Mapping Potential Metro Rail Ridership in Los Angeles County 2013

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Abstract. Los Angeles County, is coping with increasing street and highway traffic. Public transit, and particularly rail, often is regarded as a strategy to help reduce urban traffic congestion, and growing awareness of global climate change. The objectives of this paper are to identify the potential ridership and current utilization of the Metro Rail System of Los Angeles County using the process of “Trip Generation,” to support visual planning about public transit. The potential ridership produced and attracted to each station was estimated using Origin-Destination (O-D) flow patterns from residential and employment regions. Estimation of the number of potential riders accessing the Metro Rail System involves a spatial analysis of the location of current Metro Rail stations serving populations in a reasonable access time by walking. Service Area Zones (SAZ) then were delineated and mapped to indicate the areas that the potential riders could be served by existing stations within a ten minute walking interval. The potential ridership was measured to be approximately one million, a figure ten times larger than the present level of Metro Rail utilization. The analysis results across stations were compiled into the Atlas of Potential Metro Rail Ridership for the purpose of ridership promotion, system forecasting, and service planning.

Keywords: Cartography, Transportation, GIS, Spatial Analysis and Modeling

1. Introduction

Los Angeles County is internationally known as an automobile-oriented region. Like many metropolitan areas, Los Angeles County is struggling to control increasing street and highway congestion. Metro rail is an increasingly attractive strategy to reduce traffic congestion in cities with high levels of automobile dependency. The Metro Rail System is the mass transit rail system in Los Angeles County and is run by the Los Angeles County Metropolitan Transportation Authority (LACMTA).It was estimated that 100,000 riders access the system by walking, based on the 2006 On-Board Survey records. As of this date, the system encompasses 87.8 route miles, serving six rail lines and 80 stations, with an average weekday boarding of 363,000 riders (LACMTA 2013) (Figure 1).

The objectives of this paper are to identify the total potential ridership within walking access to the Metro Rail, and the current level of utilization therein, as well as the visual presentation of ridership access in the *Atlas of Potential Metro Rail Ridership*. To determine the potential ridership, a spatial analysis was completed to delineate Service Area Zones (SAZ) in which riders could access a station within a reasonable amount of time spent walking (ten minutes). Subsequently, the results were compiled into the *Atlas* for visual support of ridership promotion, system forecasting, and service planning. The article proceeds with four additional sections, which include a background, a description of the analysis method, an overview of the analysis and mapping results, and a conclusion.

2. Background

Research has found that the spatial accessibility (i.e., travel distance and travel time) to a transit connection point is the primary determinant of transit use (Murray et al. 1998; Beimborn et al. 2003). Walking access is expected to have an important role in supporting service improvement planning by increasing accessibility and potential ridership levels. The concept of Origin-Destination (O-D) flow is fundamental to forecasting potential ridership and its relationship to pedestrian access. Cartography is the generation of maps for the analysis, recognition, and prediction of spatial phenomena. The subsequent subsections treat the topics of walking access, O-D flow, and how spatial phenomena are represented cartographically in public transportation analysis.

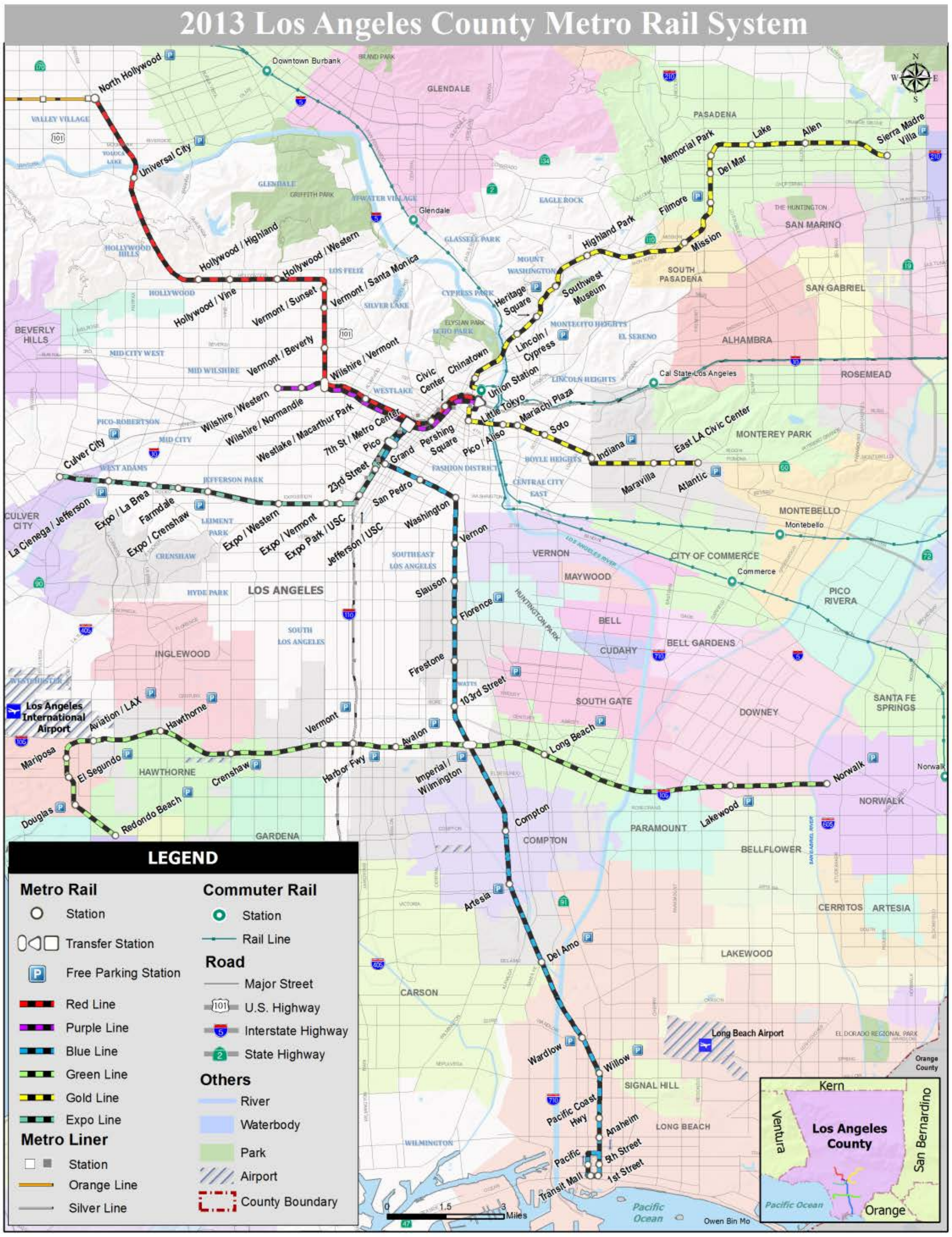

Figure 1. Map of 2013 Los Angeles County Metro Rail System

2.1. Walking Access

The term "*access*" regarding public transportation refers to the ability to make use of the transit system. Access often is perceived in spatial terms based upon physical proximity to the service and associated cost in traveling to the service. As public transit is the most economical transportation option in Los Angeles County, the analysis focuses on travel distance and travel time as the main measure of accessibility, with a specific emphasis on walking.

The choice of transportation mode for traveling to a transit station impacts the transportation management policy of an urban area. The primary form of accessing the Los Angeles Metro Rail system is by walking, with 52% of inbound riders traveling to the station by foot (Mo 2009). The percentage of walkers is higher for outbound riders of the Metro Rail system, as approximately 80% of outbound riders walk from a station to their final destinations (LACMTA 2006).

It is very important to know how much time Metro Rail riders are willing to walk, so that the effective service area of a transit station can be identified. According to AASHTO's (American Association of State Highway and Transportation Officials) walking guideline, areas within approximately five minutes walking time (at three miles per hour) are considered "well-served." Areas within approximately ten minutes' walking time are considered "served". Beyond walking access, taking the bus, driving, and riding bicycles constitute other alternative access modes for people using metro rail.

2.2. Forecasting Origin and Destination Potential Ridership

The Four-Step Travel Demand model is a well-known tool for forecasting future demand and performance of large-scale transportation systems (TCRB 2006; SCAG 2008; MWCG 2010). *Trip Generation*, the initial step in the Four-Step Travel Demand model, is applied to forecast potential ridership in Los Angeles County.

Trip Generation predicts the number of daily rider trips originating from or destined for a given region (TCRB 2006; SCAG 2008; MWCG 2010). Origin and Destination (O-D) constitute the two "ends" for each trip, which are the portions on the journey between two activities. The potential ridership produced from and attracted to each station is estimated using assumptions derived from residential and employment characteristics (Figure 2).

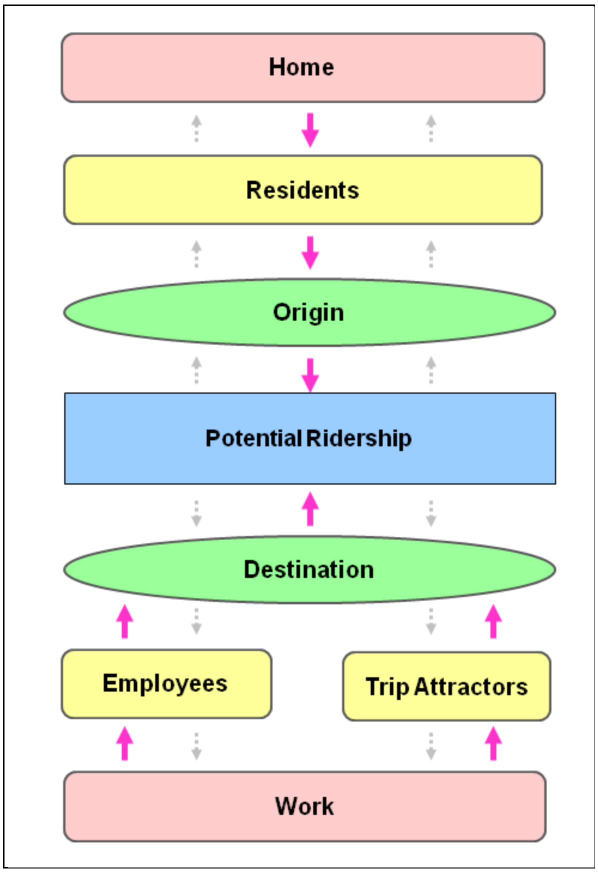

Figure 2. Potential Ridership Generation of O-D Flow

Origin ridership analysis focuses on residences. Residential population information is considered to be the most basic form of information about the travel patterns of a region. The number of potential riders is measured within the service area to calculate the possible number of trips using the transit service.

Destination ridership analysis concentrates on employees. Employment regions are important local trip destinations. The actual or projected employment in an area determines the number of home-work trips that attract riders from the original areas (SCAG 2008; MWCG 2010).

Destination ridership analysis also emphasizes trip attractors other than the workplace. Understanding the trip attractors in Los Angeles County becomes very important, particularly when estimating the Metro Rail potential ridership. The variety of trip attractors in Los Angeles County were identified through the regression coefficients for the trip attraction models employed in the year 2003 SCAG Regional Travel Demand Model. This model related the number of trip attractors to the number of employees working in different sectors of the employment region, including retail (for example, one employee leads to 4.678 trips), public administration (3.439), other services (3.303), art and entertainment and food (3.136), education and health (0.698), professional services (0.25), and information (0.227).

The geographic locations of major residences and employment can be used to establish a need for a transit service based on the concept of O-D flow analysis.

2.3. The Use of Cartography in Public Transportation Analysis

The cartographic method is to use various combinations of the procedures for analyzing and processing maps based on the rules of spatial arrangement of phenomena and their interrelationships, dependence, as well as development. A *cartogram* is a map in which the size of each entity is proportional to some value associated with the entity (Campbell 2001). Cartograms not only came to define how transit maps were produced but also have potentially limited our ability to map transit systems even more effectively.

Best known as a linear cartogram, the London Underground Tube map created in 1933 by Harry Beck has been widely adopted for other network maps around the world. For example, Beck's map represents a subway station with a dot, which does not resemble the actual station at all but rather the relative position of a station along the route. Station connections are related to one another, and different fare zones, via color-coded lines connecting all of the related route stations via vertical, horizontal, 90-degree, and 45-degree angles. As a result, information is provided to the viewer without unnecessary visual clutter.

The later application of this approach to the New York subway system map was, however, met with a different reaction. Not long after Mr. Massimo Vignelli's version was released in August 1972, complaints arose (Heller 2010; Rawsthorn 2012) (Figure 4). Many New Yorkers were outraged for the geographic accuracy of the subway was done away with in order to show a clean interpretation of New York's puzzling underground. The eye of the beholder was forced to see only the essentials. The public failed to recognize it as the map did not cater to their needs. Finally the M.T.A. bowed to the public by replacing the map, in 1979, with a geographical one.

Making a meaningful map is the ultimate goal of cartographers. The desired goal is to allow map readers to extract and analyze information from the represented spatial data. This article searches alternative visualization methods of metro rail transit in Los Angeles County to see what enables us to extract and analyze information about current and potential ridership.

3. Method

The following section describes the spatial analysis procedure used to apply and enhance the Trip Generation technique for estimating the potential ridership of Los Angeles County. The description is organized into four subsections: (1) Network Analysis, (2) GIS Program Procedures, (3) Integrated Potential Ridership, and (4) Atlas Compilation.

3.1. Network Analysis

Geographic Information Systems (GIS) technologies have proven to be a valuable transportation management and modeling platform. *Network analysis* is the technique used to calculate and determine the relationship and locations of network facilities in transportation, utility, and communication systems. The network analysis method increases spatial precision because it distributes spatial analysis along a linear length, rather than across the entire region.

Performing the network analysis requires four steps computationally, several of which have sequential sub-processes (Figure 2). The first step is the building of a road network from which have access to the Metro Rail stations. The second step is calculation of travel time in minutes from all road segments linking home or work regions to Metro Rail stations. The third step is delineating and mapping Services Area Zones (SAZs). The final step is analysis of the populations with transit access, which includes four substeps (Figure 3): (a) identifying census block group overlapping with each SAZ; (b) computing the total population of the overlapping block groups, (c) calculating populations for each portion of the SAZ based on the geometry method ratio (total population of an SAZ = the area of an SAZ / the total area of a census group * the total population of a census group), and (d) uniting all portions of the SAZ to form the population estimate.

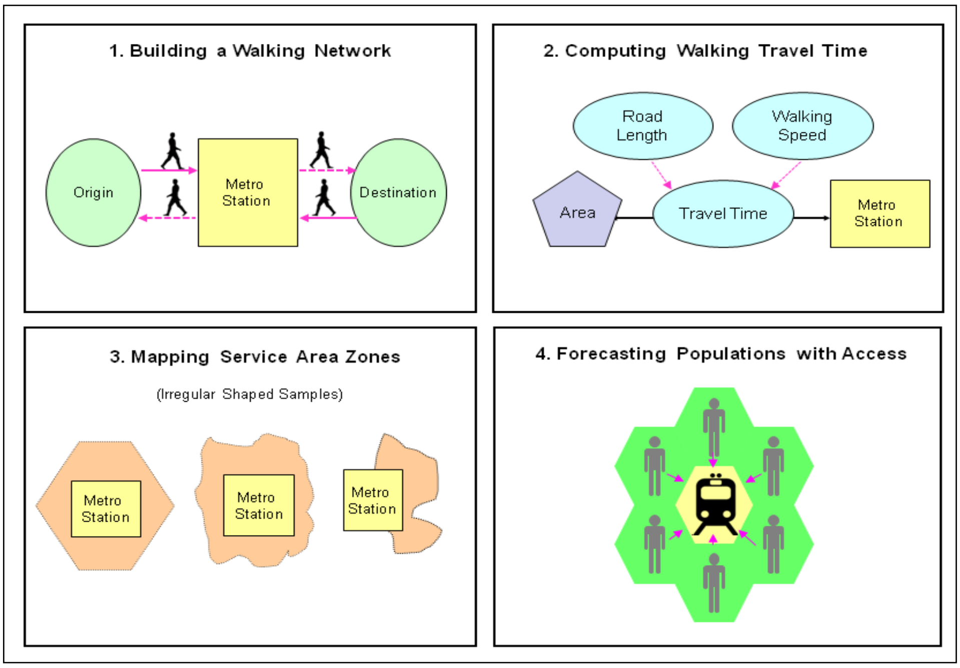

Figure 2. The procedure of Network Analysis method

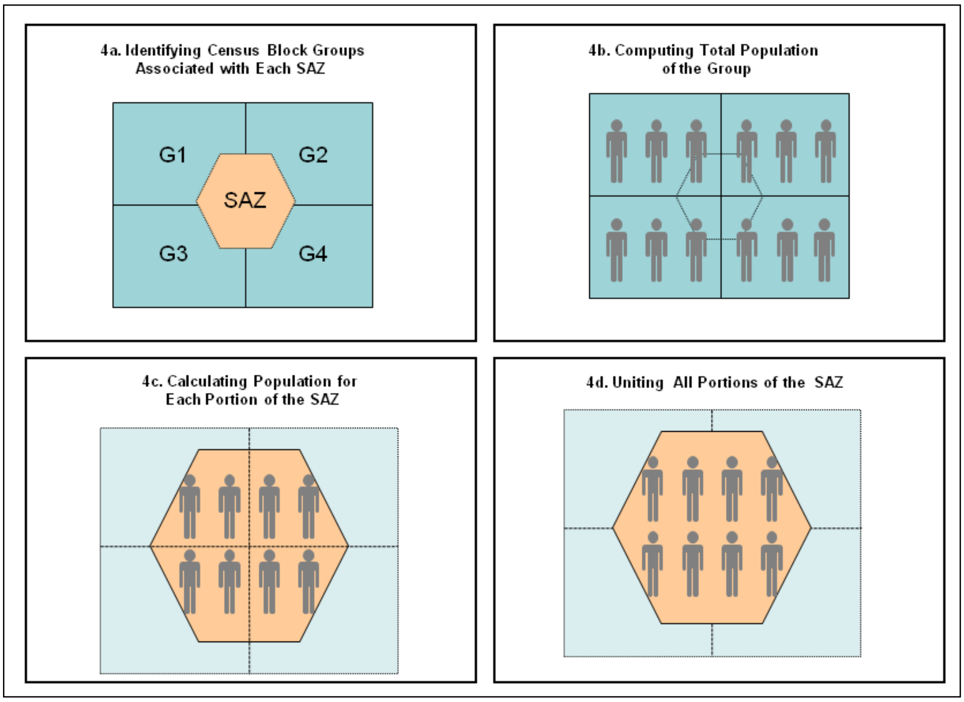

Figure 3. The sub-steps of forecasting population with access

3.2. GIS Program Procedures

The above spatial analysis was completed using the Network Analyst extension and other functionality provided in ArcGIS 10. TIGER/Line shapefiles are the essential data layers used for GIS network analysis, which were spatially extracted from the U.S. Census Bureau's MAF/TIGER database and the Thomas Brothers GIS Graphics Files. The complete GIS program procedure for analyzing potential Metro Rail ridership is pseudo-coded in Figure 4.

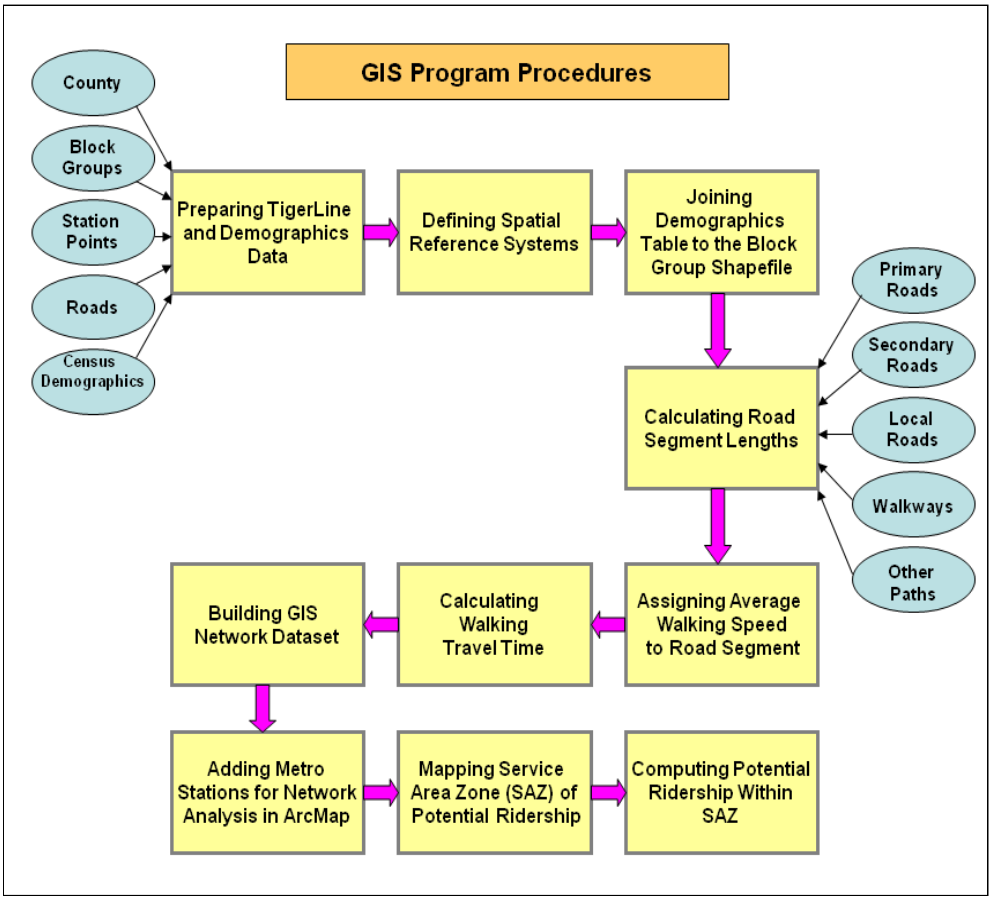

Figure 4. GIS program procedures for analyzing potential ridership

3.3. Integrated Potential Ridership

Based on the O-D flow pattern, the potential ridership of each station is integrated with the geographical location of residents, employees, and trip attractors into service coverage areas with reasonable access time to a station. The number of potential attractors was estimated based on the Trip Attraction ratio indicating the number of trip attractors generated by each employee. For example, the trip attraction ratios are 4.678 for Retail and 3.439 for Public Administration, respectively for an SAZ zone; therefore, the trip attractor for this SAZ is approximately 81 (10*4.678 + 10*3.439). The formula for the integrated potential ridership is shown as:

$$PR = R + E + A \qquad A = \sum_{i=1}^{n} E_i \beta_i$$

Where:

PR = the potential ridership

R = Residents

E = Employees

A = Trip Attractors

n = the number of categories within employment service

i = Service type

β = the ratio of trip attractions.

3.4. Atlas Compilation

The *Atlas of Potential Metro Rail Ridership* was compiled following completion of the spatial analysis to present the results. Given the nature of polycentrism (Giuliano and Small 1991; McMillen 2001; Modarres 2011; Giuliano 2004) exhibited in Los Angeles County, traditional cartographic methods for depicting the rail network and associated potential ridership could not be used.

It is necessary to generate a collection of maps in support of urban planning regarding the Metro Rail. The subsequent *Atlas of Potential Metro Rail Ridership* provides a reference map for the Metro Rail system as well as a series of choropleth, proportional symbol, isarithmic, and dasymetric maps explaining potential ridership along Metro Rail lines and stations. The basemap for the *Atlas* includes the locations of a transit station, associated transit lines, surrounding parks, neighborhoods, coastlines, and political boundaries.

The *choropleth* approach is used to represent housing density, commercial density, and industrial density by adjusting the color hue and color value, with darker areas indicating higher density. Color shading also was used to indicate additional land use categories. Table 1 provides a description of areal map features and their symbol styling (Table 1).

Primary Land Use	**Features or Objects**	**Color Scheme**
Low Density Housing	Apartments, Condominiums, Townhouses, Single Family Residents, Mixed Multi-Family Residents, *etc.*	Yellow
Medium Density Housing		Light Orange
High Density Housing		Orange
Light Commercial	Department Stores, Retail Centers, Shopping Malls, Business Parks, Recreational Regions, Offices, Stadiums, Commercial Developments, *etc.*	Light Red
Heavy Commercial		Maroon
Light Industrial	Electrical Power, Maintenance, Water Storage, Natural Gas and Petroleum, Liquid Waste, Wholesaling, Warehousing, *etc.*	Light Purple
Heavy Industrial		Purple
Institutional Use	Schools, Colleges, Universities, Day Care Centers, Medical Health Care Facilities, Special Care Facilities, Religious Facilities, *etc.*	Blue
Transportation	Bus Terminals and Yards, Park-and-Ride Lots, Truck Terminals, *etc.*	Dark Gray
Governmental Land	Government Offices, Fire Stations, Police and Sheriff Stations, Correctional Facilities, Other Public Facilities, *etc.*	Magenta
Parks / Agriculture	Parks, Golf Courses, Open Spaces, Cemeteries, Vacant Land, Agriculture Land, *etc.*	Green
Water	Rivers, Lakes, Ocean, Waterways, *etc.*	Light Blue
Others	Under Construction, Undefined Areas	Light Gray

Table 1. Areal Map Features and their symbol styling

The proportional symbol technique is applied in several ways, each using size to convey a numerical result of the spatial analysis by SAZ. The underutilization ratio is represented using a pie chart, the potential ridership is represented by a vertically stacked column chart, and boarding from walking is represented using a single-column chart.

The isarithmic technique is used to locate the SAZ boundaries for estimating potential ridership. In transportation planning, the isochrone method is commonly applied to indicate areas of equal travel time. Each line-bounded area on these maps is a ten minute walking isochrone.

Dasymetric mapping is applied to create a single value for each SAZ to reflect potential ridership linked to the distribution of the population within the effective service area by a station. In order to realistically place population data over SAZ, the dasymetric method is applied to disaggregate the census population by using boundaries to divide the area into source zones of relative homogeneity.

The maps included in the Atlas were generated at different cartographic scale ranges to support system-wide, line-based, and station-based analysis. Inclusion of a variety of themes and scales supports both a general audience as well as transit planning for future service improvements to the system.

4. Results

This section analyzes total potential ridership integrated with residents, employees, and trip attractors having station access and compares the results with the mode choices by riders from an On-Board survey completed for the Metro Rail System (LACMTA 2006). The *Atlas* was leveraged directly to identify or visually confirm the following insights into the transit use patterning.

4.1. Total Integrated Potential Ridership

With the integration of residents, employees, and trip attractors, the potential ridership is estimated to be approximately one million within a ten minute walking interval to the station (Table 2). As the Expo Line opened to the public on April 28, 2012 and no On-Board survey records were avaialbe, the Walking Boardings for the Expo Line was estimated.

Metro Rail Station	Walking Boardings	Potential Ridership (10-Minute SAZ Integration)	Underutilization	Underutilization ratio
Transfer Stations	15,169	180,762	165,593	92%
Red/ Purple Lines	43,613	425,434	381,821	90%
Blue Line	22,459	184,237	161,778	88%
Green Line	10,814	54,927	44,113	80%
Gold Line	11,400	224,526	213,126	95%
Expo Line*	*7,130*	103,946	*96,816*	93%
Total	110,585	1,173,832	1,063,247	90%

Table 2. Areal Map Features and their symbol styling

4.2. Metro Rail Transfer Stations

A transfer station is the railway facility that allows riders to transfer from more than one railway route within a public transport system . Union Station, 7th Street/Metro Center, Pico, Wilshire/Vermont, and Imperial/Wilmington are the five transfer stations in the current system. Union Station mainly is fed by the commuter rail or bus services, it was not surprising to see that its potential ridership numbers were medium-sized in the system. The 7th Street/Metro Center station, located in the Financial District of Downtown Los Angeles, shows the highest ridership on record amongst all stations in the system. Served by the Metro Blue Line and the Metro Expo Line, Pico station has very high potentil ridership numbers with 23,936. The station is within walking distances to many attractions such as the Staples Center and Los Angles Convention Center, etc. (Figure 5)

4.3. Metro Red Line / Metro Purple Line

The Red and Purples lines are grouped in one branch, as they are still jointly recorded in boarding by LACMTA. The Metro Red Line begins at Union Station and travels to the Wilshire/Vermont station. The Metro Purple Line runs to the Mid-Wilshire area from the Wilshire/Vermont station. The Civic Center and the Pershing Square stations have the highest potential ridership of stations within the Red and Purple lines (Figure 5).

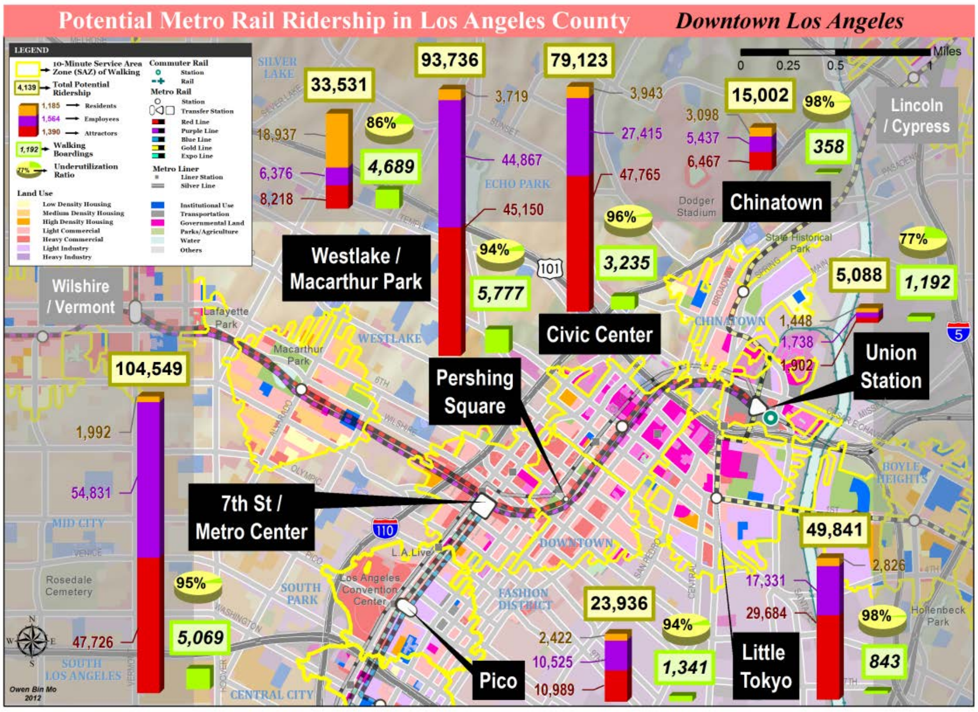

Figure 5. Map of downtown Los Angeles

4.4. Metro Blue Line

The Metro Blue Line, follows a north-south route, connecting downtown Los Angeles to downtown Long Beach. In general, most of the stations can generate more than 9,000 riders according to the model. The Transit Mall has the highest potential ridership numbers for the Metro Blue Line, followed by the Pacific Coast Highway stations (Figure 6).

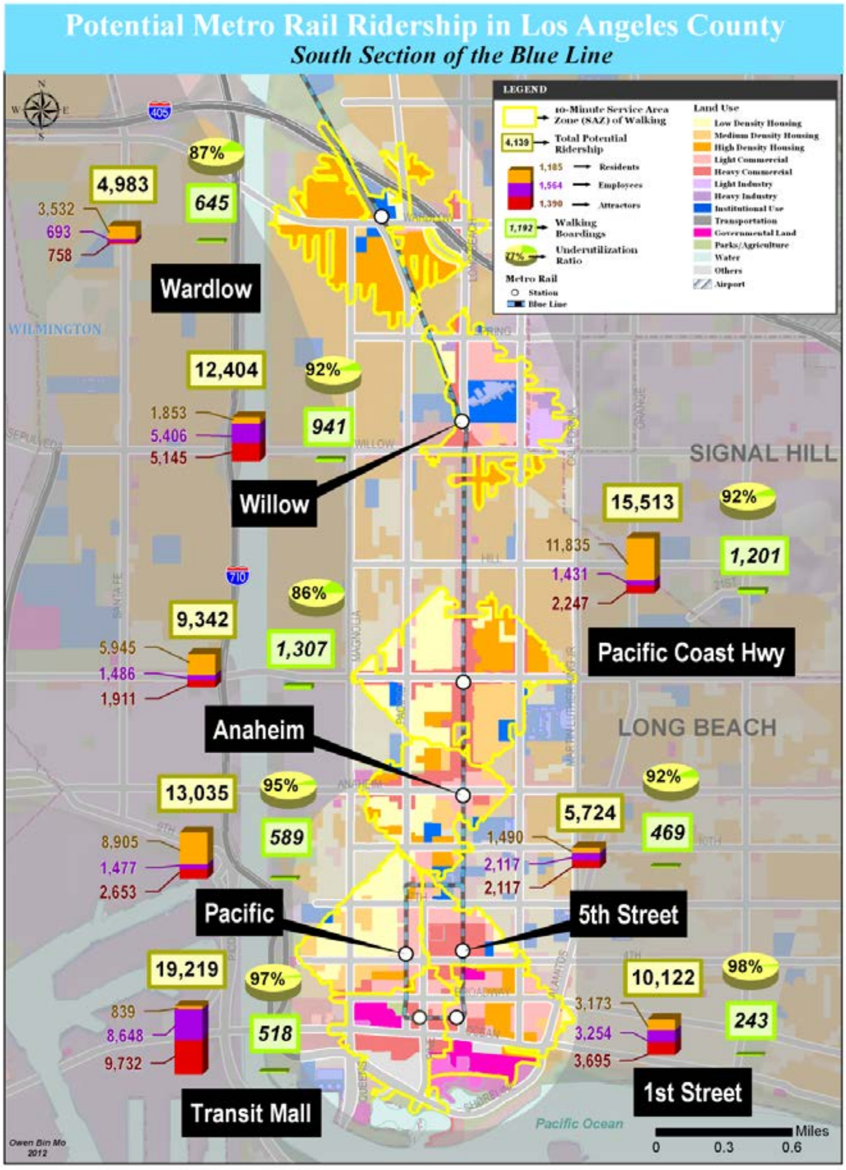

Figure 6. Map of the South Section of the Metro Blue Line

4.5. Metro Green Line

The Metro Green line runs almost entirely along the center divider of the I-105/Glenn Anderson freeway. The potential ridership of the Green Line is quite low compared with other Metro Rail system lines. Building the rail line along the freeway is problematic due to insufficient walking paths and inadequate bus connections (Figure 7). There are not many popular destinations along the Metro Green Line route, and it often is described colloquially as the train that goes "from nowhere to nowhere."

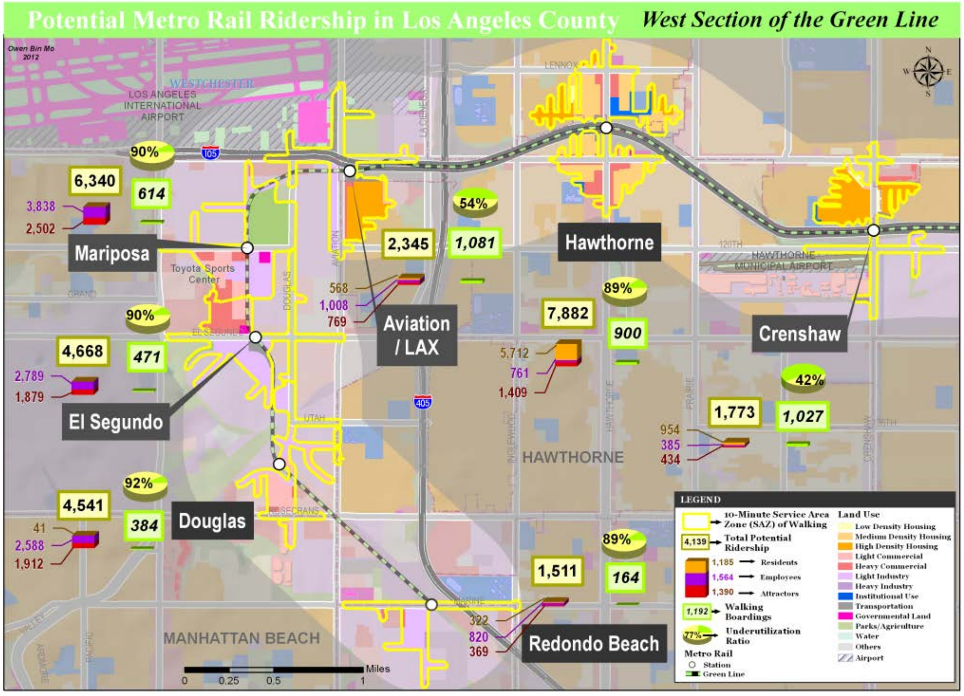

Figure 7. Map of West Section of the Metro Green Line

4.6. Metro Gold Line

The Metro Gold Line route operates between east Pasadena and East Los Angeles, passing through downtown Los Angeles. Some factors may help explain the high underutilized ratio between the actual boarding and potential ridership for the Metro Gold Line stations. First, the travel speed is one of the distraction issues, for the Metro Gold Line has the second slowest travel speed of all Metro Rail lines, with 54 minutes to travel its 19.7 mile length (21.9 mph) (LACMTA 2013). Furthermore, it is still considered as a new line and it may take time to attract ridership. The Little Tokyo station is measured to have the highest potential ridership on the Metro Gold Line. The Memorial Park station in Pasadena exhibits the second highest potential ridership numbers of the Metro Gold Line, as the station serves Old Town Pasadena, a major commercial center (Figure 8).

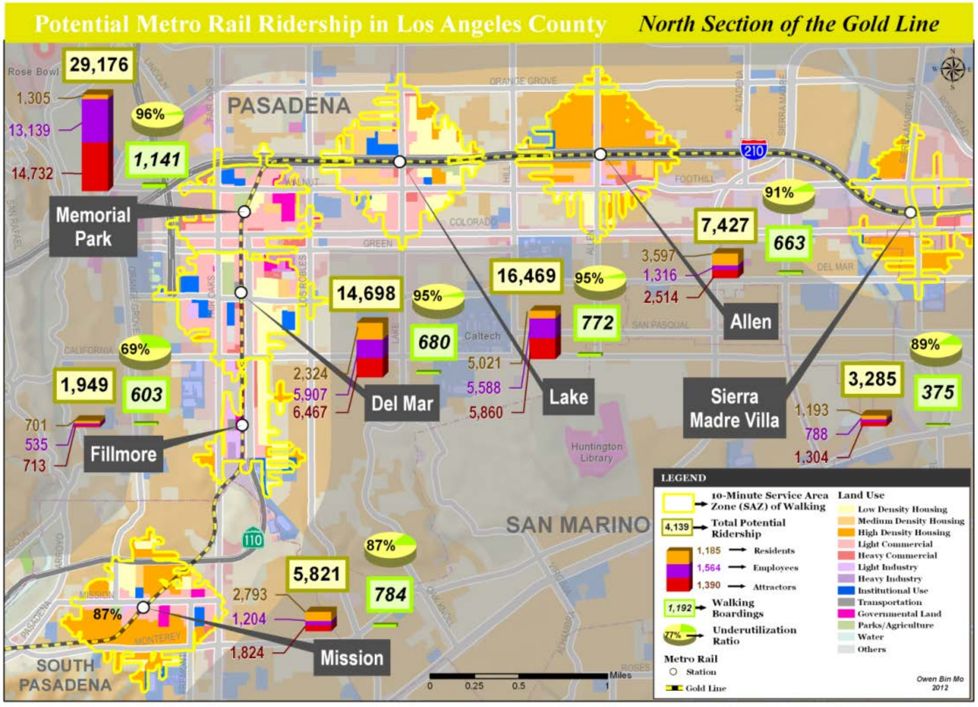

Figure 8. Map of North Section of the Metro Gold Line

4.7. Metro Expo Line

Opened in April, 2012, the Metro Expo Line is a light rail line running between Downtown Los Angeles and Culver City (Figure 7). It was estimated that Jefferson / USC station has the highest potential ridership as 19,855. Some factors might explains why most of the stations in this line have high underutilized ratios. First, the Metro Expo Line has the slowest travel speed of all Metro Rail lines, with 29 minutes to travel its 8.6 miles length (17.8 mph) (LACMTA 2013). Becasue most of the tracks are not below ground or elevated, the trains have to stop at traffic signals just like a bus where there are certain intersections. Second, when the train has to wait for automobiles at certain intersections, it possibly arrives at stations earlier or later than the schedule timetable. Morever, the Expo Line is the newested rail line added in the Metro Systems. Therefore, it may take time to attract riders for the line. The Average Weekday Boardings of Expo Line have increated more than 52% from 16,569 in June 2012 to 25,295 in February 2013 (LACMTA 2013).

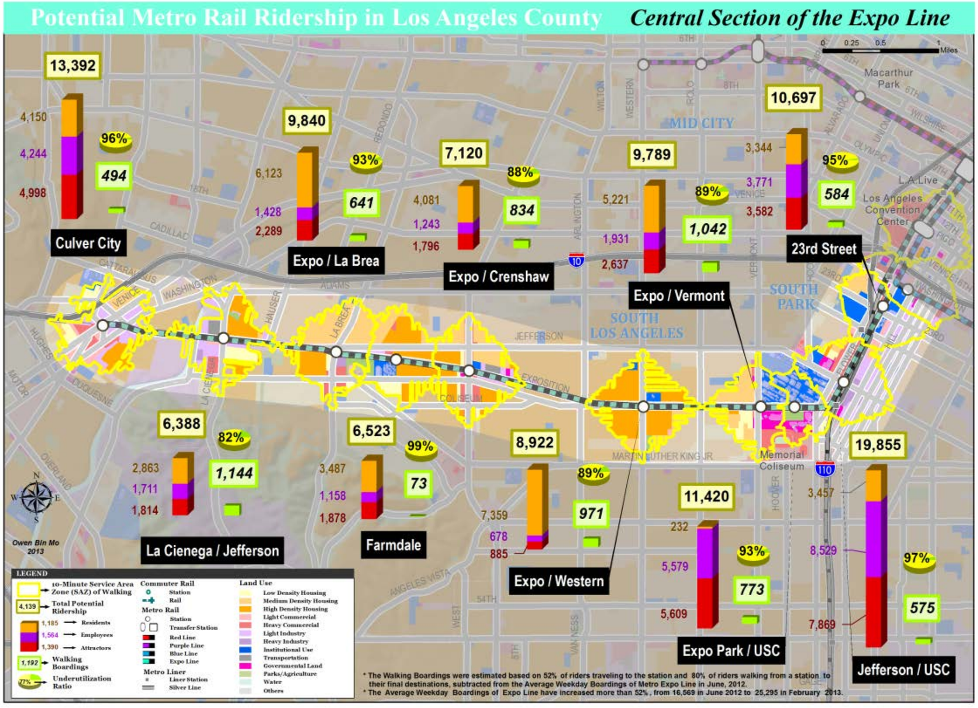

Figure 7. Map of Central Section of the Metro Expo Line

4.8. Metro Rail Station Utilization

There is a large amount of potential for the Metro Rail, as the underutilization ratio is 90% for the whole system. Unlike automobile travel, in which all activity sites have immediate access connection through roadways, the existing Metro Rail system does not directly link all sites within the Greater Los Angeles area. Riders might not utilize the Metro Rail service when it requires a longer commute time or multiple transit trips for one single personal trip. In order for Metro Rail System to be chosen over the automobile, it has to be competitive in terms of cost, time, convenience, and flexibility. New stations, hypothetical routes, or alternative access options are needed to link those "isolated" activity sites. The better the network, the higher the number of potential riders that can be converted into actual ridership.

5. Conclusion

5.1. Speculated Difficulties of Metro Rail System

What obstacle exists that prevents millions of people from having access to rail as an alternative to driving? Los Angeles County has been evaluated by many scholars as the paragon of polycentrism for which the area population is difficult to serve from a transit perspective.

It is trip density within a corridor that determines potential demand for metro rail, not population density. Making metro rail both productive and cost effective—carrying many passengers between point A and point B—is one of the only ways to be successful. Traditional downtown/outbound patterns do not conform in Los Angeles County. Spreading jobs and other destinations over more central locations, polycentrism reduces the density of activity at any single location. Los Angeles County's polycentricism makes it more difficult to justify costly investment in high-speed rail service with dedicated right-of-way in serving each activity center.

5.2. Potential Success of Metro Rail Service

Will the Metro Rail System succeed? First, the system does have a history of service upon which to build. Second, Much of the rationale for rail in Los Angeles will attract a new segment of the population to transit, who perceive the quality of rail to be faster, more comfortable, more reliable, more cost efficient, and with far fewer traffic jams. Moreover, new statistics from LACMTA indicate success: the average weekday boardings have increased more than 20%, from 300,000 in June 2011 to 363,000 in June 2012.

5.3. Future Perspectives

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. Reliable bus service is just one solution among many other alternative solutions including park-and-ride, biking, and Bus Rapid Transit (BRT). Transit properties, governments, and private developers must make a cooperative effort to increase the attractiveness of the Metro Rail System. Metro Rail will become part of the cooperative effort to improve the overall commute throughout Los Angeles County. The expansion of the Metro Rail system is but one part of the puzzle; it will help to fulfill the goal of creating a greener and more viable Los Angeles County.

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