Technical Memorandum

DATE: September 30, 2019

TO: CTPS Files

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RE: Interactive Limited-Access Highway Balanced Volumes

# 1 balanced volumes: purpose and need

## 1.1 What are Balanced Volumes?

Balanced volumes are a method of visually depicting traffic volume data that is appropriate primarily for limited-access highways where traffic can only enter or leave a section of roadway at specific on- or off-ramps. With traffic flow constrained in this manner, graphic representation of traffic volume data can also be simplified, and these schematic depictions of limited-access highway volumes are often referred as traffic flow diagrams. Examples of traffic flow diagrams for five interchanges in this project’s study area are shown in Figures 1 and 2.

Not only is the topology simplified to its basic ramp and main barrel elements, but the volumes themselves are rounded, usually to an even 100 or 1,000 vehicles. Also, as can be ascertained by inspection, the ramp and main barrel volume estimates are internally consistent within the studied roadway and the analyzed time periods. A volume of traffic is shown entering the highway section, and the highway volumes are shown to increase or decrease by the exact amounts of the associated ramp volumes. This is the characteristic feature of balanced volumes, and the derivation of useful balanced volumes from available traffic data is discussed in a later section.

## 1.2 Balanced Volume Efforts at the Boston Region MPO

The Boston Region MPO began to estimate, organize, and publish balanced volumes in a systematic manner in the 1990s. These efforts were intended to illustrate and facilitate planning for the dramatic changes to the express highway system that were being implemented as part of the Central Artery/Third Harbor Tunnel construction project. These traffic flow diagrams proved useful for understanding traffic planning issues throughout the MPO region, and the set of express highways with available traffic flow diagrams gradually expanded as different parts of the eastern Massachusetts express highway system became subjects of transportation studies.

Eventually, balanced volumes were developed for most of the limited-access highways in Massachusetts. These traffic flow diagrams were originally developed using a uniform letter-sized page format appropriate for generating hard copy. All balanced volume diagrams currently available can be downloaded as PDF files from the Boston Region MPO website: <https://www.bostonmpo.org/subjects/express-highways>

The purpose of the balanced volume work being documented here is twofold. The balanced volumes available to be downloaded as PDFs are a number of years old, and this work is the beginning of a process to selectively update the balanced volume database. The traffic volumes in the database can still be used, but it may be appropriate to estimate and apply traffic growth factors. The roadway investigated in this initial effort Is Interstate I-93 between Interchange 41 in Wilmington and Interchange 7 at the Braintree Split, and the connecting section of Route 3 between the Braintree split and Interchange 12 near Marshfield. Boston’s Central Artery is at the center of this study corridor.

The second purpose of this effort is to develop interactive techniques for viewing the traffic flow data online. The PDF images were designed in a uniform format optimized for hardcopy publication. However, only limited amount of data is available at a glance, which in Figures 1 and 2 is only five interchanges. Also, the volume data cannot be downloaded and must be transcribed by hand. The new, interactive system documented here allows users to scroll seamlessly from one end of an express highway to the other, change time periods with a mouse click, and download the underlying data.

This memorandum next discusses the process and challenges of developing balanced volumes. It then describes the technical foundation of the newly developed interactive features. The following section walks users through some of the features and places the interactive tool in the context of the traffic flows being revealed. The memorandum ends with a brief preview of how this work might be expanded.

# 2 crafting balanced volumes from available data

## 2.1 Gathering Data

Developing a set of useful balanced volumes requires large quantities of reliable and reasonably up-to-date traffic data. Critically, traffic counts on entry and exit ramps are necessary because the entire purpose of a set of balanced volumes is to illustrate how a limited-access highway facility is actually used during time periods of interest.

Figure   
Sample Weekday Traffic Flow Diagram



Figure 2  
Sample Hourly Traffic Flow Diagram



Interstate highways and some non-Interstate limited-access highways have integral traffic counting equipment installed at key locations, referred to as permanent count stations. These facilities have wire loops embedded in the pavement within which a small electrical pulse is induced when passed over by a piece of dense metal such as an engine block or a propulsion motor in a hybrid or electric vehicle.

In contrast, entry and exit ramps usually do not have permanent counting equipment and require the placement of traffic-counting hoses to obtain a count. For most parts of the Interstate Highway System, ramps are counted every three years, usually for two or three days. This practice is recommended by the Federal Highway Administration, (FHWA). Results of these are other traffic counts are available on an interactive website maintained by the Massachusetts Department of Transportation (MassDOT) which can be accessed by using this link: <http://mhd.ms2soft.com/tcds/tsearch.asp?loc=Mhd&mod=TCDS>

The first step in the process was to make an inventory of which locations have useful counts and which do not. For the purposes of this study, counts performed during the 2015-2018 period were considered suitably current. A sizeable gap of missing counts was identified within the Central Artery tunnel under downtown Boston. Setting up counting hoses inside the Central Artery tunnels requires additional MassDOT and public safety staff, and these added expenses had served as a deterrent from timely data collection. MassDOT undertook a set of underground ramp counts specifically so support this study.

## 2.2 The Balancing Process

The balancing process is operationally very simple. All the available data is displayed graphically, usually on printouts of pdf images such as in Figures 1 and 2. Ideally, small adjustments up and down to handy round numbers will complete the picture of a closed system of traffic. In practice, the balancing process poses a number of challenges.

When first considering the raw data, inconsistencies in the data are to be expected. The ramp counts may have been taken in different years and/or different times of year. Other inconsistencies, however, can be serious and appropriate adjustments to present internally consistent volumes are not obvious. Careful review of the source data can reveal circumstances such as a loop under a lane having failed or a rubber tube having been ripped off the road before the count period ended. In these situations, use of an older count may provide usable values, or with sufficient care it might be possible to extrapolate from partial counts. Clearly, these data interventions are recourse only as a last resort. Also, balanced volumes from earlier years always offer a reality check.

The balancing process described above was done for 18 distinct traffic subsystems: southbound study area traffic for 9 time periods and northbound study area traffic for 9 time periods. The time periods were average weekday traffic (AWDT), four AM one-hour periods: 6 to 7 AM, 7 to 8 AM, 8 to 9 AM, and 9 to 10 AM, and four PM one-hour periods: 3 to 4 PM, 4 to 5 PM, 5 to 6 PM, and 6 to 7 PM. One might also remember that the balancing process used in this update effort is the exact same process that was used in the earlier efforts available for download as vintage pdf files.

# 3 Developing an on-line interactive tool

## 3.1 Introduction

The development of most data visualizations entails nearly as much work to prepare the input data as to develop the visualizations *per se.* Unless the input data is structured appropriately and is available in a usable format(s), the generation of data visualizations can be needlessly convoluted, inefficient, or, in some cases, simply not possible. This general principle held true for this project. This section is consequently divided into two sub-sections: the first on the preparation of the input data; the second on the development of the visualization tool itself.

## 3.2 Preparation of the Input Data

The goal of this project is to develop mechanisms to generate and display visualizations of balanced volume data for I-93/SR-3 for 1999, 2010, and 2018. The mechanisms developed were designed to be applicable to the generation of visualizations of balanced volume data for other limited-access highways and for different years’ worth of balanced volume data.

### Structure of the Input Data

The data read by the balanced volumes visualization tool consists of tabular balanced volume data *per se* and spatial data for the geometry of the road segments comprising I-93/SR-3 and their associated ramps. The latter is used to display information in cartographic form.

### Tabular Balanced Volume Data

Each balanced volume data record consists of a unique “road segment identifier” (discussed in detail in the following subsection) and the following set of balanced volume data for that segment:

1. The average weekday daily traffic (AWDT) in 1999
2. The AWDT in 2010
3. The volume of traffic between 6:00 a.m. and 7:00 a.m. in 2010
4. The volume of traffic between 7:00 a.m. and 8:00 a.m. in 2010
5. The volume of traffic between 8:00 a.m. and 9:00 a.m. in 2010
6. The volume of traffic between 9:00 a.m. and 10:00 a.m. in 2010
7. The volume of traffic between 3:00 p.m. and 4:00 p.m. in 2010
8. The volume of traffic between 4:00 p.m. and 5:00 p.m. in 2010
9. The volume of traffic between 5:00 p.m. and 6:00 p.m. in 2010
10. The volume of traffic between 6:00 p.m. and 7:00 p.m. in 2010
11. The sum of (3), (4), and (5)
12. The sum of (7), (8), and (9)
13. The AWDT in 2018
14. The volume of traffic between 6:00 a.m. and 7:00 a.m. in 2018
15. The volume of traffic between 7:00 a.m. and 8:00 a.m. in 2018
16. The volume of traffic between 8:00 a.m. and 9:00 a.m. in 2018
17. The volume of traffic between 9:00 a.m. and 10:00 a.m. in 2018
18. The volume of traffic between 3:00 p.m. and 4:00 p.m. in 2018
19. The volume of traffic between 4:00 p.m. and 5:00 p.m. in 2018
20. The volume of traffic between 5:00 p.m. and 6:00 p.m. in 2018
21. The volume of traffic between 6:00 p.m. and 7:00 p.m. in 2018
22. The sum of (14), (15), and (16)
23. The sum of (18), (19), and (20)

A field containing a textual description of the segment was added to these for use when labeling elements of the visualization(s), and to help make the data more readily comprehensible to end users when downloaded.

Items (11), (12), (22), (23) are not required in the input data *per se* (these values could be computed by the tool), but are provided as part of the tool’s input data in order to save a bit of tool execution time.

For this project, balanced volume data for 2018 was developed for I-93/SR-3 between the northern and southern boundaries of the Boston Region MPO as described in Section 2 of this memo. Specifically, balanced volume data was developed for:

* Each segment of this portion of I-93/SR-3 between ramps
* All the on- and off-ramps for this portion of I-93/SR-3

The 2018 balanced volume data was entered into Excel spreadsheets. The balanced volume data for 2010 and 1999, however, existed *only* in the form of numerical text in PDF[[1]](#footnote-1) document images. Hard-copies of the 1999 and 2010 PDF documents were annotated with the unique road segment identifier for each road segment. The balanced volume data for 1999 and 2010 for each road segment was transcribed into spreadsheets from the annotated PDF documents, including the segment’s unique identifier. The spreadsheets for the 2018, 2010, and 1999 data were then read into database tables, a database “join” was performed across these tables on the segment identifier field of each table, and the results exported in CSV[[2]](#footnote-2) format.

### Road Segment Identification

Regardless of the form of a data visualization, it is essential to define the mechanism by which each data value (or set of data values) is associated with the graphical symbol(s) used to represent that data value. One such method is to assign a unique identifier (a number or a text string) to each data value (or set of data values.) This method was adopted for this project. The definition of unique identifiers for segments of limited-access highway between ramps and the definition of unique identifiers for ramps are discussed separately.

#### Identifiers for Limited-access Highway Segments

Defining unique identifiers to indicate each of section of limited-access highway proved to be much more involved than one might have expected. Initially, we had hoped to use identifiers from the statewide Road Inventory, but found that the Road Inventory does not define a unique identifier for the entirety of each segment of limited-access highway between ramps. We next investigated the use of Traffic Message Channel (TMC) identifiers for this purpose. However, we found that although a unique TMC is *usually* defined for each segment of limited access highway between ramps, this is *not* always the case. (For example, TMC 129N04134 spans all of I-93 southbound between the off-ramp for I-95 southbound and the off-ramp for I-95 northbound. It is not divided into two distinct TMCs at the intervening on-ramp from I-95 southbound.)

Because of this, we were compelled to develop a naming convention for segments of limited-access highways between ramps that can be used for any limited-access highway. The convention we developed needed to be sufficiently flexible to allow for the addition of new ramps on a limited-access highway without forcing a wholesale re-numbering of the identifiers for all segments on the route in question. The convention also needed to be sufficiently flexible to accommodate segments of road that once existed but no longer do. (This was required, for example, in order to accommodate the geometry of I-93 in Boston in 1999, before the completion of the ‘Big Dig’ project.)

The basic naming convention developed is as follows:

* Each segment ID consists of 3 parts
* Each part is separated by an underscore
* The first part is the name of the route, e.g., ‘i93’
* The second part indicates the route’s direction, e.g., ‘nb’ (northbound)
* The third part is a (logical) segment sequence number

The sequence number is defined as follows:

* Find the ‘starting segment’. The ‘starting segment’ is defined as follows:
  + For northbound routes, it is the southern-most segment of the route in the state
  + For southbound routes, it is the northern-most segment of the route in the state
  + For eastbound rotes, it is the western-most segment of the route in the state
  + For westbound routes, it is the eastern-most segment of the route in the state
* The ‘starting segment’ is assigned the sequence number 010
* Each successive segment of the route between ramps in the direction of travel is assigned a sequence number 10 greater than its predecessor.
* This process is continued until the end of the route or the state border is reached.

For example, the first segment of I-93 southbound inside the state boundary is assigned the ID “i93\_sb\_010”; the second segment on I-93 southbound inside the state boundary is assigned the ID “i93\_sb\_020”, and so on. (Following this convention, the first segment of I-93 southbound within the MPO boundary is assigned the ID “i93\_sb\_180”.)

In order to accommodate segments that no longer exist, this basic convention was extended as follows:

* An optional part is added between parts 2 and 3 that indicates the year in which the segment existed and for which balanced volume data was developed
* Because I-93 in Boston had a radically different geometry and segmentation scheme before the “Big Dig” than afterward, the segments that existed *only* before the “Big Dig” are assigned sequence numbers starting with 010 and incrementing by 10 in the direction of travel until the end of the end of the portion of the route that existed only before the “Big Dig” is reached. This was done in order to avoid a wholesale renumbering of segments throughout the route.

For example, according to this convention the first segment of I-93 southbound in Boston that existed in 1999 (before completion of the “Big Dig” project) but no longer does, is assigned the segment ID “i93\_sb\_1999\_010.”

#### Identifiers for Ramps

On- and off-ramps for limited-access highways are usually assigned a unique ‘ramp ID’ in the State Road inventory. These are text strings having the form ‘Rnnnnn’, where ‘n’ is a digit between 0 and 9 inclusive. However, when a numbered route (these include Interstates, U.S. Routes, Massachusetts state routes, and so-called ‘N-routes’) merges onto a limited-access highway or when a limited-access highway branches onto one of these numbered routes, the Road Inventory does not assign a ‘ramp ID’ to the segment of road for the ramp in question. These segments have the ID of the numbered carrying the ramp. (For example in the Road Inventory, the ramp from I-93 southbound to State Route 3A southbound in Dorchester has the ID of route 3A southbound.)

While it would be possible to use these ‘numbered route’ identifiers to identify these ramps in a purely schematic data visualization, this poses a problem when attempting to display such a ramp cartographically. As the identifier in question refers to the *entire* route, a query to retrieve the geometry associated with such an identifier will return the geometry for the *entire* route. Consequently, the *entire* route would be displayed in a cartographic presentation, which would be misleading.

In order to address this issue, we developed the following naming convention for identifiers for ramps from one numbered route to another:

* The identifier consists of 5 parts, separated by underscores
* The first part is the letter ‘R’
* The second part is the name of the route *from which* the ramp carries traffic
* The third part indicates the direction of the route *from which* the ramp carries traffic
* The fourth part is the name of the route *onto which* the ramp carries traffic
* The fifth part indicates the direction of the route *onto which* the ramp carries traffic

For example, according to this convention the ramp from I-93 southbound to State Route 3A southbound in Dorchester is assigned the ID “R\_i93\_sb\_sr\_3a\_sb”.

The naming scheme for ramps also needs to accommodate ramps that no longer exist, i.e., the ramps on the Central Artery that were present in 1999 but were demolished as part of the “Big Dig” project. The ideal source for the IDs for these ramps would have been the 1999 statewide Road Inventory. Although MassDOT does not publish “back issues” of the Road Inventory, CTPS keeps a copy of previous versions of the Road Inventory going back nearly two decades for use when conducting comparative historical studies. Although CTPS does not have a copy of the 1999 Road Inventory, it does have one of the 2000-2002 Road Inventory. Because the geometry of I-93 in the Central Artery area did not change until 2003, we deemed the 2000-2003 Road Inventory data usable to represent “ground truth” in 1999 for our purposes.

CTPS compared the 1999 balanced volume diagrams for I-93 in the Central Artery area with the 2000-2002 Road Inventory, and found that several ramps were missing in that version of the Road Inventory. Since it was consequently impossible to use identifiers from the 2000-2002 Road Inventory identifiers for *all* of these “1999 ramps”, we adopted the following naming convention for them:

* The identifier consists of three parts, separated by underscores
* The first part is the letter ‘R’
* The second part is the year in which the ramp existed
* The third part is a sequence number, defined as follows:
* The first ramp proceeding in the primary direction of travel is assigned the ID ‘R\_yyyy\_001’.
* Subsequent ramps in the primary direction of travel are assigned an ID 1 greater than their predecessor.
* The first ramp proceeding in the secondary direction of travel is assigned the ID ‘R\_yyyy\_101.
* Subsequent ramps in the secondary direction of travel are assigned an ID 1 greater than their predecessor.

For example, according to this convention the second ramp on I-93 southbound that existed in 1999 before the “Big Dig” (but no longer exists) is assigned the ID “R\_1999\_102.

### Preparation of Spatial Data

The spatial data prepared for the balanced volumes visualization tool includes current (i.e., 2018) spatial data for I-93/SR-3 and associated ramps within the Boston Region MPO boundary, and spatial data for the “pre-Big Dig” geometry of I-93 in Boston.

#### 2018 Spatial Data

The GIS Group within MassDOT’s Office of Transportation Planning provided a copy of the ‘LRSN\_Routes’ data layer to CTPS. (LRSN\_Routes is the raw route geometry from which state Road Inventory is constructed.) CTPS extracted the records for the portions of I-93/SR-3 and associated ramps within the study area from LRSN\_Routes into a local Geodatabase feature class. The geometry records for I-93/SR-3 were then split and the point of intersection with each ramp, creating a distinct feature for each segment of road between a pair of ramps. A ‘data\_id’ field was added to this feature class, and it was populated with the segment’s identifier, as defined above.

LRSN\_Routes (and, consequently, the state Road Inventory) does not contain line-work for the High-occupancy Vehicle (HOV) lanes on I-93. Since balanced volume data was developed for these HOV lanes, we created features for them in order to be able to display them distinct from the ‘main barrels’ of I-93 in a cartographic presentation. In order to create the most spatially correct geometry for the HOV lanes, we created these features by edit-sketching the relevant geometry in ArcMap using the most recent statewide ortho-imagery available from MassGIS[[3]](#footnote-3) as a reference backdrop.

#### 1999 Spatial Data

CTPS extracted the geometry for the Central Artery portion of I-93 and its associated ramps from the 2000-2002 Road Inventory and stored it in a local Geodatabase feature class. CTPS created features for ramps in the Central Artery area that were missing from the 2000-2002 Road Inventory by edit-sketching the relevant geometry in ArcMap, and checking the result against the MassGIS statewide ortho-imagery from the 1990s[[4]](#footnote-4) as a reference backdrop.

The records for the geometry of I-93 were then dissolved, and the result split at the point of intersection with each ramp, creating a distinct feature for each segment of road between pairs of ramps. A ‘data\_id’ field was added to this feature class, and it was populated with each segment’s identifier, as defined above.

#### Final Preparation of the Spatial Data

In order to simplify implementation of the visualization tool, it was desirable for all spatial data read from a single data source. After data fields were added to the 2018 and 1999 spatial data feature classes to whether a given record was present in 2018, 1999, or both 2018, they were merged into a single feature class. The result was then exported in GeoJSON[[5]](#footnote-5) format using the ArcMap ESRI2Open[[6]](#footnote-6) ArcToolbox plugin.

## 3.3 Developing the Visualization Tool

### Choice of Visualization Framework

The choice of the most appropriate visualization tool or framework for a given set of is governed by a variety of factors, including:

* The nature of the data: Is the data quantitative or categorical? Does it have a spatial component? Do the individual data records consist of single values, or are they aggregates of multiple values (possibly of heterogeneous types of data)?
* The number of elements in the data set and the size of the data set.
* The presentation vehicle: Is the data to be displayed by an application (possibly proprietary) running on a desktop computer? Is the data to be displayed in a web browser?
* For on-line visualizations, the rendering medium: Scalable Vector Graphics (SVG[[7]](#footnote-7)) format or HTML Canvas[[8]](#footnote-8) format?
* The degree with which a user may be able to interact with the application. For example, the ability to click on or hover over a graphical symbol to display detailed information from the underlying data record.

The answers to these questions guided our choice of visualization framework:

* The underlying data records each consist of multiple values (balanced volume values for AWDT or hourly volumes for peak hours over several years) as well as a textual description of each road segment. This is supplemented by data for the geometry of each road segment.
* The number of records in the input data set is small: There are 177 data records for I-93/SR-3 northbound, and 200 records for I-93/SR-3 southbound.
* The goal of the project was to develop an *interactive online* visualization tool, i.e., one that runs in a web browser, requiring the installation of no software by the user, and allowing the user to interact with the data.

Given these answers, the choice of D3[[9]](#footnote-9) as the visualization framework was straightforward. Since its release in 2011, D3 has become a *de facto* standard framework for building interactive data visualizations for the web. While other frameworks exist, they provide only a limited set of pre-defined types of visualization (e.g., scatter plot, bar graph, pie chart, and so on.) One of D3’s greatest strengths is that it allows for the creation of new *types* of visualizations that can be tailored to the unique characteristics of the underlying data.

Given the modest size of the input data, the choice of SVG as the rendering medium was obvious. SVG renders crisp, attractive graphics in the browser.

Given the small size of the data set to be visualized, a relatively small number of SVG elements (several hundred to at most a few thousand) would need to be generated. (The performance of web browsers begins to degrade significantly when rendering tens of thousands of SVG elements.) SVG elements reside within the HTML Document Object Model[[10]](#footnote-10) (DOM) in the web browser and can be tagged with an arbitrary set of properties (including “id” and “class” properties). These factors help to make the implementation of “interactive” features (such as those initiated by mouse-click or mouse-hover events) more straightforward than would be the case if graphics were rendered using HTML Canvas.

### Key Principles

Development of the balanced volumes visualization tool was guided by input from sample users within the CTPS Traffic Analysis and Design and Travel Demand Modeling groups, and by the previous experience of the CTPS Data Resources group producing “paper map” traffic volume visualizations.

The key principles guiding how this data is rendered are:

1. A limited-access route and its associated ramps are rendered by a ‘stick diagram’ that displays the *schematic* branching structure of the roadway
2. The primary (north- or east-bound) and secondary (south- or west-bound) directions of a route are indicated by different colors
3. The volume of traffic on a given segment of road is indicated by the relative thickness of the segment of the stick diagram representing that segment

### Development Methodology

We adopted an iterative approach to developing the visualization tool. We developed a series of prototypes based on the key principles outlined above, prior work, and input from a group of sample users. Each successive prototype fixed “bugs” reported in the previous version and implemented new features requested by users. We performed three iterations of this process, at which point the functionality of the tool converged to its current form.

The first prototype was straightforward. It provided side-by-side displays of ‘stick diagrams’ for the north- and south-bound directions of I-93/SR-3. It allowed the user to select the data value to display (AWDT in 2018, 2010, or 1990, or volume for any given peak hour in 2018 or 2010), which would cause the display to be updated to reflect the chosen metric.

The ‘stick diagrams’ were constructed from SVG <line> elements, each of which represented one inter-ramp segment of I-93/SR-3 or a ramp on this route.[[11]](#footnote-11) The ‘stick diagrams’ were *conceived* of as being located in Cartesian space, each element having start (x1, y1) and end (x2, y2) coordinates. However, these diagrams will be *rendered* in SVG (not Cartesian) space[[12]](#footnote-12); this needed to be borne in mind when generating x1, y1, x2, and y2 properties for each <line> element. The x1, y1, x2, and y2 properties of the SVG <line> elements comprising the ‘stick diagrams’ were calculated in spreadsheets, and each record tagged with the identifier of the road segment which it represents. The result was loaded as a database table and a “join” on the road segment identifier field performed with the table containing the balanced volume data. The result, exported in CSV format, is the input used by the tool to generate visualizations.

In the course of using the prototypes, users requested the following features in addition to those in the first prototype:

* A map display, allowing users to correlate the schematic location of road segments with their location in geographic space.
* The ability to synchronize scrolling of the visualizations of the north- and south-bound directions of I-93.
* The ability to display comparative side-by-side visualizations of AWDT data from two different years.
* The ability to present balanced volume data for the three morning or evening “peak periods” side-by side, along with a display of the sum of the balanced volumes for the three hours comprising the selected peak period.
* The ability to optionally display of the current lane configuration of I-93/SR-3.
* An indication of the approximate location of town boundaries in the visualizations.

#### Choice of Mapping Platform

The request by sample users for the tool to include some kind of map display raised the question of which online mapping platform to use. The choices here were many and varied: Google Maps, OpenLayers, Leaflet, MapBox, Carto, and ArcGIS Online, to name a few. We ruled out MapBox and Carto because of licensing costs, and ArGIS Online because the “heavyweight” nature of this platform.

We chose Google Maps from the remaining alternatives because of its near ubiquity, its familiarity to users, and its built-in support for displaying base maps in both symbolic (“map view”) or orthophoto (“satellite view”) form. The mapping-specific component of the code for the tool turned out to be very small. The level of effort required to migrate the tool to use OpenLayers or Leaflet as its mapping platform, for example, would be modest.

# 4 Overview of the features of the tool

The tool provides three “views” of the underlying data:

* A “Main View” that presents the data for one selected balanced volume metric for both the north- and south-bound barrels of I-93 in graphic form on either side of a Google map.
  + Hovering the mouse over an element of either graphic display causes a “pop-up” to appear, displaying the selected balanced volume metric and some information on the road segment or ramp in question.
  + Clicking the mouse on an element of either graphic display causes the Google map to be panned/zoomed to the road segment or ramp in question.
  + The Main View provides an option that allows scrolling of the graphic displays of the north- and south-bound barrels of I-93 to be synchronized.
* A “AWDT Comparison View” that presents balanced AWDT data for any two selected years (2018, 2010, 1999) side-by-side, facilitating side-by-side comparison of the data
* A “Peak Hours View”, that presents balanced volume data for the three hours of either the morning or afternoon peak period side-by-side.

# 5 next steps

We propose that CTPS continue to develop up-to-date balanced volume data for the other express highways in the MPO region. The next two logical candidates for this work are I-90 (the Massachusetts Turnpike) and I-495. Balanced volumes were developed for both these routes *circa* 2010. Up-to date traffic counts are available for I-90, because of the recently-installed electronic tolling system used on that route, and for I-495.

1. PDF format definition: <https://www.adobe.com/content/dam/acom/en/devnet/pdf/pdfs/PDF32000_2008.pdf> [↑](#footnote-ref-1)
2. CSV format definition: <https://tools.ietf.org/html/rfc4180> [↑](#footnote-ref-2)
3. MassGIS Data: Licensed Google Ortho Imagery: <https://docs.digital.mass.gov/dataset/massgis-data-licensed-google-ortho-imagery> [↑](#footnote-ref-3)
4. MassGIS Data: 1:5000 Black and White Digital Orthophoto Images (1990s): <https://docs.digital.mass.gov/dataset/massgis-data-15000-black-and-white-digital-orthophoto-images-1990s-0> [↑](#footnote-ref-4)
5. GeoJSON format specification: <https://tools.ietf.org/pdf/rfc7946.pdf> [↑](#footnote-ref-5)
6. ESRI2Open project page: <https://github.com/project-open-data/esri2open> [↑](#footnote-ref-6)
7. SVG format specification: <https://www.w3.org/TR/SVG/> [↑](#footnote-ref-7)
8. HTML Canvas specification: <https://html.spec.whatwg.org/multipage/canvas.html> [↑](#footnote-ref-8)
9. D3: Data-driven Documents: <http://vis.stanford.edu/files/2011-D3-InfoVis.pdf> [↑](#footnote-ref-9)
10. Document Object Model specification: <https://www.w3.org/TR/WD-DOM/> [↑](#footnote-ref-10)
11. A few additional <line> elements where introduced to represent segments of road with which no unique data was associated, but which were desirable for presentation reasons, e.g., the points at which HOV lanes divide from or merge with the “main barrel” of I-93. [↑](#footnote-ref-11)
12. SVG space is organized differently than Cartesian space: the origin (x1 = 0, y1 = 0) of Cartesian space is located at the lower left-hand corner of a display, whereas the origin of SVG space is located at the *upper* left-hand corner. [↑](#footnote-ref-12)