

Web Mapping Metro Rail Services in Los Angeles County

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Abstract. Developing a forecasting model for effective service areas and potential ridership of Metro Rail stations may take years for the collection and analysis of data, and model development. Web mapping is a new trend in cartography that changed the way maps are produced and used for transportation forecasting. By leveraging ArcGIS Server resources, Flex and API components, the Web Map of Metro Rail Services in Los Angeles County is developed to share and interact with the resources, locate the closest Metro Rail stations by access from specific locations, estimate the potential ridership for existing and future stations, and offer additional functionalities. The Web Map enables clients to achieve resources, but as well to analyze results easily without ArcGIS software and other program experiences. This media will be a huge advance for transit forecasting and the service planning of a transportation system.

Keywords: Cartography, GIS, Web Mapping Application, Transportation, Transit

1. Introduction

Public transportation, particularly rapid transit, is becoming a higher priority in the planning and construction of transportation facilities in the United States. According to the American Public Transportation Association (APTA), the Los Angeles County Metropolitan Transportation Authority (LACMTA) operated the second-largest public transportation systems in the United States by ridership including Metro Rail, Metro Bus Rapid and Metro Bus Services in 2012. The Metro Rail System is the mass transit rail

system in Los Angeles County and is run by LACMTA. As of February 2012, the system encompassed 87.8 miles, serving six rail lines, and 80 stations, with an average weekday boarding of 362,056 riders (LACMTA 2012).

LACMTA is focusing its efforts on creating policies and partnerships that create and enhance community livability, transportation and environmental sustainability for the county of Los Angeles. Effective methods are needed to deliver information about transit services to millions of people who access the Metro transit system's alternative to driving.

The desired goal for this project is to search alternative visualization as Web Maps over Paper counterparts to allow readers to review, extract and analyze information from Metro Rail Services through the Internet. By leveraging ArcGIS Server resources, Flex and Application Programming Interface (API) components, the Web Map of Metro Rail Services in Los Angeles County was built for users to view and interact with resources including querying general Information of Metro Services, locating the closest Metro Rail Stations from specific locations, estimating the potential ridership for existing and future stations, and other additional functionalities. This Web Map will be a very useful tool that enables clients to achieve resources, as well as receive results easily without ArcGIS software knowledge and other program experiences. This article proceeds with four additional sections, which include a background, a description of the analysis method, and overview of application results, and a conclusion.

2. Background

The theoretical foundation for this research was provided by a literature assessment, which aims to review the critical points of current knowledge of this particular topic. The subsequent subsections discuss the topics of the history of Cartography, Web Map development, and Web Map components.

2.1. A Brief History of Cartography

The term "map", also referred to as "cartography", describes a visual representation of an area. Maps are the effective way to represent spatial arrangement of phenomena and their interrelationships, and dependence, as well as development (Mo, 2012). As an integral part of human history, maps have been created and used, possibly as far back as 8,000 years ago (Bagrow, 1985). Maps have been the essential tools to help people define, explain and navigate their way through the world from cave paintings to ancient maps of China, Babylon, Greece, through the 'Age of Exploration',

and even on into the 21st century. Many significant cartographic creations are serving as a symbol of advanced science and technology in human history. Even though the earliest maps are known as exploring the sky for navigation, and began as two-dimensional drawings, maps today have evolved into dynamic platforms because of the modern graphic technologies.

A long time ago, and even today, in order to design a meaningful map, cartographers needed to spend a lot of time collecting every detail of the geographic data, as well as involving subjective decisions and complex data modeling tasks. Creating the traditional way of cartography, the paper map, not only is a time-consuming and labor-intensive task, but also it is impossible to make changes. Thanks to the invention of the internet, Web Mapping is a new trend in cartography that changed the way maps are produced and used on the Internet over their traditional counterparts. Interactivity, easy distribution, updating information easy, personalization, and multi-functionality are the advantages in favor of Web maps over traditional paper ones.

2.2. Web Map Development

The term “Web Map” might not be familiar to many people, however, when talking about maps on the Internet, Google, MapQuest, and TomTom might come to their minds, as they are the giants in the industry of Web Mapping. A Web Map can be classified as Static, and Interactive (Kraak 2001). Static Web Maps are viewed only as web maps with images like traditional paper maps in digital form, with no animation and interactivity. Interactive Web Maps are dynamic web maps allowing clients to share and interact with GIS resources. Interactive Web Maps have been one of the most significant and dynamic presentation media for the World Wide Web ever since its invention.

While the first generations were primarily static, Web Maps today can be fully interactive and integrated with multiple media. Web mapping technologies involves the designing, implementing, generating and delivering maps on the World Wide Web (WWW). Web Mapping technologies not only provide an attractive channel for publishing, sharing and updating Geographic Information Systems (GIS) resources, but also support an interactive experience with those resources through the Internet. The expansion and the demand of Web Maps are constantly growing, whether for consumer mapping or acquiring data from open sources to local governments across the globe.

2.3. Web Map Components

Web Map is a presentation media in Web GIS sharing multiple resources and allowing others to use and interact with those resources on the Internet through the web services hosted by a server. Web Map is consist of multiple components, including GIS Application, Basemap, Operational Layers, Functionalities (Tools), and a fully operational Geodatabase (ESRI 2012).

The GIS Application is the software interface with corresponding tools to visualize, interact and work with geographic information. Coded in a browser-supported programming language such as JavaScript, the web application is created and edited the work with the GIS capabilities of the server. The Web mapping application within a Web browser is typically used in GIS to work on a variety of tasks and functionalities on the Web Map (ESRI 2013).

One of the map content components, the Basemap is a map containing geographic features used for locational reference, and providing the cartographic context and framework for working with information geographically. A base map can include vector datasets such as roads, parcels and building footprints; raster graphic dataset such as aerial photos, satellite imagery and topographic features like hillshade and elevation; labels and annotations.

Another component of the map content, Operational Layers are overlain on the Basemap Layer by adding features of interest to the map reader for visualizing geographic information. These dynamic map layers indicate the end users are able to interact directly with these layers as the results of an operation. The users are able to interact with these layers as editing or making notes, receiving results from analytical models, or performing map queries on the layers.

Functionalities are tasks or tools that were created for interacting and working with geographic information. The tools enable users to locate and inspect objects in the field of their interests, as well as support the automation of workflow. The tools are either tied to the Basemap or contained to the set of operational layers in a web map application. Examples of tasks include queries to find objects based on an attribute or find a place based on an address. ArcGIS functional extensions tools including Network Analyst, Spatial Analyst and 3-D Analyst can also be included in the application to work with the operational layers.

To create and support all GIS applications, a fully operational geodatabase is particularly critical, not only for storing and managing resources, as well as features, but also modeling the spatial relationship and behavior for many GIS tasks and analytical operations.

2.3.1. ArcGIS Server Components

It is important to know that all those elements of Web Map are hosted and served using ArcGIS Server. ArcGIS Server is used for creating and managing GIS Web services, applications, and data (ESRI 2012). The components of ArcGIS Server can be summarized as GIS Server, Web Server and Clients.

GIS Server hosts and run services. The GIS service is an automated geographic information services, a standard protocol for making GIS resources such as maps, geodatabase, tools and other functionalities available to a wider audience over the internet (ESRI 2013). Server Object Container (SOC) and Server Object Manager (SOM) Server Object Containers are consisted within the GIS Server. GIS resources are hosted within one or more SOC as server objects, while the SOM manages those objects and distributes them across one or more SOC machines.

Objects running in the GIS Server are used by the Web Applications and Web Services hosted by the Web Server. These applications and services use the ArcGIS Server API to connect a SOM, make use of GIS Services and create other ArcObjects for use in the server applications. The ArcGIS Server Application Programming Interface (API) is a set of rules, routines, or protocols for building the Web application and allowing server components to communicate with each other.

A Client is a piece of computer hardware or software that can be used to connect to a Web applications running in the Web Server. Web Browsers, ArcGIS Desktop and Mobile Devices can connect either through Hyper Text Transfer Protocol (HTTP) to ArcGIS Web services running in the Web server, or connect directly to the GIS server over a Local Area Network (LAN) or Wan (Wide Area Network).

3. Method

Combining information from multiple resources into one Web Map is very common in Web mapping application development. The popular process is called mashup. The first web mashup was created in 2005 when Paul Rademacher, a programmer combining home and rental information from Craigslist and Maps from Google into his housing web site (DuVander 2010). The attempt set a precedent that influences how the web would develop in the following years.

The Web Map of Metro Rail Services is developed to review, extract and analyze resources from Metro Rail Services by combining data, presentation or functionalities from multiple resources from Web sources. The following section introduced the procedure used to develop this media into three sub-sections: (1) Authoring GIS Resources, (2) Publishing GIS Resources and (3) Using the Services. This process can simply describe it as Author - Serve - User. The workflow diagram illustrates how the participating software components are applied to distribute and interactive GIS resources through internet (Figure 1).

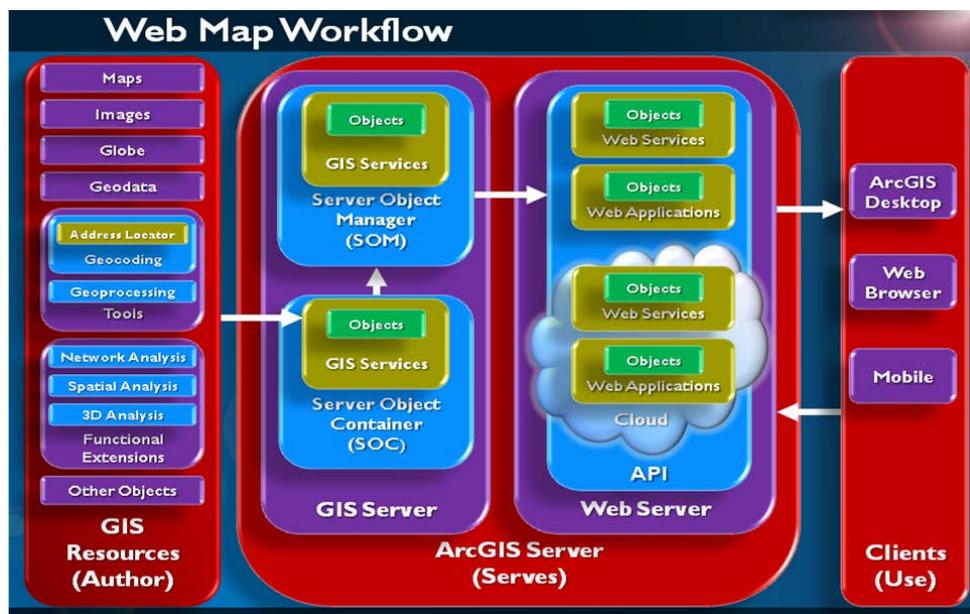


Figure 1. Web Map workflow.

3.1. Authoring GIS Resources

GIS resources are composed of maps, images, geodata, and globe, with tools such as Geocoding as well as Geoprocessing, and functional extensions including Network Analyst, Spatial Analyst and 3-D Analyst. In order to present Metro Rail services resources, GIS services containing map contents, operational layers, tools and additional functionalities need to be built, published and accessed over the net. Performing the authorization requires four steps (1) collecting GIS data, (2) building a fully operational geodatabase (3) designing an effective Basemap and (4) authorizing GIS tools and functional extensions, several of which have sequential sub-processes.

3.1.1. Collecting GIS Data

GIS data are values of qualitative or quantitative variables representing the spatial phenomena of an area. GIS data representing real objects such as roads, administrative boundaries, cities, water features, physiographic features, parks, landmarks, transportations, buildings and shaded reliefs were collected from U.S.Census Bureau, LACMTA, USGS and other resources. All the gathered source data were projected into WGS_1984_Web_Mercator_Auxiliary_Sphere projection based on the Web Map Projection guideline.

3.1.2. Building Geodatabase

Creating a fully operational geodatabase is particularly important not only to manage and store map documents, tools, functional models and scripts such like Geoprocessing and Network Analyst, address and place name locators, imagery, as well as globe documents, but also publish and serve those elements openly over the web using ArcGIS Server.

3.1.3. Designing an effective Basemap

ArcGIS for Desktop (ArcView, ArcEditor, ArcInfo) offers many tools and techniques for authoring effective and high-quality maps. The challenge of designing an effective Basemap for web mapping application is that it should be appropriate, look good at multiple scales and work directly with the result of an operation. Group layers were used for definition queries, labels or annotations, cartographic representation, and symbols for implementing the multi-scale capability of the Basemap. The layers are organized using the following order from bottom to the top for features as Tin/Terrain and Raster, Polygon, Line, Point, and Annotation.

To help the point data such as Metro Stations and line data such as Metro Lines show up even better on the base map and Operational Layer, slightly larger symbols and bright colors were used. For example, Metro lines are shown on the map with wider solid line symbols that have bright high saturation colors (Figure 2).



Figure 2. Metro Rail System in Los Angeles County shown in the Basemap.

This Basemap shows fewer and larger or more important features at smaller scales and smaller features in greater details with better graphics and high-quality symbols at larger scales. An appropriate visibility scale range for each of them were defined at the largest scale levels of 9K, 4.5K, 2K, and 1K based on the ESRI Web Map guideline. In order to view a map in greater detail, simply zoom or click the Map Switcher located at the upper right corner of the map.

The Basemap should be cartographically designed not to compete with the operational map layers that will be placed on top of the Basemap. It should be cartographically sound at all cached scales.

3.1.4. Authoring GIS tools and functional extensions

ArcGIS offers tools such as Geocoding, Geoprocessing and functional extensions such as Network Analyst, Spatial Analyst and 3D Analyst for user to interact and work with geographic information. Those tools and functionalities needed to be added in the applications and authorized in the server for users to visualize, interact with, and work with resources regarding Metro Rail Services.

Automating GIS tasks and performing spatial analysis and modeling is the fundamental purpose of Geoprocessing. Geoprocessing supports the automation of workflows as almost all uses of GIS involve the repetition of work and this creates the need for methods to automate, document, and share multiple-step procedures.

One of the functional extensions, Network analysis is the technique used to calculate and determine the relationship and locations of network facilities

in transportation, utility, and communication systems (Mo, 2012). The network analysis method employs a reasonable network of functionality to determine travel time to transit facilities.

For making GIS resources available to others, ArcGIS Desktop is the software to author those resources into ArcGIS Server. ArcMap is the desktop application for map-based tasks including cartography, map analysis, and editing. The MXD file is the GIS Map Project File, primarily associated with "ArcMap", containing a map, its layers, display information, multiple-scale capability and other elements.

3.2. Publishing GIS Resources as services

Publishing GIS Resources as services to the ArcGIS Server is the key for sharing GIS resources across the world accessing, viewing and interacting with Web Map through the internet. Publishing GIS Resources as services in ArcGIS Server involved several steps: (1) creating and configuring an ArcGIS Server Services, (2) creating a Cached Map Services on ArcGIS Server, (3) publishing tools and functionalities on ArcGIS Server, (4) developing Web Mapping Application on the ArcGIS API for Flex, (5) utilizing GIS Cloud for sharing GIS resources.

3.2.1. Creating and Configuring a ArcGIS Server Services

The first discussion focuses on creating and configuring an ArcGIS Server services. ArcGis Server needed to be installed and an administrative server connection was made. Providing a name for the new services so that this name will be seen by end users and it is used to identify the service.

3.2.2. Creating a Cached Map Services

Cached Map Services is a regular map service that has been enhanced to serve maps quickly using a cache of static images. When creating a map cache, the server draws the entire map at different scales and stores copies of the map images in a directory. Cached Map Services can dramatically improve the time clients take to display complex base maps.

3.2.3. Publishing tools and functionalities

With ArcGIS Server, GIS tools and extensions, functionalities can be published as services that allow clients to submit jobs to the server and get back a set of results. This section mainly focuses on building Network Analysis

services for use within a Web mapping application. ArcGIS Server supports performing network analysis on transportation networks. First: a map document with one or more network analysis layers was created. Second: any data layers used by the services were included. Third: publishing the map document as services and enable the network analysis capability.

When publishing a GIS resource to the server and define the various way clients can use the services by enabling capabilities of that resource. By enabling capabilities, the GIS functionality can be provided for the applications users will need.

3.2.4. Developing Web Mapping Application on the ArcGIS API for Flex

ArcGIS offers an API for Web development on various platforms including JavaScript, Flex, Silverlight and iOS, Android, and Windows for smart phones. ArcGIS API for Flex is adopted for this project because it can create applications with intuitive, visually rich and responsive user interface. The platform includes Title, Widget (Web Mapping Application) Tray, Map Switcher, Navigation, Scale Bar and Overview Map.

The ArcGIS API for Flex has great advantages of the powerful mapping, functional capabilities of ArcGIS Services for sharing and interacting GIS resources. This application can be designed and modified in the integrated development environment on the Flex Application Builder. With ArcGIS API for Flex, the web application will be able to display an interactive map containing transit data of LACMTA, locating addresses, executing GIS models, search for features or attributes, edit data and create Mashups. Using the ArcGIS API for flex take the following steps: (1) download and unzip the ArcGIS API for flex zip file, (2) specify the library path in Adobe Flash Builder, (3) create an application by writing code to access the ArcGIS Server resources, and (4) compile the code to create the application.

3.2.5. Utilizing GIS Cloud for sharing GIS resources

GIS Cloud is taking GIS to an entirely new level. *Cloud GIS* is the combination of running GIS software and services on cloud infrastructure and accessing GIS capabilities from anywhere using the web (ESRI 2013). All of the ready-to-use GIS resources including maps, databases, tools and images can be organized, accessed, stored and shared at anytime, anywhere across the globe through the internet. Cloud computing and technology is considered important in the development and vision of ArcGIS platform by ESRI. The future of GIS lies in the Cloud.

Amazon Elastic Computer (EC2), a Web-based service in the Amazon.com Cloud Computing environment is used to run the web application.

3.3. Using the Services through client applications

Client is a software or hardware system that accesses services made available by a server. Web Browsers, ArcGIS Desktop and Mobile Devices can be used to connect to Web applications running in the Web server. Once Map Services and other functional Services are published to a server, those Services will be available to clients both locally and on the web.

4. Results

This section will illustrate the functionality of some widgets for end users to view and interact with the GIS resources of Metro Rail Services in Los Angeles County. Widgets provide functionality in the Web Map to display maps and perform different tasks through the Web Map. The web address <http://23.23.95.179/owenbinmo/> is temporarily used to review the Web map application, hosted by Amazon Cloud Computing environment.

4.1. Querying Information of L.A. Metro Stations

Derived from the "Query widget" at ESRI Code Gallery, the "LA Metro Stations" widget is built to enable end users to query information of Metro Services from the server (Figure 3). When this widget is activated, typing keywords of specific Metro lines, stations or addresses in the Search Box, the query immediately executes and returns a result set in the dialog box, then the user can use the mouse or keyboard device to scroll up or down to read the information such as the address, Metro line, City, Parking, or the official Metro Services website. Simultaneously, a train icon will appear on the map, where the users can click it and retrieve information of their interests. For example, by typing "Expo", information about stations serving the Expo line will appear.

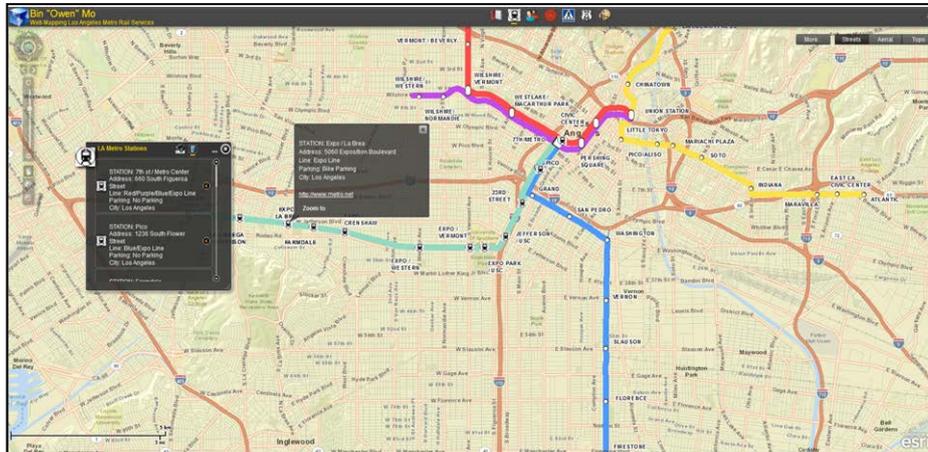


Figure 3. Widget of Driving LA Metro Stations

4.2. Driving or Walking to the Closest Metro Rail Stations

Retrieved from ESRI Widget Code Gallery “Closest Facility”, the “Driving or Walking to the Closest Metro Rail Station” was built to help riders find the closest Metro Stations to and from the 80 Metro Rail stations (Metro Red, Purple, Blue, Green, Gold and Expo Lines) and 20 Bus Rapid Transit (BRT) stations (Metro Orange Line) in Los Angeles County within a specific timeframe (Figure 4). After selecting the number of stations to be found, and maximum travel time in minutes, either entering an address or clicking anywhere on the map, the designed routes will be generated and the closest stations to and from specific locations will be identified. Road network provided by ArcGIS services, this widget automates the GIS tasks and performs spatial analysis and modeling by using the fundamental component Geoprocessing with network analysis capability, and Geocode services.

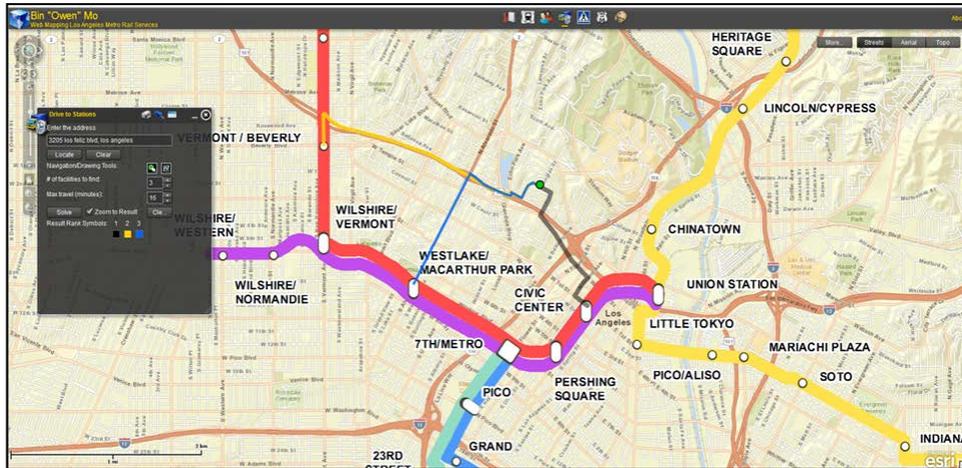


Figure 4. Widget of Driving or Waling to the Closest Metro Stations

For performing the function by walking, the first step was to create a Network Analysis Service and saved it as a map document in ArcMap. The walking network analysis layer was built combining data from the Census Bureau and pedestrian paths edited from satellite images and blueprint documents. Then, the map was published as a web service, ensuring that the Network Analysis capability was enabled. For a more detailed building the pedestrian network, please check author's article "A Custom 2D & 3D Pedestrian Network for Transit Station Routing and Navigation".

4.3. Potential Ridership and Demographic Information

Modified from the "Chart widget" at ESRI Gallery Code, the "Potential Ridership of Metro Station" widget was used to display the demographic information from a map layer by either entering an address, placing a point, or drawing a circle on the map. Once the widget is activated, a bar chart will indicate the ethnic diversity and total population in a selected area (Figure 5). This widget can also support the display of age, income, house values and other information through the Demographic Server resources from ESRI in different chart types including chart, column, line and pie.

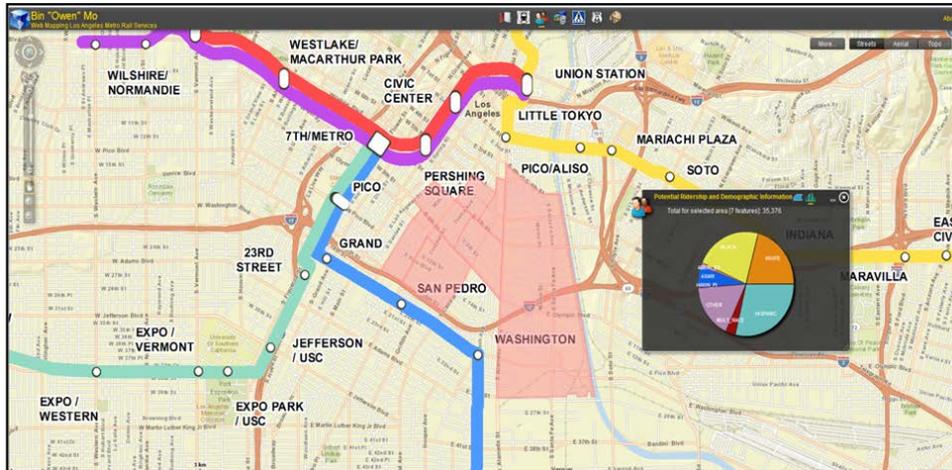


Figure 5. Widget of Potential Ridership and Demographic Information

4.4. Load Factor Analysis for Transit Services

Modified from the “Time Slider Widget”, the “Load Factor Analysis for Transit Services” was designed to perform Load Factor analysis of Metro Transit Lines based on the daily boarding for estimating when the crowd situation appears, and/or where a crowded point exists. The widget was first built with the time series databases from Automated Passenger Counts (APC data) requested from LACMTA (Figure 6). In order to understand the procedure of generating time series data from APC, please see the author’s other article “Mapping and Analyzing Transit Load Factors in Los Angeles County”.

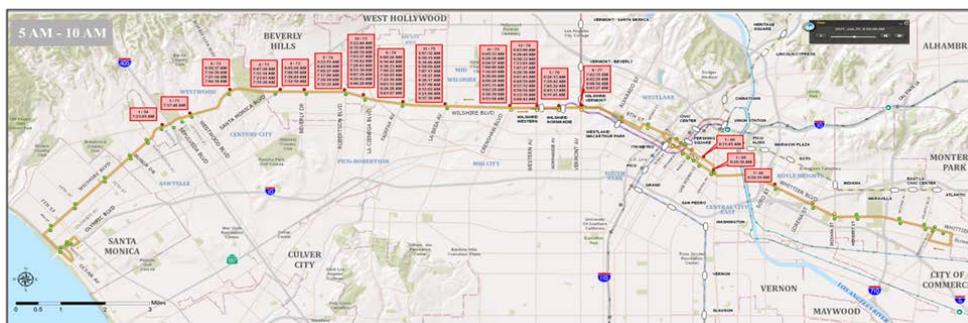


Figure 6. Widget of Load Factor Analysis for Transit Services

5. Conclusion

Maps are an important resource to assist in web design and development. Web Map involves many challenges due to the lack of accessibility of GIS software, complex set up of servers for web publishing, obstacles for authorizing and publishing resources to servers, high costs to rent cloud space, data sharing, security issues, reliability issues, technical complexities and many other issues. However, Web Map is superior in terms of usefulness and applicability. The use of Web Map can be respected as a major advancement in cartography and opens many new opportunities for the industry market.

Los Angeles County is larger than the combined areas of Rhode Island and Delaware—comprising 4,083 square miles in total—and is a conglomerate of eighty-eight incorporated cities and many unincorporated areas. The polycentric and complex landscape of Los Angeles County needs many different solutions to work together cohesively to increase the attractiveness of the Metro Rail System. Transit properties, governments, and private developers are making a cooperative effort to increase the attractiveness of the Metro Rail System. Web Map will be able to deliver information to the population who will then effortlessly witness the public commitment LACMTA is seeking to improve the overall commute throughout Los Angeles County.

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