CS 171
MBTA Sporting Events: Process Book

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GitHub: github.com/micahlanier/cs171-gameday

Web: Forthcoming.

Overview & Motivation

As one of the largest public transportation agencies in the United States, the Massachusetts Bay Transit Authority (MBTA) serves the needs of the greater Boston area and facilitates an average of 1.3 million trips (by bus and rail) every weekday. Delays and overcrowding are widely felt, and are often exacerbated by spikes in demand brought on by major public events.

Our project aims to visualize public transportation demand before and after major sporting events in Boston. The relationship between ridership and events—and the variability thereof—is difficult to quantify effectively. Observations depend on a variety of related factors: the teams and sport involved, venues' public transit connections, game length, the stakes of the contest (e.g., playoff games), and exogenous factors (e.g., weather, holidays) all hold apparent influence over ridership. For these reasons, not only is visualization an effective narrative medium for explaining their connections, but it is also extremely useful for *discovering* connections that are not apparent in the numbers. We believe that ours is an effective solution for both facets of this challenge.

Related Work

Our project stems from work that we have taken on for AC 297r, a capstone class for students in Computational Science & Engineering. We are working with two other students (both of whom are using MBTA data for a separate project in this class) to develop a predictive demand model for MBTA managers to apply to their day-to-day work (see our project website for more). We found in our work that MBTA ridership is typically predictable, but can vary widely due to events like weather and sporting events. This particular visualization project grew out of that observation and the difficulties we've encountered when attempting to engineer useful summaries of sports schedules to include in our machine learning models.

With the increasing availability of public APIs and open datasets that pertain to public services, many others have applied their analytical faculties and visualization skills to topics like our own.

Visualizing MBTA Data—developed by two WPI students and published in 2014—is a superbly-executed D3-based examination of MBTA train traffic and ridership statistics. They include observations about several basketball games in their analysis and note an apparent connection between station congestion and train delays. Our analysis primarily focuses on the "demand side" of this phenomenon (i.e., we will not make use of any train arrival data); but their evidence demonstrates the importance of understanding demand when attempting to provide optimal service.

Outside of Boston, there is no shortage of public transit visualizations that rely on D3. These include multiple ways of displaying New York subway data. Though few if any of these visualizations specifically address questions similar to our own. As such, we hope that ours will provide a novel perspective both for Boston and for public transportation services generally.

Questions

The core question that underlies our analysis is simple and intuitive: what ridership patterns distinguish gameday (and gametime) demand for public transit compared to days without games? As suggested above, we have undertaken this project both to highlight relationships that we *know* to exist between ridership and sporting events, and to provide a means for discovering dynamics that are not yet apparent to us.

Several variables describe ridership pattern changes that occur in response to sporting events. Different concentrations of ridership lift (or perhaps decline in isolated cases) might occur at different times, perhaps in response to a boring game or an exciting one that runs far longer than anticipated. Some fans might be apt to leave early and catch the next train, while others might stay in the neighborhood for several hours after each game. Predicting all of these variables is an important logistical task for MBTA planners concerned with saving money while still providing optimal service at peak times.

At a higher level, we are interested in what features of games (day of week, time of day, specific opponents, or others) might predict certain ridership distributions. On a weeknight, fans might rush home immediately after games; on Saturday evenings we might not expect them to be in such a rush. Important games—say, playoffs and rivalries—might also influence fans to arrive early and stay to the very end of games, while low-stakes contests may see late arrivals and early exits.

As suggested, our visualization aims to answer the above questions both by emphasizing the trends that we have observed and by providing an exploratory method that users may employ to discover novel relationships.

Data

Our project ultimately aligns two primary groups of datasets: home game schedules for Boston's major sports teams, and MBTA ridership statistics.

Sports Data

Our sporting data features home games and associated information for three major sports teams that play their home games in Boston: the Bruins (NHL), Celtics (NBA), and Red Sox (MLB). Records go back to the beginning of 2013 (the earliest date for which we have MBTA ridership data).

To obtain these schedules, we found it easiest to manually download each team's schedules from espn.com. Those schedules are readily available in a fairly clean HTML format (see the 2013 Red Sox schedule for an example) that we were able to process using a text editor and several regular expressions. For all sports, we were able to easily extract dates, times, home games, and opponents; we manually added identifiers for playoff games. While not a particularly technically-sophisticated process, this proved fast and effective.

The following is an example of several Boston Bruins games from 2013:

Datetime	Playoff	Opponent
2013-01-19 19:00	0	NY Rangers
2013-01-21 13:00	0	Winnipeg
2013-01-25 19:00	0	NY Islanders
2013-01-29 19:00	0	New Jersey
2013-01-31 19:00	0	Buffalo
2013-02-12 19:30	0	NY Rangers
2013-02-28 19:00	0	Ottawa
2013-03-02 13:00	0	Tampa Bay
2013-03-03 19:30	0	Montreal

We performed some additional "wrangling" of the data that is ultimately served to visitors, but the final data format largely follows the above.

MBTA Ridership Data

As part of our aforementioned capstone project, we received ridership data since the start of 2013 for MBTA trains (subways and Green Line trains, not commuter rail) and busses. Each dataset shows aggregate “entries” (bus data breaks down those who use Charlie Cards and those who do not) at fifteen-minute intervals, with varying amounts of geographic detail (discussed below).

Our underground train dataset covers 320 million trips (“station entries” to be precise) over the last two years. This is an example of several rows from April of 2014:

locationid	servicedate	servicetime	entries	exits
1002	2014-04-01	500	5	1
1002	2014-04-01	515	81	8
1002	2014-04-01	530	60	15
1002	2014-04-01	545	68	13
1002	2014-04-01	600	90	15
1002	2014-04-01	615	135	23
1002	2014-04-01	630	121	17
1002	2014-04-01	645	90	26
1002	2014-04-01	700	117	11

The “locationid” column corresponds to particular locations, which we can look up (along with associated line colors) in an associated metadata file. In terms of data volume, we have almost 4 million records in 110 MB of data.

Bus and above-ground Green line data constitute 11.1 million records, clocking in at 286 MB of data. The file structure resembles the above, omitting exits

Processing

Obviously, our raw dataset is far too voluminous and “messy” to serve to users’ browsers. To that end, we have preprocessed data using Python, and saved nine summarized files of game data, each available in the “data” directory of our Github repository.[1]

Team schedules have been modified to remove games that took place on certain holidays and service outages, as those days show deep dropoffs in ridership that we can safely intuit to *not* be associated with sports games themselves.

[1] Note that the pre-game ridership data has been generated but not committed at the time of this writing. As our datasets are still voluminous after transformation, we wanted to wait until we have made headway developing the postgame ridership visualization before committing it, in case we learn about better ways of organizing that data in the process.

Team schedules are then joined to ridership data aggregated at several levels—at various times by station, line, date, day of week, and time of day. From there, we generate a comparison dataset that aggregates ridership by time of day and day of week for days that did not feature any sporting events. We restrict the time range of this comparative aggregation to dates during the season so that we do not inadvertently pick up seasonal effects in our comparison (say, by comparing Red Sox gameday ridership to ridership in January). The difference between ridership on each day and comparison ridership for the same day of week and time of day are used in the visualization.

Exploratory Data Analysis

Naturally, we undertook exploratory analysis to determine whether or not there actually exist observable and significant trends in ridership demand before and after sporting events. Detecting those trends requires consideration of other variables, such as weekly ridership cyclicality and the extent to which holidays influence ridership (and potentially affect comparisons between gamedays and gameless days).

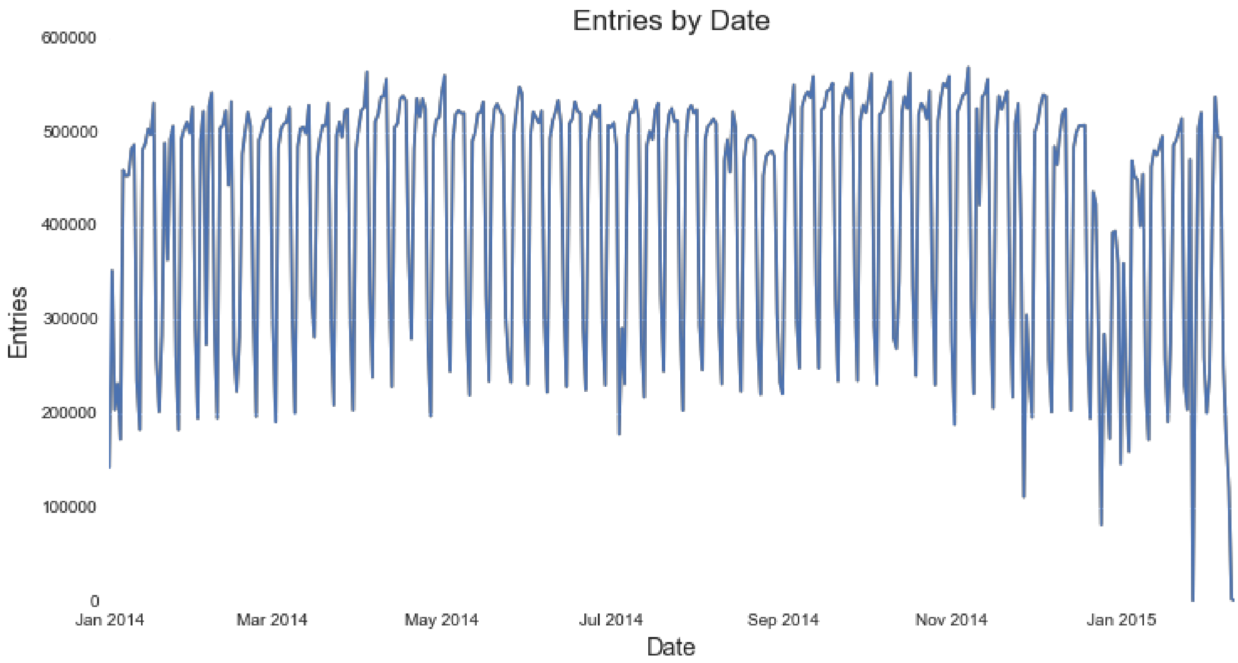
The particular distribution of sporting events will also guide our analysis. Naturally, league executives and team management schedule games for profitability, both in terms of attracting local crowds and drawing television viewers. This manifests in particular game scheduling trends, like the preponderance of prime time games on weeknights (as opposed to poorly-attended afternoon games) and differing league traditions of playing on or around major holidays (e.g., the days after Thanksgiving or Christmas).

Finally, this section will also illustrate the high-level ridership trends that a user might analyze with our visualization. This section will focus on exploratory analysis; later sections will use observations from our visualization itself.

General Ridership Trends

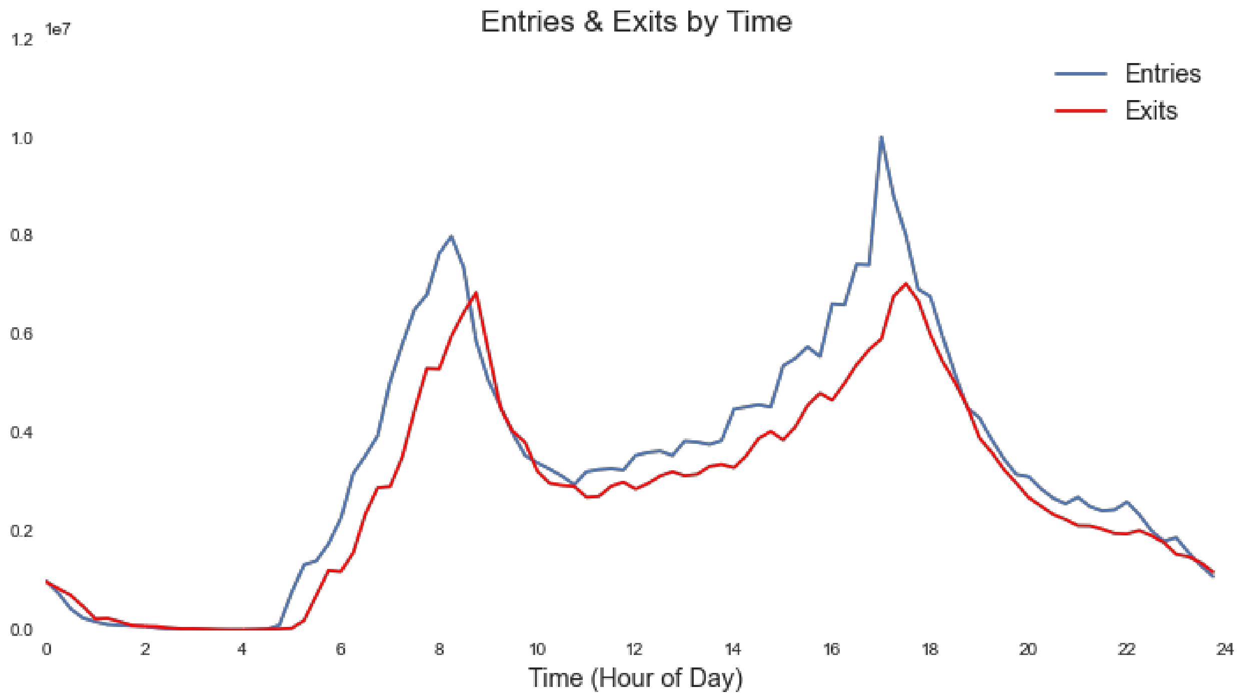
At a high level, it is worthwhile to examine aggregate ridership statistics. Doing so may reveal broad patterns applicable to more targeted analyses of traffic around sports games.

For starters, 2014-15 train data shows an obvious weekly cycle:



The regular dips occur around weekends, suggesting that we must account for day of week when comparing gametime traffic to general days. There are also apparent seasonal effects, such as students' arrivals in early September and dips in ridership around Thanksgiving and late December. The fact that TD Garden (where the Bruins and Celtics both play) is located near a major downtown station (North Station) suggests that we ought to take care when including games around holidays in our analysis.

We can also observe regular commuting patterns in our dataset:

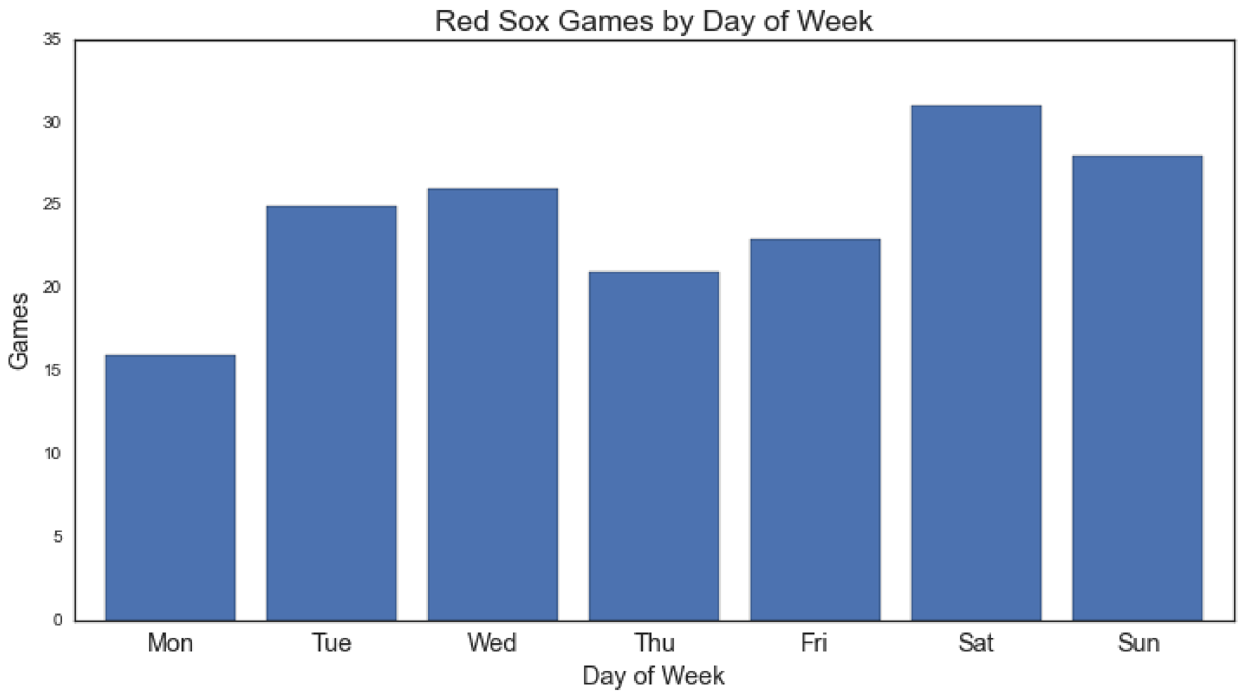


Many games occur during the "downward slope" of afternoon rush hour. Intuition suggests that many people—not just game-goers—might alter their behavior in response to a game, perhaps commuting at different times to avoid crowds or using alternative routes.

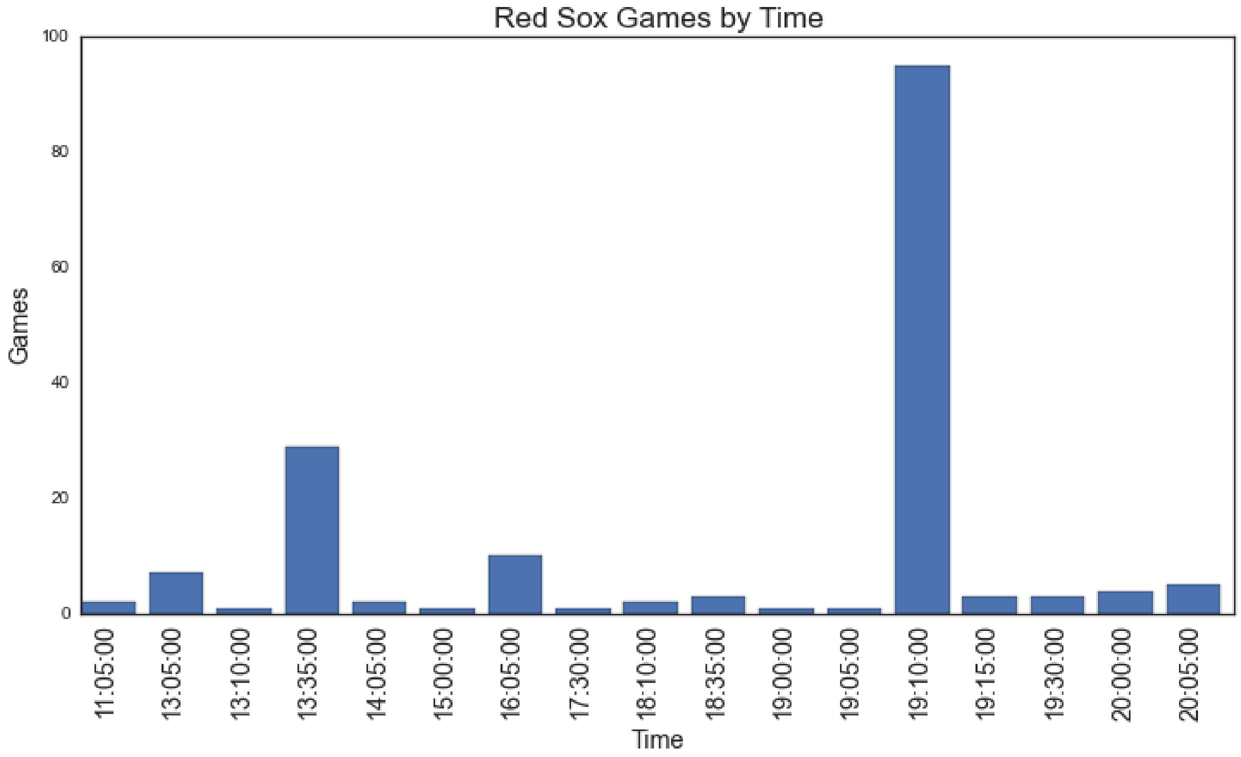
Sporting Event Characteristics

Sporting events are best analyzed in two groups: Red Sox games by themselves and Bruins/Celtics games together.

Red Sox games take place consistently throughout the week, suggesting that we have enough data to make useful conclusions about particular weekdays:

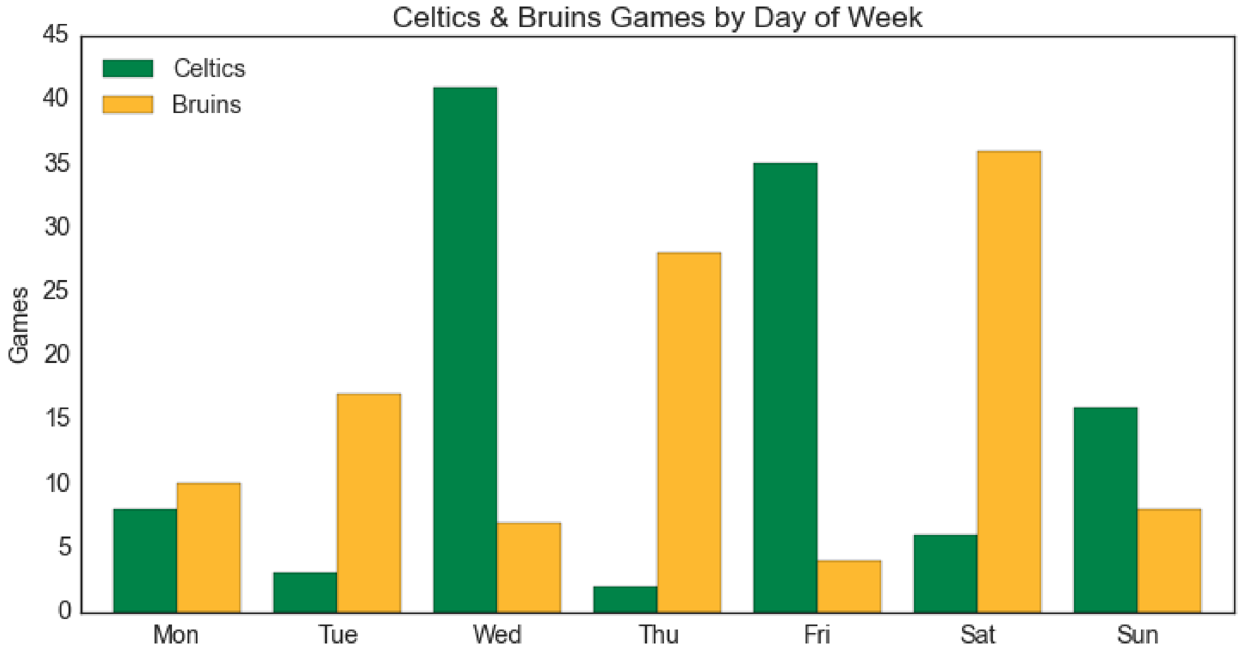


Red Sox games show an interesting distribution of times as well:



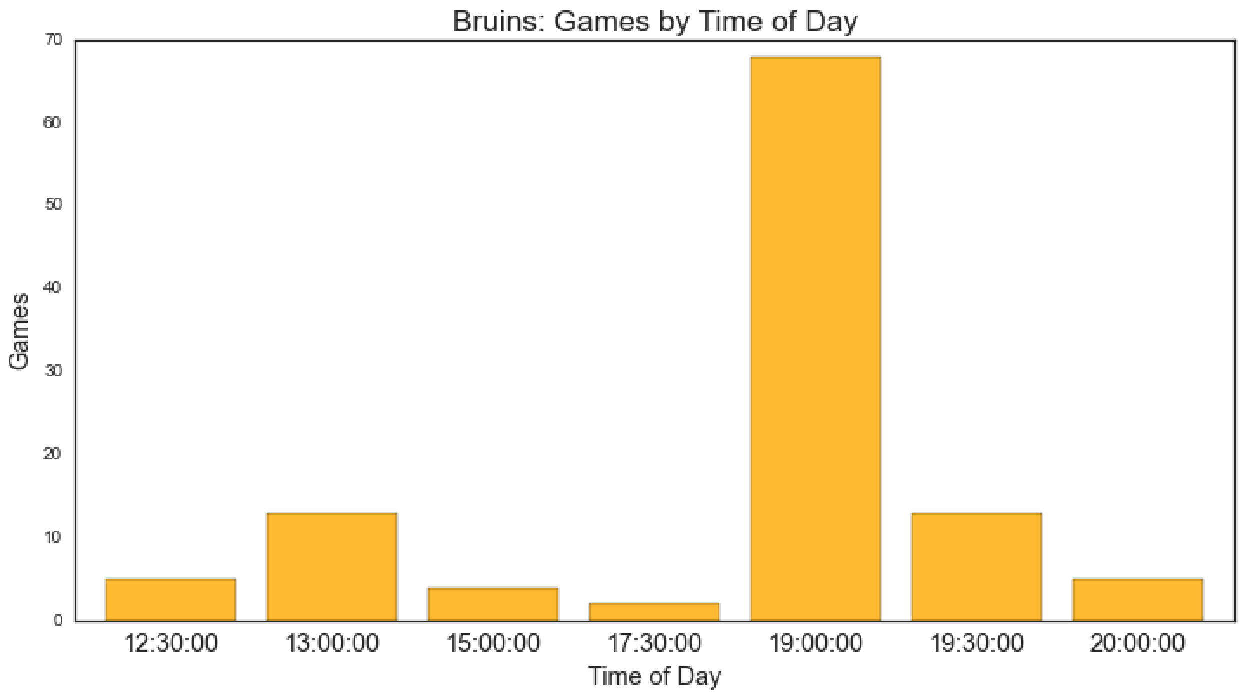
Though there is a distinct preponderance of prime time games, there is also a wide distribution of daytime games as well. Observations suggest that those tend to be held on weekends. This distinction offers a useful opportunity to distinguish among both gametimes in our analysis.

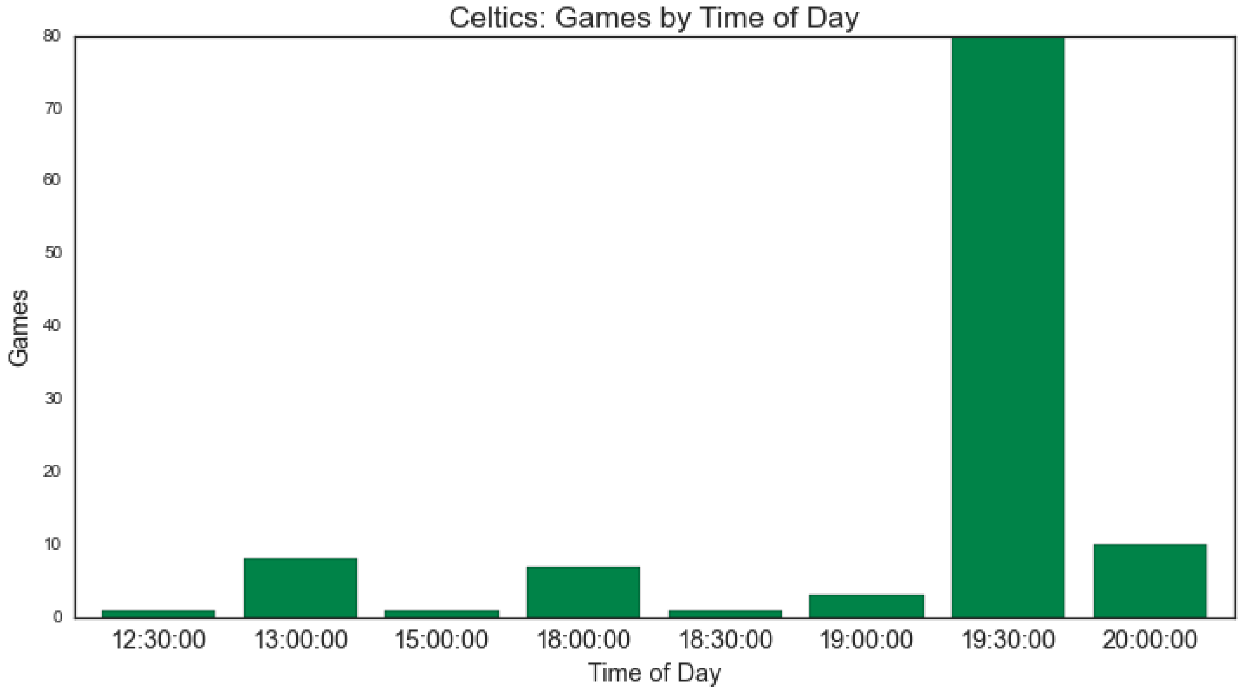
Because the Bruins and Celtics share TD Garden and their seasons take place at essentially the same time, their home game schedules show distinct patterns:



Tuesdays/Thursdays/Saturdays are distinctly Bruins days, while Wednesday and Friday show the bulk of Celtics games. This might affect the specific groups of games to which we draw the user's attention, and suggests that we will have to take care to ensure we only compare game traffic to those days where *neither* team held a game at TD Garden.

Time-of-day trends suggest a distinct preference for prime time games among both teams:

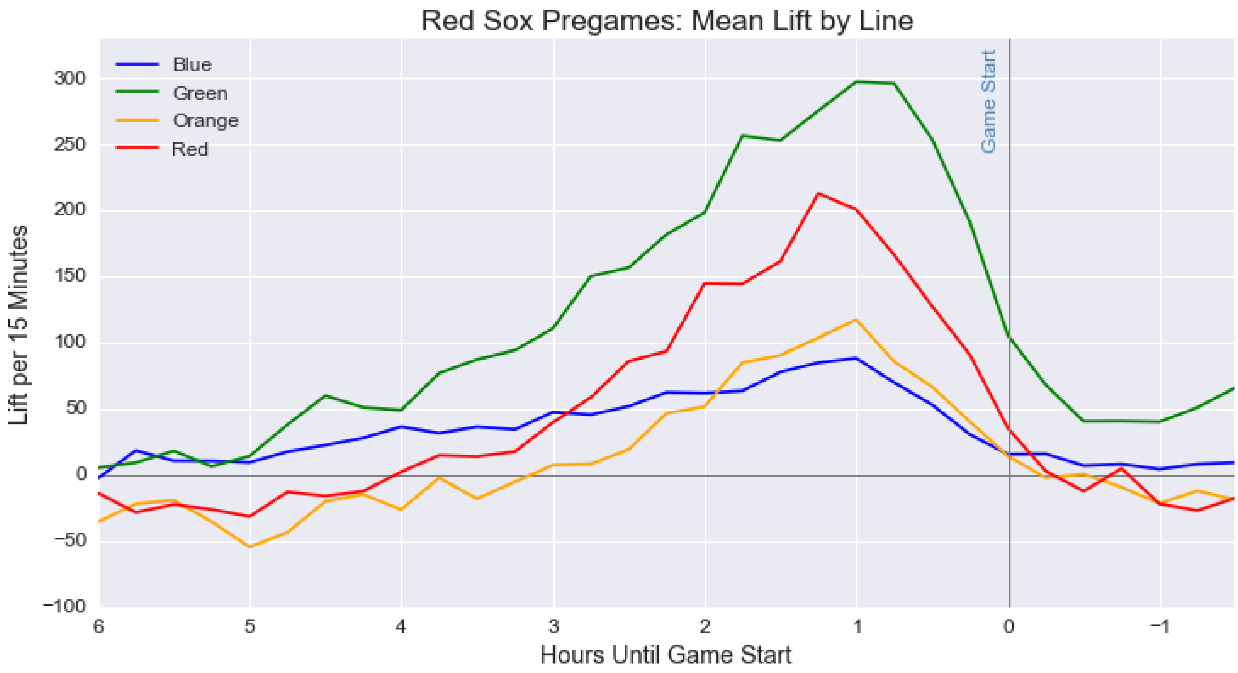




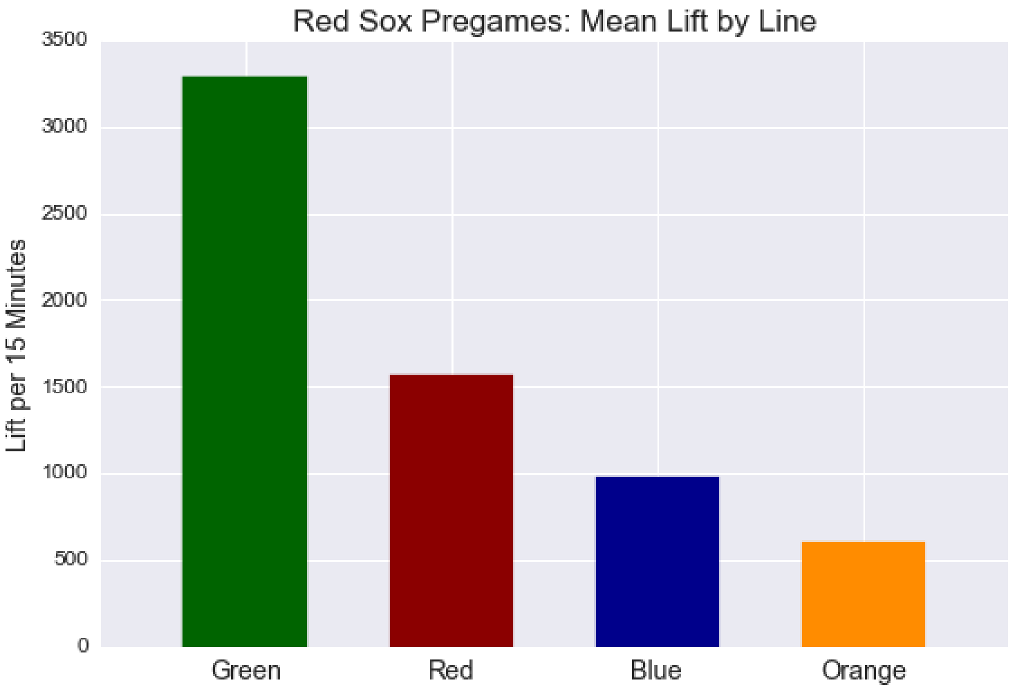
There may not be much in the way of an interesting pattern of ridership traffic by time of day, but early-day games may still be common enough that their traffic is worth understanding.

Ridership Before Sporting Events

The Boston Red Sox show ridership increases quite a while before games actually start:



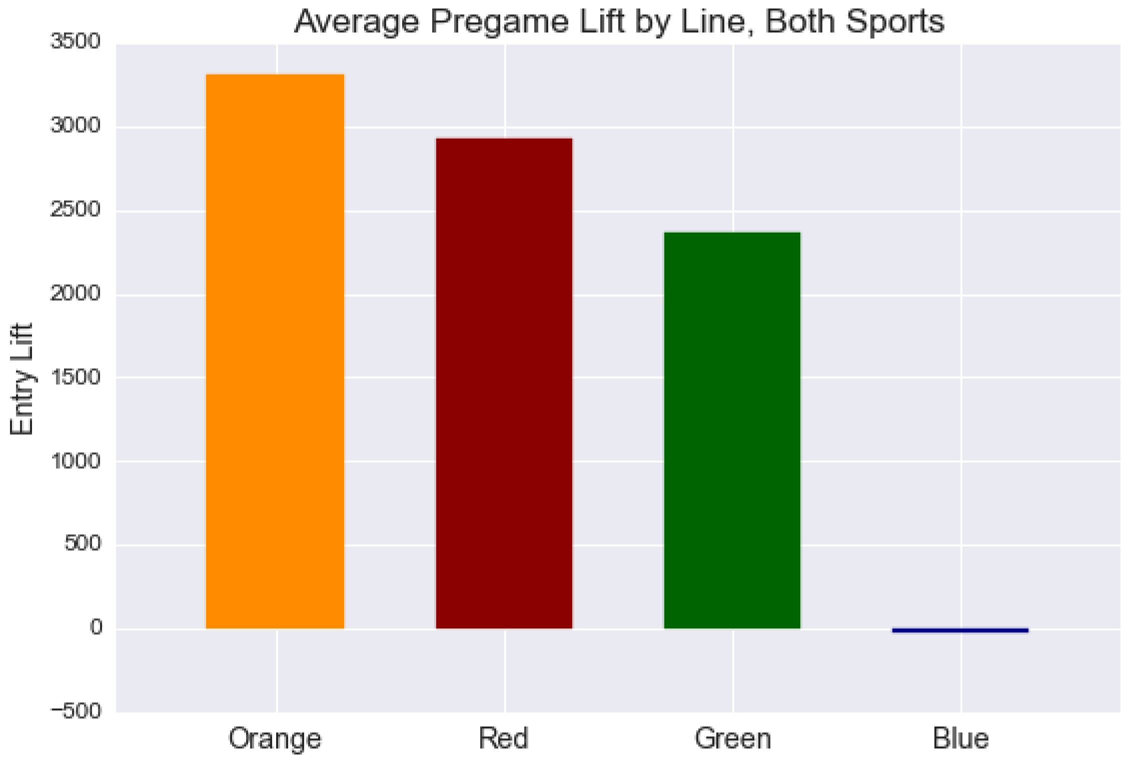
The following chart confirms the evident popularity of the Green Line:



The above chart may even understate Green Line ridership, as those who enter stations at the other lines likely transfer to the Green somewhere along the line (assuming all of these people are indeed going to the game).

Pregame lift patterns for Bruins and Celtics games (combined here for ease of analysis) also begin quite a while before games themselves:

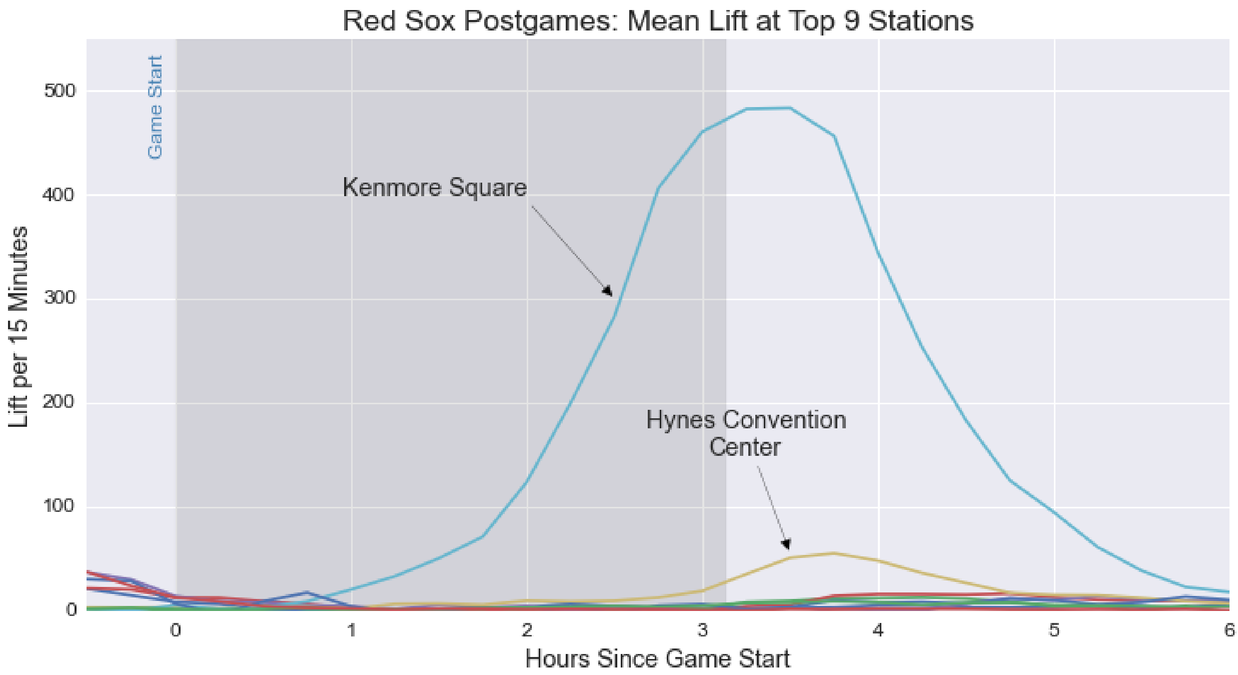
The Orange and Green lines are predictably popular (both visit North Station), but the Blue attracts few (if any) additional passengers for a typical game:



Interestingly, despite playing in a larger venue, the Red Sox appear associated with less pre-game lift than the Bruins/Celtics. This may be a function of fanbase that simply *changes* its ridership behavior rather than exclusively using MBTA services on game days; it may also result from non-game-goers being more apt to avoid crowded public transit during games.

Ridership After Sporting Events

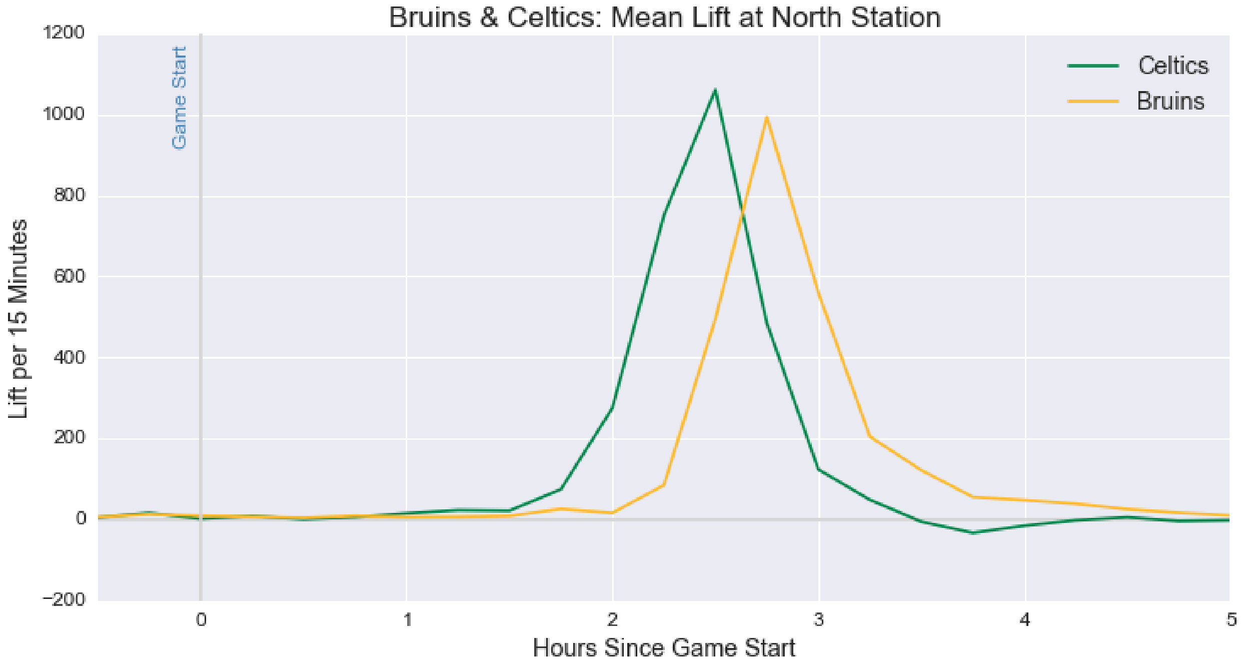
Postgame ridership increases are more moderate for both sports. Red Sox ridership peaks at two particular nearby stations:



This defied our intuition that other stations in the vicinity of Fenway Park would show a ridership boost.[2] In all, the "typical" ridership distribution is fairly spread-out. This is likely both a function of people leaving games early and the inherent time variability of baseball games.

In contrast to the Red Sox' postgame ridership pattern, the Celtics and Bruins show distinct spikes immediately following their games:

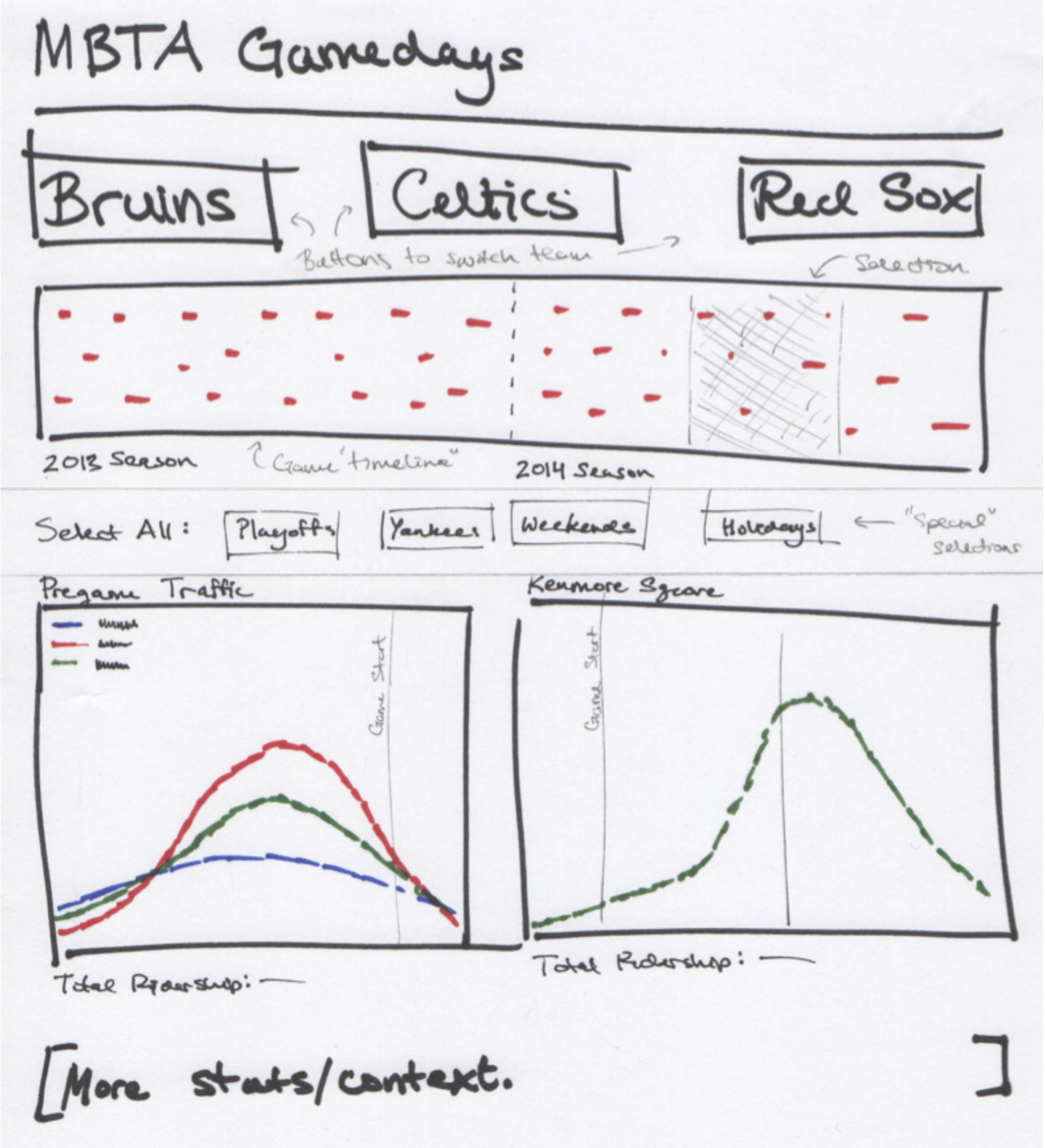
[2] Note that we have no way to detect the bulk of Green Line entrances at the Fenway Park station itself. The MBTA uses a different boarding process for which we have no data.



Note that hockey games supposedly tend to be slightly longer. It is difficult to attribute this to a particular cause, but we suspect that it occurs due to more predictable game lengths. Bruins and Celtics games also have problems measuring ridership. Particularly busy times might see a relaxation on ticket requirements—we cannot observe ridership reliably on these days. For that reason, analysis of the "shape" of the ridership distribution might be more useful than raw numbers themselves.

Design Evolution

Thus Far, our visual design has largely followed the original paper mockup that we designed as part of our project proposal. That is reproduced below for reference:



This design intended to allow users to select teams, brush over their games (divided by season) or select specific non-contiguous game groups (e.g., weekend games or games against a particular rival), and see distributions of pre-game traffic across the entire system and post-game traffic at stations around each sporting venue.

Given the geographic components of our dataset, we were interested in ways that we might display traffic across the entire MBTA system, rather than just at particular, pre-defined points in the network. We discussed this idea with another group in our design studio session and confirmed our skepticism about the value that this would add to the visualization. We plan to leave this option open but currently have no plans to pursue it.

Next Steps

We will add further details here as our design changes and solidifies over the course of development, especially with regard to user interaction and how we determine to use any leftover space at the bottom of the page.

Implementation

Technical Background

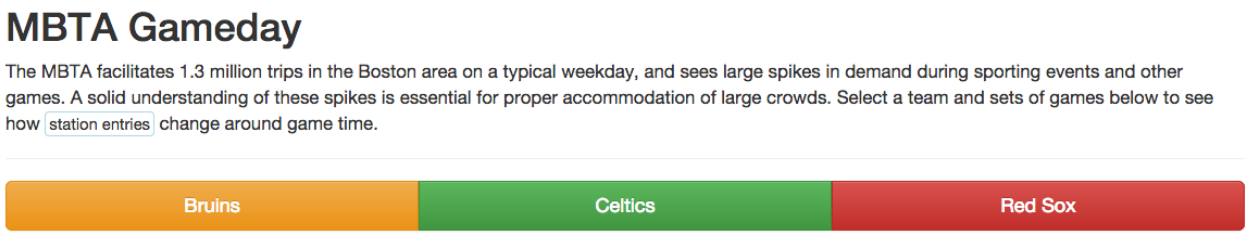
Our data processing and cleaning was performed primarily with Python. Specifically, we used Pandas to whittle down our dataset and arrange it into a format useful for visualization, and augmented that with Matplotlib/Seaborn to perform exploratory analysis and verify that our data will tell a worthwhile story.

Much like the rest of our work product in this course, our visualization is built using D3. Our visualizations are primarily “pure” D3, though we utilized Mike Bostock’s queue library to load our data. We also use jQuery in several contexts: event handling, tool tips, non-charting DOM updates, and others. Finally, we developed much of our page design using Bootstrap, and drew heavily from its set of stock elements when designing non-visualization page elements.

As stated above, we rely on jQuery bindings and triggers for event orchestration. The various components of our visualization are designed to be modular and are stored as separate Javascript files to ease collaborative development.

Page Load & Team Selection

When loading our project, the user is presented with a simple explanation of our work and given the option of selecting a particular team for visualization. This design aims to introduce the topic and make it clear that toggling among different teams will affect the data displayed below. We also include several tooltips to provide a slightly expanded introduction for unfamiliar users.



MBTA Gameday

The MBTA facilitates 1.3 million trips in the Boston area on a typical weekday, and sees large spikes in demand during sporting events and other games. A solid understanding of these spikes is essential for proper accommodation of large crowds. Select a team and sets of games below to see how station entries change around game time.

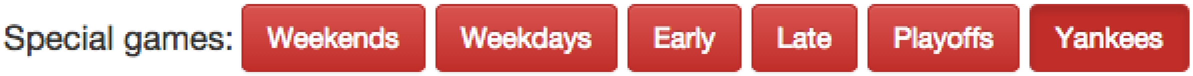
Selecting a team for the first time reveals the rest of our visualization. If a team had been selected in the past, all filters (i.e., brushes or other selections) are removed and the visual elements are updated with data for the team selected.

Game Brush

This section will be updated when the game selection mechanism is finalized.

Additional Game Filters

In addition to brushing, the user can manipulate game selections using our special filter buttons (shown below for the Red Sox):



The selection of options updates with each team selection.

Rather than defining these buttons statically, we defined them as groups of Javascript objects that are converted to DOM <button>s on page load. Each button has an associated function that can be supplied to a Javascript array filter() function, making it very easy to specify filtering rules programmatically.

Pregame Ridership Visualization

This section will be updated when the pregame traffic visualization is finalized.

Postgame Ridership Visualization

This section will be updated when the postgame traffic visualization is finalized.

Evaluation

We will add evaluatory observations here once our submission is complete.

Appendix 1: Project Proposal

For reference, our original project proposal is reproduced below.

Background & Motivation

We are members of a four-person team of Harvard students working alongside MBTA staff to analyze and better predict demand for public transportation. The primary goal of that project is a machine learning model to predict subway demand, accounting for recent past ridership, seasonal/cyclical effects, and sporadic events like severe weather and major events. When building these models, we realized that sporting events in particular precipitate acute changes in demand that we can detect at key stations before and after games.

We wish to use our insight about sporting events (Bruins, Celtics, and Red Sox games in particular) to visualize MBTA traffic flow by line and station (for stations proximate to venues) before and after games. We will allow users to intuitively select sets of games—likely by brushing and providing filters for non-contiguous games (e.g., weekend games) or particularly interesting sets of games (playoff games in particular). Beyond visualizing the specific games selected, we will provide useful visual comparisons to other events (so that users can detect notable games) and to days without games.

Note that our work with the MBTA is part of our capstone course (AC 297r), but this project is *not* a required component of that work.

Project Objectives

As suggested above, our primary objective is to help users understand how MBTA traffic changes before, during, and after major sporting events. Fans travel to games from different parts of the city and surrounding area (in the latter case, they often travel from far-flung T stations like Riverside and Alewife). They might come early or stay late in order to spend time in the surrounding neighborhood, and they might change in number or behavior for special games—say, for Patriot's Day or a late-season series against the Yankees.

Beyond simple entertainment, planners might find this tool useful for anticipating large crowds or timing shifts and train runs to best accommodate swells of riders along specific lines. For this reason, we hope to add a measure of precision to our interface, reporting relevant statistical observations with our pretty pictures. We have found these traffic patterns quite difficult to analyze, and we will consider our project a success if it is not only aesthetically pleasing, but useful as well.

Data

There are two important data sources that we will use: MBTA traffic data and sports schedules.

We have MBTA traffic data going back to 2013. It shows entries (and exits) for every subway station and above-ground Green Line route in 15-minute increments. Some example raw data for April 1 of last year:

locationid	servicedate	servicetime	entries	exits
1002	2014-04-01	500	5	1
1002	2014-04-01	515	81	8
1002	2014-04-01	530	60	15
1002	2014-04-01	545	68	13
1002	2014-04-01	600	90	15
1002	2014-04-01	615	135	23
1002	2014-04-01	630	121	17
1002	2014-04-01	645	90	26
1002	2014-04-01	700	117	11

We also have useful metadata with information about each station, including the lines that each station serves and latitude/longitude measurements for geographic plotting (should we decide to use it).

Additionally, we have sports schedules for Bruins, Celtics, and Red Sox home games since 2013. All were manually scraped from ESPN schedule listings. A few example rows for Boston Bruins games in 2014:

Datetime	Playoff	Opponent
2013-01-19 19:00	0	NY Rangers
2013-01-21 13:00	0	Winnipeg
2013-01-25 19:00	0	NY Islanders
2013-01-29 19:00	0	New Jersey

```
2013-01-31 19:00           0     Buffalo
2013-02-12 19:30           0     NY Rangers
2013-02-28 19:00           0     Ottawa
2013-03-02 13:00           0     Tampa Bay
2013-03-03 19:30           0     Montreal
```

We hope that opponents may prove to be an interesting dimension for analysis. Fan reactions to the Yankees' or Canadiens' arrivals may cause particularly interesting traffic patterns to emerge.

At this point, the only thing missing from our dataset is Red Sox playoff games. We expect that those will be easy to retrieve manually.

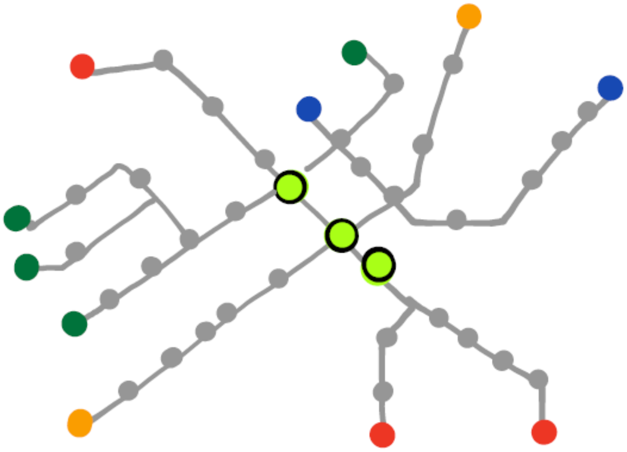
Data Processing

All of our data is very clean and low-dimensional, so we do not expect to have to contend with serious cleanliness or missing data issues. However, our MBTA is granular and voluminous—it spans several hundred megabytes and billions of individual records—it is wholly unsuitable for web visualization in its raw form. For visualization, we will have to summarize it into a compact form that still retains information pertinent to our display.

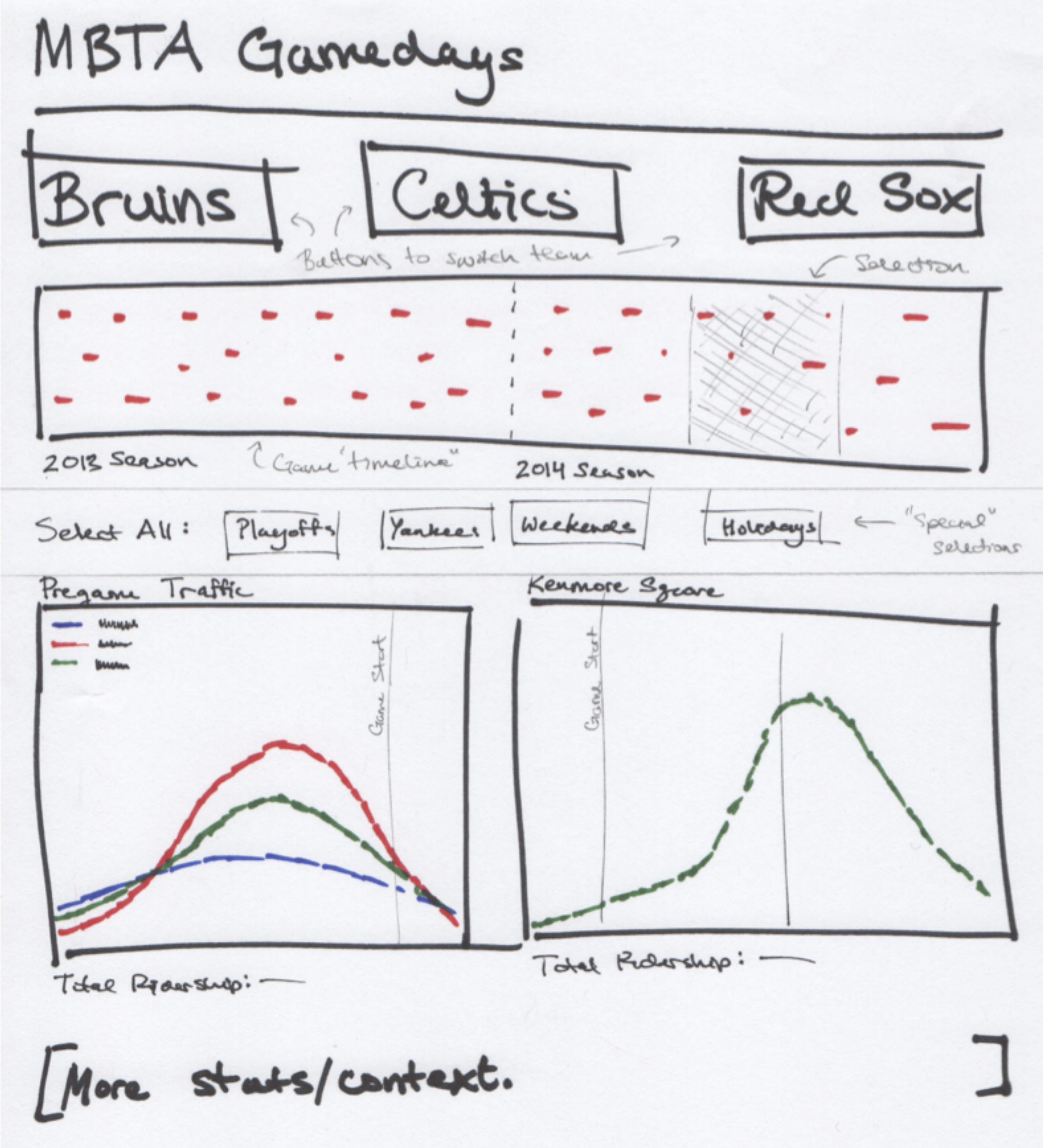
Having spent some time working with the data, we expect to be able to summarize game day traffic by line (for pre-game visualization) and by stations close to Fenway Park and TD Garden Arena (for post-game visualization). We can incorporate comparisons to average traffic in those calculations and avoid including that data in our final deliverable. This way, we can essentially "throw away" data irrelevant to gamedays themselves. Back-of-the-envelope calculations suggest that this will yield observations in the thousands—not a small amount, but an amount suitable for visualization.

Visualization

The selection of rail lines and stations could be done by providing a map representation of the MBTA rail system with the ability of selecting single or multiple stations or full lines:



The basic workflow will include a method for selecting the type of game (Bruins, Celtics, Red Sox) and the game(s) of interest. The game schedule can be displayed in a time frame indicating date/season on the horizontal axis and game start time on the vertical axis. The user can select a single game of interest or multiple ones by brushing. A different way of selecting groups of games for analysis is by selecting predefined filters including interesting sub-selections of game types such as playoffs, weekend games, and holidays. An additional grouping based on opponent will also be available. Visualizations of pre-game and post-game MBTA entries based on all selections and relevant statistics will provide a way of examining and understanding traffic trends.



Must-Have Features

In order to realize our project objective, several important features will need to be included in our final product as outlined below:

- Method for viewing and selecting specific rail station(s) of interest
- Method for viewing and selecting specific rail line(s) of interest
- View of game dates (schedule) for each type of sporting event (Bruins, Celtics, Red Sox games) including opponent information
- Method for selecting game or set of games in time range of interest
- Visualization of pre-game traffic by station or line for selected games

· Visualization of post-game traffic at stations near the sporting event for the selected games

Additional components of the traffic visualizations include:

- o Indicator of starting/ending time of the sporting event taking place where appropriate
- o Comparison of average traffic to game day traffic

Optional Features

After observing some final projects from last year, we realized that it might be interesting to add a "narrative" element to the visualization that highlights notable events that precipitated interesting demand patterns. But we do not yet know what those events might be (but using our visualization might help us find them!), so we do not know if such a feature would be valuable.

We also hope to make use of live updating as much as possible (e.g., charts will transform depending on brush extents). However, due to data volume this might not be possible to do elegantly. We will have to determine feasibility once we have a better handle on our data.

Project Schedule

Week of April 6:

- Gather final missing data (Red Sox playoff dates).
- Solidify main visualization page components.
- Begin page design and component layout.
- Summarize game day traffic for all games.

Week of April 13 (includes Milestone 1):

- Implement basic visualization framework, primary page elements (charts of traffic by line, traffic at nearby stations).
- Improve cosmetic appearance of visualization.

Week of April 20:

- Add ancillary interactions (hovering effects, additional contextual information).
- Add additional metrics and visual elements depending on fit with elements developed. These may include histograms, confidence intervals, summary statistics, etc.

Week of April 27:

- Polish visualization appearance (typography, artwork, colors, etc.).
- Potentially: add narrative page elements.

Week of May 4: By this point, we only anticipate minor polishing work before final submission.