



Transforming Geospatial Data for Visualization with D3

FOSS4G — Boston
August 17, 2017

Beatrice Jin and Benjamin Krepp

Boston Region Metropolitan Planning Organization

Agenda

- **Who we are**
- **Project context**
- **Implementation vehicle**
- **Overview of dashboard data**
- **Presentation of linear data**
- **Conclusion**
- **Q&A**

Who We Are

- **Metropolitan Planning Organizations (MPOs)**
- **Boston Region MPO**
- **Central Transportation Planning Staff (CTPS)**



Metropolitan Planning Organizations

- Federally mandated and federally funded transportation planning agencies
- Introduced by Federal-Aid Highway Act of 1962
- Required for all U.S. urbanized areas with populations greater than 50,000



BOSTON REGION METROPOLITAN PLANNING ORGANIZATION



Boston Region MPO

- **Geographic scope**
 - 101 municipalities in the Boston metro area
 - Boundary roughly defined by I-495
- **Membership**
 - MassDOT, MBTA, MBTA Advisory Board, Massport, MAPC, RTAC, 6 cities, 7 towns
 - FHWA, FTA (non-voting)



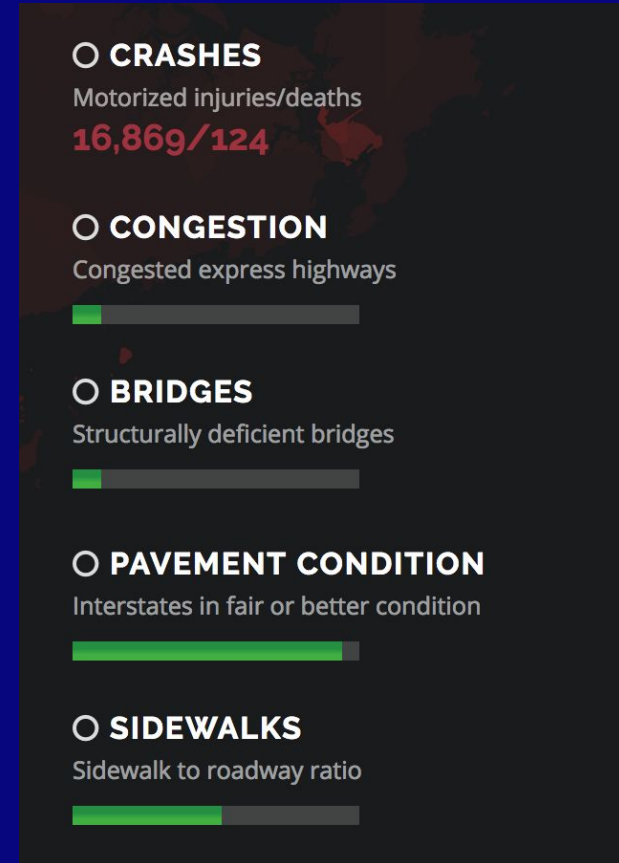
Central Transportation Planning Staff

- **Staff to the Boston Region MPO**
- **Expertise in comprehensive, multimodal transportation planning and analysis**
- **In-house dedicated GIS, data-development and software group**



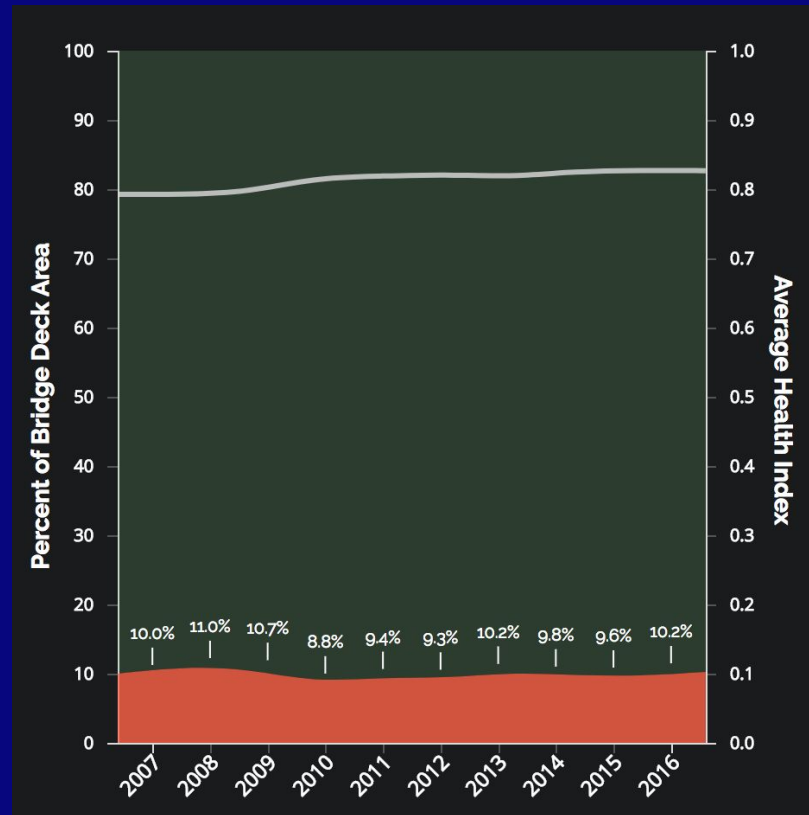
Project Context

- Federal mandate for performance-based planning
- Define performance metrics
- Set goals
- Collect data
- Track and report progress



The Performance Dashboard

- Fulfill federal requirements
- Present data to the public on the web
- Accurate, navigable, interactive presentation



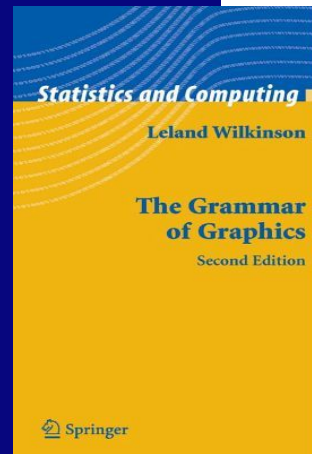
Implementation Vehicle: D3.js

- **D3 = Data-driven documents**
- **JavaScript library**
- **Developed by Mike Bostock at Stanford visualization lab**
- **First released in 2011**
- **Free / open-source**



Transformation, Not Representation

- A web page is a data structure
- Transform it, based on user data
 - Structure
 - Appearance
 - Behavior
- Foundation: *The Grammar of Graphics*



A LAYERED GRAMMAR OF GRAPHICS 19

Iteratively reproducing the depiction of Napoleon's March by Minard. (Top) Displaying the key point data. (Center) Adding town locations as reference points. (Bottom) Tweaking scales to produce a final visualization.

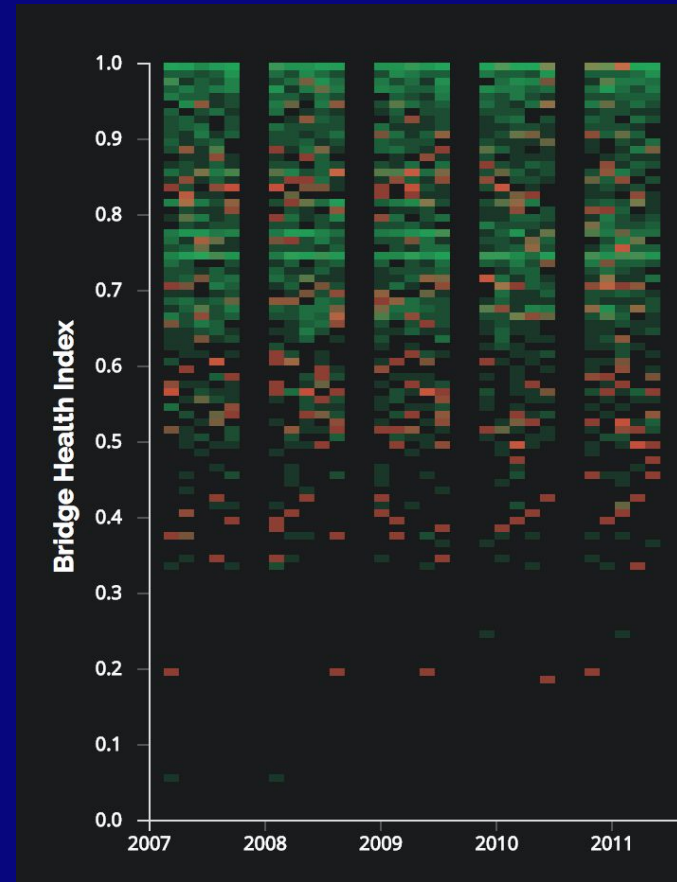
...rudimentary tools for importing, restructuring, transforming, and aggregating. Relying on other tools in R, `ggplot2` does not need three elements of Wilkinson's DATA, TRANS, and the algebra.

...is no longer needed because data are stored as R data frames; they do not need to be described as part of the graphic. TRANS can be dropped because variable transformation is already so easy in R; they do not need to be part of the grammar. The algebra describing how to reshape data for display and, in R, can be replaced by the `reshape` package (Wickham 2005). Separating data manipulation from visualization allows you to reuse the same data, and the same restructuring can be used in multiple plots. Additionally, the `ggplot2` does not easily perform aggregation or subsetting, but `reshape` can.

...advantages of embedding the grammar are somewhat more subtle, and center on the grammatical restrictions applied by the host language. One of the most important features of the grammar is its declarative nature. To preserve this nature in R, `ggplot2` uses `+` to create a plot by adding pieces of the definition together. The `ggplot` function creates a base object, to which everything else is added. This base object is not necessary in a stand-alone grammar.

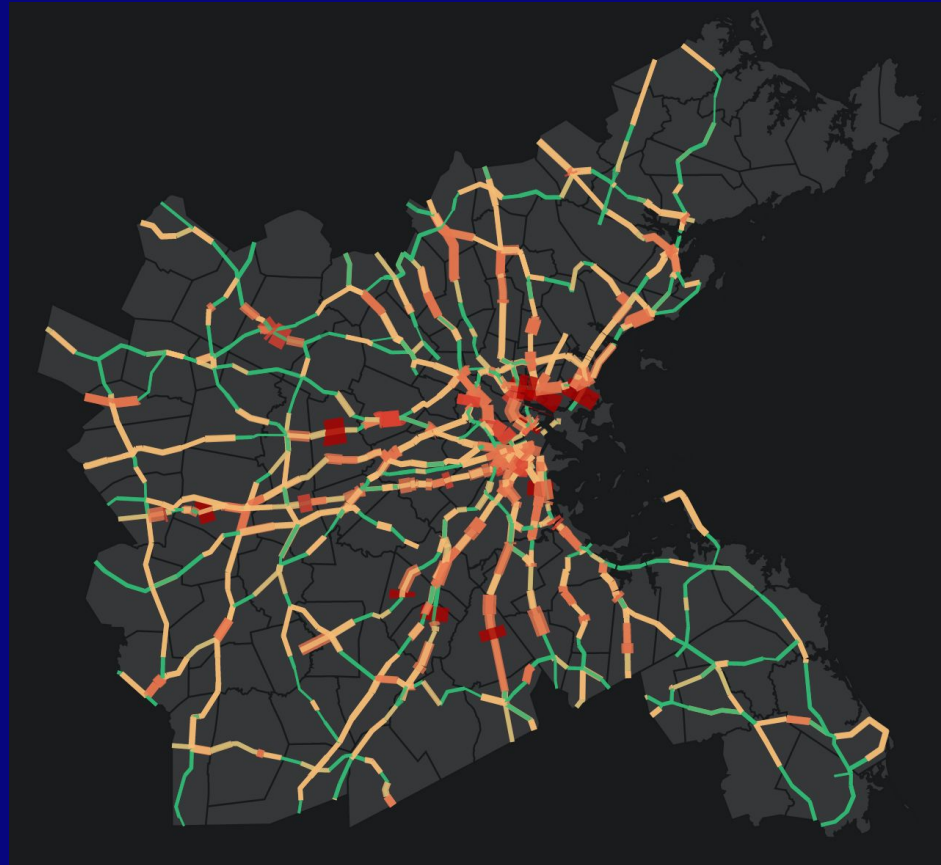
Dashboard Data

- **Tabular**
 - Census demographics
 - Crash count per town
- **Geospatial**
 - Point – crash location
 - Data is confidential
 - Line – roads
 - Polygon – town- and census-boundaries



Linear Geospatial Data

- Pavement condition
- Congestion
- Sidewalk coverage
- Bicycle facilities



Data Sources

- **Pavement condition, sidewalk coverage**
 - Annual MassDOT Road Inventory
- **Congestion**
 - INRIX speed-run data processed by CTPS
- **Bicycle facilities**
 - MassDOT Bicycle Accommodation Inventory
 - MAPC Bicycle and Pedestrian Mapping Index

Source Data Formats

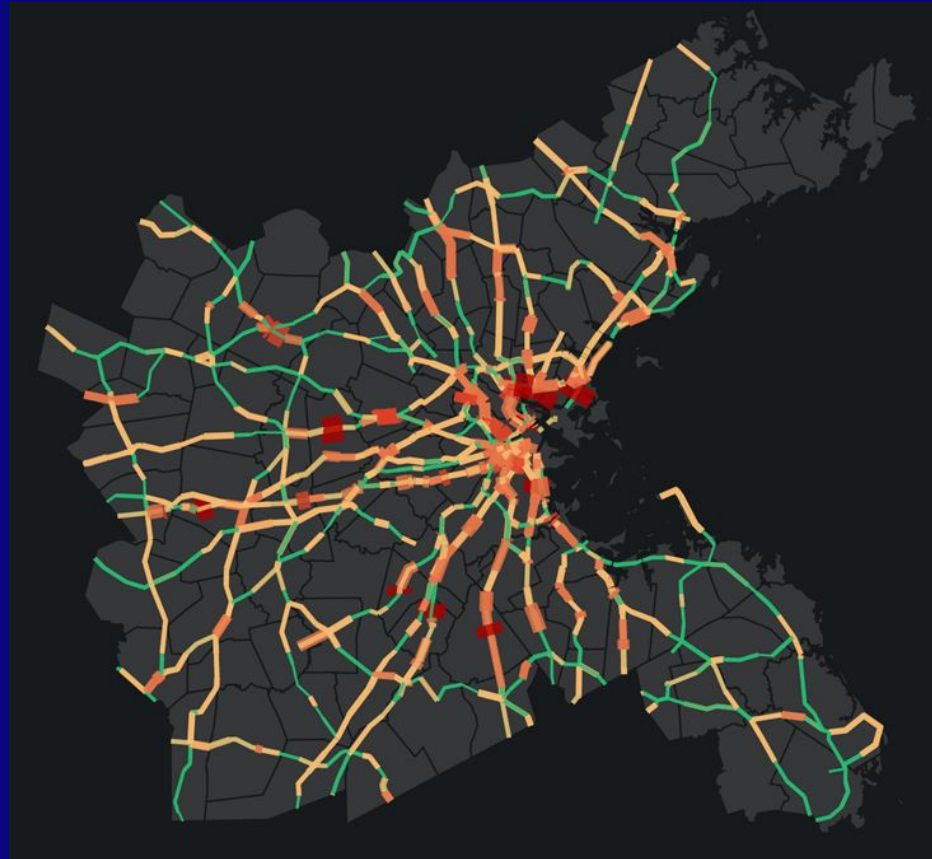
- **Pavement, sidewalks, congestion**
 - ArcSDE feature classes
- **Bicycle facilities**
 - Shapefile
 - ArcSDE feature class
- **Source data exported to GeoJSON format**
 - ogr2ogr, esri-to-open

Linear Data

- **Linear transformation**
- ***Non-linear* transformation**

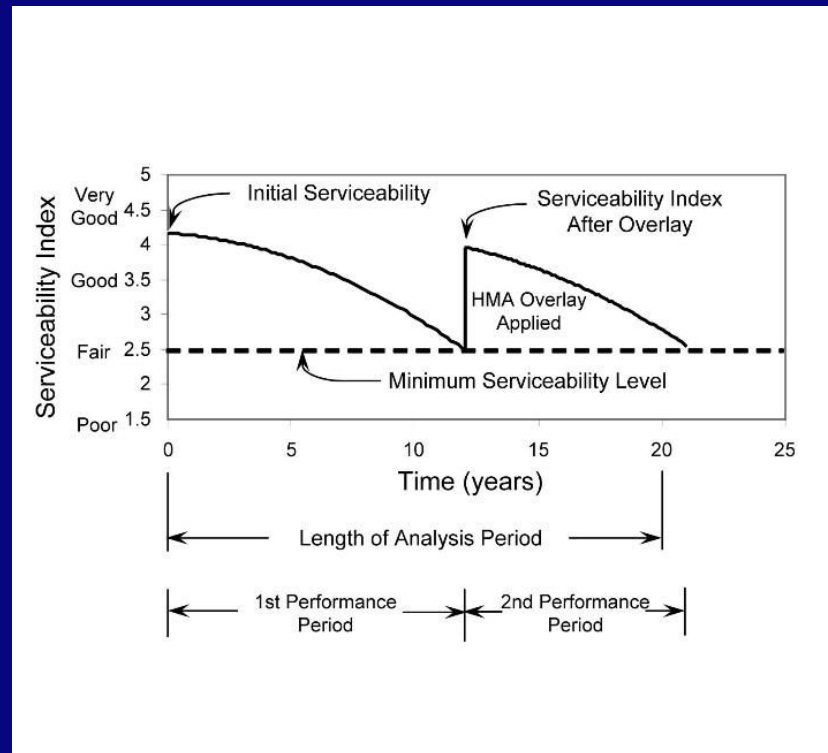
Linear Transformation

- Pavement condition
- Congestion



Pavement Condition

- Metric: **Present Serviceability Index (PSI)**
- PSI is a measure of a road's roughness
 - 5 → Excellent
 - 0 → Poor

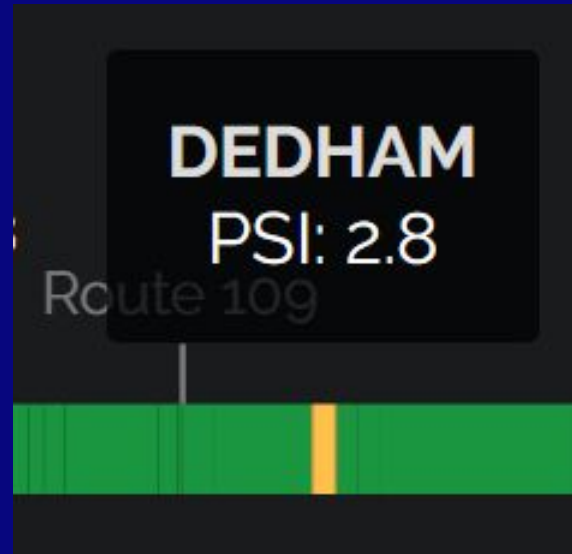


Sample Road Inventory Record (GeoJSON Format)

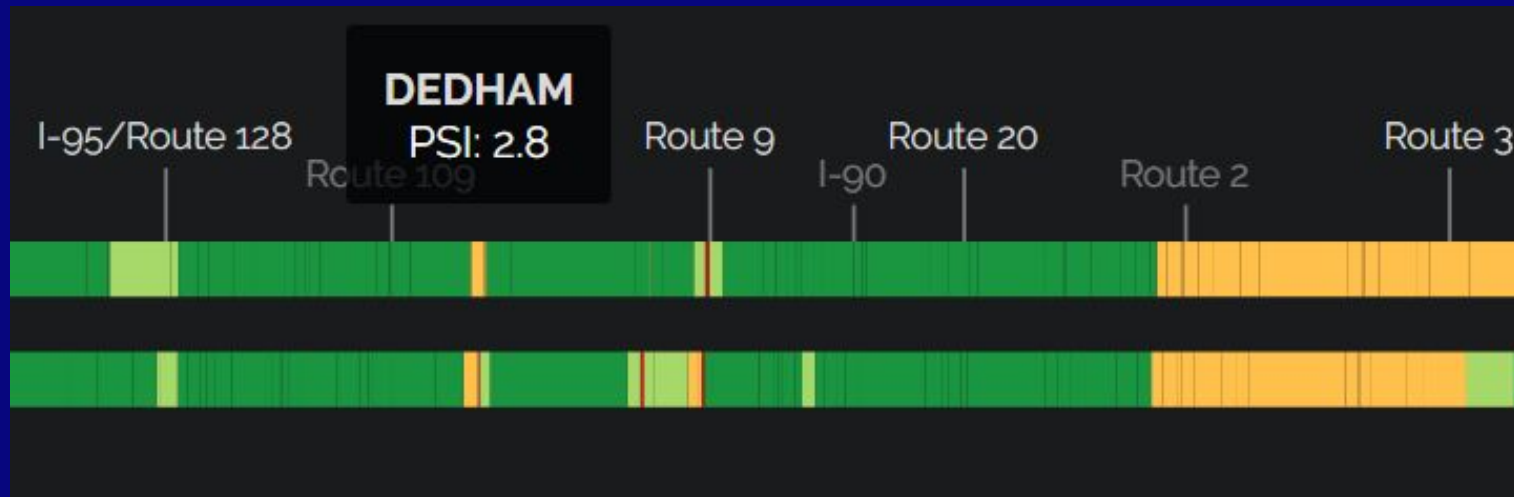
```
{  
  "coordinates": [[-71.22469420065103,  
    42.30296805460002], [-71.22474753776642,  
    42.30307874118052]]},  
  "type": "Feature",  
  "id": 1,  
  "properties": {  
    "ROUTESYSTEM": "I",  
    "MILEAGECOUNTED": 1,  
    "SURFACETYPE": 6,  
    "IRIYEAR": 2013,  
    "TOMEASURE": 0.02,  
    "FEDERALFUNCTIONALCLASS": 1,  
    "ROUTETO": 35.555800000000005,  
    "NUMBEROFPEAKHOURLANES": 4,  
    "TRUCKNETWORK": 1,  
    "RPA": "MAPC",  
    "ROUTEDIRECTION": "NB",  
    "ASSIGNEDLENGTH": 0.02,  
    "FUNCTIONALCLASSIFICATION": 1,  
    "ROUTEKEY": "I95 NB",  
    "ROUTETYPE": 1,  
    "ROADINVENTORY_ID": 26246800,  
    "PSIYEAR": 2013,
```

```
    "ADTDERIVATION": 1,  
    "ADT": 169398,  
    "JURISDICTION": "1",  
    "COUNTY": "K",  
    "IRI": 124,  
    "ROUTENUMBER": "95",  
    "FACILITYTYPE": 1,  
    "MHS": 0,  
    "CITY": 199,  
    "FROMMEASURE": 0.0,  
    "PSI": 2.88707553,  
    "ROUTEFROM": 35.5477,  
    "ROADSEGMENT_ID": 262468,  
    "NUMBEROFTRAVELLANES": 3,  
    "STRUCTURALCONDITION": 2,  
    "TRUCKROUTE": 1,  
    "FEDERALAIDROUTENUMBER": "I-95",  
    "ADTYEAR": 2013,  
    "MPO": "Boston Region",  
    "SPEEDLIMIT": 55,  
    "NHSSTATUS": 1,  
    "STREETNAME": "YANKEE DIVISION  
    HIGHWAY"]}
```

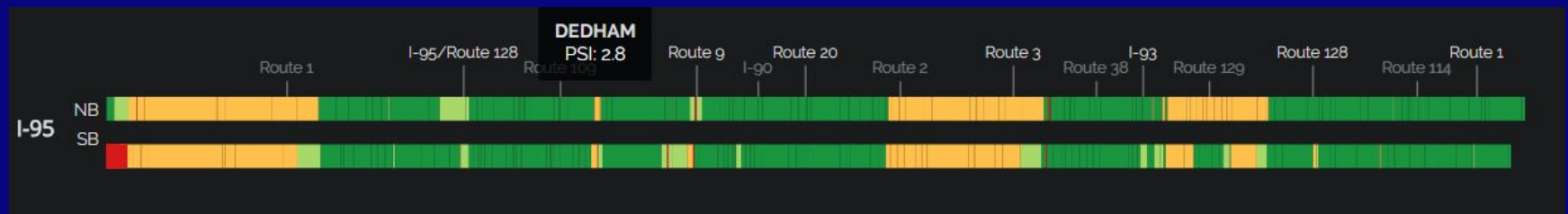
One Road Segment



One Road Segment in Local Context



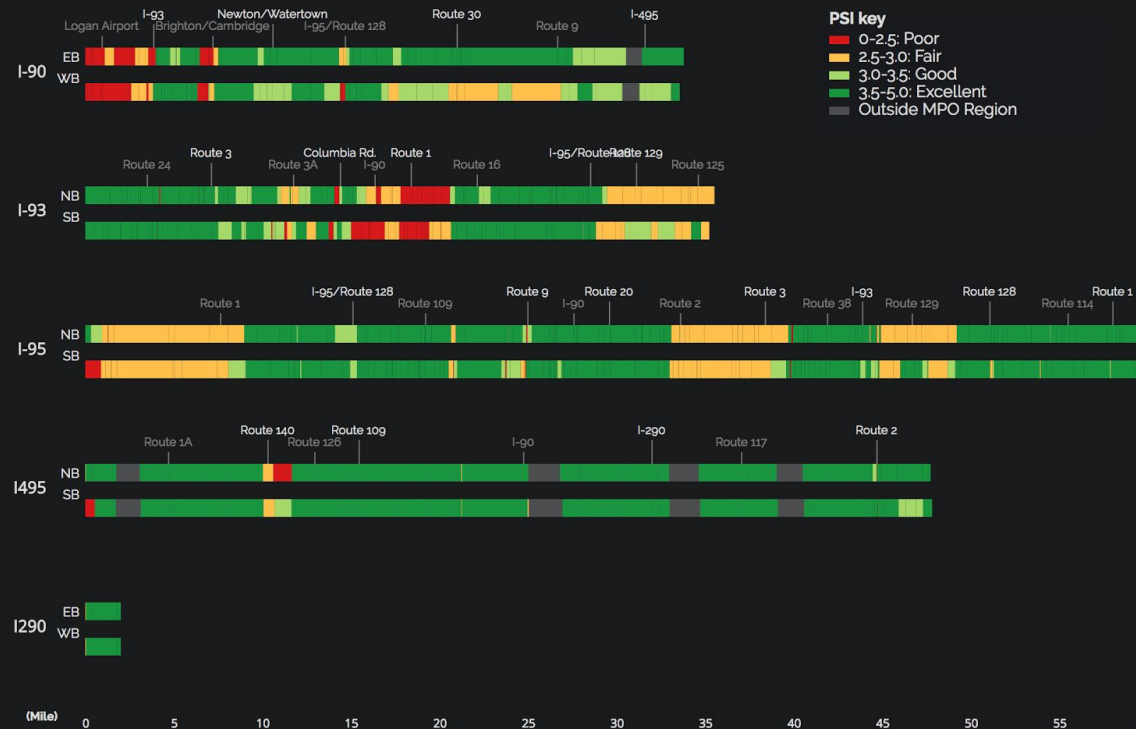
In the Context of an Entire Route



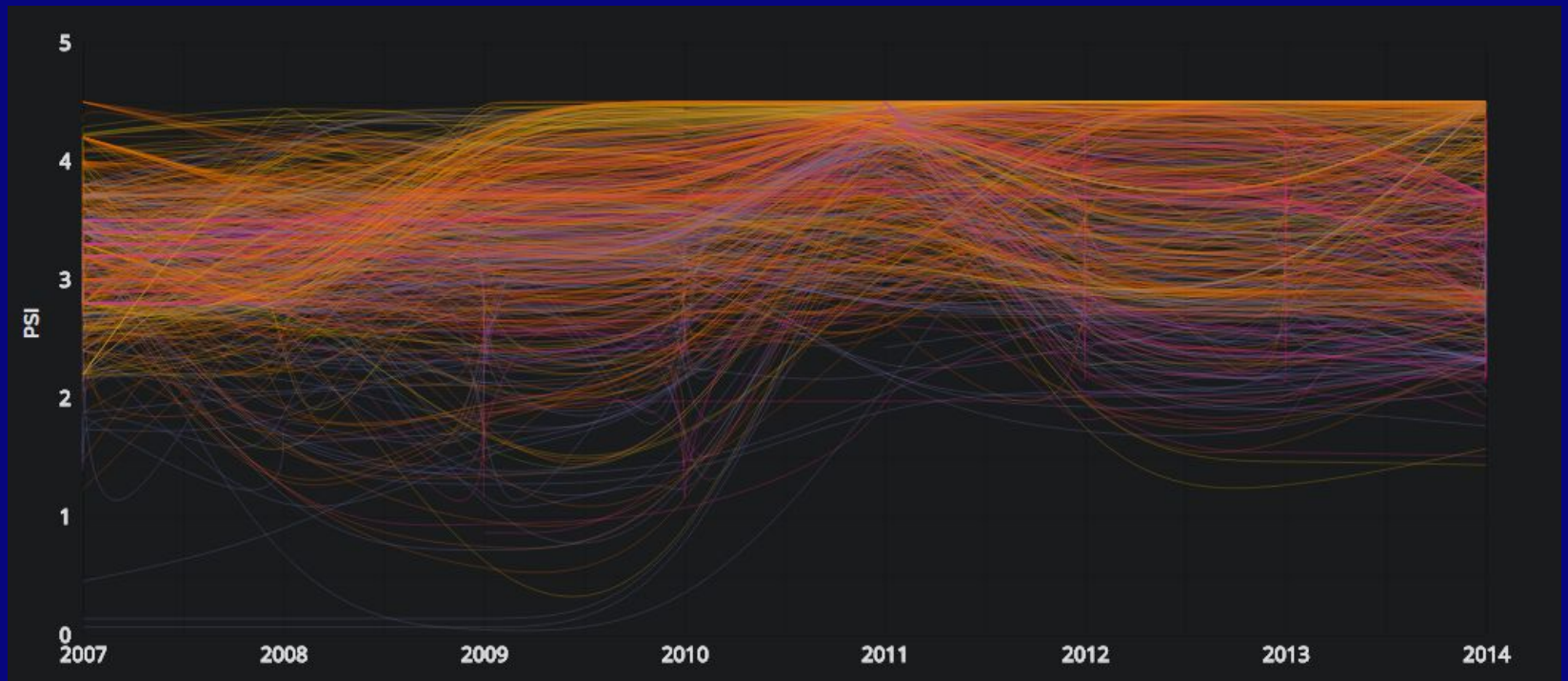
In the Context of the Regional Express Highway System

Pavement Conditions in 2014

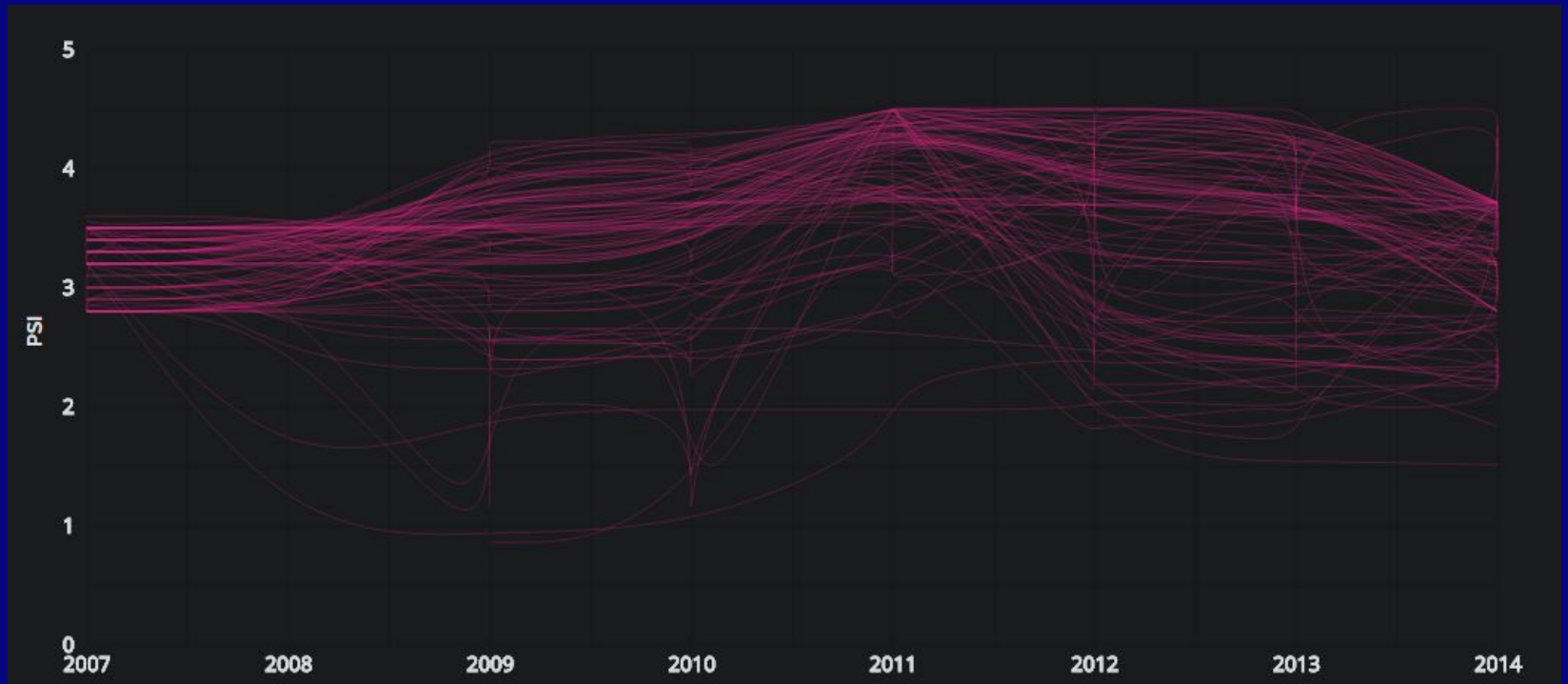
Hover over the bars below to see the pavement condition of the five interstate highways in the Boston region, as of 2014. Conditions are displayed going north southbound, or eastbound and westbound, as appropriate for each highway.



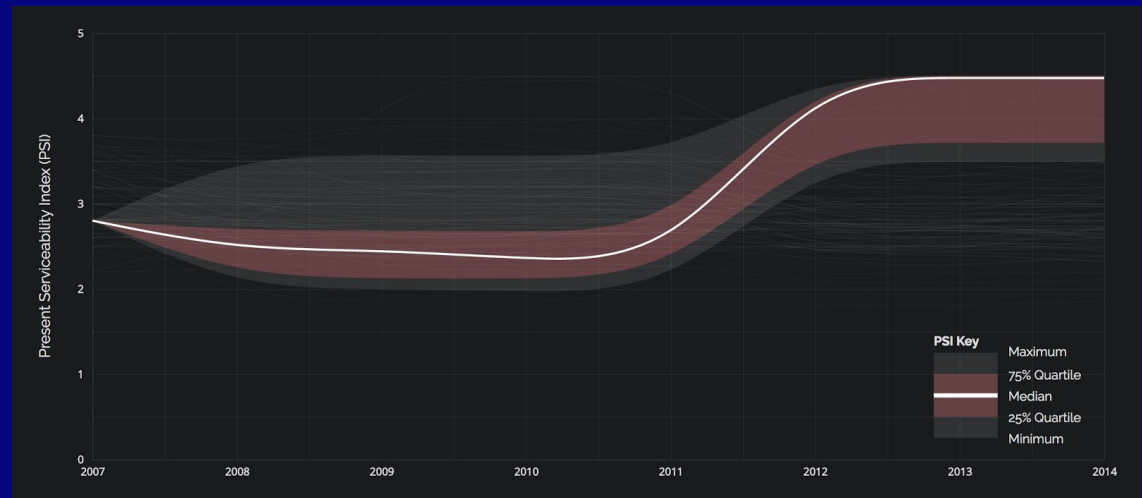
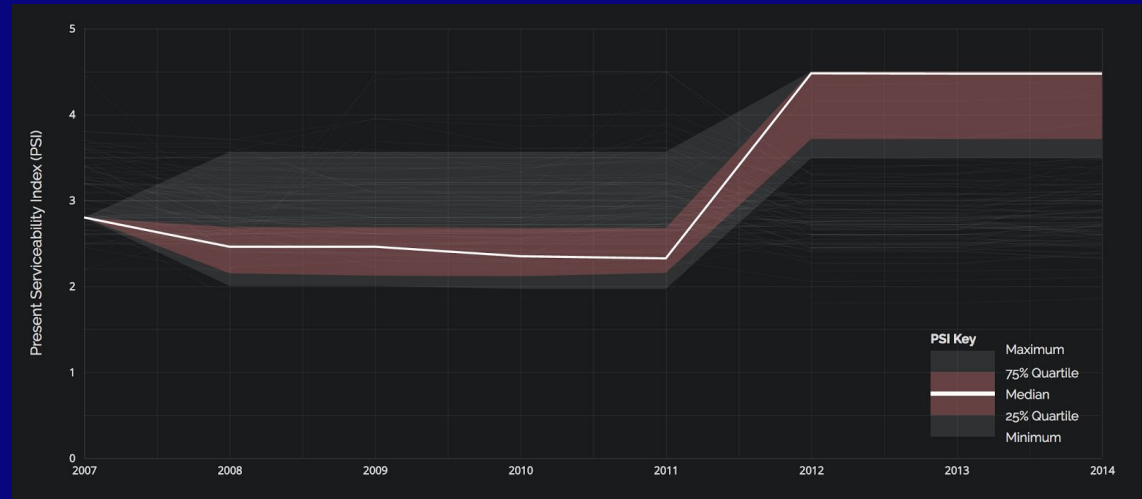
Temporal PSI Overview – All Interstates



Temporal PSI Overview – I-90



D3's curveBasis
smooths
discrete
data points



Congestion

Metric: Speed Index (SI)

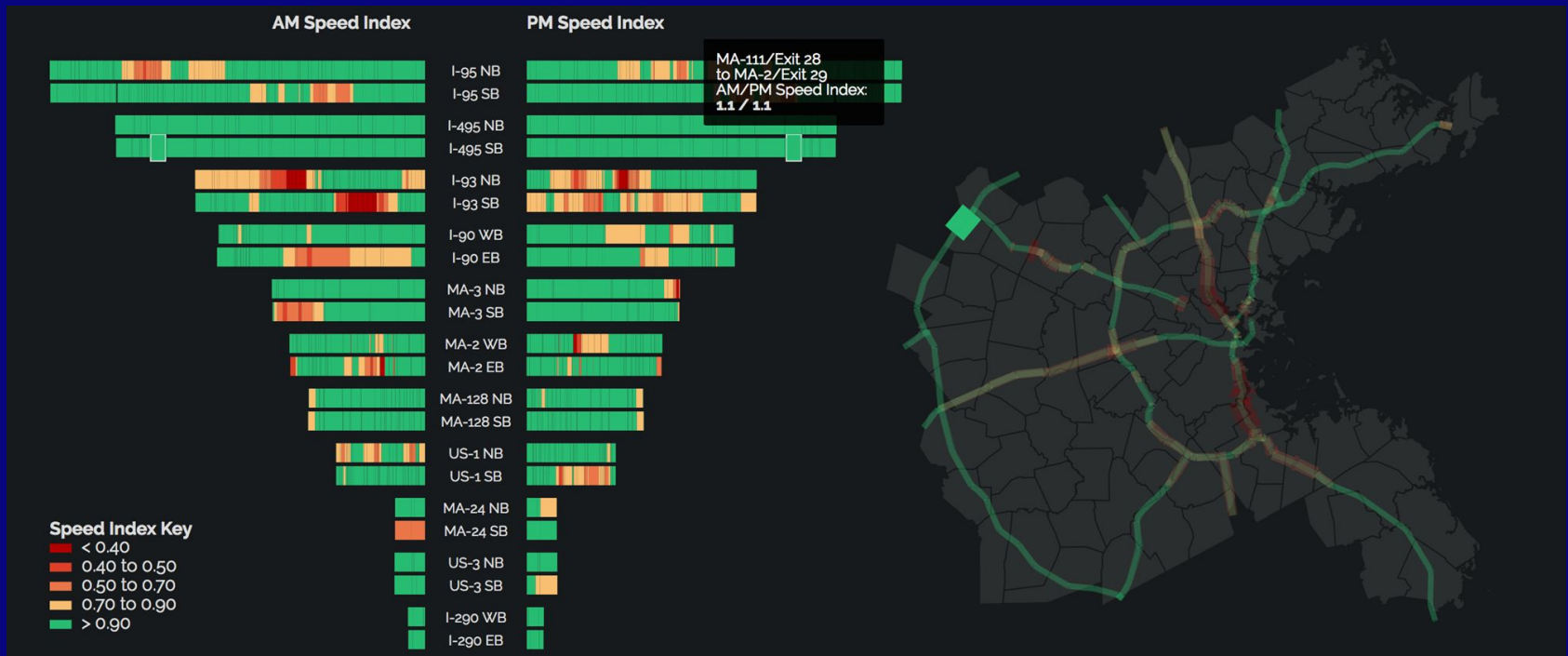
$$SI = \frac{\textit{observed speed}}{\textit{posted speed limit}}$$



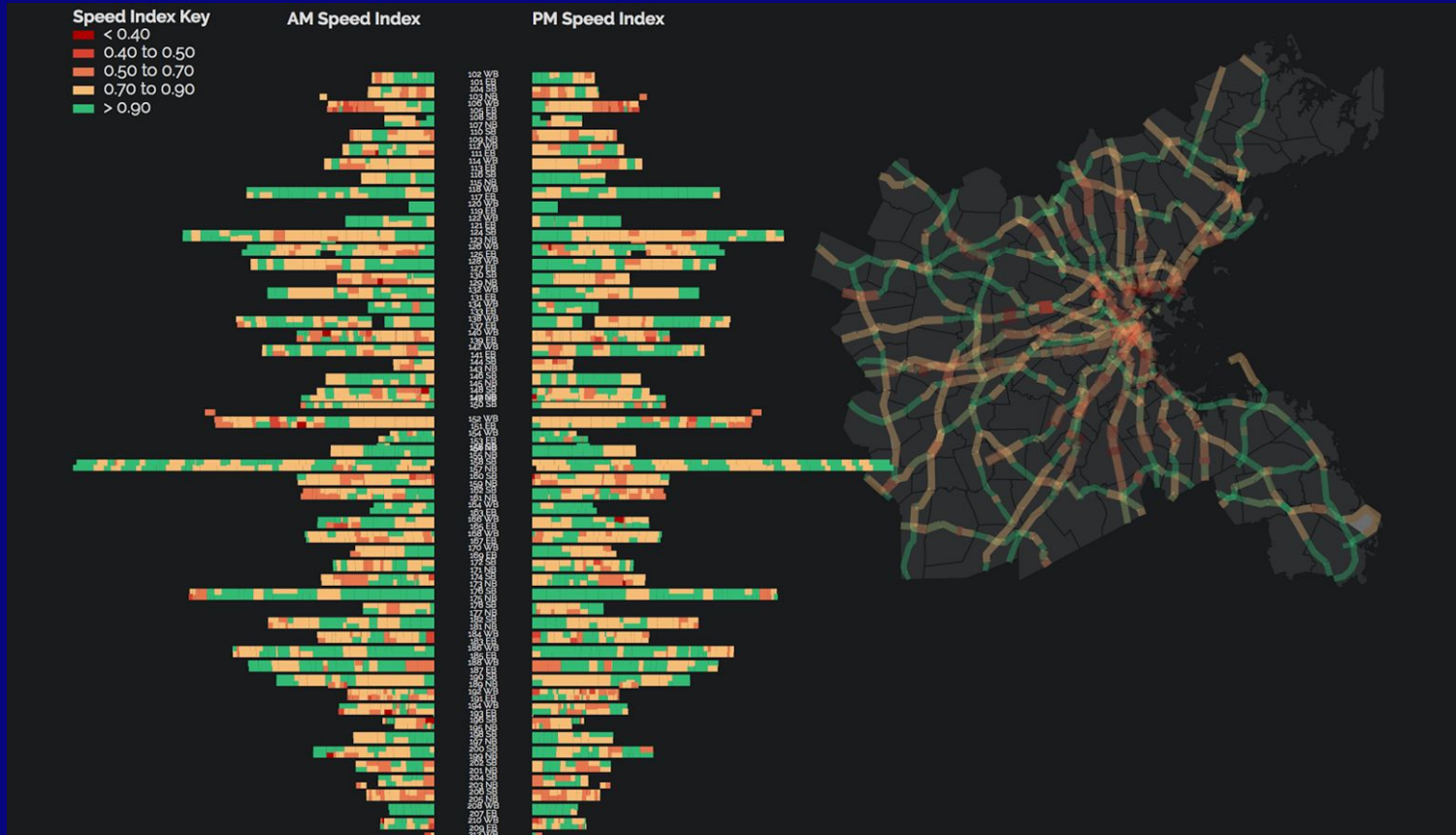
Sample Congestion Data Record (GeoJSON Format)

```
{  
  "type": "LineString",  
  "id": 8,  
  "properties": {  
    "SPD_LIMIT": 30,  
    "TO_MEAS": 11478.2641,  
    "FROM_MEAS": 10704.506300000001,  
    "ROAD_NAME": "NULL",  
    "DIRECTION": "Westbound",  
    "AM_SPD_IX": 1.2600923,  
    "SEG_END": "Toll Plaza/Exit 18",  
    "PM_SPD_IX": 0.98233948,  
    "RID": 6,  
    "ROUTE_NUM": "I-90",  
    "SEG_BEGIN": "Toll Plaza/Exit 20"},  
  "arcs": [1]}  
}
```

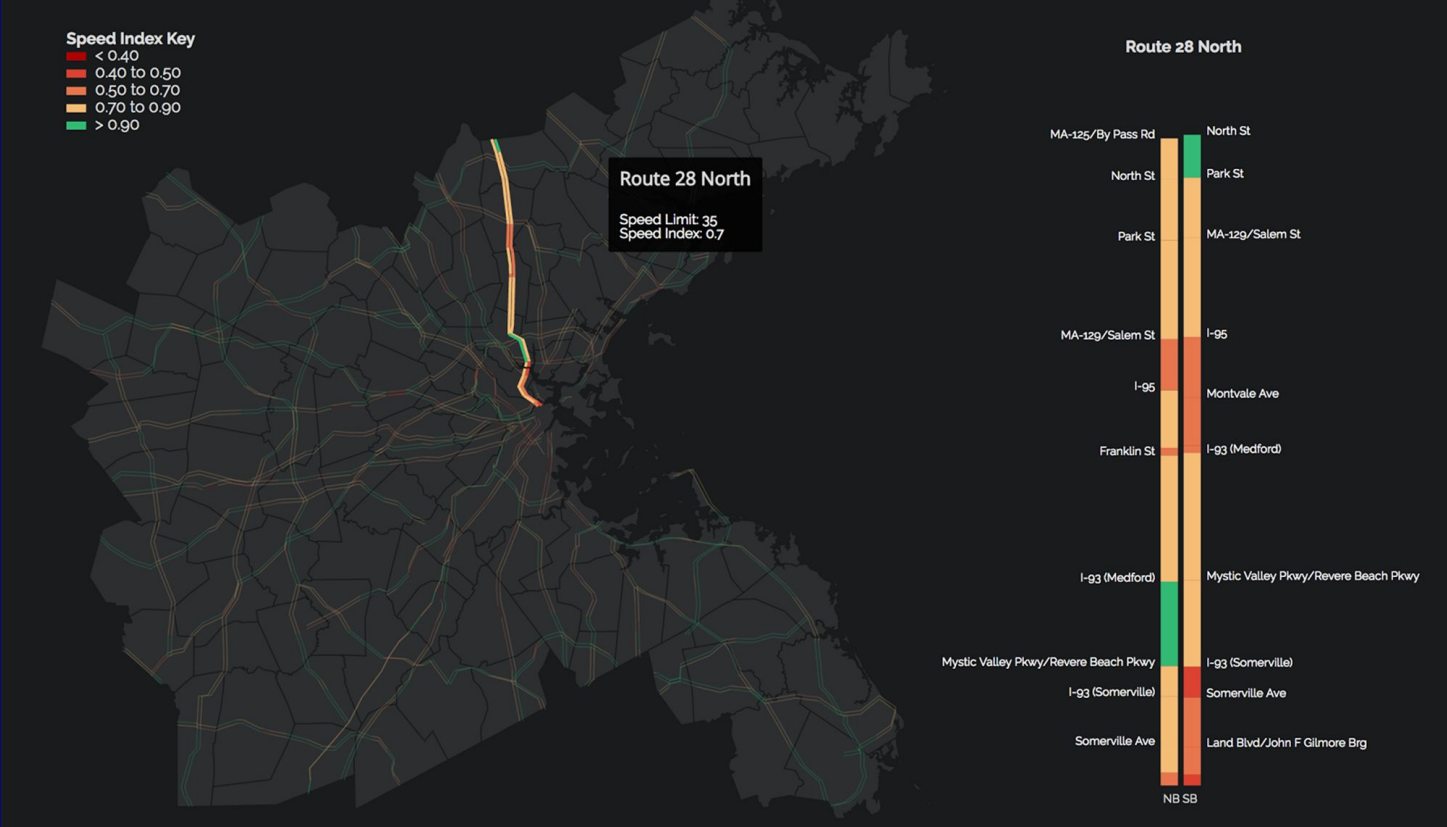
Speed Index: Express Highways



Speed Index: Arterial Routes

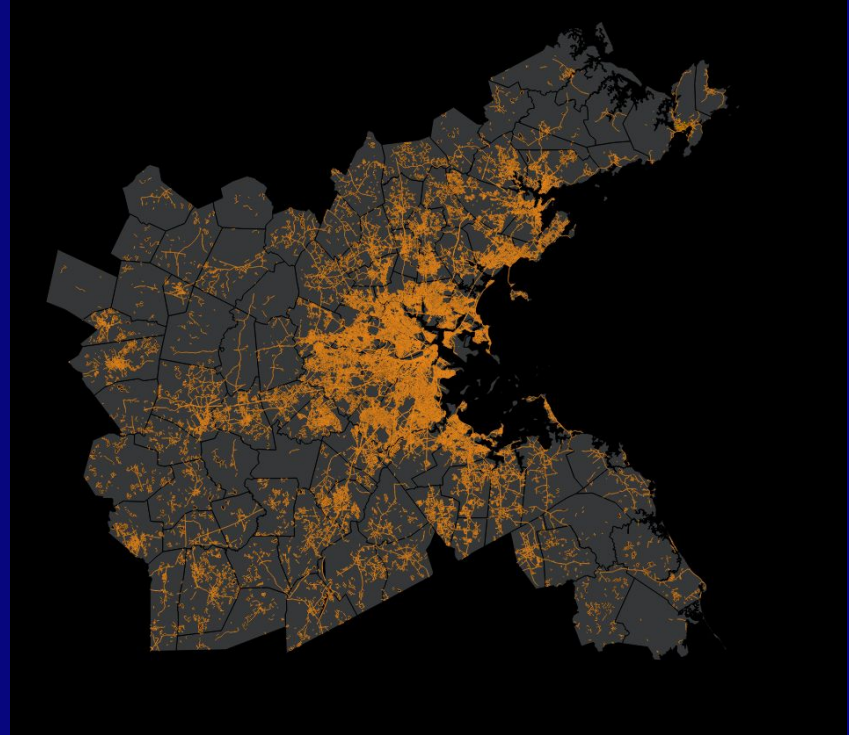


Speed Index: One Arterial Route



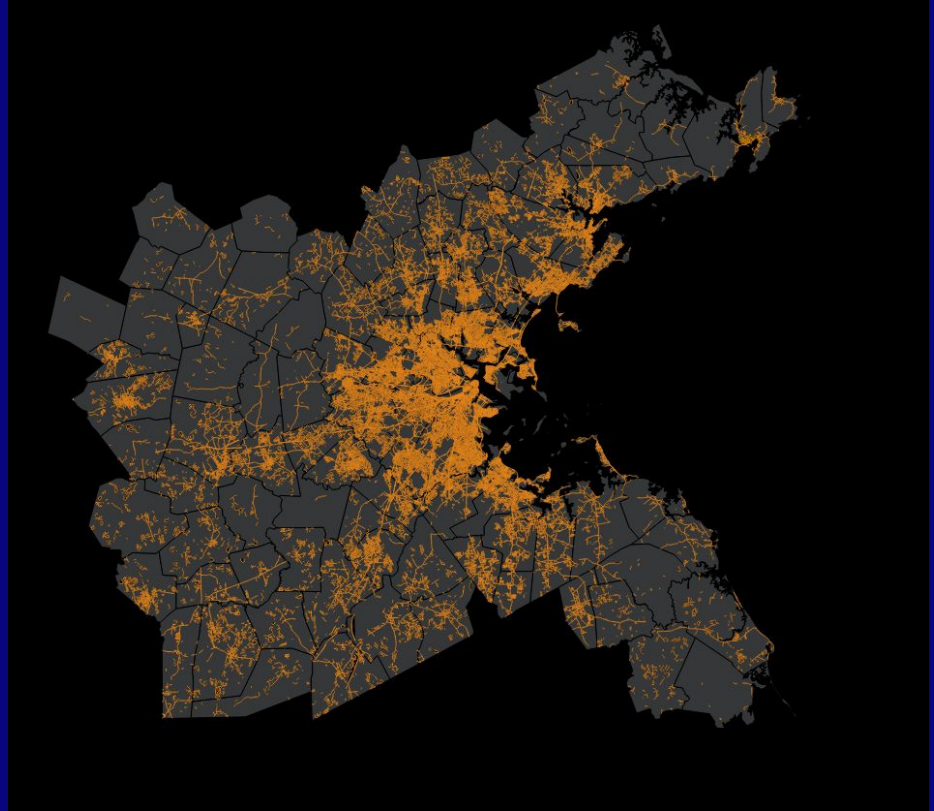
Non-linear Transformation

Linear data isn't
always best presented
as a line!



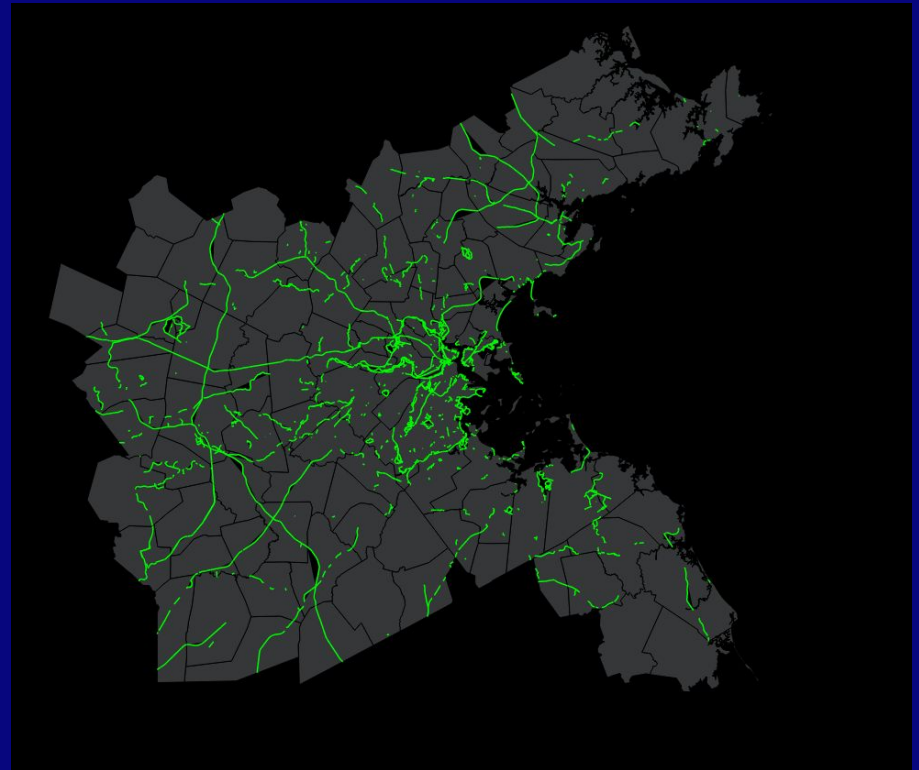
Dense Linear Data

Sidewalk coverage



Sparse Linear Data

Off-road bicycle
facilities



Solution

- **Aggregate data by geographic unit**
 - **Municipality**
 - **Census tract**
 - **Traffic analysis zone (TAZ)**
- **Display aggregated data**
 - **Choropleth map**
 - **Bar chart**
 - **Enhanced x-y scatter plot**

Metrics

- **Sidewalk coverage**

miles of non – limited access roads with sidewalks
centerline miles of non – limited – access roads

- **Off-road bicycle facilities**

- **Miles per municipality**

Sidewalk Coverage

- Enhanced x-y scatter plot

SIDEWALKS

Walking is the most basic form of transportation, and pedestrian infrastructure benefits everyone. Many people walk to get to school, work, doctors' appointments, the grocery store, and other important destinations because they do not have access to a car or even a bicycle. In areas with public transit, people walk to access transit stops. Even trips taken by car usually begin and end with a short walk. People who need mobility assistance also require pedestrian infrastructure that facilitates safe travel. Fortunately, well-designed sidewalks accommodate everyone.

Sidewalks offer a wide variety of benefits. The presence and accessibility of sidewalks allows people to incorporate walking into everyday life, which makes people more active and healthy. Sidewalks make it possible for people to swap car trips for walking excursions, which improves air quality by reducing vehicle emissions. Sidewalks draw more people to the street, which leads to vibrant commerce, crime reduction, and more neighborly communities. Simply put, safe and convenient pedestrian infrastructure underpins our quality of life. The Boston Region MPO recognizes the importance of pedestrian infrastructure in our shared transportation system and regularly quantifies and assesses this infrastructure in the Boston region.

Sidewalk Coverage

The graphic below displays the miles of roadways that have a sidewalk on at least one shoulder, identified as "sidewalk per centerline mile" of roadway. This measure is the ratio of a municipality's roadways that include a sidewalk on at least one side, divided by the total length of roadways within the boundaries of the municipality. The "sidewalk per centerline mile" measure is provided for every municipality over the past decade. The size of the outer circles and inner circles are proportional to each municipality's miles of roadway ("centerline miles") and miles of sidewalk, respectively. Hover over a circle to discover how many miles it represents.

All	Sort by Alphabetical Order					Sort by Sidewalk Miles to Centerline Miles Ratio			
	2007	2008	2009	2010	2011	2012	2013	2014	

KEY

Sidewalk Miles ● Centerline Miles ○ 100 Miles ○ 400 Miles ○ 900 Miles ○

Sidewalk per Center Line Mile



Off-road Bicycle Facilities

- Choropleth map
- Bar chart

The State of Boston Region Transportation [Crashes](#) [Congestion](#) [Bridges](#) [Pavement Condition](#) [Sidewalks](#) [Bicycle Facilities](#) [Demographics](#) [About](#)

BICYCLE FACILITIES

People bike for fun, exercise, and transportation. Cyclists include children on their way to school, commuters heading to work, athletes training, and seniors out for a relaxing ride. Bicycling is an active travel mode that can factor into a healthy lifestyle and it is an economical transportation option because bicycles burn calories instead of pricey fossil fuels. Bicycling as a travel mode is easily combined with walking and transit, providing more choices for getting around.

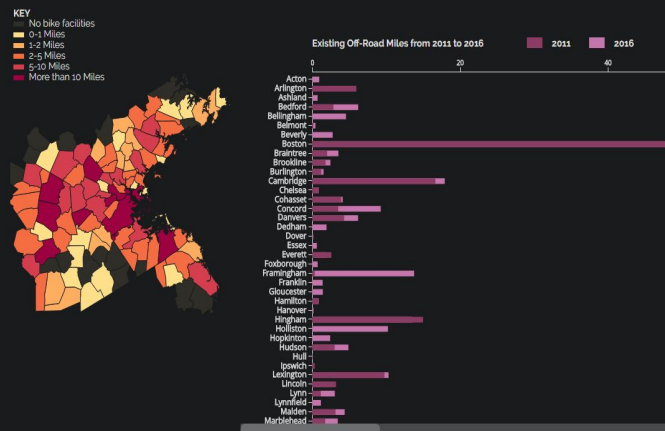
People who bike are vulnerable users of the transportation system, accounting for a growing share of crashes and a disproportionate share of injuries in the region. The majority of the Boston region still lacks adequate bicycle infrastructure, reducing the likelihood that people will choose cycling as a transportation option.

Understanding the existing network and how it can be expanded is an important part of planning for bicycle transportation in and around Boston. For this reason, the Boston Region MPO monitors the bicycle network in the region by measuring the total miles of bicycle facilities on this network. Bicycle facilities include off-road trails that are often shared with pedestrians, as well as on-road lanes and cycle tracks where people ride alongside motorized vehicles. Combined, these on- and off-road bicycle facilities are referred to as the Boston Region Bicycle Network.

Off-Road Bicycle Facilities

Existing Bicycle Facilities in 2016

The map of Boston region municipalities below illustrates the miles of existing off-road bicycle facilities (shared-use paths) in each municipality as of 2016. Hover over a city or town on the map to view the total miles of off-road bicycle facilities that were in the municipality in 2011 and 2016. The bar graph also depicts the miles of off-road bicycle facilities in each municipality and a comparison of the 2011 and 2016 data.



Conclusion

- **Single visualization framework**
 - Spatial data
 - Non-spatial data
- **Web server *is* spatial data server**
- **Open format data**
 - CSV, TSV, GeoJSON, TopoJSON
- **Rich presentation**

Check Out the Dashboard

www.ctps.org/dv/lrtp_dashboard



Thank You

- **David Knudsen – CTPS GIS Analyst**
- **Kathy Jacob – CTPS GIS Analyst**
- **Paul Reim – CTPS GIS Analyst**
- **Matt Archer – CTPS Intern**
- **Jennifer Rowe – CTPS Public Participation Manager**
- **Anne McGahan – CTPS LRTP Project Manager**
- **Lourenço Dantas – CTPS Certification Activities Manager**
- **Scott Peterson – CTPS Director of Technical Services**
- **Robin Mannion – CTPS Deputy Executive Director**
- **Karl Quackenbush – CTPS Executive Director**



Q&A

- **Beatrice Jin — bjin@ctps.org**
- **Ben Krepp — bkrepp@ctps.org**

