Title: Driving Operations Monitoring and Decision Making by Leveraging Multidimensional Data Visualizations

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Abstract
Data collection and retrospective analysis are integral and important components of business operations in any industry, and particularly in aviation where data serves as a backbone of operations. To present findings that can lead to operational improvements, it is important that the synthesized data be presented in a readable, interpretable, and understandable format. Historically, traditional crosstabs/tables, bar charts, and line charts have been used for this purpose. Advancements in visualization tools now make it possible to present information in an interactive, multidimensional format which is easy to understand and interpret. Data visualization tools are enabling users to be more inquiring, and allowing them to delve further into the analysis and reasoning, thereby acting as a catalyst in driving decisions to improve operations. Optimal visualizations require thoughtful organization and preparation of the data. This paper focuses on the evolution of aviation visualizations within the Federal Aviation Administration’s (FAA) Air Traffic Organization (ATO). It also describes how visualization tools are currently being adopted to help drive operational monitoring and excellence in the FAA ATO. Finally, lessons learned and best practices to develop meaningful and actionable multidimensional visualizations are mentioned.

Keywords: Digital Dashboards, Business Intelligence, Air Traffic Visualization, Operations Monitoring
Introduction

Data is everywhere! The Federal Aviation Administration (FAA) has been collecting and analyzing data related to flight delays for many years, and key performance indicators (KPIs) have been added over time to help monitor the performance of the National Airspace System (NAS), as well as a variety of reports and dashboards to help illustrate the trends in KPIs along with other necessary reportable information. These reports are used across all levels in the FAA to review operations, and make decisions to improve operation of the NAS.

Advancements in data architecture and storage strategy has allowed incorporating the large amount of new data and data sources to make them readily accessible and usable; however until recently the traditional two dimensional visualizations (bar charts, line graphs etc.) were still used to visualize the data, thereby, at times, limiting the ability to clearly represent complex situations in a concise manner. With two dimensional visualizations, multiple charts are often required to communicate the entire message, which dilutes the importance of the message, or obscures it altogether. Further, the FAA needed to employ computer programmers and specialized analysts to create such visualizations as many times it requires in-depth knowledge of databases and ETL (Extract, Transform, and Load) methods and tools, which front-line and operational personnel don’t typically possess, thus limiting their ability to consume data for decision making purposes.

Recent advancements in data architecture and storage strategy have allowed incorporating new data sources to make them readily accessible, and advancements in data visualization and analysis tools have put the power of presentation and visualizations in the hands of the front line personnel, who may or may not have in-depth knowledge about databases or Structured Query Language (SQL). Creating complex visualizations is now easily achievable with little or no database knowledge, once the data has been structured and prepared for efficient retrieval and display. But with so much power in users’ hands there are certainly best practices to be recommended to create meaningful visualizations that are actionable and cater to decision making in the organization.

This paper discusses complex visualizations developed to monitor operations and help in decision making process at the FAA to help enhance the safety and efficiency of air traffic. Specific use cases are provided illustrating the evolution of a single report through various time periods of visualization.

Growth of Data

KPIs and supplemental data from Technical Operations (TechOps), National Oceanic and Atmospheric Organization (NOAA), Mitre, Performance Data Analysis and Reporting System (PDARS), and National Traffic Management Log (NTML), and other FAA operational systems are used in analysis and reporting.

Circa 1997, when the FAA first began to make performance data readily available through the internet, monthly data feeds for three data sources were available – ETMS (today referred to as Traffic Flow Management System (TFMS)), Airline Service Quality Performance (ASOP), and Official Airline Guide (OAG) schedule data and fed into the Consolidated Operations and Delay Analysis System (CODAS).
Today, the FAA Office of Data Integration collects data from several data sources, such as NTML, TechOps, and NOAA, from which KPIs and supporting fields are extracted and fed into Aviation System Performance Metrics (ASPM) on a daily basis for reporting on many aspects of NAS performance. The graphic below shows contrast between 1997 and today, including the future where more data may be available on a more frequent basis for processing and visualizing.

The FAA has come a long way in terms of data collection, processing, storage, and aggregation, and additional improvements are coming down the road. This paper describes recent significant progress in the FAA’s endeavor to make operational information for retrospective analysis and decision-making more readily available and customizable for front-line and support teams at the FAA.

![Figure 1: Growth of Data](image)

**Figure 1: Growth of Data.** Shown is growth of number of data sources from 1997 to 2017. CODAS: Consolidated Operations Delay Analysis System; TFMS: Traffic Flow Management System; ASQP: Airline Service Quality Performance; OAG: Official Airline Guide; ASPM: Aviation System Performance Metrics; NTML: National Traffic Management Log; CountOPS: FAA system utilizing data from National Offload Program (NOP); CDM: Collaborative Decision Making; TechOps: Technical Operations; Innovata: Data provider for flight schedule data; OPSNET: Operations Network; Mitre: Mitre Corporation; PDARS: Performance Data Analysis and Reporting System

Most of the data sources accessible to FAA analysts to date are structured. In other words, the data is highly organized within tables and databases, searchable via traditional search and query methods such as the SQL. Increasingly however, unstructured data is available to be pooled and analyzed along with structured data, and the combination can facilitate deeper actionable insights. Unstructured data may be difficult to store, and may not appear relevant or insightful when considered in isolation of the operating environment at the time, but may be immensely beneficial in deriving deep insights when considered and analyzed along with the structured data. An example of the benefits of unstructured data are assessing the outcome Traffic Management Initiatives (TMI) by supplementing information on operations, delays, and the TMIs duration and affected traffic, with customer comments providing their perspective on the impact. Additionally, collecting and structuring customer input over time can illuminate patterns and better allow the FAA to respond to challenging weather and traffic conditions,
and also in planning for specific situations. The analysis could be further supplemented, and applied to other situations, by using radar data along with the conversations between Air Traffic Controller and the pilot to help provide essential information that may not be available today.

**Data Preparation**

Data Preparation is often an unspoken piece of the visualization puzzle. Today’s business intelligence tools make it very easy for users to generate visualizations by connecting to the data sources and dragging or dropping fields onto columns and rows shelves. The unspoken truth, however, is that much; if not most data sources require significant preparation before they can be ingested by business intelligence tools for meaningful and accurate displays. As the graphic below shows, there is an important component of ‘data preparation’ that needs to happen before any data can be considered visualization ready.

![Data Preparation Diagram](image)

**Figure 2: Data preparation**: Data preparation is an important component to make data visualization ready.

Preparation can involve a variety of steps but generally includes the following:

- **Indexing**: Indexing is defined as applying structure to the data that helps improve speed of data retrieval and operations on the database table. It is best practice to index tables utilized for visualizations.

- **Pre-Calculating Variables**: Business intelligence tools are fully capable of performing calculations on the fly while generating visualizations. If the calculation is complex, however, it is best practice to pre-calculate values, store them in the table/view, and then make them field available to the visualization. This is because the resources needed for a complex calculation may be significant and deter performance of the dashboards/visualizations in the long run.

- **Database views**: Database view is a searchable object in a database that is defined by a query. A view does not store data; it consolidates data from various tables into a single virtual table. As

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dashboards become more complex and the need for full drill down capability gets established, it is always a good strategy to create views from the original tables and store them in a separate schema ready for access by a business intelligence tool. Views can be set to update regularly to ensure recent data is available for display on the dashboard.

The above mentioned data preparations steps were key in generating visualizations mentioned in this paper. If skipped, the constructed dashboards would have been difficult to use particularly due to performance related issues. It is worth noting that each of these dashboards is pulling well over a million records at a time. Some of the tables are large both length and width-wise, and therefore data preparation is an extremely important and necessary step in the dashboard construction process.

**Evolutions of Air Traffic Dashboards**

Early visualizations of air traffic data that pre-date Aviation System Performance Metrics (ASPM) systems were sophisticated at the time, but basic compared to current visualizations. The evolution of computers, data storage, networks, and software have made it possible to quickly process and synthesize increasing amounts of data in support analysis and decision-making.

**NAS Daily Report**

One of the first dashboards used in in daily senior management briefings at the FAA was the NAS Daily. It is a static, tabular report without graphics or drill-down capabilities. The FAA end-user cannot manipulate or augment the data contained in the report, and any changes requested by the FAA must be implemented by a programmer.

This report enables users to conduct some secondary analyses including comparison of two different time periods, but with no drill down capabilities.

![NAS Daily Report](image)

**Figure 3: NAS Daily Report:** Example of NAS Daily report showing key metrics/KPIs for Core airports.

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Air Traffic Organization (ATO) Efficiency Report Online (AERO)

Since implementing ASPM, the visualizations, even though in a very simplistic form have helped in understanding the aviation data across all levels of management in the Federal Aviation Administration (FAA) and monitoring operations. Air Traffic Organization (ATO) Efficiency Report Online or AERO provides both a summary and a comprehensive view of the day for a specific facility\(^3\). While the format of this report is simple and easy to understand, it is generated from a complex network of data sources and aggregation, and which required several programming hours to generate the report.

For each selected location, this report provides a summary view of Operations, Weather, Efficiency Metrics such as Terminal Arrival Efficiency Rate (TAER), System Arrival Efficiency Report (SAER), Taxi-in and Taxi-out, Go Arounds, and Equipment Availability. An hourly trend is shown for Taxi-in, Taxi-out, TAER, Arrivals, and Departures. Additionally 90-day trends are provided for Taxi-in, Taxi-out, Go Arounds, and TAER. In order to construct this report, data is aggregated from multiple data sources such as Operations Network (OPSNET), ASPM, COUNTOPS, and PDARS, queries are developed to extract data from each of these data sources and aggregate it to a desired level.

The AERO report was conceptualized and designed by the need to visualize ATO data and metrics and allow for easy understanding of ‘the day’ at a given facility, and also aid in decision making based on the operational performance at each facility. Drill down capabilities are provided, where the user can click on any of the metrics provided on the report and drill down to the next level of detail, in most cases to the individual flight level.

This report has enabled a range of users from senior management to Air Traffic operational staff to get a daily overview as well focus in on the most granular level of data. A related dashboard called the NAS AERO consolidates information on thirty core airports into one report for a more system-wide view.

\(^3\) “Aviation System Performance Metrics (ASPM)”, accessed April 7, 2017, aspm.faa.gov.
Both the AERO Report and the NAS AERO report provide critical information to the users, and both these reports are actively used by all levels of management in daily FAA ATO operations monitoring and decision making. However, these reports still fall short, not because they lack information, but because the visualizations used for these reports limit the features, and it would be inherently complex and busy if both the reports would need to be combined. Additionally, both these reports are prepared to be print-ready vs. screen-ready, thereby preventing users from interacting with these reports.

Both these reports and many others like these provide a good summary of the operations, but also create a need for a secondary analysis, which is a more in-depth analysis of KPIs at each facility. Typically a secondary analysis entails drilling down in the data, conducting analysis, and visualizing the result. Also traditionally, secondary analysis reports / charts have been kept independent than the summary reports / charts as it has been difficult to combine, or a combination thereof results in information overload for the consumer.

In order to maintain clarity and impact of the information, it must be presented in a clear and concise manner. Interactivity also enables users to be more engaged and inquiring about the information. It also helps them understand the interconnectivity and relationships between KPIs and other metrics.

**Visualizing Air Traffic Data – Interactive Dashboards**

To that end, in 2016 FAA Office of Performance Analysis launched an initiative to leverage a business intelligence platform and transform static PDF reports to interactive dashboards that can be accessed by range of users within the organization, and the users can drill down to the most granular level of the data that is available, typically the flight level. Next section provides examples of dashboards
constructed under this initiative and have been leveraged by the FAA for operations monitoring and decision making.

Business intelligence and visualization tools have come a long way from requiring users to have technical knowledge about databases, tables, queries etc., to allowing users to drag and drop fields to create impactful and engaging visualizations in a matter of minutes. Almost all heavy lifting is done by such tools themselves. But this does not minimize the importance of subject matter expertise. Without the subject matter expertise in the area, it would be extremely difficult and perhaps impossible to successfully interpret visualizations and derive insights from it.

First set of interactive dashboards to be designed under the new initiative were operational dashboards to be used by Air Traffic personnel including Air Traffic Managers and Deputy Directors for monitoring operations and assisting in decision-making. These dashboards would not only allow the users to get a summary view of the data, but also provide them with an opportunity to interact and drill down to the most granular level on the same screen, and perform secondary analysis including comparing different time periods.

FAA defines secondary analysis as a more in-depth research and analysis resulting from a summary review of NAS performance for the prior day. The result of secondary analysis is discussing findings which serve as a major input into executive and operational decision making required to efficiently operate the NAS.

Below are some examples of interactive dashboards developed and deployed to production at the FAA, and used by operational staff on a routine basis.

**Facility Summary Dashboard**

Facility summary dashboard is positioned as an enhancement to the current Daily AERO and the NAS AERO reports. It provides the same information as on the Daily AERO report but in a different representation including comparison of current day metrics to established benchmarks.

Below figure shows the Facility Summary dashboard for JFK airport for a specific day. On this day, there was a weather event which affected operations and efficiency metrics at the airport. The top section of the dashboard provides summary metrics for the selected day for JFK airport and the bottom section provides hourly view of the metrics starting at 0000 hours through 2300 hours.

This dashboard is extremely helpful for Facility Managers and Air Traffic Specialists to take a ‘day’s’ view at the facility. They can also compare KPIs on ‘like’ days to determine any differences or conduct secondary research.

**Dashboard Construction**

To assemble the KPIs on the dashboard the data is pulled from 5 different data sources which are essentially views built from the same data that is available in ASPM.
The summary section of dashboard shows KPI values for the selected day. The color coding in the top section is based on comparison to established benchmarks. For example – red indicates that the current value is over established benchmark and green indicates that the current value is under the established benchmark.

In the chart section of the dashboard, details for a selected day are shown by the hour. Various KPIs are shown including, Airport Arrival Rate (AAR), Airport Departure Rate (ADR), Average Taxi In, Average Taxi Out, Actual Departures, Actual Arrivals, and Terminal Arrival Efficiency Rate (TAER). This dashboard also overlays weather impact (None, Minor, Moderate, Severe) to add more meaning to the fluctuation in KPIs throughout the day.

Figure 6: Facility Summary Dashboard: Example of Facility Summary Dashboard showing daily summary and hourly trend of metrics/KPIs for selected airport and date. Total Ops: Total Operations; TAER: Terminal Arrival Efficiency Rate; Dept / Dep: Departures; ARR: Arrivals; GS: Ground Stops; EDCT: Expect Departure Clearance Times; AH: Airborne Holding; Avg. AAR: Average Airport Arrival Rate; Avg. ADR: Average Airport Departure Rate; None-Minor-Moderate-Severe: Weather impacts

A pop up feature, displayed below, displays the runway configuration and METAR for a selected hour. When an hour is selected, all the other hours fade, to help the user to focus on the time period in question.
Figure 7: Facility Summary Dashboard: Example of Facility Summary Dashboard showing daily summary and hourly trend of metrics/KPIs for selected airport and date, including runway and weather details overlay for the selected hour. Total Ops: Total Operations; TAER: Terminal Arrival Efficiency Rate; Dept / Dep: Departures; ARR: Arrivals; GS: Ground Stops; EDCT: Expect Departure Clearance Times; AH: Airborne Holding; Avg. AAR: Average Airport Arrival Rate; Avg. ADR: Average Airport Departure Rate; None-Minor-Moderate-Severe: Weather impacts.

The fade feature is also activated when one particular KPI is selected, which enables the user to focus on that KPI, but at the same time keep the other metrics visible to help understand the relationship between KPIs.

Figure 8: Facility Summary Dashboard: Example of Facility Summary Dashboard showing daily summary and hourly trend of metrics/KPIs for selected airport and date with Taxi-In trend highlighted. Total Ops: Total Operations; TAER: Terminal Arrival Efficiency Rate; Dept / Dep: Departures; ARR: Arrivals; GS: Ground Stops; EDCT: Expect Departure Clearance Times; AH: Airborne Holding; Avg. AAR: Average Airport Arrival Rate; Avg. ADR: Average Airport Departure Rate; None-Minor-Moderate-Severe: Weather impacts.
Impact on Operations and Performance Monitoring

In addition to providing facility managers with a summary of a day’s performance, the Facility Summary Dashboard can also be used to compare performance across days. For example at a recent briefing to the executives at the FAA, a comparison between two days with similar weather events for a single facility triggered discussions on best practices and approaches to recover operations and efficiency after a weather event.

Another significant benefit provided by this dashboard is consolidation of valuable information on a single screen. Prior to the Facility Summary dashboard, users had to refer to multiple static reports in order to provide a comprehensive picture, and this process was extremely time consuming and slow.

Implementing the pop up for METAR and runway configuration information has saved users time and are now able to pull all necessary information for the briefing from one single dashboard.

Future enhancements include addition of METAR and SPECI information to this dashboard, which will provide more relevant and complete information to operational staff. Dashboards such as this one helps Air Traffic personnel visualize data and obtain critical information that helps in decision making to efficiently operate the National Airspace System (NAS).

Looking at the above figures, the Facility Summary dashboard paints a comprehensive picture of the day at the JFK airport. From the dashboard it can be seen that the severe weather impacted arrivals and departures at the airport. There was capacity, but Air Traffic Control could not get flights in or out of the facility. As the weather eased, departures can be seen picking up and at the same time taxi times increase, this is mainly as the aircrafts line up on the taxi way for departures. Between 1500 hours and 2100 hours we can see that there was no weather, and arrivals and departures were within the expected capacity, which is generally an example of a normal operation.

The Facility Summary dashboard is a good example an actionable dashboard that can be used to derive insights and drive operational decisions.

Operations Drill Down Dashboard

Operations Drill Down dashboard provides a summary of operations at Core 30 airports in the NAS for any given day. Users are able to select a Region and Date they want to review the data for.

Dashboard Construction

Information on this dashboard flows from left to right and top to bottom. The top left chart in this dashboard provides a summary view of the number of operations across all Centers, TRACONS, and Airports within the selected region for a specific date. The lower section of the dashboard provides dissection of the operations along various dimensions including the Type of Operations, Arrivals and Departures, and critical KPIs for ATO such as Completion Rate, Average Daily Capacity (ADC) and TAER.
Similar to the Facility Summary dashboard, multiple data sources are utilized to provide users with full drill down capabilities up to the Air Carrier level.

![Dashboard Image]

**Figure 9: Operations Drill Down dashboard:** Example of Operations Drill Down dashboard with full drill down capabilities. Summary and detailed metrics/KPIs shown for selected date and region. Comparisons shown for selected dates. Current: Metrics for selected date; 3Y Avg: 3 year average; 3Y Avg DOW: 3 year average for day of week; Seasonal 3Y Avg: Seasonal 3 year average; P1 Avg Ops: Average operations for period 1; P2 Avg OPS: Average operations for period 2; Comp Rate: Completion Rate; ADC: ADC: Average Daily Capacity; TAER: Terminal Arrival Efficiency Rate

Furthermore, users also have the ability to select on screen any group of airports or facilities they wish to analyze, and the dashboard will refresh all charts based on the selection. Figure below shows metrics from NY area airports which is driven by selecting EWR, JFK, and LGA in the top left chart.
Figure 10: Operations Drill Down dashboard: Example of Operations Drill Down dashboard with New York area airports selected. Comparisons shown for selected dates and airports. Current: Metrics for selected date; 3Y Avg: 3 year average; 3Y Avg DOW: 3 year average for day of week; Seasonal 3Y Avg: Seasonal 3 year average; P1 Avg Ops: Average operations for period 1; P2 Avg OPS: Average operations for period 2; Comp Rate: Completion Rate; ADC: ADC: Average Daily Capacity; TAER: Terminal Arrival Efficiency Rate

Impact on Operations and Performance Monitoring

This dashboard is designed for Facility Managers, Director and Deputy Directors of Systems Operations, and all Air Traffic personnel to monitor operations within the region. Since this dashboard groups facilities by type – Airports, TRACONS, and Centers, it paints a good picture of the system load at a specific facility/facilities or region at a given time.

This dashboard is also an invaluable tool while planning for major events such as Super Bowl or other major sporting events, which creates a spike in aviation activity within the region, resulting in increase in operations managed by the Center, TRACON, and airports in the region. Increasing operations mean increase in demand and potentially capacity, which requires additional staff to efficiently operate the NAS. As an example, Operations Drill Down dashboard can serve as an input to the planners while planning for Super Bowl 2018 in Minneapolis, MN.

Future enhancements to this dashboard include integration of specific airports to help in monitoring and planning for special events, and inclusion of operations by air carrier for the selection region and facility.
Taxi Drill Down Dashboard

Similar to the Operations Drill Down dashboard, the Taxi Drill Down dashboard provides users with an ability to compare two different time period for Taxi In and Taxi Out times. The key factor in making this dashboard more actionable is to allow users to drill down from a summary level to a granular level on a single dashboard. Additionally, the multi-dimensional nature of the charts on the dashboard provides users with a cross-sectional view of the data on various dimensions.

![Dashboard Image](Image)

**Figure 11: Taxi Drill Down dashboard:** Example of Taxi Drill Down dashboard with full drill down capabilities. Comparisons shown for selected dates. Avg T-In: Average Taxi In; S. Avg T-In: Seasonal Average Taxi In; Avg T-Out: Average Taxi Out; S. Avg T-Out: Seasonal Average Taxi Out; P1 Avg T-In: Average Taxi In Period 1; P2 Avg T-In: Average Taxi In Period 2; P1 Avg T-Out: Average Taxi Out Period 1; P2 Avg T-Out: Average Taxi Out Period 2; T-In: Percent change Taxi In; T-Out: Percent change Taxi Out; 3Y Avg T-In: 3 year average Taxi In; 3Y Avg T-Out: 3 year average Taxi Out

Dashboard Construction

For example, the top left section of the dashboard lists summary metrics for Taxi In and Taxi Out. Here selected day’s values are compared to Seasonal averages, which is an established comparative benchmark for the FAA. The top right section of the dashboard provides users an ability to compare two different time frames. However, the key categorizing this dashboard as actionable vs. informative dashboard are the charts in the lower half section of the dashboard.

These charts aggregate data along multiple dimensions providing a multi-dimensional view on a single screen. For example, we can see Taxi Times by the hour of the day, by runway configuration, and by air carrier. The users can also select a specific airport from the summary chart, which then filters the dashboard for that specific airport. User can also select a specific metric i.e. Taxi In or Taxi Out at a
specific hour in the line chart, and the entire dashboard will filter and provide the runway configuration in effect at the time, and the airlines taxiing at that hour as shown in the figure below.

**Impact on Operations and Performance Monitoring**

Similar to other dashboards mentioned in this paper, Taxi Drill Down dashboard is designed for Facility Managers, Director and Deputy Directors of Systems Operations, and all Air Traffic personnel to monitor Taxi times within a region and for a specific facility.

Taxi time is a better indicator of Runway Usage, and ADC, which is a critical metric for individual facilities. Higher taxi times lead to delays, which then leads to reportable delays if they are beyond 15 minutes. Air Traffic managers and other personnel pay a close attention to all reportable delays.

Taxi Drill Down dashboard provides an excellent visual into the Taxi data for a region and a specific facility. It also allows user to compare two different time periods to evaluate the day’s Taxi In and Out metrics to any period of time and to the established benchmarks.

Additionally, the dashboard also shows the runway configuration in use at a specific hour and corresponding Taxi In and Taxi Out time including the Air Carriers that were Taxiing at the selected hour. Such visualizations have helped Air Traffic personnel respond to queries such as:

- What was the loading on specific runway?
- Did higher taxi times translate into reportable delays?
- Why wasn’t a specific runway used at a specific time when we were observing departure delays?
- Which carrier(s) or a specific flight(s) was a driver of taxi times at a given time?

Future enhancements to this dashboard include providing taxi information by specific runway by air carrier for each facility within the selected region and integrating with the Delay dashboards to help correlate reportable delays to high Taxi Out time at a specific facility for a specific day.

**Go Aroun ds Drill Down Dashboard (Map Integration)**

The Go Arounds Drill Down dashboard leverages the tool’s ability to provide multi-dimensional representation of the data and also provide users with an ability to simulate a particular day / time.

**Dashboard Construction**

Shown below is a dashboard that illustrates Go-Around information at JFK airport. This information is available for all airports with ASPM data available. The upper half of the dashboard illustrates detailed flight level data for Go Aroun ds including Altitude, Range from Airport, Return Distance from Airport, and Return Time to Airport.
The map is generated using the Latitude and Longitude of the position where the event occurred according to PDARS data source. Also represented is the time of the day when the event occurred. Traditionally, this would have been another column in the chart, but instead is represented as a color.

By incorporating visuals such as a map, and representing data in the format familiar to the Air Traffic personnel, we are able to convey large about of information in clear and succinct manner without labeling each variables/measure shown on the dashboard. For example, since the map represents Go Arounds, and the labeling is done as typically seen on an ATC radar screen, we don’t need to call out each element shown in the map.

Shown on the map is the period of the day when the Go Around event occurred, Air Frame number, Aircraft Type, Speed, and Altitude.

**Impact on Operations and Performance Monitoring**

The Go Arounds Drill Down dashboard is designed for Facility Managers, Director and Deputy Directors of Systems Operations, and all Air Traffic personnel at a particular facility. This dashboard is a spinoff of the main Go Arounds Drill Down dashboard and is developed to monitor Go Arounds at the New York area airports.
With the map representation the users are able to see the location of the event. Additionally selection of multiple facilities on the dashboard enables users to see Go Arounds in a specific region. Prior to the Go Arounds Drill Down dashboard, the users had to look at multiple reports to obtain required data, which was time consuming.

Potential enhancements to this dashboard include considering weather and other data that will help explain the cause of the specific Go Around.

Many other dashboards have been developed as part of the FAA ATO initiative led and managed by the Office of Performance Analysis, which collectively allows users to interact with the operational data and derive actionable insights. The tool also allows users to export the dashboard information in multiple formats including JPG, PDF, XLS, for further analysis and distribution.

The Adoption Path

All operational dashboards developed under this initiative have been in production for less than six months. Even though the dashboards are in their infancy stage, they are being adopted quickly throughout the organization. Air Traffic Specialists from various regions are accessing these dashboards on a regular basis to conduct the secondary analysis and report to operational managers and executives on a regular basis.

A steady rise in traffic to the dashboards is reported, with expectation that the traffic will increase multi-fold as the dashboards mature and are enhanced with additional features, meaningful visualizations, and more data to tell a story.

In order to facilitate agency wide adoption of these dashboards an information session is planned, and a SharePoint site is established for users to provide comments and feedback.

While most dashboards are currently open to internal FAA users, there are specialty use dashboards intended to be used by both internal FAA users and external stakeholders including air carriers. An example of one such dashboard is a runway usage and summary dashboard for the New York area airports developed in response to a construction project at JFK airport.

Users have also made requests for additional and more complex dashboards that combine different KPIs for various time periods to provide a causal – impact analysis, a key component of the secondary analysis and research.

Lessons Learned

The dashboard development team documented several lessons learned in the process of developing and implementing the dashboard. Some key lessons are highlighted below.

- **Data preparation is a key to building a successful dashboard**: Ensure that the data is available and visualization ready. Having access to the data does not mean it is ready to be visualized. Data must be cleaned, normalized, and stored in an accessible location for visualization.
- **Manage user expectations**: While managing user expectations is not new to software or application development processes, it is more important in case of development of digital dashboards. Complex visualizations can be generate in a short amount of time, and can open up possibilities to show big picture operation, but at the same time it can also be confusing to the users especially if they are used to looking at bar charts, tables, and other familiar visualizations. It is therefore important to know and understand the user base and slowly introduce them to newer – more elaborate visualizations so they understand the incremental value of them.

- **Digital dashboard is not a replacement for a report**: Business intelligence tools can be used to develop both reports and dashboards. However there is a difference between the two. A report depicts KPIs at a point in time and seldom allows user to drill down into the data. A dashboard, on the other hand, is used more for research and analysis. Therefore, while it tempting to convert all Excel and PowerPoint reports to dashboard, a question must be asked on how can these reports be made more interactive and what additional information can be provided so that the users can harness the full power of a dashboard developed using a business intelligence tool.

- **Beware of limited real-estate**: Dashboards are generally expected to be comprehensive and impactful. As such it is tempting to include a lot of information on a dashboard. However, attention must be paid to the amount of information shown on a single dashboard as more information generally means confusion.

- **Beware of varied aggregation levels**: Varied aggregation levels of data create a problem for a dashboard that is expected to have a full drill down capability. For example, if it is expected that a dashboard be developed to provide a daily level summary for a specific KPI, and hourly level detail for the same KPI and another, when one data source contains information at a daily level and the other at hourly level, it becomes difficult to represent such information on a single dashboard. Necessary work-arounds must be employed to obtain the desired result. Generally, as rule of thumb, it is better to have the data at the lowest aggregation level so that it can be summarized in a dashboard and full drill down capabilities can be provided to the users for research and to derive actionable insights.

- **Establish distribution channel**: Dashboards are valuable if they provide actionable information, but also if they can be accessed by the user community when needed with minimum effort. To that end, determining the best distribution channel for the visualizations is critical. Since the visualizations are of immense benefit to various groups within the organization, at FAA, SharePoint – Knowledge Services Network (KSN) was deemed as the best distribution channel for this information. KSN allows the dashboards to be easily accessible and help retain most features of the business intelligence platform.

Air Traffic Operations Metrics (ATOM) is a collection of dashboards that are developed with a goal to help Air Traffic personnel monitor operations and make decisions to efficiently operate the National Airspace System. In addition to dashboards mentioned in this paper, the FAA has also implemented
dashboards that provide details on Aircraft Diversions, Delays, and Special Use dashboards based on specific airport/facility requirements.

### Air Traffic Operations Metrics

![Air Traffic Operations Metrics](image)

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<td>Facility Summary</td>
<td>Facility Summary</td>
<td>Aircraft Diversions</td>
<td></td>
</tr>
<tr>
<td>Top 5 Facility Watchlist</td>
<td>Facility Summary</td>
<td>Aircraft Go-Arounds</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Top 5 Facility Watchlist</td>
<td>Aircraft Taxi Times</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Aircraft Flight Delays (Summary)</td>
<td></td>
</tr>
</tbody>
</table>

Figure 13: Air Traffic Operations Metrics dashboard homepage. A SharePoint site accessible by FAA staff.

### Key Benefits

Key benefits observed while developing dashboards include:

- **Ability to blend data sources**: Blending is defined as ability to join data sources with different formats. Many business intelligence tools available today are data agnostic and connecting to a number of different data source formats. This has been immensely beneficial to dashboard development as up to 6 data sources have been used in some of the dashboards. Additionally, data in different formats can be blended, for example, blending Excel, with Oracle, with CSV files, thereby allowing dashboards to have a full drill down capability across multiple dimensions.

- **Ability to model within a tool**: Another benefit of business intelligence platforms is the ability to create parameters and calculated fields with complex calculations within the dashboard. Typically, when an analyst builds a model for a specific purpose, it is utilized for a specific period and retired. At the FAA, a dashboard was created for a specific airport to monitor KPIs and impact of a runway closure due to construction. A model was implemented within the dashboard that determines optimal runway configuration, ADR, and AAR given the wind angle and speed. Calculations were implemented to determine the head wind, tail wind, and cross wind component, which then was utilized in determine the runway configuration that can be used. This dashboard can be extended to other airports by making fairly minor changes to the model.

- **Time to market**: Historically a request to build a dashboard or a report would take weeks and may be even months depending on data availability and complexity of the calculations and visualizations.
This time has been cut down to days due to advances in business intelligence tools. As long as the data is available and is visualization ready, a dashboard can be constructed within a few of days. Below graphic shows trend for turnaround time in relation to visualization evolution. However, the question remains can it be any faster than it already is?

**Actionable Business Intelligence – Untapped Space**

Another advantage of business intelligence is their ability to integrate with statistical programs such as R. Tableau and other business intelligence products can embed an entire R script into the dashboard. This allows the script to be repeatable and can run in perpetuity as long as the data and necessary elements are available in a required format.

With R integration, the model and visualization becomes self-learning, as the model is able constantly take in new information, run analysis, and display results in an easy, understandable, and interpretable format.
The above figure illustrates the difference between informational and actionable dashboards. Also depicted in the above figure is the integration of R to develop actionable dashboard. Successful modeling of data with R not only requires cured data, but also required subject matter expertise in order to understand the data and ensure its relevance to the problem at hand. Large amount of data may be collected and ingested in the model. However, not all of it is significant and only significant data when further analyzed and visualized, results in an actionable dashboard that can be used to make operational decisions.

**Aviation Application - Predicting Taxi-Out Times**

A potential application of this concept could be to Taxi Times – specifically Taxi Out times. Taxi times are critical for operational performance, as they drive the capacity calculations for a facility. Determining how long it takes for an aircraft to taxi to the runway and wheels off determines the departure capacity of a facility. This is further complicated by inclusion of other factors including gates, terminal, equipment, carriers, and other operational factors.

Leveraging integration of statistical programs such as R with business intelligence and visualization applications such as Tableau, such model can be configured and implemented for each facility. Data can be pulled into and analyzed within the tool and the results can be visualized for easy interpretation by the user. Additionally because this model is embedded within the business intelligence and visualization tool having a constant input of data, this model becomes self-learning. As additional data is ingested by the model, the results are refined, thereby improving the accuracy of predictions of taxi times. Furthermore, any variables that are not significant can also be eliminated from the analysis. Significance of variables can be visualized in an easy interpretable format than in a statistical result table for easy understanding.

Lastly, the model can also be enabled to tag ‘like’ days depending on the ‘like’ criteria, so that the users can compare two days and analyze the differences that can be discussed and addressed. This will also enable users to adopt best practices across ‘like’ facilities for ‘like’ days in the NAS.

Ability for a facility to perform surface planning, delay planning, taking into account the schedule and slot control could help drive the decisions to efficiently operate the facility and in turn the National Airspace System (NAS).

**Conclusion**

The aviation industry collects massive amounts of data that is gathered using various methods and housed in disparate data stores. The industry relies on analytical models and systems that are built to consume data from these various data stores and output information to gauge operational efficiency. To date, access to such data and its integration with other data was difficult if not impossible, which in turn limited the types of analysis that could be performed.
However given the current era of big data coupled with advancements in business intelligence tools, we are now able to connect to various types of data sources via a single tool and blend them together to generate visualizations that help derive true actionable insights.

The FAA has adopted Tableau, a business intelligence platform that allows development and publishing of the interactive digital dashboards to be used across the agency. Similarly other agencies can review available tools and platform, and implement one that is best fit for them. Such tools allow creation of visualizations similar to the ones mentioned in this paper, and beyond. It enables users to perform secondary analyses and be more inquisitive about the data.

It is important to know that such tools are not just for generating reports. The true power of these tools, which allow creation of multi-dimensional dashboards, can be harnessed when it is used for research and analysis by generating interactive, impactful dashboards with full drill down capability and interactivity. Also, screen real-estate is limited, and therefore a careful attention must be paid to the amount of information included in the dashboards.

Some of the best dashboards take users through the funnel beginning at a summary level using specific simple visualization, through a set of visualizations increasing in complexity to more granular level. If a drill down is desired on the same screen, then left to right and top to bottom approach is recommended, where the summary visualizations are placed at the top left and the detailed visualizations at bottom right.

There should be some flexibility in data storage and retrieval strategy. Existing strategy may not be optimal for the dashboard exercise. At FAA, new schemas were setup and views were constructed to prepare data for visualization. Some data was pre-blended / joined before it was imported for visualizing. This helped improve the dashboard performance given that there were millions of records included in visualization. Additionally, data preparation steps such as harmonizing multiple sources, indexing, normalizing, extracting, transforming and loading are required. Once the data are prepared, it is considered visualization ready.

Leveraging business intelligence tools to connect to disparate data sources and developing multi-dimensional visualization to represent data can be immensely helpful in operational monitoring within aviation. Visualizations can be extremely powerful and convey a story in a clear and instructive manner. Users are more quickly engaged by seeing trends and outliers. By seeing the cause and effect of multiple factors, managers are able to more clearly forecast the effect of policies and drive decisions and operating practices that make the system more efficient and responsive.

**Future Applications to Aviation**

The business intelligence space is continually evolving specifically in developing self-service analysis and intelligence platforms for mainstream business users. These tools enable mainstream business users to conduct basis data analysis and generate data visualizations similar to the one illustrated in this paper.
Companies such as Tableau, which is a platform chosen by the FAA for business intelligence, have provided business users with the power to connect to, analyze, and visualize data on their own. Once the dashboard is developed it can be made accessible to various groups within the organization. The management can also determine the amount of data that needs to be made available for visualization. As long as the data is available, users can go back in time, perform comparative analysis and can derived actionable insights from the dashboards.

Some of the upcoming advancements in business intelligence platforms that can be applied to aviation are as follows.

**Natural Language Processing:**
Natural Language Processing (NLP) is a natural language interface that helps users interacts with data and visualizations. Users can ask questions in natural language and the result is a visualization responding to those questions. Example questions include: “How do the NAS operations in 2017 compare to 2016 YTD?” The expected result would be a visualization that shows NAS operations for January 2016 to April 2016 compared to NAS operations for January 2017 to April 2017.

A follow on question can be asked, for example, “How many Air Carrier operations were there between the specific time period?” In this case the expected response would be a revision of the visualization showing only Air Carrier operations for the above time frame.

Currently this technology / approach is available through specialized tools, which are programmed for a specific use case and have a predictive / machine learning component attached to it. But in the near future this will be in mainstream business intelligence platform. Users will be able to query the data, ask follow on questions, and the application will respond with visualizations that are pre-developed but displayed on the fly.

**Integrating Media in Dashboards**
Integrating media such as video, pictures, and simulations in dashboards is existing technology. However being able the queue media to a particular point upon selection of a specific measure would be an innovative way to help drill down into the details. This feature is on the roadmap for implementation in ATOM dashboards, especially the ones to be used for FAA executive briefings.

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