [due north] to 359 degrees, formed from the Airport Reference Point[2] [ARP] to the point of radius crossing). As more flights are directed by air traffic control (ATC) to follow efficient lateral and vertical profiles, an airport's average daily DFE/AFE metric values go up. For a given operational day[3], a high metric value shows that many flights were expedited, indicating efficient airport operations.

Calculation of DFE/AFE and Required Data Sources

DFE/AFE are calculated on a per-flight basis as follows:

$$\text{DFE } or \text{ AFE} = \frac{\text{Unimpeded Flight Time}}{\text{Observed Flight Time}}$$

[2] Defined as the geometric center of the ends of the usable runways.

[3] Defined herein as the 24-hour interval beginning 06:00 UTC (Coordinated Universal Time).

Observed flight time is the actual flying time from radius crossing to landing (departures) or from take-off to radius crossing (arrivals). Unimpeded time is taken as the average of the observations between the 5th and 15th percentile values (CANSO, 2013) of the set of observed times in the prior 12 months belonging to a particular “stratification class” (SC). By stratifying the overall population of departure flights, homogeneous sub-populations are created (a sample size is 30 is required), and the unimpeded times are more meaningful. An SC is defined as a set of observed times grouped by the following attributes:

- Engine Type (Piston, Turboprop, Jet)
- Weight Class (Small, Large, Heavy, B757, Super)
- Departure or Arrival Runway
- Weather Impacted Traffic Index category
- Egress/Ingress Wedge (numbered 1,2,3, …)

The Weather Impacted Traffic Index (WITI) is a unitless measure of weather impact (Klein et al., 2007), which also considers traffic intensity level. The range of WITI values for ORD were divided into four categories for the analysis here.

Egress/ingress wedge is computed using the flight’s azimuth crossing of the 40 or 175 NM radius. Supporting analysis is needed to define appropriate azimuthal bound for the wedges, see Figure WEDGE. Eight-hundred flight tracks departing ORD were selected at random from March 2012, and plotted out to the 175 NM radius. Via visual assessment, five wedges were determined (delineated with black marks); two additional wedge boundaries were considered (green marks at 90 and 270 degrees), but not chosen. Such assessment was done separately for arrivals and departures and for the 40 and 175 NM radii.

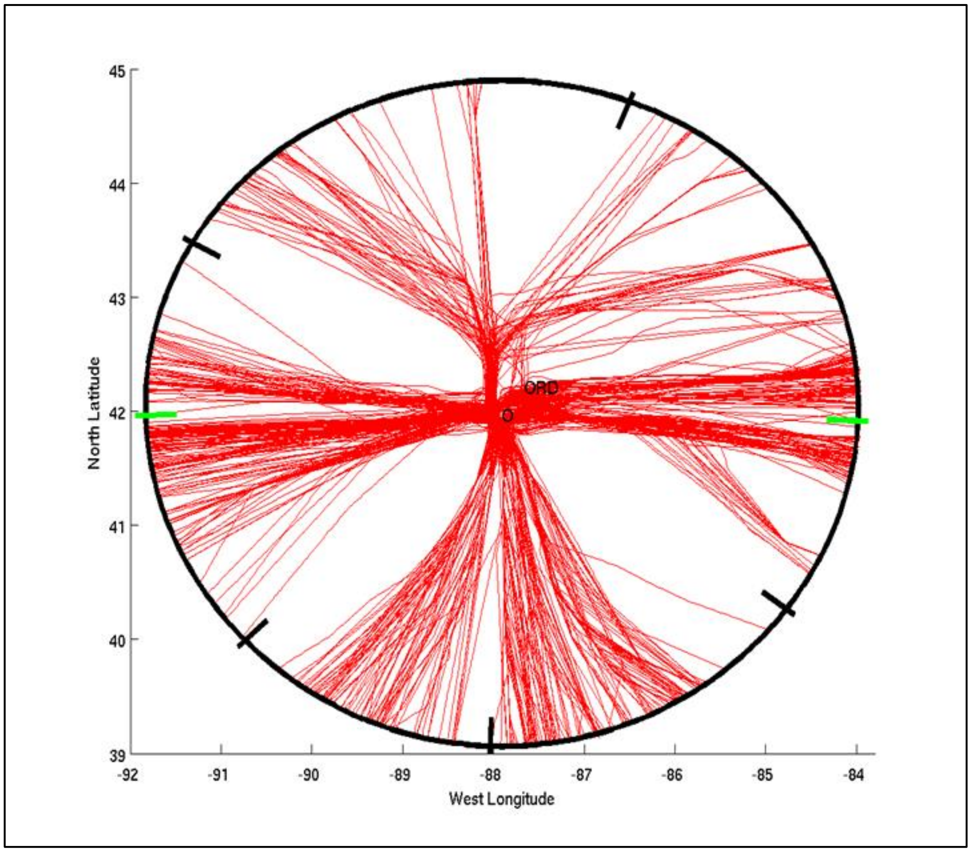


Figure WEDGE. Defining Azimuthal Boundaries

Sample Applications of DFE

DFE and AFE can be useful for the FAA to monitor and manage airport operations. As examples, two major applications of the DFE metric are described: trend analysis and next-day performance review.

Trend analysis would examine average daily airport DFE over time, to make sure that the trend, if not improving, was at least not worsening. Part of that inquiry could also be the identification of low-DFE days. Figure AVG-DFE shows such values for December 2013. The $95^{th}/5^{th}$ percentile lines were developed using the prior 12 months of average daily DFE values. Some low efficiency days can be seen.

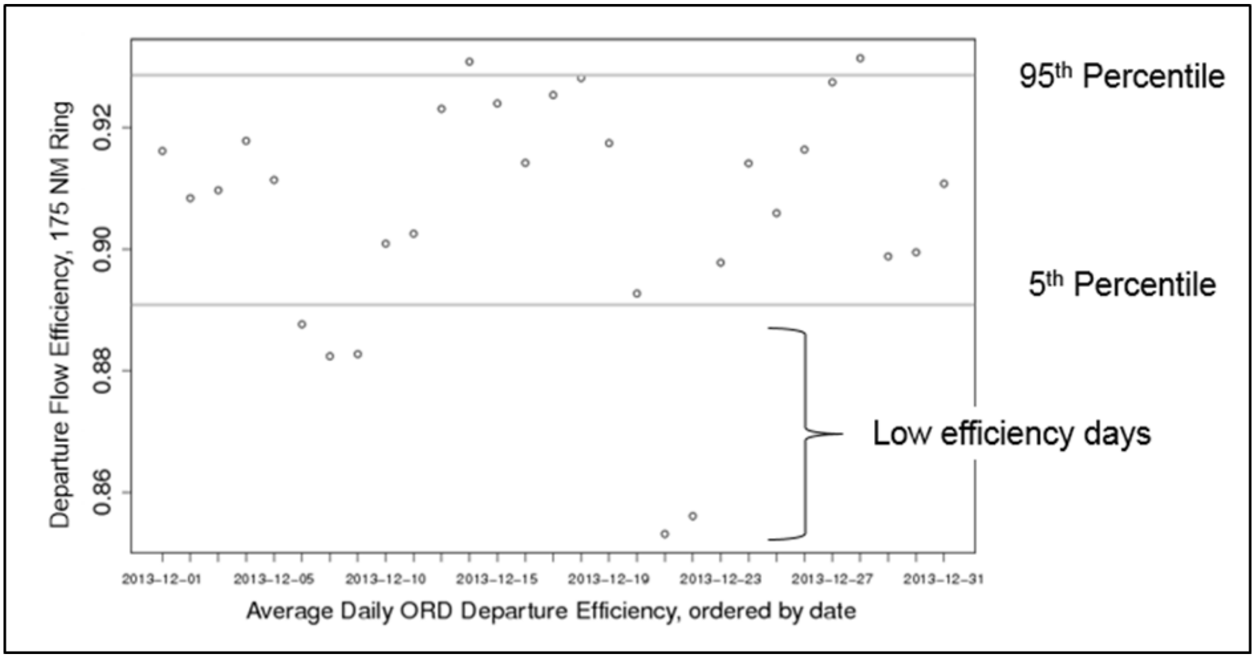


Figure AVG-DFE. Average Daily DFE for ORD, December 2013

As an example of next-day performance review, an FAA traffic flow manager may see yesterday having low average DFE: further "drill-down" investigations could identify the contributing low-DFE flights and associated operating conditions. A recent paper (DeArmon et al., 2014) proposes a supplementary analysis capability which pulls together various sources of information and posits meteorological or other causes for prolonged climb-outs. That is, a production reporting system might include an "exception report" as an adjunct to standard reporting, to identify delayed flights and a "best-guess" on operating conditions which may largely contribute to the delay. Examining the next-day report, a manager may see an airport with low average DFE; further perusal of the exception report would identify the contributing low-DFE flights and associated operating conditions. As an example, Figure DEVIATE[4] shows six flight tracks departing ORD on May 6, 2012 (a low-DFE day) during severe weather conditions. The bold blue flight track is for a low-DFE flight – a large course deviation was applied for weather avoidance. The other five flights made smaller course deviations.

Figure DEVIATE has the following features:

- Dark blue lines – flight tracks
- Green circle – 175 NM radius
- Green, yellow, orange, red masses – weather regions of varying precipitation levels
- Light blue mass – Lake Michigan
- Light gray lines – United States (U.S.) state boundaries
- Cyan lines – boundaries for Air Route Traffic Control Centers (ARTCCs)

[4] Source of graphic is the MITRE All-NAS replay tool, developed for use by the FAA, which integrates Traffic Flow Management System (TFMS) flight tracks, National Traffic Management Log-derived (NTML) Traffic Management Initiatives (TMI) and National Convective Weather Diagnostic (NCWD) weather data (and other information) in a concise format.

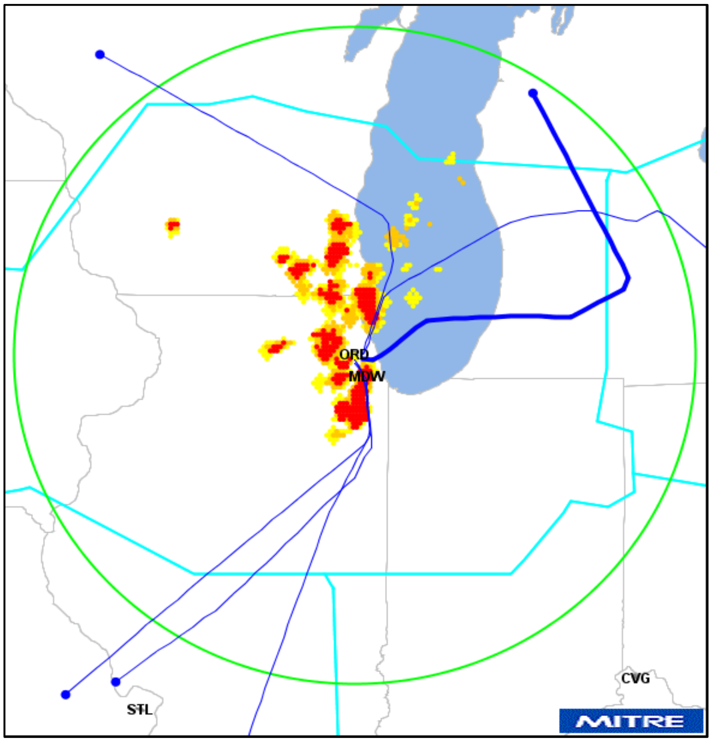


Figure DEVIATE: Six Flight Tracks Departing ORD, May 6, 2012

In summary, the DFE and AFE are proposed new metrics for assessing the efficiency of departure and arrival operations for an airport. They should be useful for FAA managers for their trend analysis and next-day performance review. The metrics are simple in that they rely only on the measurement of flight time to/from airport and radius crossing. Additional flight information in terms of runway, aircraft type, and geographic orientation are needed for stratifying the population prior to computation of the metric. Adjunct data sources would be needed to fully investigate the contributors to a flight's low AFE or DFE valuation, but these data sources are readily available to FAA managers and analysts.

Upstream Flow Efficiency

Upstream Flow Efficiency (UFE) is a measurement of the delivery performance to the 175 NM radius, for flights inbound to the subject airport. It is a means of extending the AFE: if delivery upstream of the 175 NM radius is subpar, it means that TRACON and airport resources for servicing arrivals may experience underutilized capacity.

Calculation/Data Sources

Calculation of the UFE relies on already-computed quantities used for AFE calculation, plus additional data. UFE is computed via the following formula:

$$\text{UFE} = \frac{\text{ETE - (Unimpeded Time 175 NM-to-landing)}}{\text{(Observed Off-to-On) - (Observed Flying Time 175 NM-to-landing)}}$$

A description of the terms is as follows:

ETE is the Estimated Time En Route, i.e., predicted Off-to-On time duration, provided by the Traffic Flow Management System (TFMS) trajectory modeler, available in the Aggregate Demand List (ADL), as provided by FAA

Wheels-off times are available either via Airport Surface Detection Equipment-Model X (ASDE-X) or TFMS

Unimpeded and Observed Flying Time 175 NM-to-landing are taken from calculation of the AFE.

Sample Application

A chart similar to Figure AVG-DFE was constructed for the UFE metric, to compute 5th and 95th percentile values and identify low UFE dates. One such date was August 24, 2014 wherein severe weather in the NAS extended over a large area. Inbound flights to ORD experienced airborne reroutes and some holding. See Figure UFE for graphical depictions of en route weather deviations of flight paths. There was weather in the North Central and Southeast U.S. on that date. For multiple flights the “Observed Off-to-On” time duration was high, which drove the daily metric valuation down.

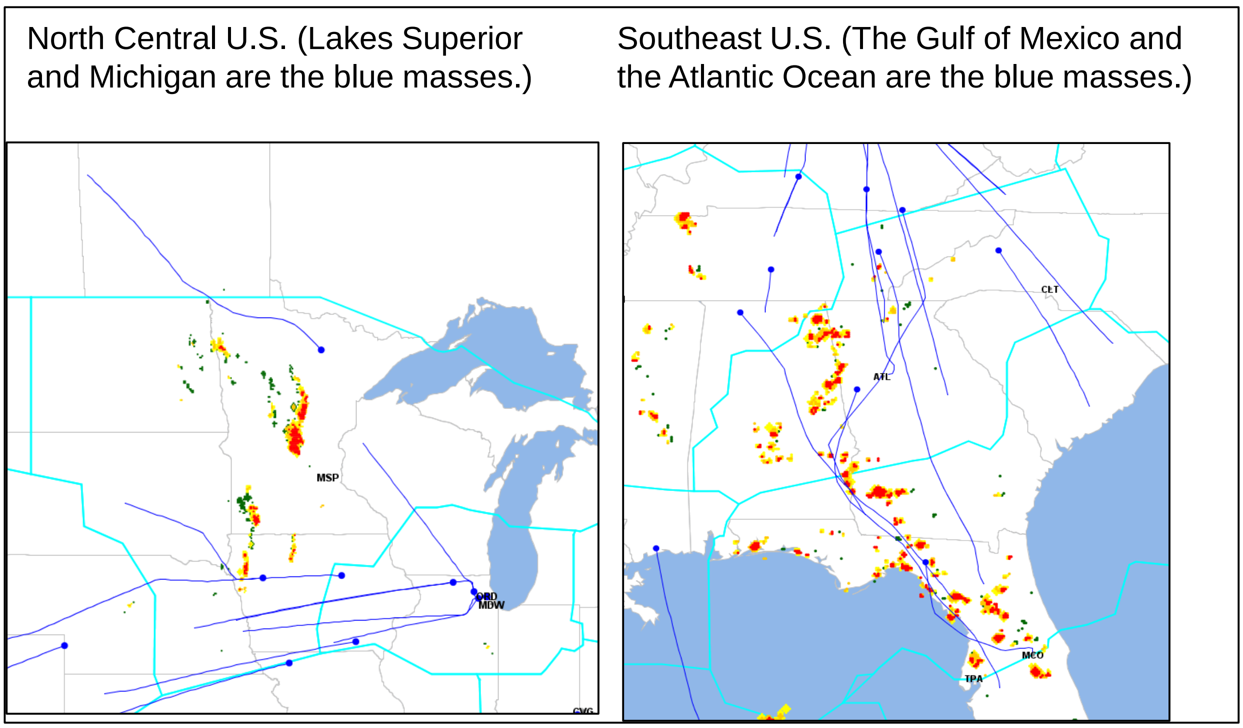


Figure UFE. En Route Weather and Flight Track Deviations on August 14, 2014

Taxi Efficiency

Taxi efficiency measures how quickly flights are able to transit the airport surface from terminal to runway (for departures) or runway to terminal (for arrivals), compared to an unimpeded taxi time. As surface congestion increases, one would expect taxi times to increase, leading to a drop in taxi efficiency. The TTE metric is broken up into two sub-components, DTE and ATE. Other than the distinction of which flight set is included (departures, arrivals, or both), the taxi efficiency metrics are all computed using the same approach.

Calculation of Taxi Efficiency and Required Data Sources

TTE, DTE, and ATE are the surface equivalents of DFE and AFE. Thus they are computed, on a per-flight basis, as:

$$\text{TTE } or \text{ DTE } or \text{ ATE} = \frac{\text{Unimpeded Taxi Time}}{\text{Observed Taxi Time}}$$

The observed taxi time is the duration between the start of taxi-out through wheels-off-runway time for departures, and between wheels-on-runway through the completion of taxi-in for arrivals. The unimpeded taxi time for each SC is defined in the same way as for the DFE/AFE SCs: it is the average of all times falling between the 5^{th} and 15^{th} percentiles of the distribution of observed taxi times, over the previous 12 months, for all flights in that SC. The attributes used to define SCs for surface efficiency are:

- Runway
- Taxiway Segment (surrogate for handoff spot[5]) or Terminal
- Weight Class
- WITI category

As with the DFE and AFE, we require a sample size of at least 30 to compute nominal times for an SC.

We fused two main data sources, on a per-flight basis, to gather the necessary transit time and SC data. These are:

- Aviation System Performance Metrics (ASPM)[6]: runway information (from CountOps[7]), plus gate-out, gate-in, wheels-off, and wheels-off times (fused from Out, Off, On, In [OOOI], Airline Service Quality Performance [ASQP], ADL, and TFMS data)
- GroundTracker (Srivastava, 2011): terminal and taxiway segment information, derived from raw ASDE-X position data

Finally, the taxi efficiency metrics are initially computed for each individual flight in the dataset. Hourly, daily, and weekly efficiency metrics are then computed for the corresponding set of flights for each time period using a time-binning approach.

Terminal and Taxiway Segment Data

The SCs for taxi efficiency include taxiway segment or terminal as one of the defining attributes. We used ASDE-X (FAA, 2015a) data, post-processed by The MITRE Corporation's Center for Advanced Aviation System Development (MITRE CAASD) in-house GroundTracker departure queue monitoring platform, to associate flights with terminals. GroundTracker uses adaptation files which partition the airport surface into several logical areas, based on historically-observed airport operations:

[5] A handoff spot is a location on the airport surface where pilots must contact ground control before proceeding into the active movement area (for departures), or where flights are said to leave the movement area and enter the ramp/terminal area (for arrivals). A single terminal building may have multiple handoff spots, and there are some gates at some terminals which do not have a clearly defined handoff spot (flights push back from the gate directly onto an active taxiway).

[6] https://aspm.faa.gov/

[7] CountOps is an FAA-developed software program which utilizes the data from National Offload Program (NOP), Standard Terminal Automation Replacement System (STARS), and Common Automated Radar Terminal System (ARTS) to count air traffic activity at TRACON facilities.

- Terminals: ramp/gate areas
- Taxiways: general taxiways in the movement area
- Queues: taxiway segments specifically observed as being used for queuing flights for departure
- Runways

GroundTracker processes ASDE-X data in near real-time as input to Traffic Flow Management (TFM) decision support prototypes. It also archives integrated flight histories based on the raw, operational ASDE-X data. The terminal area associated with GroundTracker flight histories is directly suitable for taxi efficiency SC determination. However, GroundTracker adaptations do not directly capture handoff spots, and not all terminals have easy-to-define handoff spots. Therefore, we used the first taxiway segments adjacent to the defined terminal areas as surrogates for handoff spots. Figure SURFACE shows the surface adaptation for the passenger terminals at ORD. The orange handoff spots were added for visual reference, but are not part of the GroundTracker adaptation file. Although there are no distinct handoff spots for Terminal 5, using GroundTracker's taxiway segments does provide a "sub-terminal" level of resolution, as Taxi-51 and Taxi-52 are both used as separate movement area entry points. The GroundTracker flight history archive thus provides a key input for the data fusion required for the taxi efficiency metric computation.

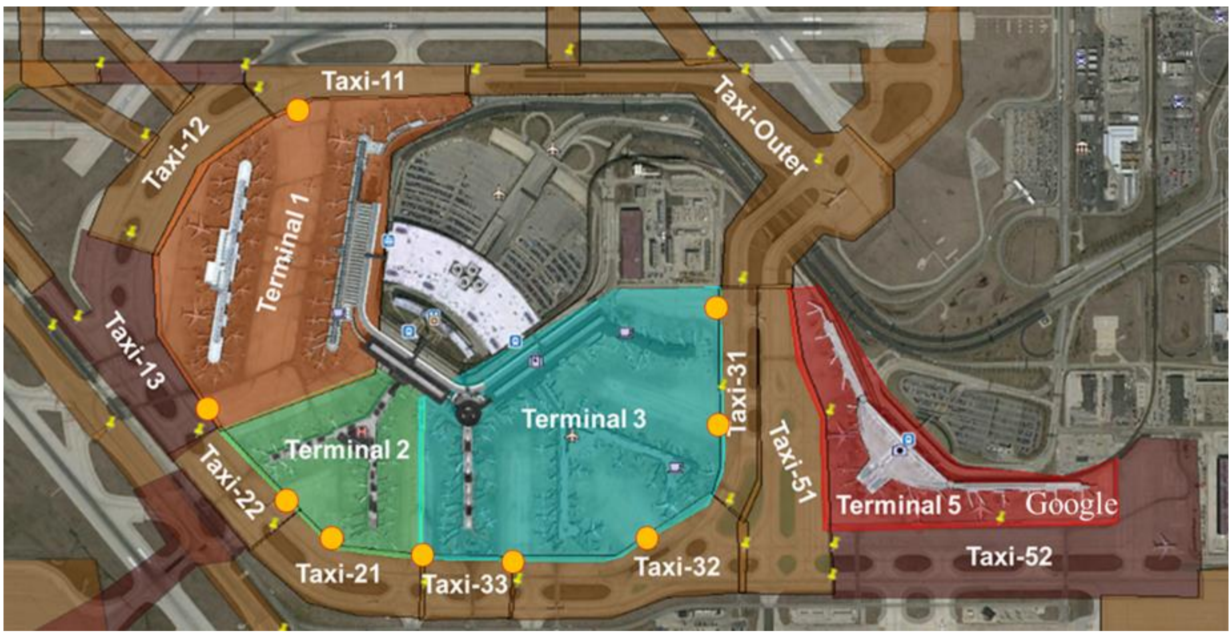
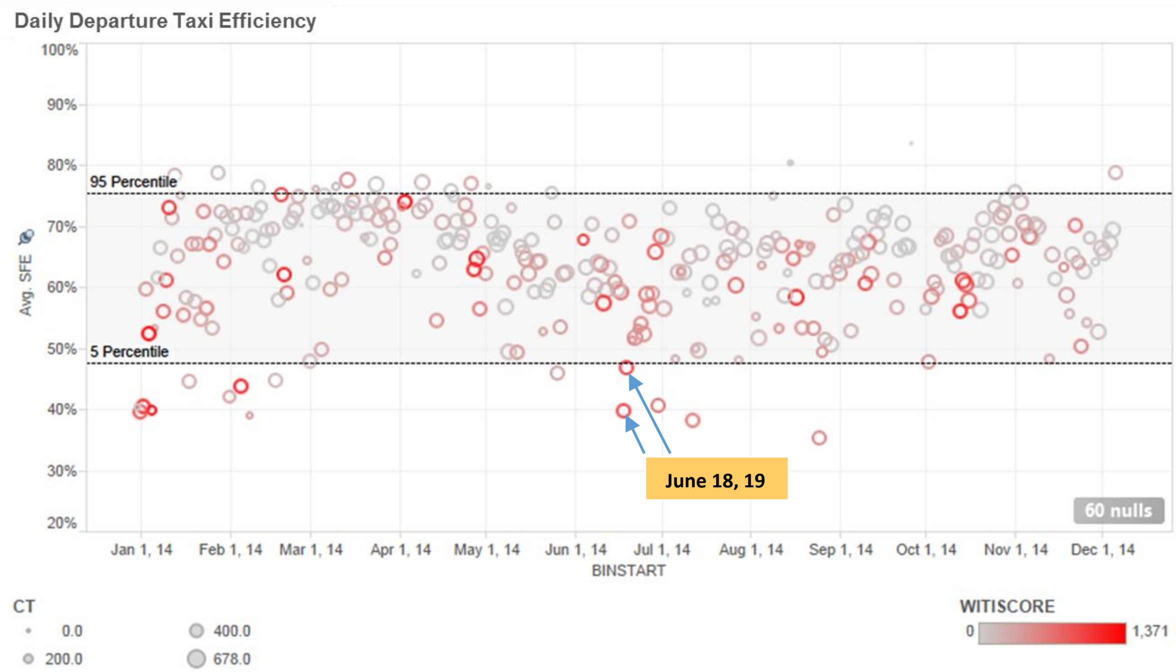


Figure SURFACE. GroundTracker Surface Adaptation for ORD

Sample Application

Figure DTE plots the DTE daily scores for ORD in 2014. The figure shows two dates which had typical departure counts (491 and 536, respectively), fairly high average WITI scores (974 and 936), and DTE scores below the 5^{th} percentile for the year (40% and 47%).



Circle size indicates flight count (larger circles represent more flights) and color indicates weather severity (brighter red represents higher WITI score).

Figure DTE. DTE for ORD in 2014 by Day

Widespread convective weather and associated rerouting likely caused the surface congestion and resultant prolonged taxi-out times observed at ORD on these dates. Figure LONG-TAXI shows the surface movement of a departure flight (thick orange line) on June 18 with an especially extended taxi time. The figure confirms the ability of the taxi efficiency metrics to easily identify time periods and individual flights which have anomalous airport surface transits.

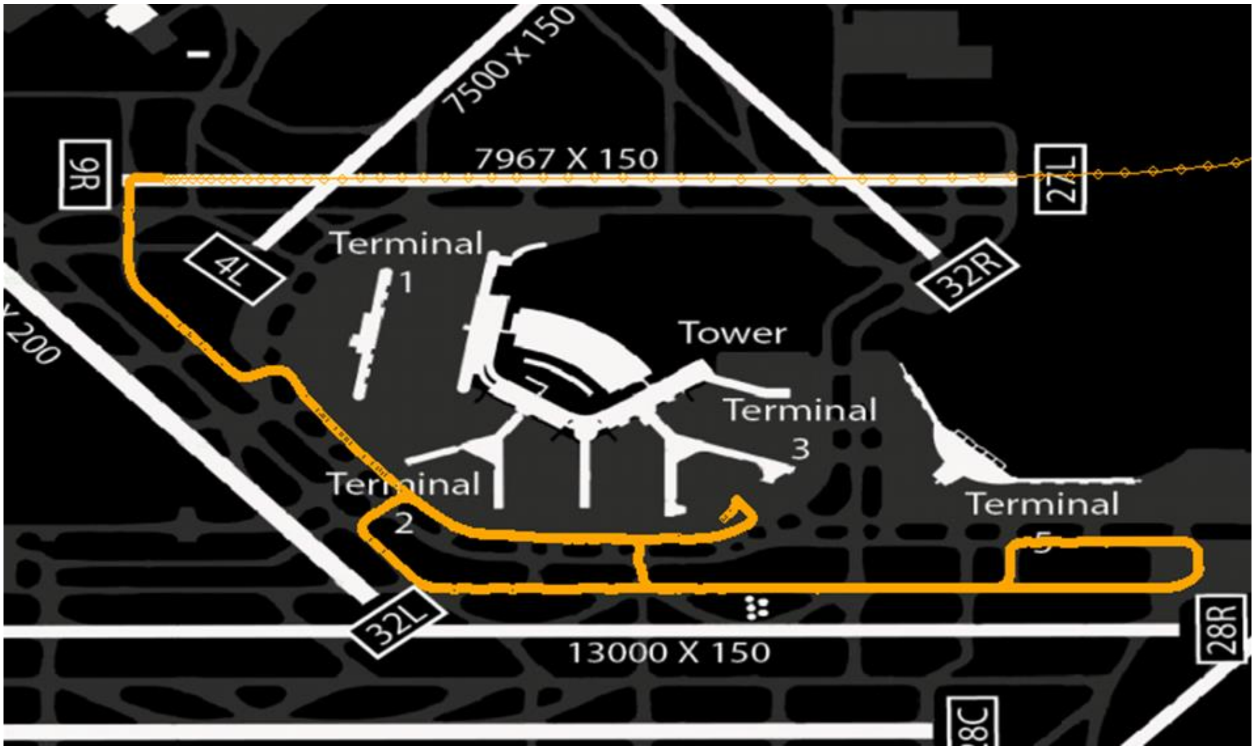


Figure LONG-TAXI. Surface Transit for AAL115 (thick orange line) on June 18, 2014

Runway Utilization Rates

Departure and arrival runway utilization rate metrics assess how effectively the capacity of an airport's runway system is utilized. Utilization rate metrics described below are variants of airport efficiency metrics currently in use in existing FAA performance analyses, namely, AER, DER, SAER, and TAER described earlier.

Definition

Utilization rate is defined as the ratio of operation counts to capacity. One challenge in undertaking this computation is that departure and arrival runway capacity values are not commonly measured and recorded by terminal facilities. Rather, ADR and AAR are used as proxies for capacity, even though these quantities may be affected by conditions in the terminal area, such as compression on final approach and convective weather.

Departure Runway Utilization (DRU) is defined as the ratio of actual departure count to the effective departure capacity in a given time period:

$$\frac{Actual\ Departures}{Effective\ Departure\ Capacity}$$

where: effective departure capacity is the minimum of the ADR and the departure demand for the period. The purpose of employing effective capacity as an adjustment to ADR (or AAR for arrivals) is to avoid low metric valuations for time periods which have low demand.

Similarly, arrival runway utilization is defined as the ratio of actual arrival count to the effective arrival capacity in a given time period:

$$\frac{Actual\ Arrivals}{Effective\ Arrival\ Capacity}$$

The FAA's ASPM provides necessary data of demand, observed counts, and capacity to compute the proposed new utilization rate metrics. For arrival demand, there are two definitions in ASPM. One arrival demand variable is developed for computing TAER: the projected hourly arrival demand at the runway, calculated at the time the flight crosses the 100 NM radius from the airport/ (The details of arrival demand estimation in TAER calculation can be found at [FAA, 2015c].) The other arrival demand variable is developed using the ETA at the time of take-off, and is generated every quarter hour for the SAER calculation. Consistent with the FAA's having two variant measures of terminal arrival efficiency, TAER and SAER, we calculate analogous measures, Terminal Arrival Runway Utilization (TARU) and System Arrival Runway Utilization (SARU).

Sample Application

The runway utilization rate metrics can be used to identify particular runway events, such as a capacity drop due to a change in runway configuration or a slow-down in departures caused by a Ground Stop (GS). Figure SARU illustrates the SARU metric for ORD on August 4, 2014. The figure shows hourly variation of actual arrivals, arrival demand, AAR, and the utilization rate metric. From 6:00–14:00 local time, the effective capacity was determined by the arrival demand (it was lower than the AARs), while the SARU metric valuation (blue line) is steady. However, between 14:00 and 22:00 local time, ORD had a Ground Delay Program (GDP) due to thunderstorms – the AAR was adjusted downward during the convective weather period, but the actual throughput fell even further (with high arrival demand), so the utilization rate dropped in that period.

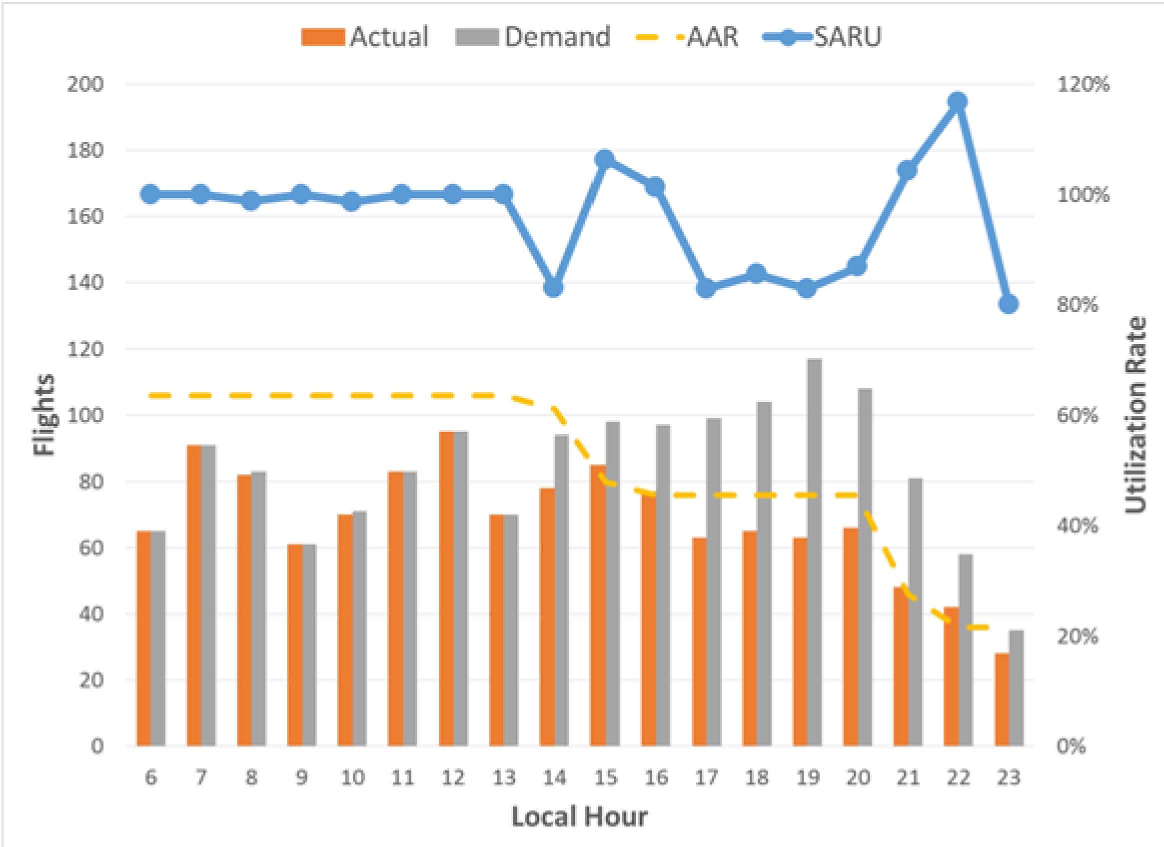


Figure SARU. System Arrival Runway Utilization (SARU), August 4, 2014 at ORD

Rate of Flights not Cancelled or Diverted

This rate for arrivals is defined as:

$$\frac{\#Arrivals\ Scheduled - \#Diversions - \#Cancellations}{\#Arrivals\ Scheduled}$$

The rate for departures is defined as:

$$\frac{\#Departures\ Scheduled - \#TaxiBacks - \#Cancellations}{\#Departures\ Scheduled}$$

The rate is the measure of the fraction of a set of scheduled flights which get to their final destination without being cancelled (not flown), and which do not encounter major disruptions from their intended course: taxi-backs to the departure gate or diversions to another destination after becoming airborne. Only scheduled flights are included.

To calculate the metric, each flight in the TFMS ADL data with a flight schedule (FS) message is counted as a scheduled flight. These flights are joined individually to the ASPM cancelled flights, and also the MITRE CAASD-calculated diversions and taxi-backs. The data is determined at the flight level. The data are then aggregated based on the scheduled departure time or scheduled arrival time. Normally these rates would be reported by airport and operational day.

Sample Application of Rate of Flights not Cancelled or Diverted

Figure ARR-COMPLETE depicts the daily values of the ORD Rate of Flights not Cancelled or Diverted rate, plus cancelled arrivals and diverted arrivals. Note that the daily number of cancelled arrivals are generally much larger than the daily number of diverted arrivals. In this chart, the range from the 5^{th} to the 95^{th} percentile arrival completion rate, which is 74% to 99%, is indicated by the gray shaded region. The days with large numbers of cancellations may occur in sequence, if a large weather event (e.g., the snowstorm event from January 5-7, 2014) disrupts the network of carrier flight schedules to the degree that several days are required to re-establish the normal schedule. As such, low completion rates on these days can be tied to an event which may have happened on one or more neighboring days.

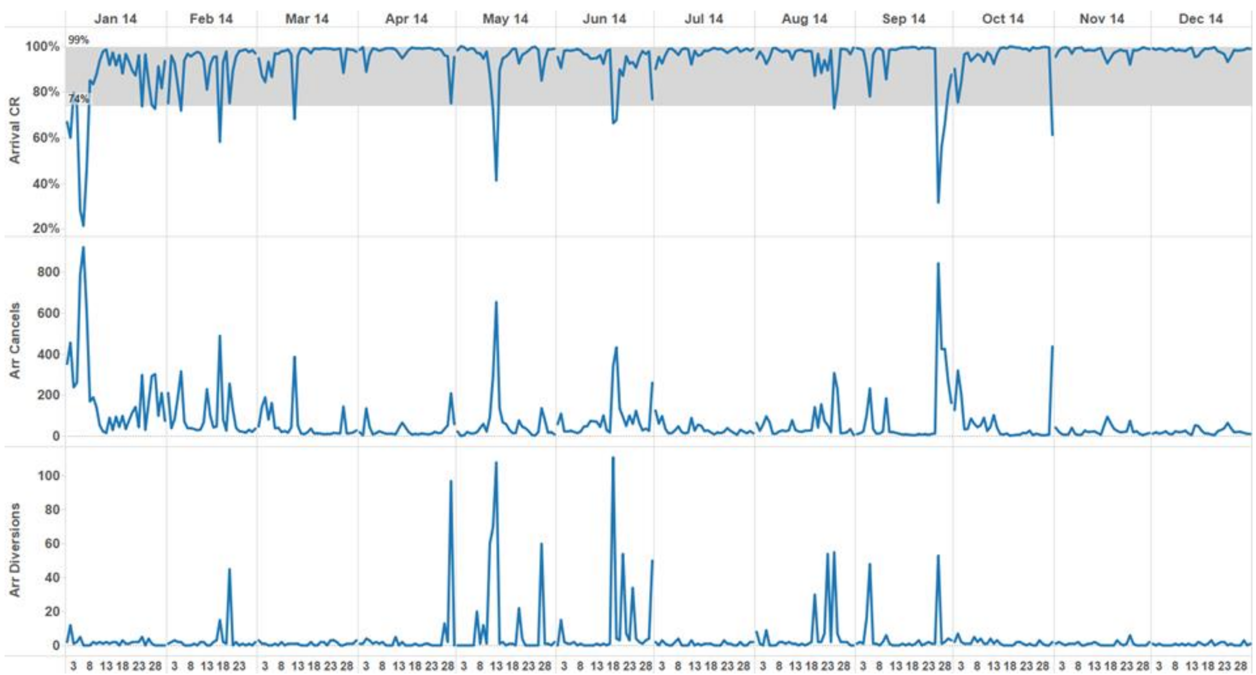


Figure ARR-COMPLETE. ORD Daily Arrivals' Rate of Flights not Cancelled or Diverted

Integration of the Metrics

The 13 metrics discussed in detail above can be used, one at a time, to provide useful information on efficiency performance in different regions of the NAS with respect to the subject airport for a given date. But considering all of these metrics together can provide a complete picture of a day.

We propose a daily integrated metric: a simple tally of the number of 11 of the 13 individual metrics which are non-subpar, i.e., those which do not fall below their respective 5^{th} percentile threshold. (For simplicity and to avoid redundant reporting, two of the thirteen metrics are ignored for this roll-up: TTE and SARU). The sense of this metric is like that of the other metrics described in this document – higher valuations reflect more efficient operations in the NAS.

Daily scores were computed and plotted for 2014, and February 17 was identified as a low-performance day in which ORD and the Chicago area experienced a winter snowstorm. The National Traffic Management Log (NTML), see (FAA, 2015b) notes heavy snowfall, traffic management initiatives (TMIs) consisting of GDP, GS, and miles-in-trail (MITs), a low AAR, and at times, single runway operations. Seven of 11 metrics were subpar, as shown in Figure SUBPAR as red-filled diamond symbols. The vertical bars show the 5^{th} to 95^{th} percentile range for each metric. The x-axis shows labels for the 11 metrics.

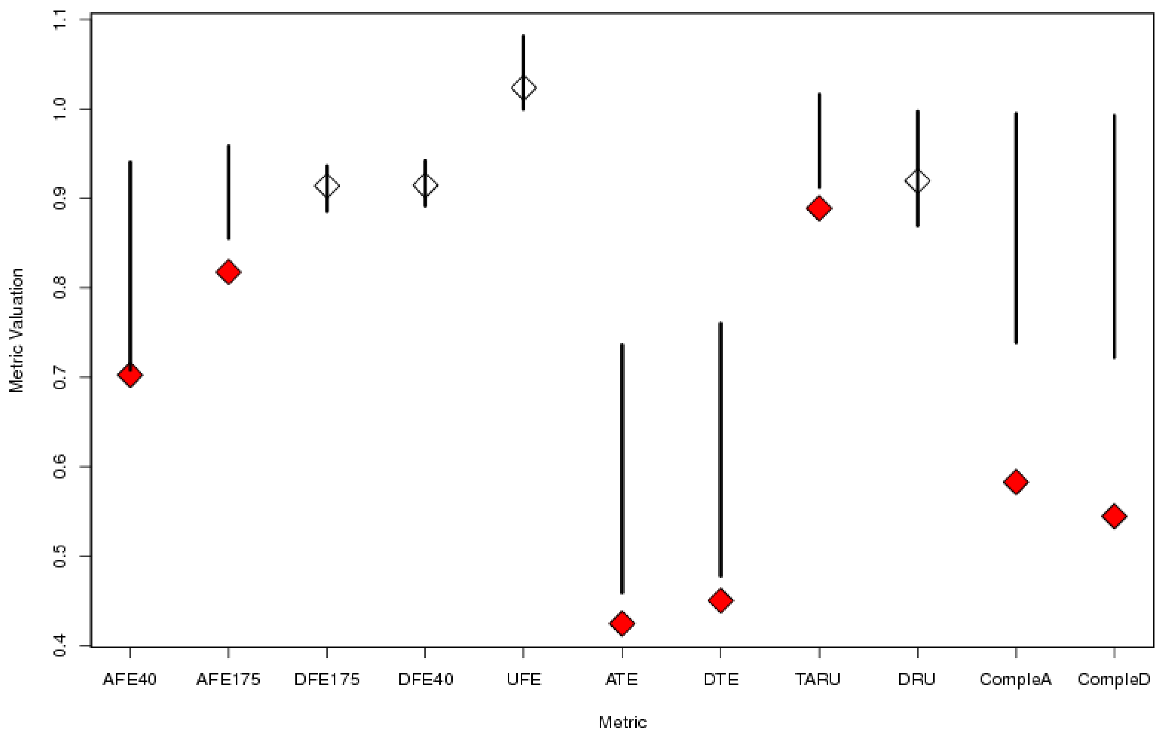
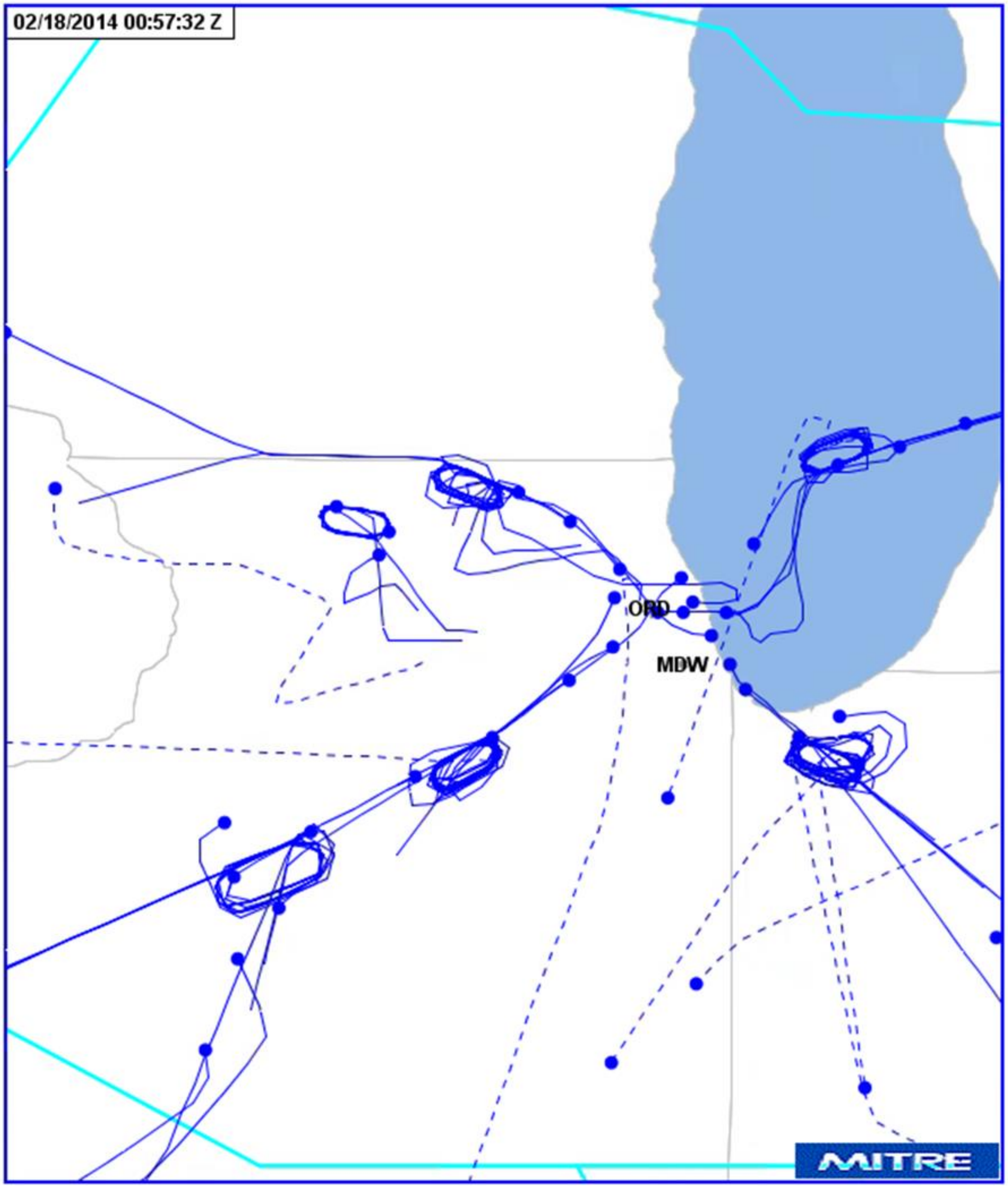


Figure SUBPAR. Percentile (5^{th}/95^{th}) Bars plus Metric Valuations for February 17, 2014

Figure FEB17 shows a graphic of flight tracks filed to arrive at ORD on that operational date, at 0057Z. Note the holding patterns as flights wait for an available landing runway. Dotted blue lines show diverted flights, forced to land at an alternate airport.



Dotted blue lines represent diversion flights, landing at alternate destination airports

Figure FEB17. Flight Tracks for Arrivals Filed for ORD February 17, 2014

Next Steps

The goals of this work are ultimately to:

- Complete development of these metrics for the busiest airports. This may potentially involve modifications to the algorithms presented in this paper. One example would be to calculate runway utilization using a modeled capacity instead of the reported AAR and ADR
- Develop an operational concept of use for these metrics, demonstrating in a more comprehensive way how they may be used to diagnose issues and provide insights into potential improvements in operational procedures. It may be advantageous to tailor the metrics to reflect facility characteristics
- Develop estimates of the normal range for these metrics given the actual weather conditions on a particular day. While these metrics have been developed using weather in the stratification used to estimate unimpeded times, the final metric values themselves are still correlated with weather intensity. Thus, for these metrics to be most useful in identifying anomalous conditions, the normal ranges used (i.e., 5^{th} and 95^{th} percentiles) should be based on the actual weather conditions occurring on the day of operation.
- After acceptance of the final form of these metrics by the FAA, tech transfer the process to calculate them in production FAA systems

To achieve these goals, additional work would be necessary to:

- Process data for a minimum of three years, in order to calculate each metric at each airport
- Consider refinements to the current algorithm for calculating unimpeded times
- Develop the algorithm to calculate the normal range for each metric by operational day
- Develop the detailed documentation needed for tech transfer

References

CANSO (Civil Air Navigation Services Organization), 2013, "Methodologies for Calculating Delays/Improvement Opportunity Pools by Phase of Flight," Website: https://www.canso.org/methodologies-calculating-delays (accessed October 2014).

DeArmon, J. et al., 2014, "Departure Flow Efficiency and the Identification of Causes for Inefficiencies," 33rd Annual Digital Avionics Systems Conference (DASC), Colorado Springs, October 2014.

FAA, 2015a, Federal Aviation Administration webpage describing ASDE-X: https://www.faa.gov/air_traffic/technology/asde-x/ (accessed May 2015).

FAA, 2015b, Federal Aviation Administration, webpage describing National Traffic Management Log: http://hf.tc.faa.gov/projects/ntml.htm (accessed March 2015).

FAA, 2015c, Federal Aviation Administration webpage describing TAER calculation: http://aspmhelp.faa.gov/index.php/TAER (accessed May 2015).

Klein, A. et al., 2007, "Weather Index with Queuing Component for National Airspace System Performance Assessment," 7th USA-Europe ATM R&D Seminar, Barcelona, Spain, July 2007.

Srivastava, A., 2011, "Improving departure taxi time predictions using ASDE-X surveillance data" 30th Annual Digital Avionics Systems Conference, Seattle, October 2011.

Wine, C., 2005, "System Airport Efficiency Rate (SAER) and Terminal Arrival Efficiency Rate (TAER)," Webpage: https://aspm.faa.gov/aspm/Customer%20Satisfaction/TAER%20SAER%20Updated%20Briefing.pdf (accessed May 2015).

Disclaimer

The contents of this material reflect the views of the author and/or the Director of the Center for Advanced Aviation System Development (CAASD), and do not necessarily reflect the views of the Federal Aviation Administration (FAA) or the Department of Transportation (DOT). Neither the FAA nor the DOT makes any warranty or guarantee, or promise, expressed or implied, concerning the content or accuracy of the views expressed herein.