# Mapping Potential Metro Rail Ridership in Los Angeles County

Bin (Owen) Mo | owenbinmo@gmail.com
Los Angeles County Metropolitan Transportation Authority (LACMTA)
One Gateway Plaza
Los Angeles, CA 90012


## ABSTRACT

Los Angeles County, like many metropolitan areas, 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, especially in these times of economic downturn, rising gas prices, pollution, 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," a travel demand forecasting model, and to present the results of the Trip Generation analysis in the *Atlas of Potential Metro Rail Ridership* 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:** Transportation, Spatial Analysis and Modeling, GIS, Cartography, Urban

## INTRODUCTION

Los Angeles County is internationally known as an automobile-oriented region. Residents living in the area are accustomed to the convenience of freeways and the independence provided by automobiles. Like many metropolitan areas, Los Angeles County is struggling to control increasing street and highway congestion. Public transit such as metro rail is an increasingly attractive strategy to reduce traffic congestion in cities with high levels of automobile dependency, but so far has seen minimal success in Los Angeles County due in part to its deeply ingrained polycentrism, or urban structure of multiple, poorly connected economic centers. 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 figures of the 2006 On-Board Survey records. As of June 2011, the system encompasses 79 route miles, serving 70 stations, with an average weekday boarding of 300,000 riders (LACMTA 2011 (Figure 1)).

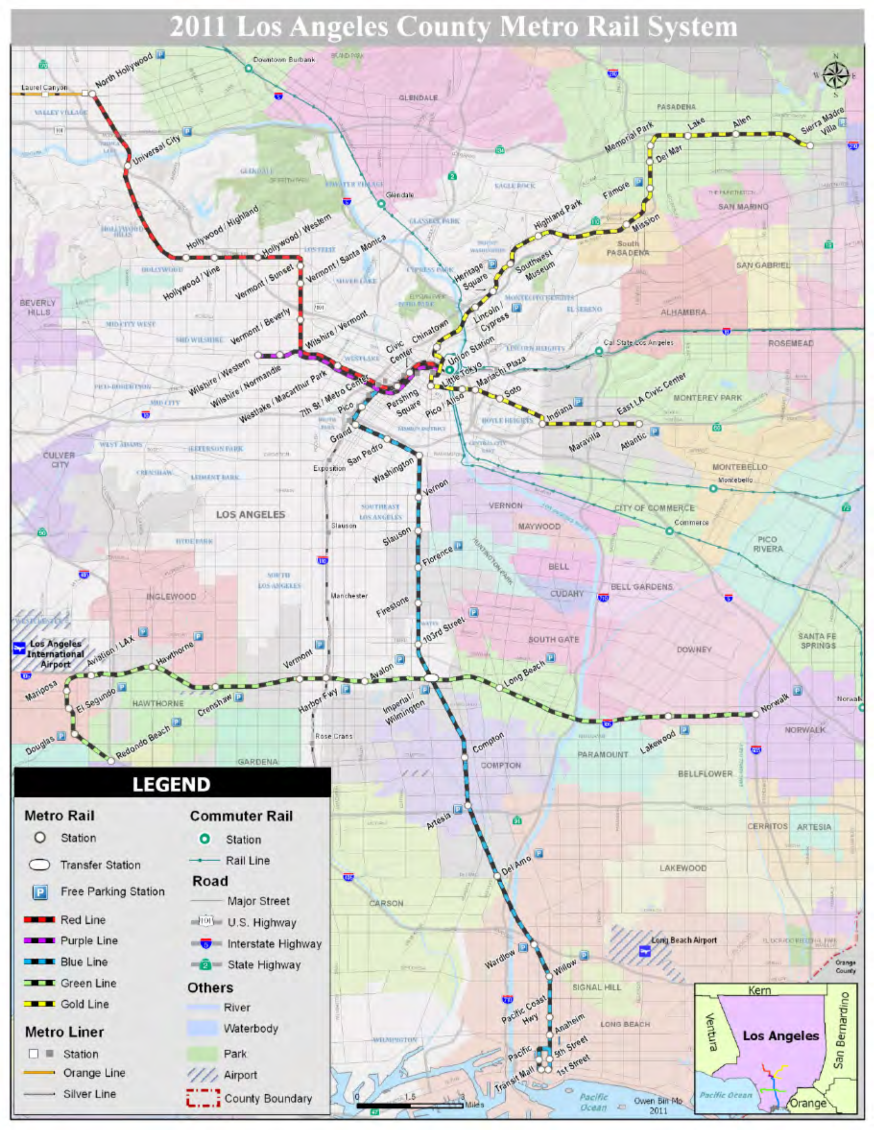


Figure 1. Map of 2011 Los Angeles County Metro Rail system.

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 *Atlas* is available for download at the *Cartographic Perspectives (CP)* website. 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.

## 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.

### *WALKING ACCESS*

The term "*access*" regarding public transportation refers to the ability to make use of the transit system, a process associated with riders arriving to and departing from the services of the Metro Rail system. Access often is perceived in spatial terms based upon physical proximity to the service and associated cost in traveling to the service. Access to public transit also is influenced by socioeconomic components such as income, vehicle ownership, and family size. As public transit is the most economical transportation option in Los Angeles County, socioeconomic characteristics are not considered in the following analysis. This analysis instead 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).

Ensuring suitable service coverage is a worthwhile objective, as the time taken to reach a station has a major impact on total travel time, which influences potential ridership (Murray et al. 1998). 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. AASHTO's (American Association of State Highway and Transportation Officials) walking guideline was applied for analyses of walking access to the San Francisco Bay Area Rapid Transit (BART) stations and Light Rail Transit (LRT) stations in Edmonton, Canada. In general, 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" (O'Neil et al.1992; O'Sullivan et al. 1998). Beyond walking access, taking the bus, driving, and riding bicycles constitute other alternative access modes for people using metro rail.

### FORECASTING ORIGIN AND DESTINATION POTENTIAL RIDERSHIP

Transportation forecasting is the process of estimating the number of people or vehicles that will use a specific transportation facility in the future. 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.

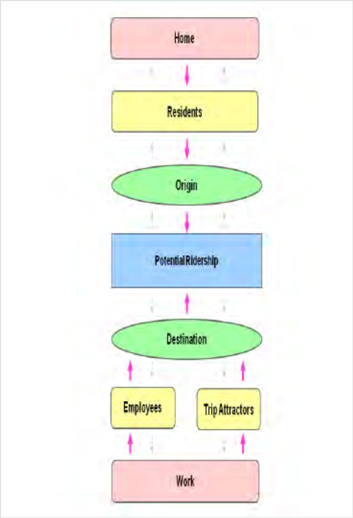


*Figure 2. Potential Ridership Generation of O-D Flow.*

*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).

*Origin ridership analysis* focuses on residences. Typically, people start from home in their first trip. 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 that could be made from the home to work, shopping, school, social, recreational, or other kinds of places.

*Destination ridership analysis* concentrates on employees. Employment regions are important local trip destinations where employees may utilize transit services. 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). The more employment within an area, the more potential riders can be generated.

Destination ridership analysis also emphasizes trip attractors other than the workplace. Typically, trip attractors are concentrated in and around major employment centers such as shopping malls, commercial retail centers, and hospitals, while trip origins are spread across a wider geographical area. 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 retail services have the highest rate of attractions due to the large number of customers drawn to department stores, supermarkets, and other daily-use facilities. Excluded for analysis were: Employees working within the transportation sector, facility maintenance and operations, construction, agriculture, fire protection, manufacturing, and the wholesale food processing industries. All of these have very little chance of attracting clients specifically to their workplace on a daily basis in the Los Angeles area.

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, forecasting potential ridership can be provided by aggregating measurements of residents, employees, and trip attractors. Estimating the potential ridership generated from residential and employment areas served by Metro Rail stations is beneficial for transit planning, marketing, and system expansion.

## 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.


*Figure 3. London Underground Tube map designed by Henry C. Beck in 1933.*

Best known as a linear cartogram, the London Underground Tube map created in 1933 by Harry Beck (Figure 3) has been widely adopted for other network maps around the world, according to London's Transport Museum. A *linear cartogram* displays a network in a way in which the length of a connection is related to certain characteristics of the connection. This linear cartogram concept shows not necessarily the geographic location but rather that of where a place is topologically. 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 map quickly became popular because the metro railway ran mostly underground and therefore the physical locations of the stations were irrelevant to travelers wanting to know how to get to one station from another.


*Figure 4. New York Subway Map designed by Massimo Vignelli in 1972.*

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). Vignelli's version included some geographical references—for example, outlines of Central Park and the boroughs—but many New Yorkers were outraged by what, to them, was a misrepresentation of their city. Tourists struggled to relate to Mr. Vignelli's design, for what they had witnessed above ground was completely different to that of the map. The geographic accuracy of the subway was done away with in order to show a clean interpretation of New York's puzzling underground lines, which located many of the stations in the wrong places. White geometric shapes were used to reduce the boroughs. Conventional topographic details including streets and parks were eliminated. The color beige, instead of blue, was used to picture the waters surrounding the city, which was even more radical. A dull gray was used to depict Central Park, whose geometry and size were also presented in unconventional fashion (Rawsthorn 2012). The eye of the beholder was forced to see only the essentials for the simplified map that looked less like a traditional map and more like a schematic depicting electronics. The public failed to recognize it as the map did not cater to their needs; it seemed the linear cartogram concept was ahead of the time. Finally the M.T.A. bowed to the public by replacing the map, in 1979, with a geographical one—reintroducing all the basic map conventions including blue water, and most important, the New York City street grid. The revision of the 1998 map contained more information, including alternate bus services and free transfer points, as well as more emphasis to the size and color of the lines, and route numbers. Considered as a more cheerful map by the public, the newly revised subway map for New York City was released in June 2010. To assure a more simplified navigation system, the map has a user-friendly appearance and brilliant colors (Figure 5).


*Figure 5. New York Subway Map released by MTA in 2010.*

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. Both subjective decisions and complex data modeling tasks are involved in the design of a map. 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.

# METHODS

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.

## *NETWORK ANALYSIS*

Geographic Information Systems (GIS) technologies have proven to be a valuable transportation management and modeling platform, due to the ability to model linear and network features within the system, whether it is the assessment of broad-scale regional policies or linking specific capacities (Nyerges 1995; Biba et al. 2010). 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 employs a reasonable network of functionality to determine travel time to transit facilities. The network analysis method increases spatial precision because it distributes spatial analysis along a linear length, rather than across the entire region; therefore, there is less chance of overestimating the ridership compared with the buffer method (O'Neill et al. 1992).

Routing, districting, and allocations are the three advanced applications of network analysis (Briggs 2009). Routing finds the shortest path between two points, such as locating hotels from an airport. Districting expands the study area along a network until one or more criteria (time, distance, or object count) is reached, and then defines a districting plan for services like voting, schools, policing, or fire protection. Allocation assigns locations to the nearest center based on the travel time or distance through a network.

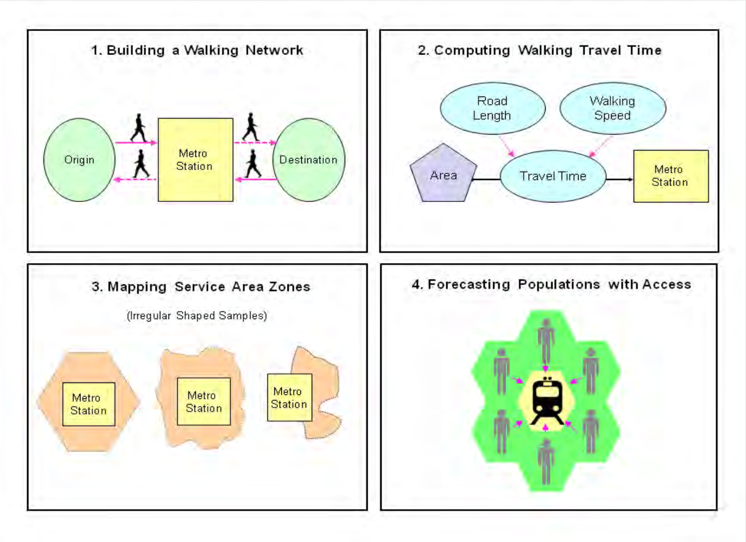


*Figure 6. The procedure of Network Analysis method.*

Performing the network analysis requires four steps computationally, several of which have sequential sub-processes (Figure 6). The first step is the building of a road network from which riders in each census block group 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 length of each road segment was calculated in feet and three miles per hour is assigned as the average walking speed. Single walking time measurement of ten minutes for all individuals in each area was applied. The third step is delineating and mapping Services Area Zones

(SAZs), or contiguous areas within which potential riders could walk to a station in ten minutes or less. The final step is analysis of the populations with transit access, which includes four sub-steps (Figure 7): (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.

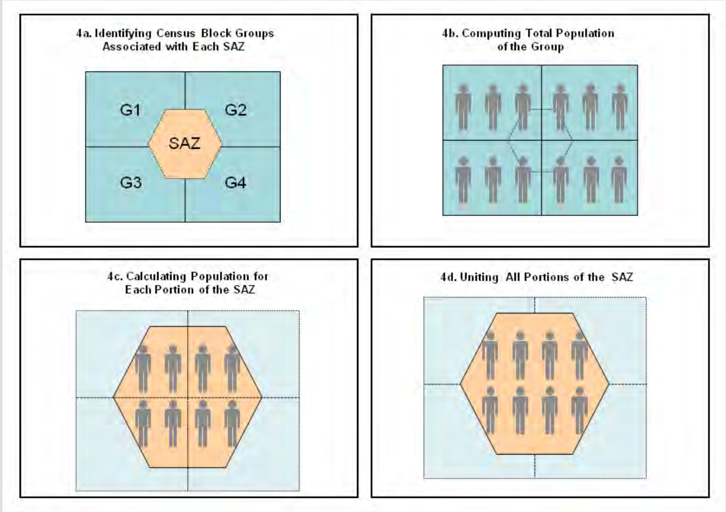


*Figure 7. The sub-steps of forecasting population with access.*

### 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, a private company with proprietary geospatial information sets; the pair of information sources included datasets for roads, railroads, rivers, legal boundaries, and statistical geographic areas. The GIS processing involved numerous steps and intermediate database captures, including preparing data, defining spatial reference systems, matching demographic data with GIS data layers, calculating traveling time for road segments, building a network dataset, mapping SAZ, and computing potential ridership; the complete GIS program procedure for analyzing potential Metro Rail ridership is pseudo-coded in Figure 8.

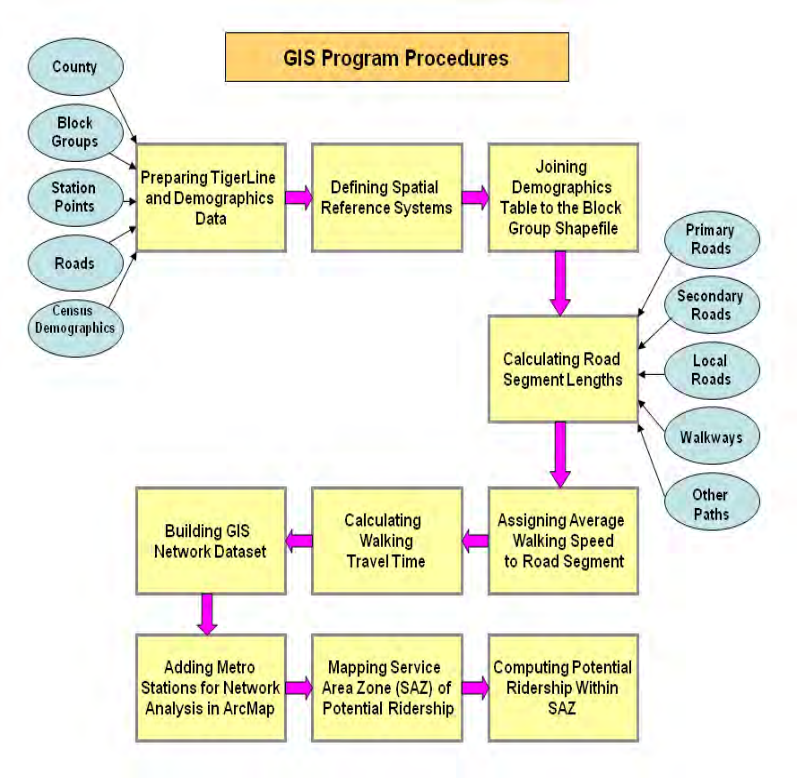


*Figure 8. GIS program procedures for analyzing potential ridership.*

### 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 same procedure was used to forecast the population of residents and employees with access to the system within the SAZ, with the aid of the Network Analyst extension. Then the number of potential attractors was estimated based on the category of employment services located in the SAZ, the number of employees working in those regions, and the Trip Attraction ratio indicating the number of trip attractors generated by each employee. For example, consider an SAZ containing two types of employment services: Retail and Public Administration, with 10 employees for each service. The trip attraction ratios are 4.678 for Retail and 3.439 for Public Administration; 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:

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

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.

## ATLAS COMPILATION

The *Atlas of Potential Metro Rail Ridership* was compiled following completion of the spatial analysis to present the results. 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. Further, Los Angeles County is an urban center characterized by extreme *polycentrism*, or multiple regions of economic activity (rather than a single center or core region) with few connections among the regions (Giuliano and Small 1991; Gordon 1996; McMillen 2001; Modarres 2003 and 2011; Giuliano 2004).

Given the nature of polycentrism exhibited in Los Angeles County, traditional cartographic methods for depicting the rail network and associated potential ridership could not be used. For example, the well-known linear cartogram concept designed by Harry Beck in 1933 for the London underground, displaying subway stations as dots connected by lines, is not suitable in all circumstances. The same concept was adopted for generating the New York Subway map, with several additional geographical references, as designed by

Massimo Vignelli. These, however, failed to be recognized by New Yorkers and tourists (Heller 2010; Rawsthorn 2012). With public pressure, the map was replaced with a geographical one in 1979, and was revised again in 2010. The map changed throughout time to reflect the ever-changing characteristics and needs of people in the city, or the region.

It instead 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 (e.g., community, city, region, and county, where appropriate). Each map's specific theme is layered atop the basemap reference.

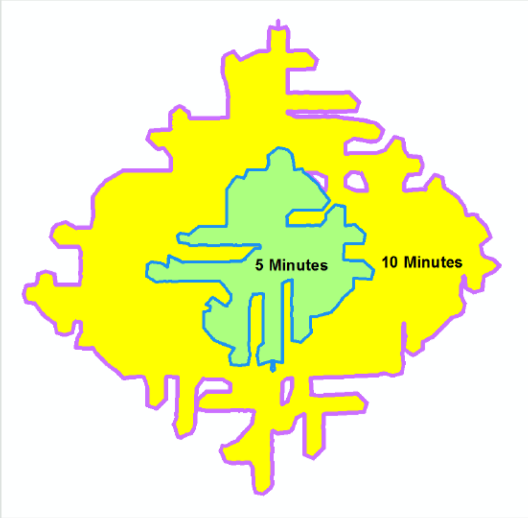


*Figure 9. Isochronic map of area within 5-minute and 10-minute intervals for riders to access a station.*

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, such as institutional use, transportation, government land, parks/agriculture, water, and others. Table 1 provides a description of areal map features and their symbol styling (Table 1, page after next).

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 (split among residents, employees, and attractors) 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. Isochrone is defined as a curve line drawn on a map connecting points at which something occurs or arrives at the same time. 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, or line of equal walking time, with areas within the boundary requiring less than ten minutes to reach a station, and areas outside of the region requiring more than ten minutes (Figure 9).

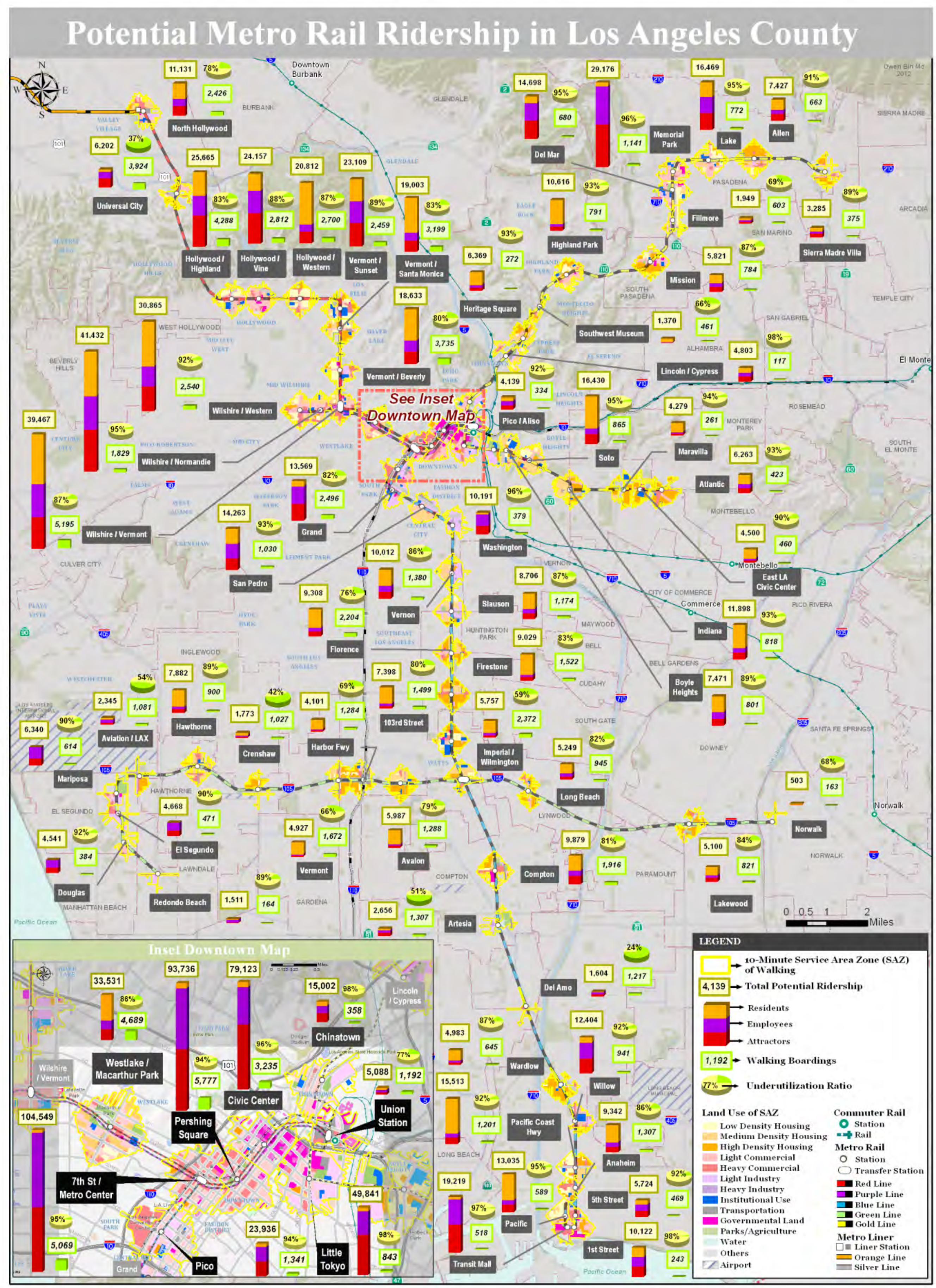


*Figure 10. Map of Potential Metro Rail Ridership in Los Angeles County.*

| Primary Land Use | Features or Objects | Secondary Division | Color Scheme |
|---|---|---|---|
| Housing | Apartments, Condominiums, Townhouses, Single Family Residents, Mixed Multi-Family Residents, etc. | Low Density | Yellow |
| | | Medium Density | Light Orange |
| | | High Density | Orange |
| Commercial | Department Stores, Retail Centers, Shopping Malls, Business Parks, Recreational Regions, Offices, Stadiums, Commercial Developments, etc. | Light | Light Red |
| | | Heavy | Maroon |
| Industrial | Electrical Power, Maintenance, Water Storage, Natural Gas and Petroleum, Liquid Waste, Wholesaling, Warehousing, etc. | Light | Light Purple |
| | | Heavy | 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.*

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 (Figure 10). Population distribution is commonly displayed using decennial census data. However, those data are aggregates of geographic units such as census tracts or block groups whose boundaries do not reflect the actual distribution of population for the service area. 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. Then, source zones are overlaid within the ancillary data set, the SAZs. Moreover, the populations of every source zone associated with each SAZ are estimated with the purpose of portraying the potential ridership for each station.

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 improvement to the system.

# 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). Comparing the differences between potential ridership and actual boarding data, a utilization ratio is calculated to indicate the level of utilization. To efficiently analyze the results and make accurate comparisons, transfer stations and non-interchange stations with varied routes are categorized into different tables. The results are intended as a support service for improvement planning regarding the Metro Rail system. The *Atlas* was leveraged directly to identify or visually confirm the following insights into the transit use patterning.

## 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, which is about ten times higher than the actual amount of boardings having walking access to rail stations according to the 2006 on-board survey (Table 2 and Figure 10).

| Metro Rail Station | Walking Boarding | 10-Minute SAZ Integration | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Residents | Employees | Trip Attractors | Potential (Total) | Under-utilization | Under-utilization ratio | Cover Area (sq mi.) |
| Transfer Stations | 13,828 | 23,065 | 68,867 | 64,894 | 156,826 | 142,998 | 91% | 1.24 |
| Red/ Purple Lines | 43,613 | 124,218 | 131,936 | 169,280 | 425,434 | 381,821 | 90% | 4.68 |
| Blue Line | 23,800 | 83,158 | 59,382 | 65,633 | 208,173 | 184,373 | 89% | 5.94 |
| Green Line | 10,814 | 26,173 | 15,227 | 13,527 | 54,927 | 44,113 | 80% | 2.88 |
| Gold Line | 11,400 | 73,733 | 63,795 | 86,998 | 224,526 | 213,126 | 95% | 6.17 |
| Total | 103,455 | 330,347 | 339,207 | 400,332 | 1,069,886 | 966,431 | 90% | 20.91 |

*Table 2. Total integrated potential ridership of Metro Rail system in Los Angeles County.*

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, Wilshire/Vermont and Imperial/Wilmington are the four transfer stations in the current system (Figure 11). As the maps indicate that

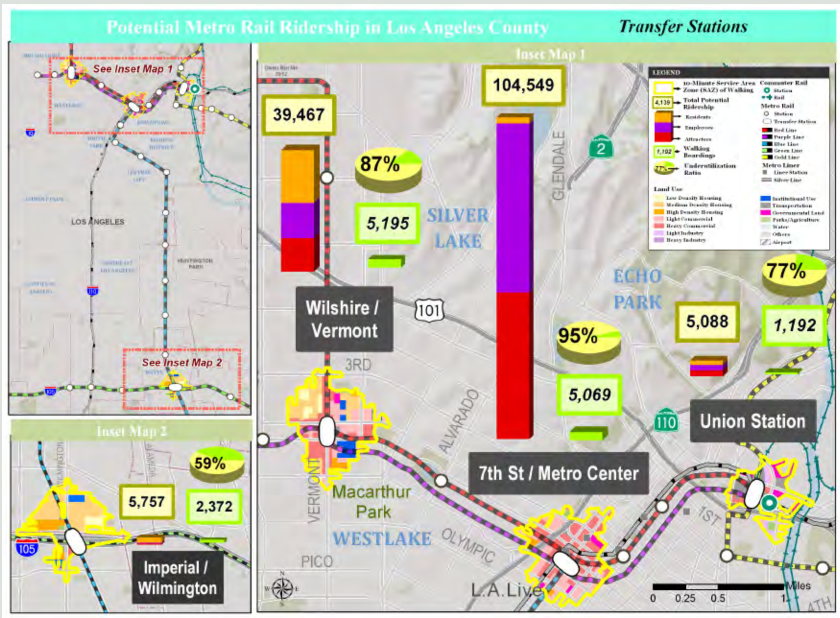


*Figure 11. Map of the Metro Rail transfer stations.*

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. When integrating all of the factors to determine potential ridership, 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. The Wilshire/Vermont station is another top-ranked station with potential ridership at 41,432, eight-times higher than actual recorded boardings, one of the top-five highest potential ridership numbers resulting from the analysis. Functioning much like Union Station, Imperial/Wilmington has medium-sized ridership as well.

### *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, where the track is shared with the Metro Purple Line, then runs north through North Hollywood; the Metro Purple Line runs to the Mid-Wilshire area from the Wilshire/Vermont station. Most of the stations in this group show great potential ridership, netting over 20,000 potential riders as this branch travels through the central business district of Los Angeles. The Civic Center and the Pershing Square stations have the highest potential ridership of stations within the Red and Purple lines

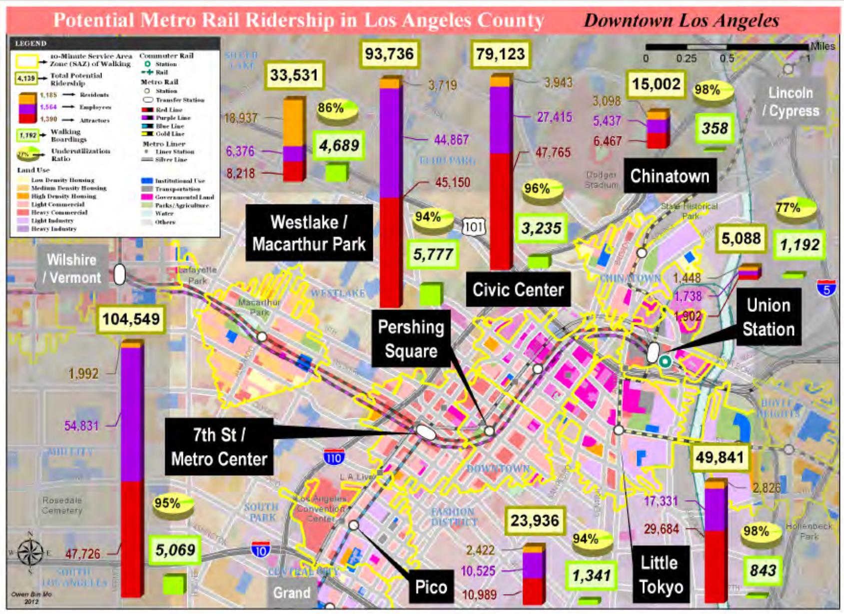


Figure 12. Map of downtown Los Angeles.

(Figure 12). Along with the Wilshire/ Normandie station, the Civic Center and the Pershing Square stations also have large underutilization ratios.

### *Metro Blue Line*

The Metro Blue Line, which is a light rail 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. Pico Station has the highest potential ridership numbers for the Metro Blue Line, followed by the Transit Mall and Pacific Coast Highway stations. Even though the Del Amo station captured the smallest potential ridership of all stations on the Metro Blue Line with the ten-minute SAZ, it is the most utilized station across the entire system, with a value of 76% (Figure 13). This suggests that when the pedestrian environment around the station improves, ridership numbers also may increase.

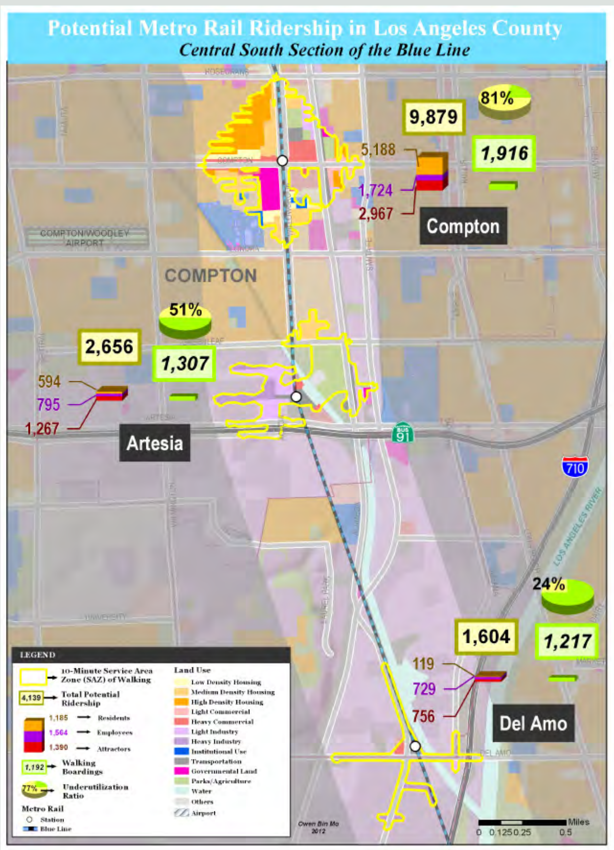


Figure 13. Map of the Central South Section of the Metro Blue Line.

### *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 (Figure14). Building the rail line along the freeway is problematic due to insufficient walking paths and inadequate bus connections. Another factor includes non-direct linking with other transportation facilities such as commuter rail and the airport. The Aviation/ LAX station does not provide right-of-way access to the airport; instead, the station uses shuttle bus service to connect the station to the Los Angeles International Airport (LAX). The situation is similar for the Norwalk station, as bus services are required for transfer to the commuter rail station. Further, 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." The freeway stations also are perceived as inhospitable due to freeway pollution, noise, safety, and accessibility. The Hawthorne station is estimated to have the highest potential ridership on the Metro Green Line. The Douglas station is the least utilized while the Crenshaw station is the most utilized station, followed by Aviation/LAX.

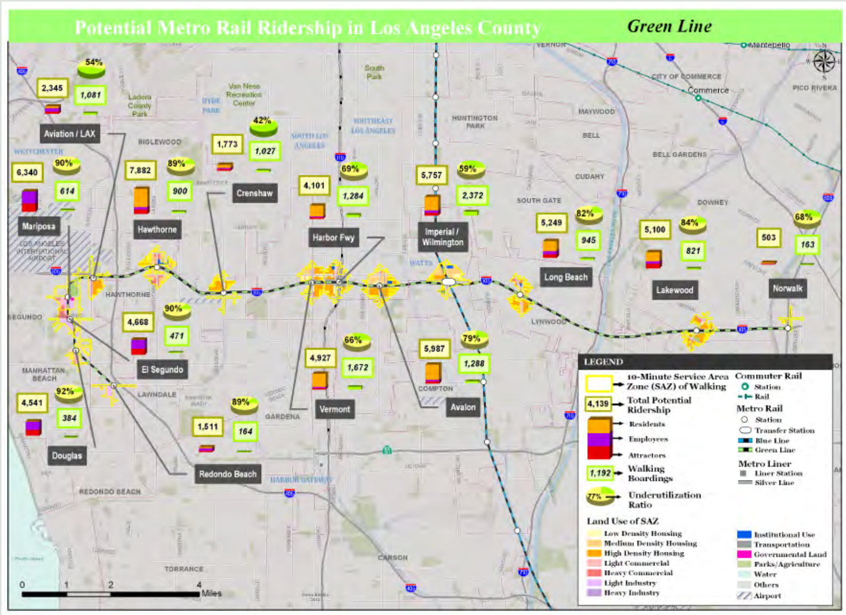


Figure 14. Map of the Metro Green Line.

## *Metro Gold Line*

The Metro Gold Line route operates in a crescent shape 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 slowest travel speed of all Metro Rail lines, with 54 minutes to travel its 19.7 mile length (21.9 m/h) (LACMTA 2011). Furthermore, it is a new line and it may take time to attract ridership. If more direct connections were available along the Metro Gold Line, it could attract more commuters to use the service; therefore, it may be the Metro line that could see the highest increase in boardings. The Little Tokyo station is measured to have the highest potential ridership on the Metro Gold Line. Along with the Lincoln/Cypress and Chinatown stations, the Little Tokyo station also has a low utilization ratio. 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 15). Even though the Southwest Museum station is the most utilized station on the Gold Line, the actual boarding record is not very high

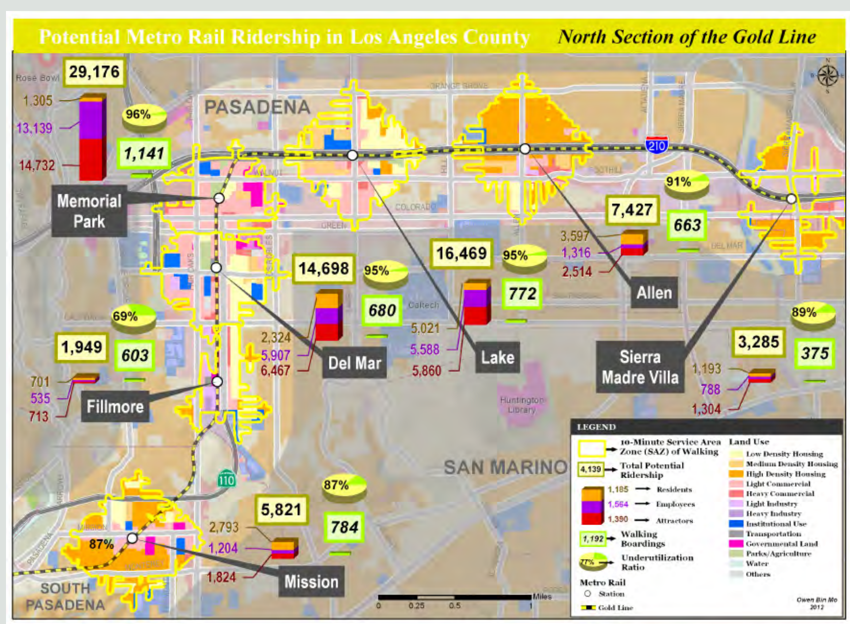


Figure 15. Map of North Section of the Metro Gold Line.

since the station mainly served the Southwest Museum, which was closed in 2011.

### *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. The Little Tokyo station (Metro Gold Line) exhibits the great disparity between potential ridership and actual boarding, followed by Lincoln/Cypress (Metro Gold Line) and 1st. Street (Metro Blue Line). The Del Amo station (Metro Blue Line) is the most utilized station in the system, followed by Universal City (Metro Red/Purple lines) and Crenshaw (Metro Green Line).

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. Many residential regions are not served by the existing Metro Rail system; there are many job opportunities and commercial centers located outside of the service 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.

## CONCLUSION

### *SPECULATED DIFFICULTIES OF METRO RAIL SYSTEM*

Metro Rail must compete with the automobile, which is still the most attractive mode of transportation. 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 (Giuliano and Small 1991; Gordon 1996; McMillen 2001; Modarres 2003 and 2011; Giuliano 2004).

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. Dotted with very large centers of activity, railroads will work best in compact population corridors with at least one end in a very dense population center (Rubin 2000). 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; that is, not every destination will be able to have an easy connection to a rail line. 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. This further decreases the attractiveness compared to the automobile, given the need to travel to different destinations serving multi-purpose trips, and to combine multiple errands in a single trip.

### *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. The Pacific Electric Railway, also known as the Red Car System, interconnected cities in Los Angeles, Orange, San Bernardino, and Riverside Counties using streetcars, light rail and buses, beginning in 1901 (Walker 2006). The systems also connected with the "Yellow Car" system serving downtown Los Angeles and cities of Hawthorne, Gardena, and Torrance. Second, it is fairly well documented that it was automobile companies that bought out the rail and dismantled the service in the 1930s and 1940s (Snell 1974 and 1995; Span 2003). By intentionally running the rail out of business, auto companies helped to reinforce the market for their major product, meaning that the automobiles created the polycentrism, not that polycentrism created the need for automobiles. Third, increasing population, environmental concerns, traffic congestion, and gasoline prices are other factors that push the need for mass transit services. Furthermore, the existing transit system already serves users with few economic resources. 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.

### *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). In most cases, the quality of the pedestrian environment around rail stations should be addressed. When real and even perceived delays and inconveniences create a sense of insecurity, riders usually choose to use their personal automobiles.

Transit properties, governments, and private developers must make a cooperative effort to increase the attractiveness of the Metro Rail system. For providing rapid transit services to more parts of the county, the LACMTA is seeking public commitment to fulfill its Long Range Transportation Plan for the county as more rail and bus rapid transit extensions are opened, under construction, and planned for millions of people to have access to a rail alternative to driving. 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.

## ACKNOWLEDGMENTS

Sincere appreciation is given to Dr. John Kirchner for his direction, assistance, and guidance. Kudos to Dr. Hong-Lie Qiu and Dr. Stephen Mulherin for their positive reviews and support. I also wish to thank Dr. Chausie Chu, the Systems Analysis and Research team of the Long Range Planning and the Coordination Department of the Los Angeles County Metropolitan Transportation Authority (LACMTA) for providing an opportunity to gain professional work experiences in transportation planning. Moreover, recognition is extended to Robert Cálix, Gene Manley, and Mark Gerardy for their insightful comments, which greatly improved this paper. I am particularly grateful to the editor and reviewers from *Cartographic Perspectives* for guiding this paper through every stage of writing and production. Their support and editorial insights when crucial decisions had to be made were invaluable.

## REFERENCES

Biba, S. Curtin. K, and Manca, G. 2010. "A New Method for Determining the Population with Walking Access to Transit." *International Journal of Geographical Information System*, 24 (3): 347–364.

Beimborn, E. A., Greenwald, M. J., and Jin, X. 2003. "Accessibility, Connectivity, and Captivity: Impacts on Transit Choice. " *Transportation Research Record*, 1835: 1–19.

Briggs, R. 2009. "Analysis and Modeling in GIS." *Dallas: The University of Texas.* **http://www.elbuscadorppt.com/ppt/analysis-and-modeling-in-gis.html** (accessed June 1, 2010)

Campbell, J. 2011. *Map Use and Analysis*. McGraw-Hill, Boston, 4th edition.

Giuliano, G., and Small, K. 1991. "Subcenters in the Los Angeles Region." *Regional Science and Urban Economics* 21, 2: 163–82.

Giuliano, G., 2004. "Analysis of Los Angeles Metropolitan Spatial Structure." University of Southern California.

Gordon, P., and Richardson, H. 1996. "Beyond Polycentricity: The Dispersed Metropolis, Los Angeles, 1970-1990." *Journal of the American Planning Association*. 62 (3): 289–295.

Heller, S. 2010. "A More Cheerful New York Subway Map." The New York Times. **http://www.nytimes.com/2010/06/02/arts/design/02map.html** (accessed August 8, 2012)

Los Angeles County Metropolitan Transportation Authority (LACMTA). 2006. "On- Board Survey Results Gold Line Transit Rider Survey." *Austin: Nustats.*

———. 2011. "Ridership Statistics." *Los Angeles County Metropolitan Transportation Authority.* **http://www.metro.net/news_info/ridership_avg.htm** (accessed June 1, 2011)

Metropolitan Washington Council of Governments (MWCG). 2010. "Four-Step Travel Model." **http://www.mwcog.org/transportation/activities/models/4step/4_step.asp** (accessed September 1, 2010)

McMillen, D. P., 2001. "Nonparametric Employment Subcenter Identification." *Journal of Urban Economics* 50.

Mo, B. 2009. "GIS Network Analysis for Finding the Potential Metro Rail Ridership in Los Angeles County." *2010 AASHTO GIS for Transportation Symposium.* **http://www.gis-t.org/files/bCRt4.pdf** (accessed April 1, 2010)

Modarres, A. 2003. "Polycentricity and Transit Service." *Transportation Research Part A: Policy and Practice*, 37 (10): 841–864.

Modarres, A. 2011. "Polycentricity, Computing Pattern, Urban Form: The Case of Southern California." *International Journal of Urban and Regional Research*, DOI: 10.1111.

Murray, A., Davis, R., Stimson, R. and Ferreira, L. 1998. "Public Transportation Access." *Transportation Research Part D: Transport and Environment,* 3(5): 319–328.

Nyerges, T. 1995. "Geographical Information Systems Support for Urban/Regional Transportation Analysis." *Geography of Urban Transportation,* 2: 53–77.

O'Neill, W.A., Ramsey, R.D., and Chou, J., 1992. "Analysis of Transit Service Areas Using Geographic Information Systems." *Transportation Research Record*, 1364: 131–138.

O'Sullivan, S., and Morrall, J. 1996. "Walking Distance To and From Light-Rail Transit Stations." *Transportation Research Record 1538*: 19–26. National Research Council (U.S.). Transportation Research Board.

Rawsthorn, A. 2012. "The Subway Map That Rattled New Yorkers." *The New York Times*. **http://www.nytimes.com/2012/08/06/arts/design/the-subway-map-that-rattled-new-yorkers.html?_r=1** (accessed August 8, 2012)

Rubin, T. 2000. "Learning from Los Angeles: Rail and Transportation Equity." *Technology Transfer Newsletter,* Spring 2000.

Snell, B. 1974. *American Ground Transport: A Proposal for Restructuring the Automobile, Truck, Bus, and Rail Industries.* Washington: U.S. Government Printing Office.

Snell, B. 1995. "The Street Car Conspiracy: How General Motors Deliberately Destroyed Public Transit." *Lovearth.net.* **http://www.lovearth.net/gmdeliberatelydestroyed.htm** (accessed August 8, 2012)

Southern California Association of Governments (SCAG). 2008. "2003 SCAG Model Validation and Summary Regional Transportation Model." *Resolving Regional Challenges.* **www.scag.ca.gov/modeling/pdf/MVS03/MVS03_TOC.pdf** (accessed December 1, 2010)

Span, G.2003. "Paving the Way for Buses—The Great GM Streetcar Conspiracy." **http://www.baycrossings.com/Archives/2003/03_April/paving_the_way_for_buses_the_great_gm_streetcar_conspiracy.htm** (accessed August 8, 2012)

Transit Cooperative Research Program (TCRP). 2006. "Fixed-Route Transit Ridership Forecasting and Service Planning Methods."*TCRP Synthesis 66.* **http://gulliver.trb.org/publications/tcrp/tcrp_syn_66.pdf** (accessed December 1, 2010)

Walker, J. 2006. *Images of Rail: Pacific Electric Red Cars*. Arcadia Publishing: 7