# DAWDLE

## A Visual Guide to Flight Delays

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# ABSTRACT

This paper provides a detailed overview of the development of an online, interactive visualization referred to as Dawdle. We describe the motivation behind our goals and the discovery of our target users. A brief analysis of the underlying data is provided as well as a description of the tasks users are able to complete using Dawdle. A detailed examination of three previous, related works is provided for functionality comparison purposes. A detailed description of the design process is given which includes discussion of initial data exploration, competitive analysis, user interviews, sketches and story boards, persona development, and initial prototype generation. Three rounds of user evaluation, including methods, results, and the resulting changes made to each prototype are discuss. An in-depth evaluation of the effectiveness of the final resulting visualization is provided which includes discussion of encodings, visualization type, and adherence to best practices according to Shneiderman's infovis tasks. Lastly, suggestions for future enhancements to better aid in task accomplishment are discussed.

Link to visualization: http://kdubdev.com/511/index.html

# TABLE OF CONTENTS

## INTRODUCTION

The Bureau of Transportation Statistics reported a record breaking 751 million passengers flew domestically in 2015 [1]. According to U.S. Travel Association, U.S. residents logged 459 million person-trips for business purposes in 2015, with 37% for meetings and events [2]. Ask any person who flies often for business what their largest concerns when choosing a flight to purchase and more often than not their response will be ticket price and potential for delays [3]. It comes as no surprise that people generally don't want to pay a lot for tickets and despise delays. Passengers want to get to their destination at the time that was advertised. A delayed flight has the potential to disrupt carefully laid-out plans, or cause a passenger to miss a connecting flight or important meeting. The fear of flight delay affects what travelers' choice when purchasing flights, potentially changing which airports they fly through, which airline they book with, and even when they fly.

Dawdle was originally envisioned as a tool to help people purchase specific flights based on ticket price, and specific airline and airport reliability data. Finding freely available data sets for flight ticket prices proved to be a daunting task. Airline carriers tend not to share such information and regarding this information as a closely guarded secret. Commercial services do provide such data but unfortunately are beyond the scope of this project. Nevertheless, user research indicated visualizing flight delay data and thereby determining airport and airline reliability to be a useful tool. This is especially true among business travelers as they fly often and are typically inconvenienced by delays the most. Dawdle aims to assist business travelers in making a more informed decision when booking flights by providing them a simple method of visualizing individual airline and airport reliability.

During initial user research, it quickly became apparent that people generally have many misconceptions regarding airport and airline carrier reliability, often based solely on anecdotal evidence. To address these common misconceptions, Dawdle also aims to answer the slightly broader question of "which airports and airlines are more likely to get you there on time?" in hopes that providing information about general trends in reliability will enable potential passengers to make a more informed decision when booking flights and hopefully avoid those nasty delays. This way, customers can make truly informed choices about which flight they book based on flight delay.

## ABOUT THE DATA

Dawdle utilizes a data set provided by the U.S. Department of Transportation's (DOT) Bureau of Transportation Statistics (BTS) [4] which tracks the on-time performance of non-stop domestic flights operated by airline carriers that have at least one percent of total domestic scheduled-service passenger revenue and provides summary information on the number of on-time, delayed, canceled and diverted flights.

The BTS data set consists of approximately 216,000 rows with 24 variables. These variables include nominal data like airport and airline unique identifiers, names, city, and state as well as quantitative data such as number of on-time flights and number and length of delays by cause for major airlines by airports. Each row contains the data reported monthly by a specific carrier

for a single airport spanning 2003 to 2016. A complete description of the data set dimensions can be found in Appendix A.

Only flights arriving more than 15 minutes past their scheduled arrival time are considered late. Causes include by carrier, late aircraft, extreme weather, and national aviation system (NAS), which refers to a broad set of conditions, such as non-extreme weather conditions, airport operations, heavy traffic volume, and air traffic control. Airport latitude and longitudes from openflights.org [5] were blended to allow geographical mapping of airport locations.

## SUPPORTED TASKS

Through the BTS data set, Dawdle implements a variety of functions to accomplish the aforementioned goals of providing a simple method of visualizing and comparing individual airline and airport reliability and also providing information about general trends in airline and airport reliability to assist potential passengers in making a more informed decision when booking flights and hopefully avoid potential delays.

To eliminate common misconceptions regarding reliability of airlines and airports by providing the viewer with a general overview of reliability trends for airlines and airports which includes visualizing the top 10 most and least reliable airlines and airports, the best and worst months for travel in terms of delay, and the underlying causes of delays for a selected year between 2003 and 2016.

Additionally, for those passengers interested in a particular airline or airport, for a selected year between 2003 and 2016, Dawdle provides a method to view delay performance for individual airlines and airports, compare delay performance of airlines servicing a particular airport, and compare delay performance of airports within a selected radius which is useful for determining which airport to use when there are multiple options in close proximity.

## PREVIOUS WORK

A plethora of flight related data sets are available through both free and commercial channels. Given the prevalence of airline travel, analysis and visualization of flight data has proven to be a useful undertaking. As such, flight data can commonly be found in a variety of publications both online and in print form. For instance, the data set utilized for Dawdle has been used for just about everything from simple infographics such as those commonly found in news articles, to much more complex and intensive cognitive task laden publications. Additionally, there are many interactive visualizations which attempt to facilitate analysis and understanding of the multitude of dimensions in the data.
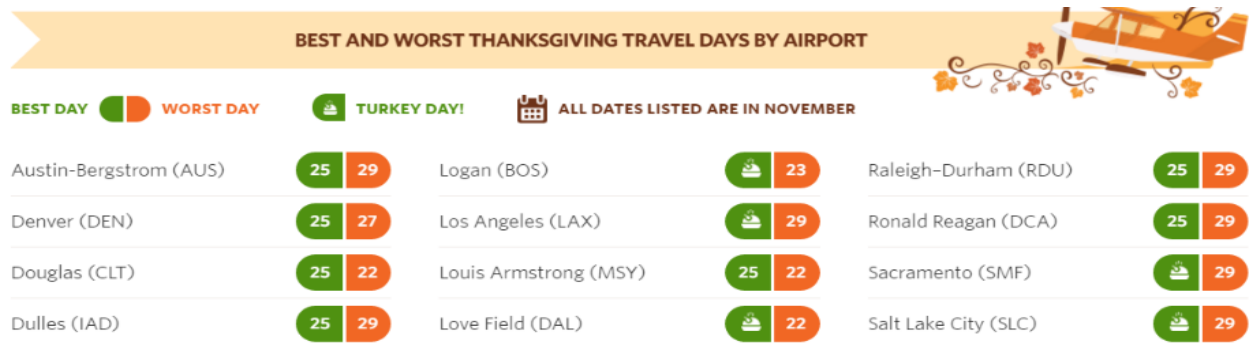
Figure 1: RewardExpert Best and Worst Thanksgiving Travel Days by Airport Infographic

## RewardExpert

A question Dawdle aims to answer is "When are the best and worst times of year (in terms of delay) to travel at a particular airport?" Using data provided by BTS, RewardExpert attempted to answer the same question specifically pertaining to Thanksgiving travel. In the article "The Best and Worst Thanksgiving Travel Days at the 45 Busiest Airports" [6], as shown in Figure 1 above, the viewer is presented with an infographic showing the best and worst days to travel through 45 of the busiest airports around Thanksgiving. Unfortunately, the infographic is little more than a glorified table, again forcing the reader to extend much cognitive effort to answer a relatively simple question leaving much room for improvement.

TABLE 2. NUMBER OF REPORTED FLIGHT ARRIVALS AND PERCENTAGE ARRIVING ON TIME D/ BY CARRIER AND AIRPORT (REPORTABLE AIRPORTS ONLY)

| CARRIER* | IAD | | IAH | | JFK | | LAS | | LAX | | LGA | | MCO | | MDW | | MIA | | MSP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME | # OF ARR. | % ON TIME |
| ALASKA | 31 | 90.3 | 51 | 90.2 | 31 | 100.0 | 372 | 91.7 | 797 | 89.7 | 0 | 0.0 | 72 | 80.6 | 0 | 0.0 | 0 | 0.0 | 82 | 84.1 |
| AMERICAN | 238 | 69.3 | 721 | 66.7 | 1677 | 65.2 | 1380 | 70.6 | 3891 | 69.1 | 2405 | 69.3 | 1622 | 68.4 | 0 | 0.0 | 4569 | 68.6 | 753 | 68.0 |
| DELTA | 237 | 79.7 | 286 | 73.8 | 2808 | 70.8 | 1197 | 82.5 | 3433 | 75.1 | 2109 | 74.4 | 1526 | 77.2 | 241 | 81.7 | 836 | 80.6 | 6278 | 80.0 |
| EXPRESSJET | 15 | 86.7 | 3959 | 79.4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 1321 | 67.4 | 0 | 0.0 | 66 | 63.6 | 0 | 0.0 | 226 | 69.5 |
| FRONTIER | 67 | 52.2 | 151 | 60.3 | 0 | 0.0 | 535 | 72.0 | 155 | 65.8 | 93 | 50.5 | 649 | 64.4 | 0 | 0.0 | 154 | 67.5 | 98 | 72.4 |
| HAWAIIAN | 0 | 0.0 | 0 | 0.0 | 31 | 80.6 | 75 | 93.3 | 180 | 82.8 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| JETBLUE | 180 | 78.3 | 0 | 0.0 | 3732 | 70.4 | 416 | 70.4 | 450 | 72.2 | 558 | 65.1 | 1801 | 69.4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| SKYWEST | 46 | 76.1 | 1331 | 76.6 | 0 | 0.0 | 106 | 68.9 | 2367 | 80.4 | 32 | 78.1 | 0 | 0.0 | 57 | 84.2 | 0 | 0.0 | 3117 | 85.0 |
| SOUTHWEST | 178 | 74.2 | 0 | 0.0 | 0 | 0.0 | 6599 | 83.5 | 3661 | 67.5 | 990 | 71.8 | 2999 | 80.3 | 7474 | 83.1 | 0 | 0.0 | 783 | 78.4 |
| SPIRIT | 0 | 0.0 | 527 | 69.3 | 0 | 0.0 | 961 | 76.8 | 806 | 71.7 | 341 | 68.0 | 479 | 72.9 | 0 | 0.0 | 0 | 0.0 | 403 | 70.0 |
| UNITED | 2018 | 84.2 | 4651 | 80.7 | 0 | 0.0 | 1002 | 81.1 | 2712 | 69.2 | 759 | 66.1 | 978 | 74.8 | 0 | 0.0 | 220 | 66.4 | 407 | 77.6 |
| VIRGIN AMERICA | 172 | 80.2 | 0 | 0.0 | 364 | 70.9 | 396 | 82.1 | 1269 | 74.5 | 81 | 65.4 | 31 | 71.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| TOTAL | 3182 | 80.9 | 11677 | 78.0 | 8643 | 69.7 | 13039 | 80.6 | 19721 | 72.7 | 8689 | 69.8 | 10157 | 74.1 | 7838 | 82.9 | 5779 | 70.2 | 12147 | 79.8 |

Figure 2: Table 2 in the October 2016 Air Travel Consumer Report

## Air Travel Consumer Report

Similar to the goals of Dawdle, The Department of Transportation's Office of Aviation Enforcement and Proceedings (OAEP) produces a monthly report titled "Air Travel Consumer Report" [7] which aims to provide consumers with insight into flight delays as well as mishandled baggage, oversales, consumer complaints, customer service reports to homeland security, and airline animal incident reports for a given month. The overwhelming majority of the pages in the report contain complicated tables which impose significant cognitive load upon any reader tasked with deciphering the information presented. For instance, readers attempting to discover which airline carrier was on time most often arriving at a particular

airport are tasked with deciphering the information in the table shown in Figure 2. In the report published in October 2016, the most effective visualization offered was a single pie chart (the only one in the report) showing overall causes of delay for which a simple bar chart would have been more effective at portraying. The report attempts to sift through the overwhelming amount of data available to provide consumers with useful information on the quality of services provided by various airline carriers but fails to take advantage of the many advanced visualization options to simplify the analysis.
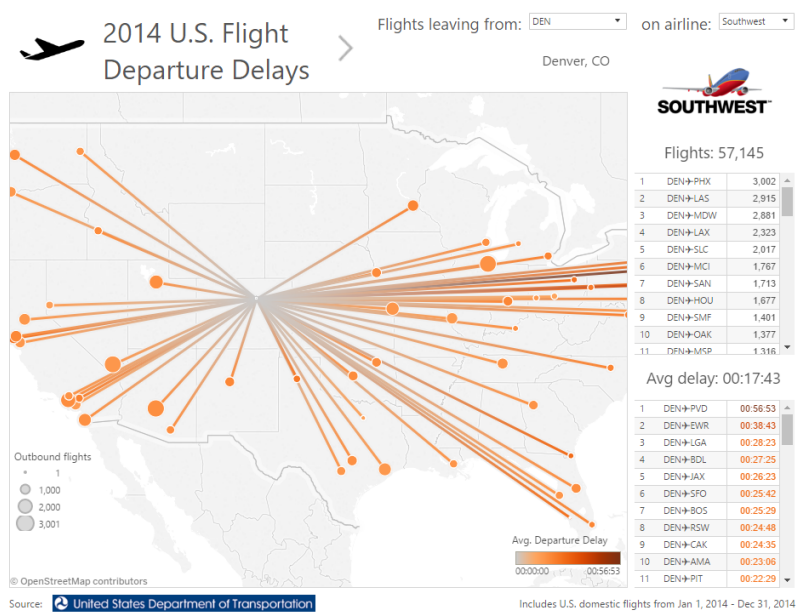


*Figure 3: Ben Jones' interactive visualization showing flight departure delays for 2014*

## Flight Departure Delays

A bit more in line with Dawdle visually, Ben Jones used the BTS data with Tableau Public to create a dashboard entitled "2014 U.S. Flight Departure Delays" [8] which allows the viewer to visualize average departure delay times for specific non-stop, domestic flights. As shown in Figure 3 above, the viewer chooses an airport of origin, for instance Denver International (DEN), and an airline carrier, such as Southwest, and is then presented with the number of flights to each the selected domestic airport as well as the average departure delay times experienced by travelers in 2014. Through the visualization, the viewer can see that flying Southwest Airlines from Denver International to Theodore Francis Green State Airport (PVD) has the longest average delay time at approximately 57 minutes. This leads one to conclude the airport, the airline, or both are typically terrible. However, using the scrolling table of flights for further analysis, one discovers that out of Southwest's 57,000 flights in 2014 only 10 went from DEN to PVD. Here again the viewer is not presented with the entire picture. The visualization doesn't provide enough information to facilitate an informed decision about how likely passengers on this flight are typically delayed or even by how long. Were ten flights delayed one hour or was one flight delayed ten hours? The former indicates a 100% delay rate which is terrible. The latter indicates a 10% delay rate which according to the data is far better

than average. Certainly, this visualization is a step in the right direction but it fails to portray the abundance of flight data available in a manner that easily and accurately educates passengers.

# DESIGN PROCESS

## Overview

Dawdle was designed using an iterative user-centered design process. The overall process can be discussed in three phases: exploration, research & design, and testing & iterating.
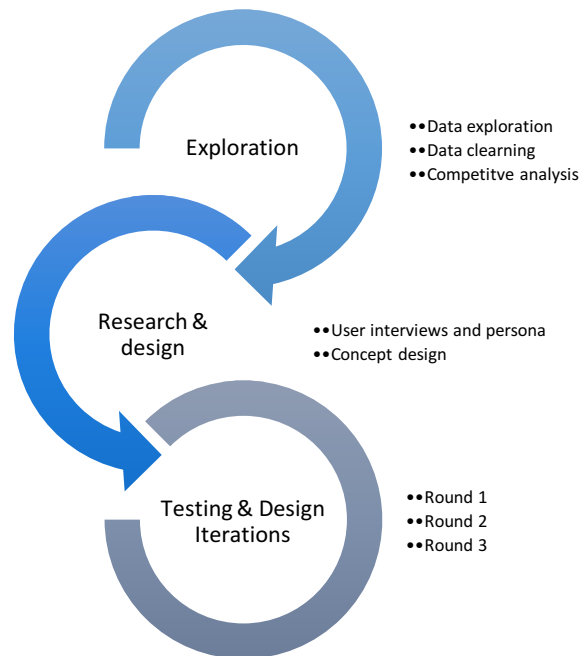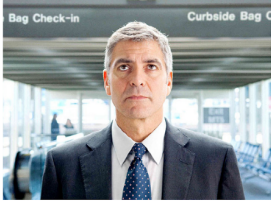


Exploration
•• Data exploration
•• Data clearning
•• Competitve analysis

Research & design
•• User interviews and persona
•• Concept design

Testing & Design Iterations
•• Round 1
•• Round 2
•• Round 3

*Figure 4 - Dawdle design process*

During the initial exploration, the data set from the Bureau of Transportation Statistics was identified. This data set was then joined with a set of airport location data from OpenFlights.org. The entire data set was cleaned using Excel to identify duplicate or incorrect values. In total, 362 of the 216,019 rows had to be removed. A competitive analysis was then conducted on relevant, public visualizations. This analysis was supplemented by a literature review for published research related to the problem space. The initial user research involved qualitative interviews with two personal and two business travelers. Interviews with personal travelers revealed price as the dominant motivation for the majority of travel decisions. However, a clear trend emerged that delay performance was an important factor to business travelers than to personal travelers. The research also revealed a nuance that many business travelers held strongly help beliefs about delays from personal experience and anecdotal evidence. This insight would inform much of the development of Dawdle's feature focus and feature set. A persona was developed based on the analysis of the qualitative research and served as the target user throughout development.

*Figure 5: Business traveler persona*

Four different initial paper prototypes were developed based on insights from the data exploration and the qualitative research. These prototypes were evaluated based on how well they offered insight into educating business travelers on delay performance. A final paper prototype was developed based on this evaluation.

An initial interactive digital prototype was then developed and tested with participants form the target business traveler community. Two addition rounds of testing and iterating were conducted to hone the effectiveness and usability of the visualizations. These iterations evolved the visualization from a single dashboard concept to an interactive report card format to our final website that offers parallel guided and personalized experiences. The final Dawdle project addresses the two primary user goals that emerged from the user research and usability testing.

## Initial Prototype

The initial paper prototype concept included a dashboard of four different types of visualizations: a symbol map of delay percentage by airport, a box plot of delay percentage by airline, a stacked bar charts of delay by cause, and a scatter plot of delay percentage and delay time. This prototype sought to enable the user to answer the following questions:

- What is the most reliable airport for on-time arrival?
- What is the most reliable airline for on-time arrival?
- What are the most common causes of delays?
- Are there any historical trends in delays by airline carrier and/or airport?
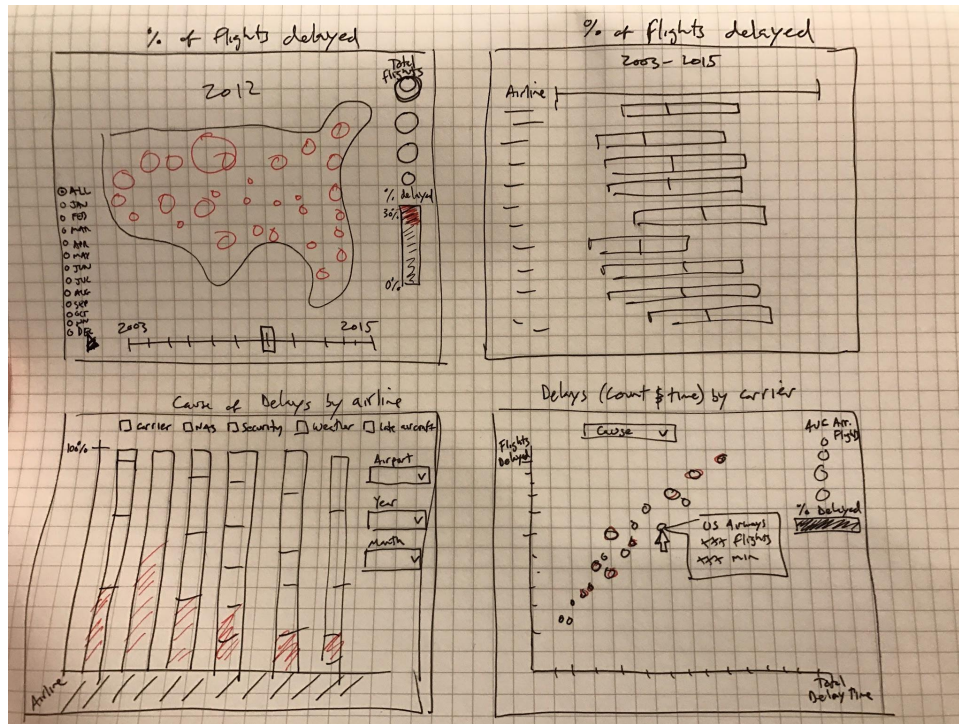
*Figure 6 - Initial paper prototype sketch*

In the process of creating the initial digital prototypes, several of these visualizations proved to be difficult to interpret or lacked meaningful insight when executed with the actual data. Additionally, more emphasis was placed on filtering functionality to enable user exploration of the data through the lens of different airlines, airports and periods of time. This initial prototype concept was then tested and iterated on through three rounds of usability testing.

## PROTOTYPES AND USER EVALUATION

### Prototype Round 1

The first prototype was created in Tableau. It featured a dashboard style visualization with four panels that contained the following: airport map, airport bar chart, airline bar chart, delay stacked bar chart, and time series of delays per month.

*Figure 7: Dashboard from prototype 1*

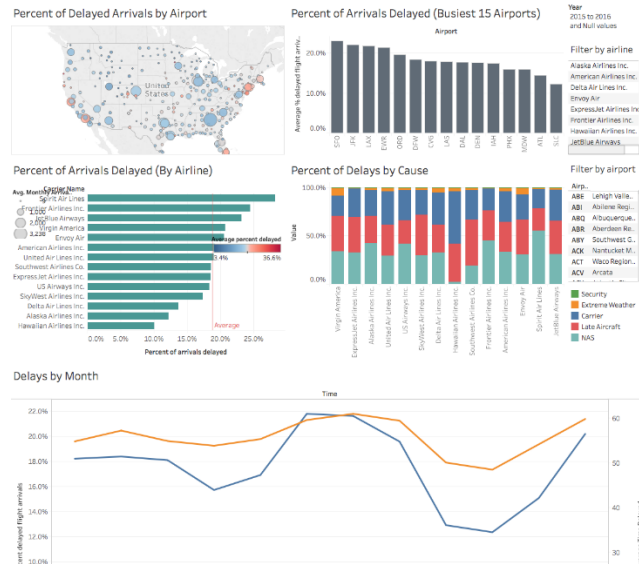The airport map geographically mapped all airports that were included in the dataset. We encoded delay percentage to color, and total arrivals to size.

The airport bar chart (Figure 9) showed the percentage of arrivals delayed for the 15 busiest airports as a bar graph. There were too many airports to effectively show all airports on one graph. So it was decided to only show the top 15 busiest airports.

The airline bar chart (Figure 10) showed the percentage of arrivals delayed for all airlines.

The stacked bar chart of cause of delay (Figure 11) showed the breakdown percentages of what caused the delayed arrivals for each airline.

The time series graph (Figure 12) showed the average percent of delayed arrivals (orange line) and average total minutes of delay (blue line) per month for the year range that was selected in the user filters.

The dashboard had user filters for year, airline, and airport on the right side. The filters updated the airport map, airline bar graph, cause of delay stacked bar graph, and time series line graph. The airport bar graph only updated with the year filter.
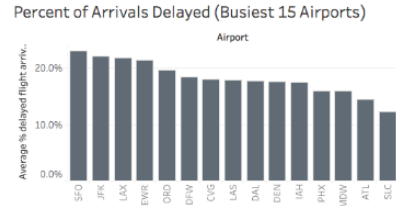
Figure 8: Airport map from prototype 1


Figure 9: Airport bar chart from prototype 1
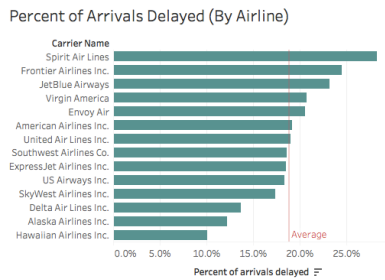

Figure 10: Airline bar chart from prototype 1
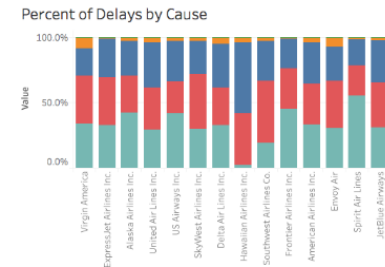

Figure 11: Stacked bar chart of delay causes from prototype 1
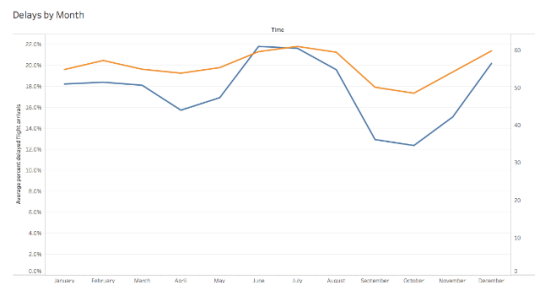

Figure 12: Time series graph from prototype 1

## User Test Round 1

### Methods

The first prototype was tested by asking users to think out loud while they completed a set of user tasks. The tasks included a series of questions about airport delay performance, airline delay performance, and delay causes. The user had to use the prototype in order to answer the questions. After the specific tasks, the users were asked to freely explore the prototype and answer open ended questions about what they liked and didn't like. Observers took notes on the user's thoughts and actions while using the prototype.

Each member of the team tested the prototype with one person, resulting in qualitative data from four users total.

### Results

Overall, the results were mixed. Most of the users required guidance or some prompting to discover some of the features that they needed to complete the tasks. In general, many users expressed initial confusion and disorientation when they first saw the visualization. For instance, one user said "Whoa, what am I looking at here… I'm not sure exactly". This may have

been caused by a lack of familiarity with the Tableau interface, as the user tests were done on the Tableau software.

The results and feedback received from the first prototype is summarized in Table 1.

*Table 1: Results and Feedback Summary from User Test 1*

| Theme | Results/Feedback |
|---|---|
| Airport Map | • Most users wanted the map to be bigger, since they used the map to find and compare airports<br>• Users could not figure out Tableau map controls of zoom and pan<br>• Some users wanted the map to automatically zoom into an airport when an airport was selected on the airport filter<br>• Took some time to orient themselves to what the encodings meant, but once they saw the key, users understood how to read the map<br>• One user had to be prompted to know that she could hover over and get details-on-demand<br>• Hard to find specific airport by zooming. Some users did not know exactly what part of the state to search. |
| Airport Bar Graph | • It was not obvious that this graph did not update with the airport and airline filters<br>• Users tried to use this graph to find the airports that they were looking for in addition to the map |
| Airline Bar Graph | • Was easily understandable for users to compare airline delay percentages<br>• Users did not immediately understand that this graph updated if you selected an airport on the map |
| Cause of Delay Stacked Bar Chart | • Users did not know what NAS or Carrier Delay meant<br>• Stacked bar chart was not intuitive to read. There was confusion if the graph was showing percentage of delayed flights that were delayed by a specific cause, versus showing percentage of total arrivals that were delayed by a specific cause |
| Time Series Line Graph | • Didn't know what different colored lines meant |
| User Filters | • All users did not see user filters or did not immediately recognize user filters as places for user input.<br>• Airport filter had too long of an option list, which made finding a specific airport tedious. Users wanted a search function to expedite finding a specific airport. |
| Interactivity between Panels | • It was confusing to users that some panels updated with the filters, while others did not |

| | |
|---|---|
| | • It was not immediately intuitive that clicking on items in one pane would update information in another pane<br>• All users didn't understand that the airport bar chart was a static bar chart and did not update with filters |
| Comparing Airports | • One user mentioned that with certain destinations, there are multiple airports that he can fly into, and he wanted to compare the delay performance of those airports<br>• It was not immediately intuitive that users could select multiple airports in the filter bar<br>• Users would compare airports by using the map and zooming into a specific location, and hovering over the different airports to see the delay percentage. This was not efficient in terms of time, and was not effective in presenting the data necessary to compare the airports. |
| Tableau Interface | • Users were disoriented by an unfamiliar interface in the Tableau software |

## Discussion

We discovered that there is a learning curve when presenting interactive visualizations to the general public. None of our users had used Tableau before, so it took some time for users to figure out that panels were interactive. They were used to seeing static visualizations, so they assumed that this was static as well. This meant that some users needed to be prompted to discover the extra features that we had built into our visualization, like the filtering between panels or the hover-over details-on-demand. We decided that we would have to make our design more "traditional" by having the user filters be the primary method of filtering the data.

The biggest takeaway from the first round of user testing was that users were successfully uncovering "surprise" findings. For instance, one user selected her local airport and said in a surprised manner, "Wow! Spirit airlines *really* sucks!" Another user thought that Kennedy International Airport (JFK) was the worst airport to fly into when flying to New York City. However, the map showed that in fact Newark Airport (EWR) was the worst airport to fly into when flying to New York City. This validated that the visualization was helping to discover new findings or debunk preconceptions.

Another thing that we validated was that most users were able to read the map and the different encodings that were assigned to it. It did take a little bit of time (~5 seconds) for users to orient themselves, but eventually all users were able to find the key and successfully figure out what was being shown on the map.

Users reported that finding their local airport and filtering for their frequent flier airline(s) were important tasks. Once they were presented with the interactive features of the visualization, they immediately started searching for their local airport and their airline that they had a loyalty program with. This created a user expectation that the entire dashboard would update for the airline and airport that they picked. This was revealed by the confusion caused by the airport bar graph, which did not update with the filters.

After the team found out that the task of finding a local airport and looking up a frequent flier airline was paramount, we had to make a decision. We had to decide between highlighting interesting finds in the data for our users so they could discover the truth about flight delay, or having an interactive tool for users to look up their specific airport and airline. The team felt that we could not accomplish both on the same visualization without causing confusion to the users. So the decision was made to create two visualizations: one that highlighted interesting finds in the data, and one that served to directly address the task of finding a specific airport and airline.

Table 2 contains a summary of the design recommendations made after the first round of user testing.

*Table 2: Design Recommendations for Prototype Round 2*

| Theme | Design Recommendations |
|---|---|
| Airport Map | • Increase map size<br>• Add auto-zoom feature in map<br>• Remove small airports that most of the general public is not flying to. These clutter the map |
| Airport Bar Graph | • Move this visualization into the one that highlighted interesting finds in the data for users in Prototype Round 2<br>• Create an airport bar graph that updated to the airport(s) selected by the user |
| Cause of Delay Stacked Bar Chart | • Remove stacked bar chart<br>• Present cause of delay data differently |
| Time Series Line Graph | • Add color key to line graph |
| User Filters | • Move filters to the top of the visualization to make filters more immediately visible<br>• Add filter headers that use action words to indicate that users can filter<br>• Add search function (if possible) for airport filter |
| Interactivity between Panels | • User filters should filter the entire dashboard, not just some parts of the dashboard<br>• Add dynamic titles or captions to provide confirmation to users what data is being presented<br>• Clicking on items in the graphs (e.g. clicking on an airport in the map) should not be the primary way to filter other panels in the dashboard. Filters should be primary, clicking in the graph should be secondary. |
| Comparing Airports | • Add a user filter that allows users to search for all airports within a region |

| | |
|---|---|
| | • Have an airport bar graph that updates to only show the airports within that region |
| Tableau Interface | • Publish visualizations to Tableau Public. Users can then be presented with visualizations on the web via an interface that they are more familiar with (i.e. the internet). |

## Prototype Round 2

The second prototype attempted to accommodate all of the design recommendations listed in Table 2 as much as the Tableau skills of the team members allowed. The result was two separate visualizations: A "report card" style visualization that would highlight key findings for users, and an interactive prototype that would allow users to explore the data as they wished. These prototypes were created on Tableau and were published to Tableau Public.

The "report card" prototype (Figure 13) summarized one year's data. The report card included top 10 best and worst airports, best and worst airlines, a stacked line graph of delay over time with cause of delay stacked under it, and bar charts of airport and airline percentage of delay by cause. The user could select a single year at the top of the dashboard to filter all of the panels for that year's data. At the bottom where the cause of delay graphs were, there was a second user filter where the user could select to filter the data for a single cause of delay. This would just update the time series and the two bar charts that were presenting cause of delay data. A caption below these graphs contained the definition of the types of delay causes.
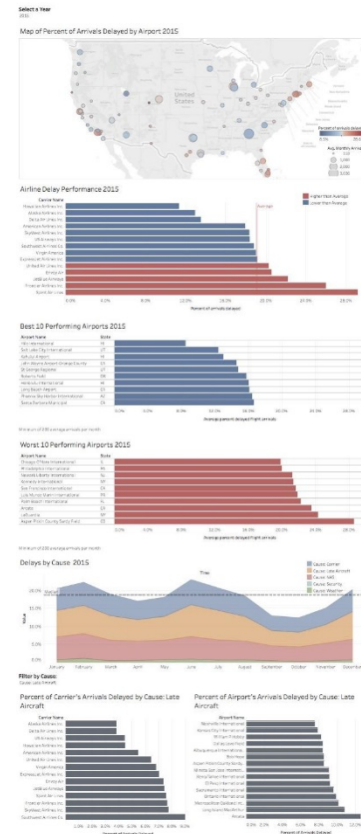


Figure 13: Report card prototype

The interactive prototype (Figure 14) included a map with airports geographically mapped. The airports were encoded by color for average percentage of arrivals delayed, and size for average total monthly arrivals. Below the map wa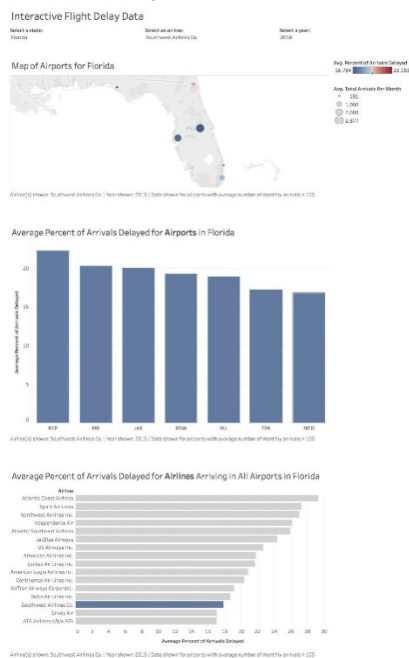s an airport bar graph that compared the airports shown in the map. The airport bar graph displayed the delay percentages by airport. Below the airport bar graph was an airline bar graph that compared the airlines that serviced the airports shown in the map. User filters for state, airline, and year were located at the top of the visualization. To clarify how this operated together, an example will be described using a person looking for airports near Miami International (MIA). The person would enter Florida in the state filter. The map would update to show airports in Florida. One of these is MIA. The airport bar graph would update to show all airports in Florida and their respective flight delay percentage. The airline bar graph would update to show airlines that service these airports in Florida. If the user selects an airline in the filter drop-down menus, then the map and airport graph would update to only show airports that had flights with that airline, and the airline graph would brush the selected airline to be a different color. If the user selects a year, then the entire dashboard would update for that year's data. If the user wants to look at data for a specific airport, the user would click on the airport in the map. This would brush the airport graph with the selected airport, and update the airline graph to filter for the selected airport's data.



Figure 14: Interactive prototype

Both of these prototypes filtered the airport map by airports with arrivals > 200 per month, so very small, local airports did not show up on the map.

## User Test Round 2

### Methods

The prototypes were tested on Tableau Public. Users were asked to think out loud while they completed a new set of user tasks. Most of the tasks required users to use the report card prototype. The tasks included a series of questions about airport delay performance, airline delay performance, and delay causes. Then we asked the users to use the interactive prototype to find their local airport, a frequent destination airport, and filter for the airline that they flew the most. After the specific tasks, the users were asked to freely explore the two prototypes and answer open ended questions about what they liked and didn't like. Observers took notes on the user's thoughts and actions while using the prototype.

Each member of the team tested the prototype with one person, resulting in qualitative data from four users total. Two of the users were repeat users from the first round of user testing, and two users were brand new users that had never seen an iteration of the prototype before.

## Results

There was a marked improvement in comprehension from all of the users, both repeat and new. The new users still took a little bit of time to orient themselves to what they were seeing, but they were able to answer their own questions as they were asking them out loud. The repeat users commented that this version was much easier to understand than the previous version. There were still a few usability issues that occurred, which are summarized in Table 3.

The users were able to complete all of the tasks for the report card prototype successfully with minimal prompting. Some users did not see the option to filter by cause of delay, so they had to be prompted to locate that filter. Some users also did not see the year filter at the top of the dashboard.

The users were all able to find an airport and filter by airline on the interactive prototype. However, there was a significant issue for two users who were trying to compare airports. One user was looking at airports that service New York City. Since the prototype filtered by state, Newark Airport (EWR) did not show up when New York State was selected, as that airport is located in New Jersey. This also occurred for another user who was looking at airports near Washington, DC. There are three airport options when flying into Washington, DC: Dulles International (IAD), Reagan National (DCA), and Baltimore Washington International (BWI). IAD and DCA showed up when "District of Columbia" was selected, even though they technically are located in Virginia, and BWI did not show up, as it is located in Maryland.

All of the usability findings are summarized in Table 3.

*Table 3: Results and Feedback Summary from User Test 2*

| Theme | Prototype | Results/Feedback |
|---|---|---|
| Cause of Delay Line Graph and Bar Graphs | Report Card | • Users did not see caption defining what NAS or Carrier Delay meant, so they were still confused what those meant.<br>• Users commented that they did not know why those airports were shown in the airport cause of delay bar graph. They seemed chosen arbitrarily.<br>• Most users did report that it was interesting to see when the best months of the year were to minimize risk of flight delay.<br>• Users asked if they could see flight delay for days of week and times of day. |
| User Filters | Report Card | • Some users did not see user filters, as other items had stronger visual weight and took visual precedence away from the filters |
| Clarification on which Airports are Displayed | Report Card | • Not discovered from user testing, but a team member mentioned a friend who was looking at airport in Montana. This airport did not show up on the map, because of the total arrivals filter. However, nowhere on |

| | | |
|---|---|---|
| | | the map did it communicate that there was a total arrivals filter, so users would know. |
| Tableau Map Controls | Interactive | • While the map automatically zoomed into the selected state, users still sometimes accidentally moved the map. Then it was difficult to figure out how to reset the map without reloading the entire web page. |
| Find my airport and airline | Interactive | • Filtering by state omitted some local airports that users wanted to see (e.g. Newark was not shown when map was filtered by New York, because Newark is technically in New Jersey) |
| Airport Identification | Both | • Users mentioned that they know some airports by name (e.g. O'Hare) and some by their airport code (e.g. LAX). So they would be looking for airport codes, but they were not included in the airport graphs |
| Inconsistent Labels between Panels | Both | • Axes titles, panel titles, filter labels, etc were not using consistent wording |
| Tooltips (Details-on-demand feature in Tableau) | Both | • The Tooltips for each panel were not showing the same information between panels. Users were expecting to see the same information when hovering over data between all of the panels.<br>• Users would click on Tooltip commands for include/exclude to see what it did, or accidentally clicked on them. They would not know how to undo that command |

## Discussion

Overall impression was that the visualization was going in the right direction. Our repeat users did report that the usability had improved since the previous prototype. They understood why we split the visualization into two prototypes, and they thought that it adequately addressed the problem of some graphs not updating compared to others.

The team also felt like it was going in the right direction for addressing the user task of finding a specific airport, filtering for their preferred airline, and comparing to other airports nearby. Filtering by state, however, did not seem to be the best way to filter the airport map to compare multiple airports, due to the fact that nearby airports may reside in different states. Instead, it would be preferred to have a destination airport and show airports within a certain distance of that airport.

Some users mentioned seeing data for days of the week or time of day. The team agreed that this was important information to include, but should be included in future extensions of this

visualization. Downloading, sorting, cleaning, and mapping the new daily and hourly data in our existing Tableau workbooks was deemed out of scope for finishing the project.

Design recommendations for the next prototype are summarized in Table 4.

*Table 4: Design Recommendations for Prototype 3*

| Theme | Prototype | Design Recommendations |
|---|---|---|
| Cause of Delay Line Graph and Bar Graphs | Report Card | • Move delay definitions to the top<br>• Make definitions have more visual weight by changing font colors<br>• Add "10 Worst Airports" to title |
| User Filters | Report Card | • Create storyboard to instruct users how to filter |
| Clarification on which Airports are Displayed | Report Card | • Add note that maps are filtered by certain size airports |
| Tableau Map Controls | Interactive | • Remove Tableau map controls, as these are not intuitive for the user and the team cannot customize these controls. The map should just automatically zoom into the airports that are being shown. |
| Find my airport and airline | Interactive | • Use airport radius filter instead of filter by state |
| Airport Identification | Both | • Display airports with airport code but have airport name in the Tooltip |
| Inconsistent Labels between Panels | Both | • Make labels consistent for all visualizations |
| Tooltips (Details-on-demand feature in Tableau) | Both | • Make Tooltip details-on-demand consistent<br>• Remove Tootltip commands option in Tableau |

## Prototype Round 3

The third prototype moved the visualization interface from Tableau Public to embedded Tableau visualizations within a website (Figure 15). The website featured five tabs: Best and Worst Airlines, Best and Worst Airports, Map of Airport Delays, Causes of Delays, and Advanced Exploration.

Best and Worst Airlines showed storyboards that walked the user through highlighting the best and worst airlines in terms of delay performance. Best and worst airports showed storybords that walked the user through highlighting the best and worst airports in terms of

delay performance. Map of airport delays was an interactive map that allowed users to see overall trends and patterns of airports within the United States. Causes of delays had a storyboard that showed a line graph of delay over time with stacked area underneath showing cause of delay. It also had the two cause of delay per airline and per airport bar charts that were included in prototype round 2. All of these could be filtered by year.

Advanced Exploration upgraded the previous Interactive Prototype from prototype round 2. This version included an airport filter and a radius filter that would show airports within 25, 50, or 100 miles of the selected airport. The airport filter used a wildcard search using the three letter airport code, so that users didn't have to sort through a 300+ list of airports.
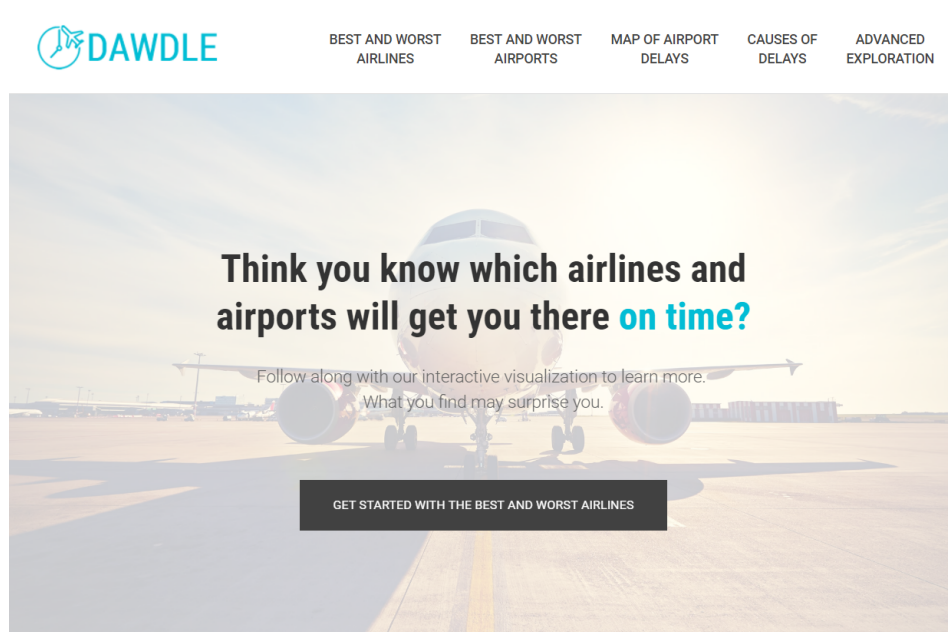


*Figure 15: Prototype 3 splash page*

## User Test Round 3

### Methods

The prototype was tested on the web. Users were asked to think out loud while they completed a set of user tasks. One user was asked to complete a System Usability Scale (SUS) evaluation. Most of the tasks were high level questions, and were used to orient the users to the website. The questions were about airport delay performance, airline delay performance, and delay causes. We then asked users to openly explore the website and comment on what they liked and didn't like, and what could be improved. Observers took notes on the user's thoughts and actions while using the prototype.

Each member of the team tested the prototype with one person, resulting in qualitative data from four users total. Two of the users were repeat users from the first and second round of user testing, and two users were brand new users that had never seen an iteration of the prototype before.

## Results

The overall impression of this prototype was positive in terms of usability. Users had no problems with understanding how each visualization was encoded, and were able to follow the storyboards very easily. Repeat users mentioned that the visual styling, organization, and guidance had greatly improved from previous iterations. For instance, in a previous prototype, one of the repeat users was not able to figure out the hover-over details-on-demand feature. With this version, she appreciated that these features were pointed out in the storyboard. She felt like we had addressed her problems from the previous test.

For one user who seemed more comfortable with interactive visualizations, he felt that it was unnecessary to have so many steps to get through one simple visualization. He felt that there was a little too much "hand-holding" and that it got in the way of getting to answers quickly.

All of the users stated that the Advanced Exploration tab successfully addressed their need to find data for their local airport and their preferred airline. Users were also able to successful compare airports with nearby airports using the radius filter option.

A summary of the results/feedback are located in Table 5.

*Table 5: Results and Feedback Summary from User Test 3*

| Theme | Visualization | Results/Feedback |
|---|---|---|
| Storyboarding | Best and Worst Airports<br>Best and Worst Airlines<br>Map of Airport Delays<br>Cause of Delays | • All users reported that the stories were easy to follow<br>• One user mentioned that the stories were easy to follow but they were "annoying" to follow; he didn't feel like he needed to be walked through each visualizations<br>• Multiple users mentioned that the stories were okay the first time, but they would want to skip ahead the next time |
| Filter for Airline | Map of Airport Delays | • One user mentioned that it would be nice to filter by his preferred airline |
| Advanced Exploration | Advanced Exploration | • One user mentioned that he was only interested in seeing specific airports and airlines, and that the other tabs were not useful to him. He didn't know that he could just go to the "Advanced Exploration" tab and skip the other tabs. |
| Arrivals Calculation | All | • One user mentioned that the number of arrivals per month seemed suspiciously low for Sea-Tac. This led to a discovery that we needed to fix our average monthly total arrivals calculation. |

## Discussion

In our quest to improve the time it took our users to comprehend the visualization and all of its features, we may have overcorrected. While some users liked the step-by-step guidance the storyboards presented, one user in particular thought it made the process of getting to the interactive part too long. So the team was faced with the dilemma of trying to figure out how to simplify the visualization so users could more quickly get to the interactive part of each tab, without sacrificing the guidance that some novice users needed. In the end, the team decided to reduce the number of steps to get through the storyboard. Some of the storyboard guidance could just be converted to static text instructions, removing the need for clicking through story steps.

While the users stated that the Advanced Exploration tab addressed their need to find data for their local airport and their preferred airline, one specifically mentioned that he would like to see a way to get to that tab faster. He said that this tab was more like the "tool" that he would use regularly, and that he didn't necessary want to have to go through all of the other tabs to get to this one. In general, the team discussed that the tab title of "Advanced Exploration" did not communicate to users that they could find their personalized set of data in that tab. After lengthy discussion on what to title that tab in the next prototype, the team settled on "Find my Airport or Airline". This was because time and time again, users mentioned that the most important task to them was to find their specific airport and their preferred airline. Specifically spelling out that task in the tab title would help users know exactly where to go to accomplish that task.

One major issue that was discovered was that using the Tableau auto-calculated average for [Total Arrivals] was not calculating Average Total Arrivals per Month for that airport. What it was really doing was calculating average total arrivals per month per airline for that airport, and it was not looking at the aggregate number of total arrivals. This skewed the data to have very low monthly arrivals numbers that did not make sense when looking at data for the total number of flights in the United States. This needed to be fixed for the final visualization, or the data was going to look wrong.

Overall, the team felt like the visualization had improved progressively with each iteration in terms of usability and addressing specific user tasks. The added visual branding and styling of the website added a sense of branding and quality to the visualization. It also allowed us to effectively organize multiple visualizations in an interactive way.

A summary of design recommendations to address the identified issues is included in Table 6.

*Table 6: Design Recommendations for Final Visualization*

| Theme | Visualization | Results/Feedback |
|---|---|---|
| Storyboarding | Best and Worst Airports<br>Best and Worst Airlines<br>Map of Airport Delays<br>Cause of Delays | • Simplify and condense storyboards<br>• Storyboards should only be used to highlight key data points. If they are used |

| | | to be instructional, then change these to just plain instructional text |
|---|---|---|
| Filter for Airline | Map of Airport Delays | • Add airline filter |
| Advanced Exploration | Advanced Exploration | • Change "Advanced Exploration" tab title to "Find my Airport or Airline"<br>• Add button on home page to go directly to "Find my Airport or Airline" |
| Arrivals Calculation | All | • Create calculated field of [SUM][Total Arrivals]/12 and filter using Airport |

# FINAL VISUALIZATION

## Overview

Based on the user research two primary user goals were identified. One is for users to learn about overall airline and airport delay performance to confirm or refute their own assumptions and experience. The second goal was to specifically find out how their preferred carrier performed at their local and neighboring airports. The final visualization is designed to support both a guided interpretation of the former and a personalized exploration of the latter. Users can also skip ahead to the personalized visualization at any point in the guided process.

The guided exploration follows a "martini glass" narrative structure [9], in which users are walked through a narrative presentation that headlines key insights and observations from the recent year of data (2015) while also delivering a tacit tutorial to the encodings and key functionality for each visualization. After advancing through this, the structure opens up to a fully interactive visualization for user-driven exploration. The same basic layout and structure is used across pages, with colored story tabs to help the user realize they have transitioned between visualizations.

The fully interactive visualizations are also organized according to Shneiderman's Mantra: "Overview first, zoom and filter, then details-on-demand." [10] Each interactive visualization defaults to an overview for the most recent year of data (2015). Users can then filter by criteria (e.g. year or airline) or zoom in (e.g. map search) to explore the visualizations. Finally, all of our visualizations feature details on demand that offer precise values of our underlying data (e.g. total arrivals) and additional relevant details (e.g. airport code).

## Evaluation of Final Visualizations

The following section offers brief descriptions of the purpose of each of the final visualizations and how they relate to specific user goals. Also included are tables offering a detailed breakdown of the visual encodings and screenshots of the final interactive visualizations. Finally, the success of each visualization is analyzed in relation to the intended user needs and goals.

## Best and Worst Airlines

This horizontal bar chart depicts the percentage of arrival delays for each airline by year. It is intended to quickly allow users to compare the delay performance of all the active carriers for a given year. Because there is no traditional benchmark for airline delay percentage, users are also given a dynamic reference line for the average performance in that year, and color encodings to pre-attentively process whether an airline is above or below average for the year.

*Table 7: Visual Encodings for Best and Worst Airlines*

| Data | Encoding |
|------|----------|
| % of arrivals delayed | Length (sorted ascending) |
| Comparison to average % of arrivals delayed | Color (red/blue) |
| Average % of arrivals delayed | Reference line |
| Year | Filter, dynamic title |
| Airline name and % of arrivals delayed | Details on demand (tool tip) |
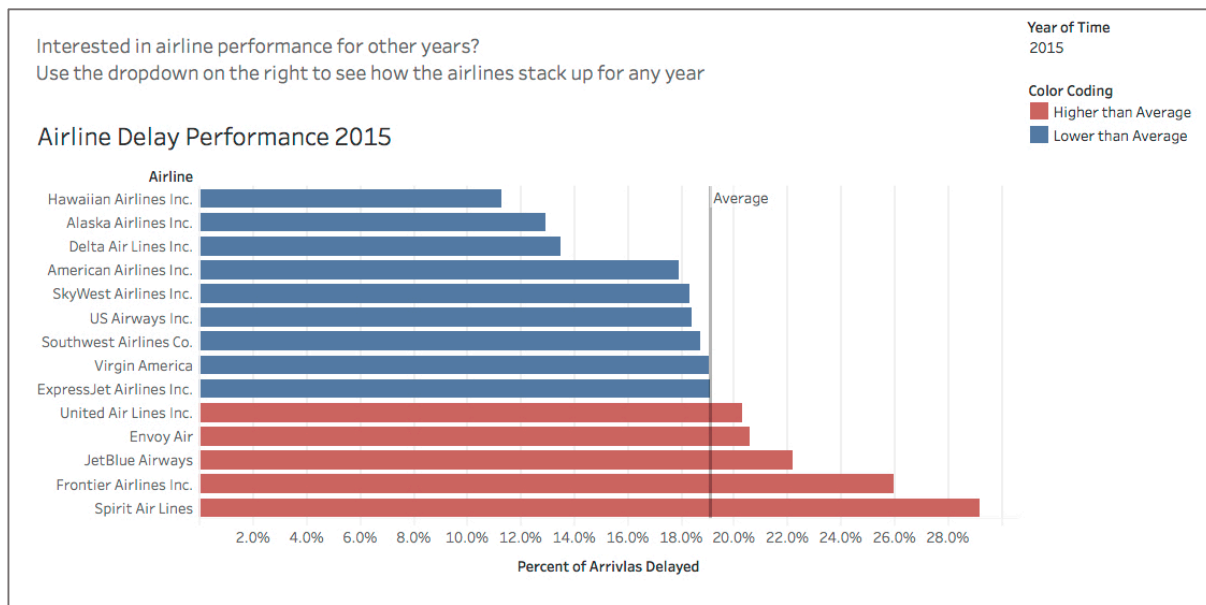


*Figure 16: Interactive visualization of airline delay performance by year*

As the first interactive visualization in the guided flow, this visualization offers clear and straightforward encodings. Sorting the airlines in ascending order and providing a dynamic reference line allows for easy visual comparison of performance. Additionally, all meaningful encodings (length and color) can be processed pre-attentively, allowing the user to quickly interpret the visualization. Filtering by year allows a degree of exploration, without

overwhelming the user with too many options before they are familiar with the interface and layout of the series of visualizations.

## Best and Worst Airports

This visualization features two horizontal bar charts with the same axis scale depicting the percentage of arrival delays for airports with the ten lowest and the ten highest delay percentages. This visualization is intended for users interested in the best and worst performing airports, as opposed to locating the percentage for a specific airport. Because the differences in values of percentage delay might be relatively small, labels are provided for each row.

*Table 8: Visual Encodings for Best and Worst Airports*

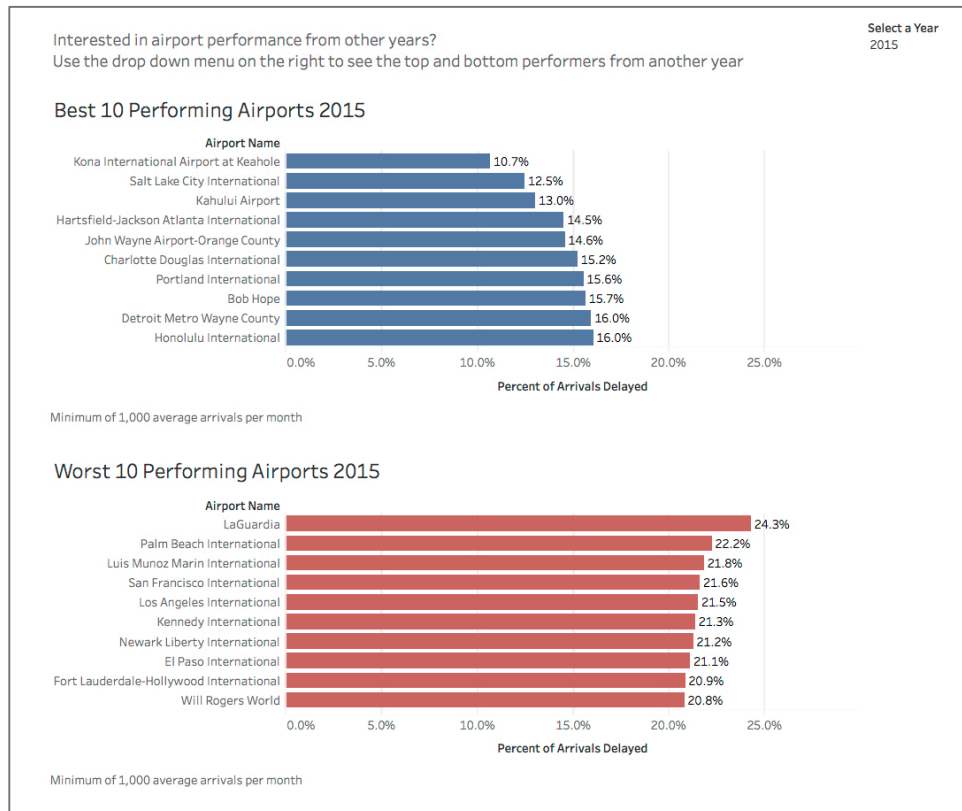| Data | Encoding |
|---|---|
| % of arrivals delayed | Length, Labels (sorted ascending/descending) |
| Year | Filter, dynamic title |
| Airport code, name, state, and % of arrivals delayed | Details on demand (tool tip) |
| Best/Worst | Color (blue/red between charts) |

*Figure 17: Interactive visualization of airport delay performance by year*

Because this visualization serves as a companion to the airline bar chart, it uses similar encodings. With too many airports in the dataset to be displayed in a bar chart format, the charts instead feature the ten lowest and ten highest delay percentages. This decision aligns well with the user goal of uncovering the best and worst performing airports. While the color encoding has a slightly different meaning in this visualization, it is still semantically consistent with the representation of blue as good performance and red as poor performance. Reversing the sort order of the bottom chart ensures the most prominent airports in each chart relate directly to the meaning of the title. Additionally, keeping consistent scales allows for comparisons across the top and bottom charts to offer perspective on relative performance. Filtering options are again kept relatively simple and consistent with the previous visualization.

## Map of Airport Delays

This interactive symbol map displays location, volume of flights, and percentage of delays by airport. While it defaults to an overview of the performance of all contiguous US airports for all airlines in the most recent year, it also enables zoom functionality and filtering by airline and year. It also features a tool tip upon rollover that provides details on demand for the user. This visualization was intended as an exploratory tool for users to quickly browse the performance of different airports in one view by moving the cursor over airports organized by their geographic location.

*Table 9: Visual Encodings for Map of Airport Delays*

| Data | Encoding |
|---|---|
| Average monthly arrivals | Size of circle |
| % of arrivals delayed | Color (blue-red diverging) |
| Latitude and Longitude | Position |
| Year | Filter, dynamic title |
| Airline | Filter |
| Airport code, name, state, average monthly arrival, and % of arrivals delayed | Details on demand (tool tip) |
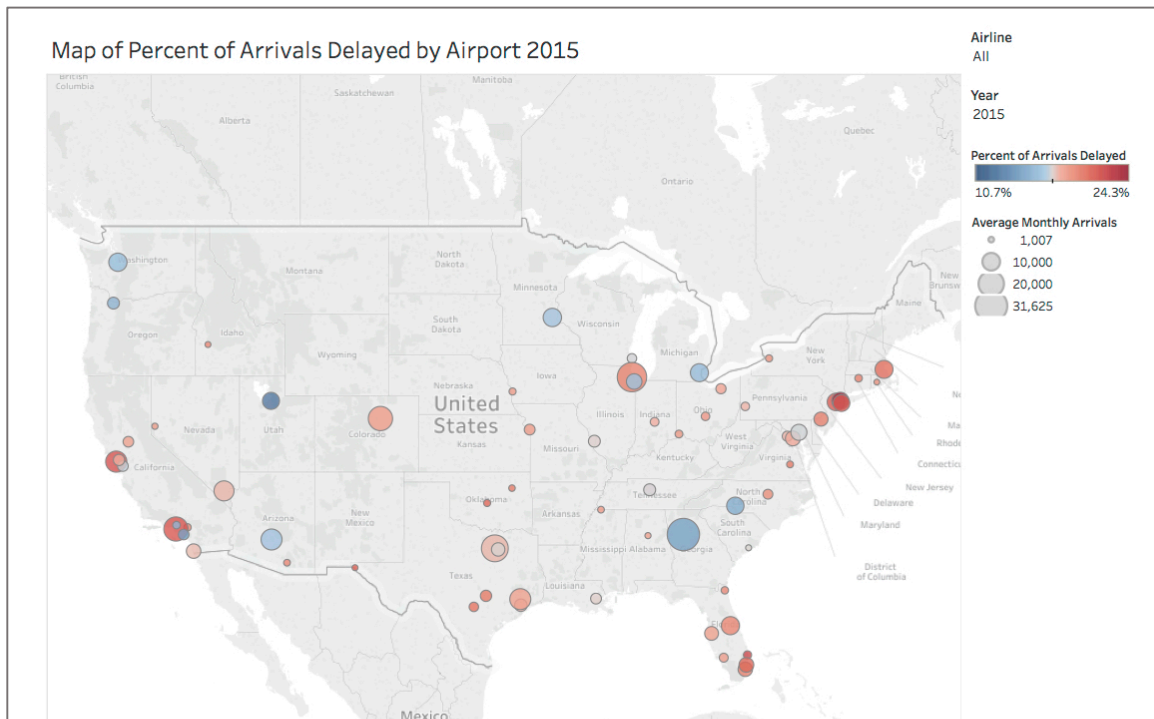


*Figure 18: Interactive map visualization of percent of arrivals delayed by airport*

This visualization is the most effective exploratory analysis tool provided to the user, as it allows for a variety of comparisons across a large number of airports all within a single view. It also empowers the user to drill down to more specific data by filtering by airport and zooming into a specific state or geographic region. Because the map controls built into Tableau are challenging for users, the visualization uses a more limited, text-based search option for zooming/panning.

The color encodings are consistent with previous visualizations, and are easy to interpret. Combining this with the size encoding for total arrivals allows the major airports to "pop-out" of the background map for immediate assessment. Additionally, the ability of the tooltip to provide details on demand helps overcome the precision limitations of encoding total arrivals by size, and helps compensate if the user lacks familiarity with the geographic location of a specific airport. This visualization allows user to easily discover surprising insights and to confirm or refute their anecdotal evidence of delay performance of major US airports.

## Causes of Delays

This visualization features a stacked area chart depicting the percent of arrivals delayed by cause by month for a specific year. This chart serves to answer two important user questions: when is the best/worst month to travel and what are the biggest cause of delays. To answer the first, the top shape of the area chart serves as a time series line chart showing the cumulative delay total per month. To answer the latter, the stacked area format enables a part-to-whole comparison for each cause to see how it contributes to the overall percentage delayed. Because the definitions of each cause are not intuitive, a large legend is included to help users understand the classification of causes.

As a companion to this visualization, there is an additional tab featuring two horizontal bar charts visualizing the percent of delayed arrivals by a specific cause for airlines and the ten highest delayed airports.

*Table 10: Visual Encodings for Cause of Delays*

| Data | Encoding |
|---|---|
| % of arrivals delayed over time | Area |
| Cause of delay | Color |
| Year | Filter, dynamic title |
| Cause, month, % of arrivals delayed | Details on demand (tool tip) |

*Figure 19: Interactive visualization of percent of arrivals delayed by cause*
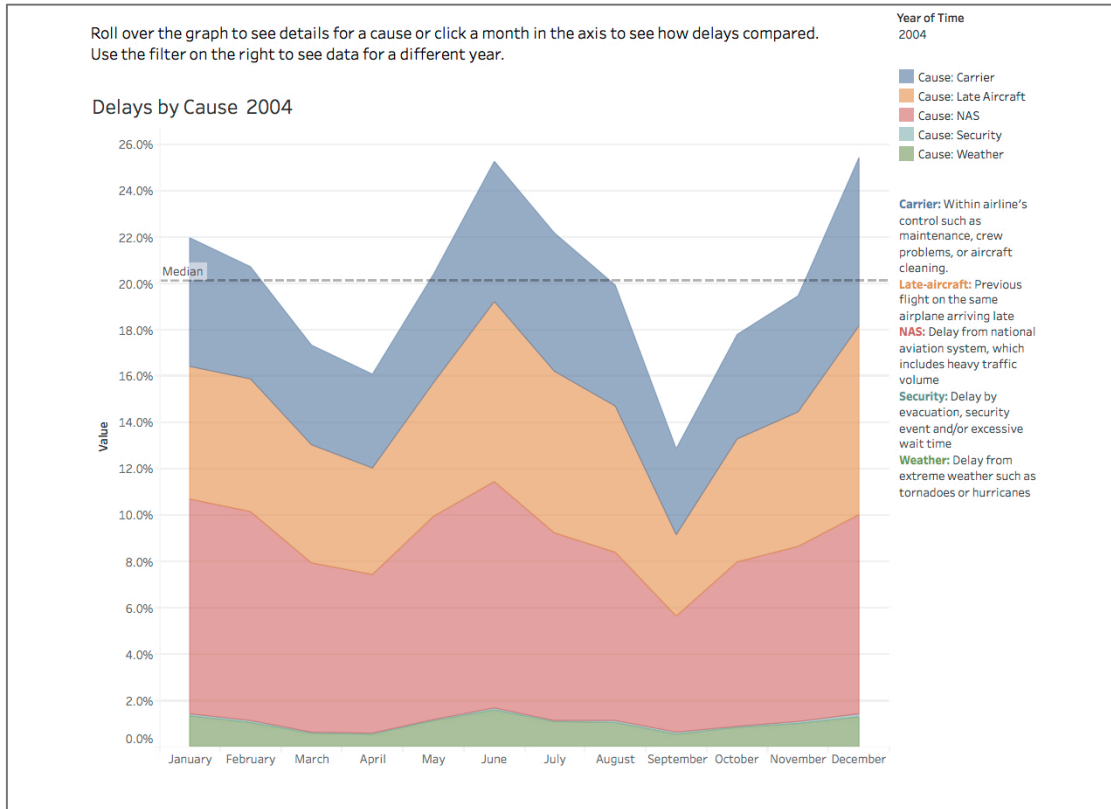
The stacked area chart was chosen for its ability to depict the overall trend of delays over the course of the year and the part-to-whole relationship of each cause, rather than specific values for each cause. However, using a roll over tool tip, the visualization does provide detailed percentages on demand. Because of the complexity of the visualization, rollover and highlighting functionality encourage exploration to help the user identify trends. Unfortunately, the data set used did not enable the ability to drill down beyond the month and there was no way to isolate weather delays outside of the extreme storms included in the "weather" classification.

## Find Your Airline or Airport

This personalized visualization allows a user to find specific delay data for their preferred airline and local and neighboring airports. It features four linked visualizations based on those filters that provide users with comprehensive information to evaluate their choice of airline and airport. A map provides delay performance for your selected airport and airports within the selected distance filter. A vertical bar chart reflects the same airport delay percentage data encoded as bar length for easier visual processing. A horizontal bar chart reflects the selected airline's delay performance at the selected airport compared to other airlines servicing the same location. Finally, a time-series line chart shows the selected airline's performance at the selected airport by month over the course of the year.

*Table 11: Visual Encodings for Personalized Dashboard*

| Data | Encoding |
|---|---|
| % of arrivals delayed over time | Label (map), length (bar), vertical position (line) |
| Total monthly arrivals | Size (map only) |
| Airline, airport, distance radius, year | Filter, dynamic titles |
| Time | Horizontal position (line) |
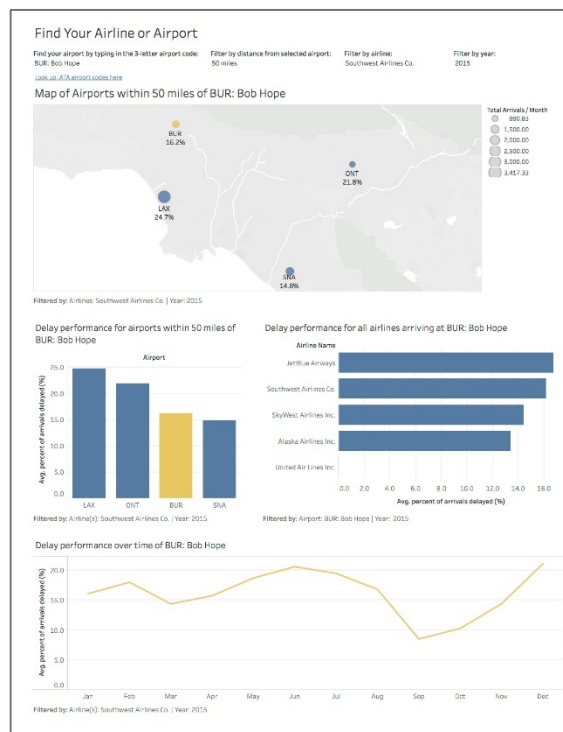


*Figure 20: Personalized visualization dashboard featuring a symbol map, bar charts, and a line graph*

This dashboard directly addresses the other primary user goal: to see delay performance for their preferred airline and airport. It easily allows direct comparisons between neighboring airports, other airlines servicing the same airport, and different times of year. While the visualization successfully employs brushing techniques for the map and vertical bar chart, it does not successfully apply the brushing colors to all charts. Brushing and linking would help call attention to the most important element in each visualization and provide feedback that the personalized filters were active.

## FURTHER WORK

While user surveys indicate that overall Dawdle was successful in educating about flight delays and aiding in their decision process, there is much room for improvement. In regards to the limitations of the chosen data set, including more granular data such as daily and hourly in addition to monthly, as well as including departure delay data in addition to arrival delay data would most likely provide a more accurate representation of flight delays and prove to be a more useful tool for users. Currently, the data represents non-stop flights only. As such the inclusion of flights with connections would certainly be of use. However, at this time there are no known data sets which include connecting flights. User reports during user testing also suggest the inclusion of international airlines and airports would greatly increase utility for business travels.

The use of Tableau to create the Dawdle visualizations also severely handicapped overall functionality. While the Dawdle team was able to accomplish most basic operations using Tableau, limited experience and convoluted or often times missing features such as dynamic filters with brushing actions and dynamic parameters plagued the project. A significant amount of work was required to bring the visualization to a functional level and enable users to complete the necessary tasks. Perhaps migrating to a more easily customizable visualization framework such as D3 [CITATION] would provide the desired functionality and allow for more streamlined navigation to aid in accomplishing user tasks.

## ACKNOWLEDGMENTS

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# APPENDIX

## Appendix A – Data Variable Table

| Variable | Category | Description |
|---|---|---|
| Month | Ordinal | Each row represents one month in time for a single airline and airport |
| Year | Ordinal | Year (2003-2016) |
| Carrier code | Nominal | Airline carrier code |
| Carrier name | Nominal | Airline carrier name |
| Airport code | Nominal | Airport code |
| Airport name | Nominal | Airport name |
| Airport Lat/Long | Quantitative (Geographic) | Geographic coordinates of airport locations |
| Arriving flights | Quantitative | Count of arriving flights |
| Arr Delay 15 | Quantitative | Count of flights with arrival delayed >15 min |
| Percent Delayed | Quantitative | Percentage of arriving flights classified as delayed |
| Delays caused by carrier | Quantitative | Count of flights attributed to carrier |
| Delays caused by weather | Quantitative | Count of flights attributed to weather |
| Delays caused by NAS reasons | Quantitative | Count of flights attributed to NAS reasons |
| Delays caused by Security | Quantitative | Count of flights attributed to security delays |
| Delays caused by late aircraft | Quantitative | Count of flights attributed to late arriving aircraft |
| Arrival canceled | Quantitative | Count of arriving flights that were canceled |
| Arrival diverted | Quantitative | Count of arriving flights that were diverted |
| Arrival delay | Quantitative | Sum of minutes delayed |
| Average delay | Quantitative | Average delay time for a delayed flight |
| Total time delayed caused to carrier | Quantitative | Sum of total time delayed attributed to carrier |
| Total time delayed caused by weather | Quantitative | Sum of total time delayed attributed to weather |
| Total time delayed caused by NAS reasons | Quantitative | Sum of total time delayed  attributed to NAS reasons |
| Total time delayed caused by Security | Quantitative | Sum of total time delayed attributed to security delays |
| Total time delayed caused by late aircraft | Quantitative | Sum of total time delayed attributed to late arriving aircraft |

# Appendix B – Competitive Analysis Table

| Name | Link | Description | Notes |
|------|------|-------------|-------|
| Example using flight data in R | https://arxiv.org/pdf/1502.00318v1.pdf | Paper on using R for data analysis. Includes an example of using what I beleive is our same dataset | This pdf is also in the 'visualization examples' folder |
| US Airline Flights | https://www.mapd.com/demos/flights/ | View flight delays and activity from almost 3 decades, and see which airlines got you there on time. | Good insperation for visualizations |
| Which Airline Has the Most Comfort and Customer Satisfaction Per Dollar? | https://www.hopper.com/research/airline-comfort-customer-satisfaction-per-dollar/ | Hopper looked at ticket prices, airline fees, customer satisfaction surveys and seat size and pitch to identify the best and worst airlines for different types of travelers | |
| Flight Delay Calculator | http://lasvegassun.com/guides/flightdelays/ | This interactive map shows how frequently individual direct flights were delayed by 15 minutes or more when traveling to and from McCarran International Airport in the last 12 months. | Pretty awesome visualization that lets users do pretty much what Diane was talking about where the user can input a flight number or origin, destination, and time of flight and the map will show you the route with a popup that shows delay info specific to that route |
| Current North American Airport Delays | http://www.flightstats.com/go/Airport/currentAirportDelays.do | Map showing real-time delays and weather conditions at about 25 airports throughout north america. Provides a delay index for comparison. | |
| Current US Airport Delays | https://weather.com/maps/travel/airportdelays | Map showing minutes airports around the US are currently delayed and current weather conditions | |
| The Weather Isn't the Biggest Cause of U.S. Flight Delays | http://www.bloomberg.com/news/articles/2016-08-23/blame-the-airlines-not-the-weather-for-most-u-s-flight-delays | Airline miscues -- such as the computer glitches that grounded hundreds of thousands of passengers this summer -- are now the biggest cause of flight delays in the U.S. | Some interesting graphics about cause of delays over time for all airlines and also minutes of delay by cause over time. Article talks about what I expect our findings to also be since they appear to have used the same data set as us. Has some great examples of questions that can be answered looking at the data. |
| Travel trouble? Here's why your airline flight is delayed | http://www.usatoday.com/story/money/2016/08/11/airlines-complex-aging-systems-lead-to-flight-delaying-computer-glitches/88539190/ | No graphs. The article discusses the recent massive computer system glitches that have caused delays for several airlines in the last year. A big point is that the aging infrastructure will continue to contribute to delays in the future. | The article is relevant to our visualization as it points out the need to visualize delays and their causes. It also indicates there is an obvious need for analysis capabilities. Depending on how recent our data is, it may provide the visual support that this article lacks. |
| The Biggest Cause of Flight Delays | http://www.cntraveler.com/story/the-biggest-cause-of-flight-delays | Weather is no longer the leading cause of flight delays. | Another summary article referencing at least one other article in this list. No graphs but provides a summary analysis of available delay data. |
| Coping With Flight Delays | http://airconsumer.ost.dot.gov/publications/delays.htm | Facts for Air Travelers from the Aviation Consumer Protection Divisio | A high level analysis providing some interesting insight into delay data. References other good sources of on-time performance summaries |
| Air Travel Consumer Report issued October 2016 | https://www.transportation.gov/sites/dot.gov/files/docs/2016OctoberATCR.pdf | information about airline on-time performance, flight delays, and cancellations based on data filed by airlines each month with the Department of Transportation's Bureau of Transportation Statistics | This is a 50 page monthly report providing insight in airline performance data gathered. Includes like 100 tables and 1 pie chart. Obviously there is a plethora of opportunity to enable better understanding of the data in the tables by utilizing some visualizations. |
| These Are the Best Airlines to Fly With This Thanksgiving to Avoid Delays | http://www.travelandleisure.com/airlines-airports/top-airlines-thanksgiving-travel | A summary of RewardExpert's annual Thanksgiving Holiday Air Travel Forecast highlighting which airlines are least likely to have delays. | |
| Thanksgiving 2016 Holiday Air Travel Forecast | https://www.rewardexpert.com/blog/studies/thanksgiving-2016-holiday-air-travel-forecast/ | RewardExpert looks at the best and worst days to travel and the airports and airlines to avoid | Asks many of the same questions we hope to answer with our visualization. Utilizes by day data so some of the infographics are more granular thatn our data will allow but still a great starting point. |
| The Best and Worst Thanksgiving Travel Days at the 45 Busiest Airports | https://www.rewardexpert.com/blog/studies/thanksgiving-2016-holiday-air-travel-forecast/45-busiest-airports/ | RewardExpert looked at the 45 busiest airports and determined which are the best and worst days to travel through each airport for avoiding delays to help plan your trip around high-traffic dates. | Unfortunately more granular than our data allows but it shows exactly the kind of questions we want to answer with our visualization. Luckily there is lots of room for improvment over their rather non-intuitive visualization |
| Visualizing More Than Five Million Flights | https://public.tableau.com/en-us/s/blog/2015/05/visualizing-more-five-million-flights | a dashboard that allows you to choose an airport of origin, such as JFK or LAX, and a carrier, such as Delta or United, and see the number of flights to each domestic airport along with the average departure delay times experienced by travelers in 2014 | |
| Which Flight Will Get You There Faster | http://projects.fivethirtyeight.com/flights/ | FiveThirtyEight analyzed 6 million flights to figure out which airports, airlines and routes are most likely to get you there on time and which ones will leave you waiting. | Pretty much exactly what we were hoping to accomplish. has not been updated in a year |

## Appendix C – User Interview Questions

1. What are the top five factors that affect your decision when purchasing a flight?
2. How much does flight delay affect your decision when purchasing a flight?
3. Tell me about a time that you were delayed on a flight?
4. If you had more information about the flight delays of that particular airport or airline prior to purchasing that ticket, would you have made a different decision?
5. What do you think are the worst airlines for flight delays?
6. What do you think are the worst airports for flight delays?
7. What do you think are the worst times of the year for flight delays?
8. What information about flight reliability would you like to see?

## Appendix D – Usability Test 1: Tasks and Questions

1. Which airport in New York city does the worst in terms of flight delay? (NWK, LGA, JFK)
2. Which airline is the most delayed to your local airport?
3. Which airline experiences the highest percentage of its delays due to extreme weather at O'Hare (ORD)?
4. Which month is the best/worst to fly into SeaTac (SEA)?
5. What did you like about this visualization?
6. What did you dislike about this visualization?
7. What would you change about this?
8. Would you use this? How would you use this?

## Appendix E – Usability Test 2: Tasks and Questions

### For the "Report Card"

Description: This is a report card that tells you the best and worst performing airlines and airports in terms of delayed arriving flights for any given year. A delayed flight is defined as any flight that arrives more than 15 minutes after its scheduled arrival.

1. What airport have you often experienced delays at. Can you find it on the map? What does it tell you about its delay performance in **2016**?
2. Which **airline** do you think is the <u>worst</u> in US for limiting delays last year (2015)? Can you find if you are right? Is the result what you expected?
3. Which **airport** do you think is the <u>best</u> in US for limiting delays last year (2015)? Can you find if you are right? Is the result what you expected?
4. Which month was the worst for delays in 2015? What is the most common cause for that?
5. Which airport had the worst <u>weather</u> delays in 2015?
6. Which airline had the worst delays from <u>late aircrafts</u> in 2015?
1. Go ahead and play around with the visualization for a few minutes. What other questions do you have about delays that you might want answered?

### For the "Interaction Detail"

Description: This is an interactive visualization that allows you to find out personalized information based on the airport and airline you fly most often.

1. Please explore the interactive visualization for a few minutes and then I will ask you to complete a few tasks using it. As you explore, please think out loud so I can know what your thought process is as you use it.
2. You want to know what the best performing airport in the New York area is. How would you find out?
3. Is there an airline that you fly with most often? You want to know how it performs relative to other airlines for delays?
4. What's the airport that you fly in and out of the most? You want to find out how your preferred airline performs at that airport.
5. What other questions do you have about delays that you might want answered?
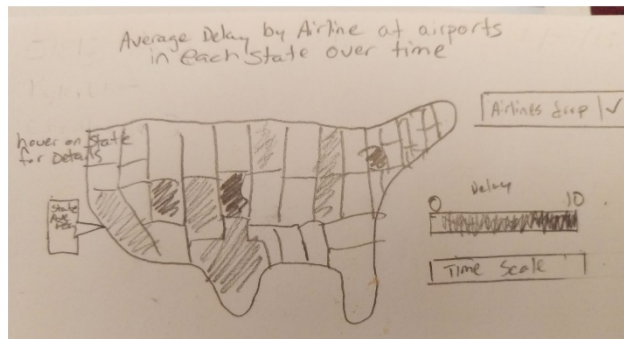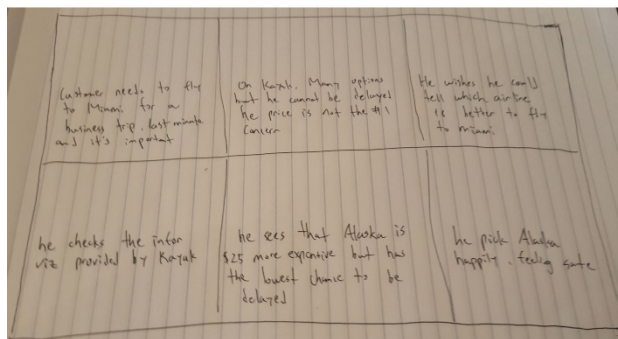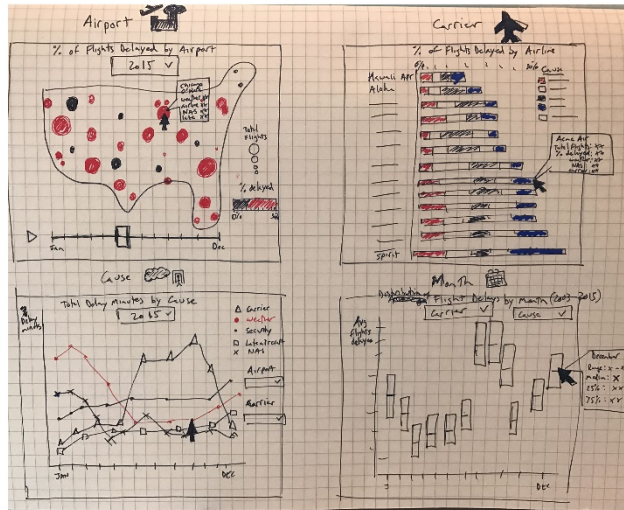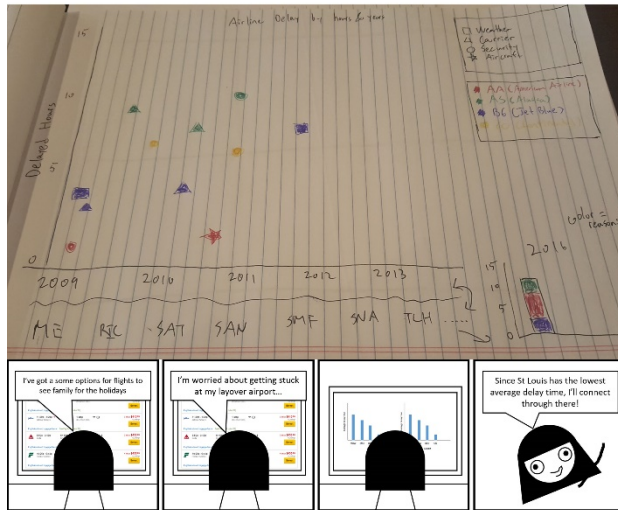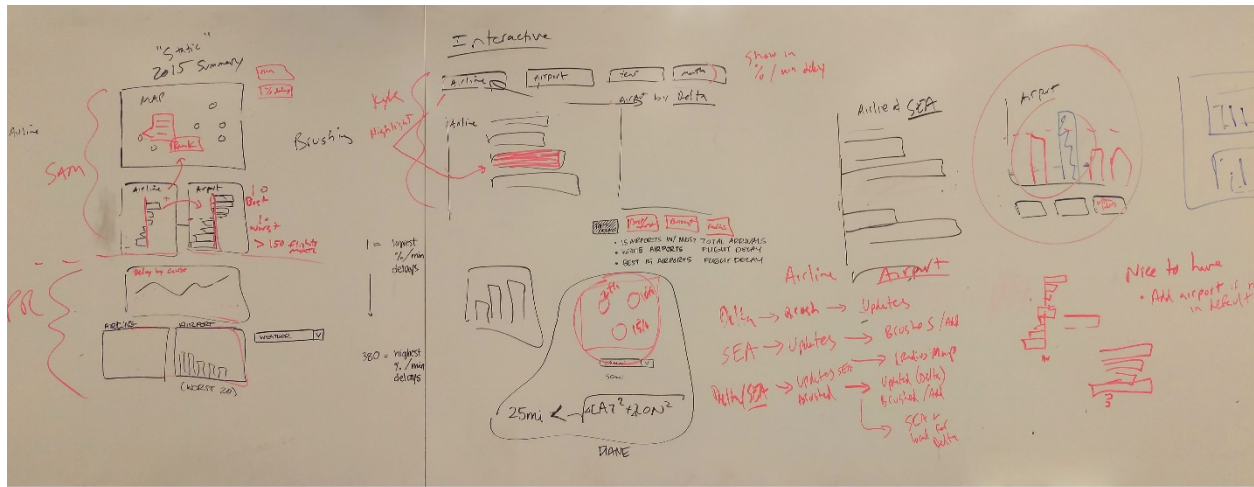
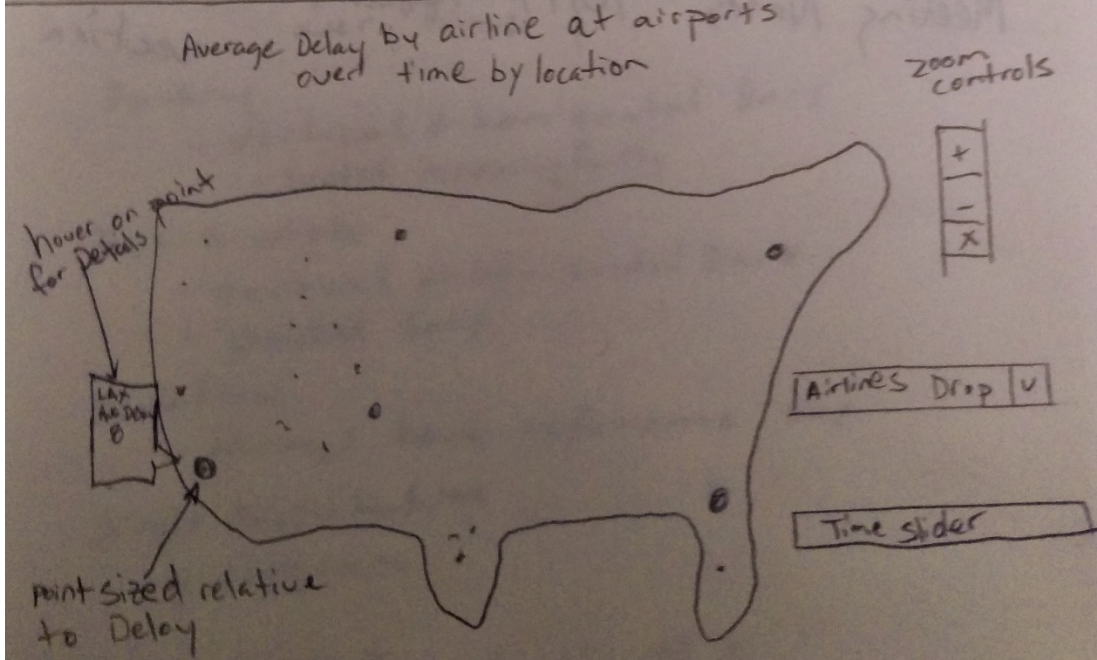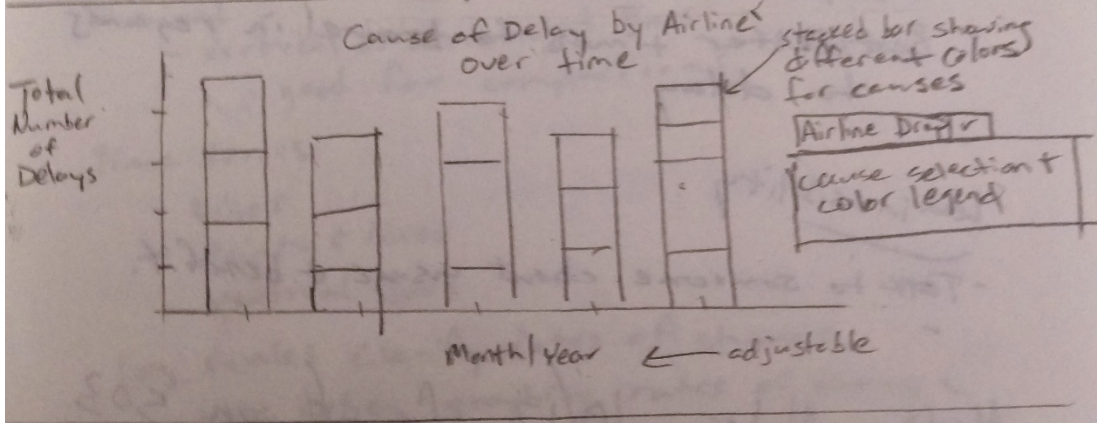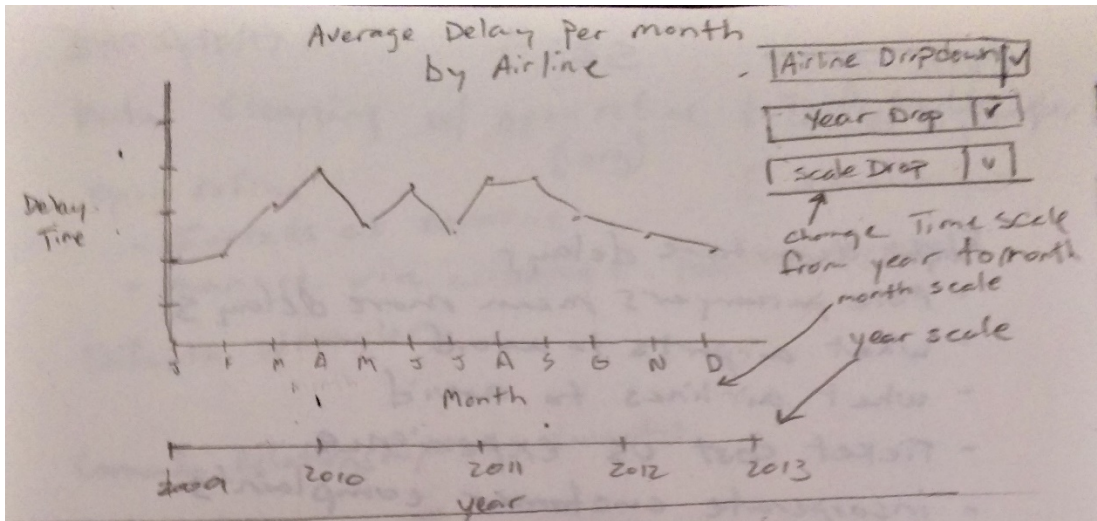## Appendix F – Usability Test 3: Tasks and Questions

Description: This is an interactive visualization that allows you to find out personalized information based on the airport and airline you fly most often.

1. Please explore the interactive visualization for a few minutes and then I will ask you to complete a few tasks using it. As you explore, please think out loud so I can know what your thought process is as you use it.
1. Is the navigation clear? Is it obvious where the two buttons on the homepage will take you?
2. Please take some time to interact with the best and worst airlines visualization. Is it clear how airlines compare to each other? What are your thoughts?
3. Please take some time to interact with the best and worst airport visualization. Is it clear how airports compare to each other? What are your thoughts?
4. Please take some time to interact with the map of airport delays. Is it clear how the map functions? What are your thoughts?
5. Please take some time to interact with the causes of delays visualization. Are you able to easily see the prevalence of different causes? What are your thoughts?
6. How does this experience compare to your experience with the last prototype?
7. Please take some time to find the delay information specific to your airline and airport. What did you learn? How difficult was the task?
8. What suggestions do you have for improving the visualization?

Average Delay Per month
by Airline                    Airline Dropdown ☑

                              Year Drop ☑

                              Scale Drop ☑
                                    ↑
Delay                         change Time scale
Time                          from year to month
                                    month scale
                                    year scale

  J F M A M J J A S O N D
            Month

1009    2010    2011    2012    2013
              year

Cause of Delay by Airlines     stacked bar showing
        over time              different colors
                               for causes
Total                         Airline Drop ☑
Number
of                            cause selection +
Delays                        color legend

            Month/year  ←— adjustable

Average Delay by airline at airports
      over time by location              zoom
                                         controls
hover on point                              +
for details                                 -
                                            X
        LAX
        Air Drop                      Airlines Drop ☑
        8

point sized relative                 Time slider
to Delay

41

## Appendix H – Additional Persona



### The Family Planner - Mark

*"So proud of you Sara! Let's have an awesome vacation in Hawaii"*

**Age:** 47
**Work:** Creative Director
**Family:** Married, 3 kids
**Location:** Dallas, TX

#### Bio

Mark has been married for 16 years and he has 3 grownup kids. His oldest daughter Sara is 22 and she recently graduated from college. To celebrate Sara's achievement, Mark decided to take the whole family out to vacation in Hawaii. With 12 days of PTO (Paid Time Off) available for the rest of the year, Mark is planning ahead to make sure he picks a good time and a reliable airline to minimize potential issues.

#### Goals

- Pick a good time in the year to avoid potential problems such as extreme weather
- Book flights ahead with a reliable airline
- Plan ahead for vacation rentals such as resort, hotel, and car

#### Frustrations

- Spending very valuable family vacation time in the airport instead of the resort
- Getting delayed and therefore messed up his vacation schedule
- Flying with the wrong airline at the wrong time while he had time to make a better decision