AN EVALUATION OF PROJECTED VERSUS ACTUAL RIDERSHIP ON LOS ANGELES' METRO RAIL LINES

A Thesis

Presented to the

Faculty of

California State Polytechnic University, Pomona

In Partial Fulfillment

Of the Requirements for the Degree

Master

In

Urban and Regional Planning

By

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2019

SIGNATURE PAGE

THESIS: AN EVALUATION OF PROJECTED VERSUS ACTUAL RIDERSHIP ON LOS ANGELES' METRO RAIL LINES

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ACKNOWLEDGEMENTS

This work would not have been possible without the support of the Department of Urban and Regional Planning at California State Polytechnic University, Pomona. I am especially indebted to Dr. Rick Willson, Dr. Dohyung Kim, and Dr. Gwen Urey of the Department of Urban and Regional Planning, who have been supportive of my career goals and who worked actively to provide me with educational opportunities to pursue those goals. I am grateful to all of those with whom I have had the pleasure to work during this and other related projects with my time at Cal Poly Pomona. Each of the members of my Thesis Committee has provided me extensive personal and professional guidance and taught me a great deal about both scientific research and life in general.

Nobody has been more supportive to me in the pursuit of this project than the members of my family. I would like to thank my parents Larry and Laurie Janicek, whose love and guidance are with me in whatever I pursue. They are the ultimate role models. Most importantly, I wish to thank my loving and supportive partner, Connor Francis, and who provided unending inspiration and care. To my sisters Loni and Lanelle and their families, thank you for reminding me to always smile, even when times are tough. Thank you to Lexi, Cavan, and Brayden for actively keeping me young. To Oakley and Temma for ensuring I navigated out of the house throughout the writing process. And lastly, I'd like to thank Douglas and Al for being gems that provided glimmers of inspiration.

ABSTRACT

The Los Angeles County Metropolitan Transportation Authority, also known as Metro, has ambitious goals to expand the rail transit network throughout the county. Corridor studies and Environmental Impact Reports assess and recommend the best alternatives for rail developments using ridership as a primary factor in judging overall performance. This study compares current and historical ridership data with projections provided in environmental impact reports for all fourteen segments of the light and heavy rail network. It compares the ridership with projections set forth in the pre-construction stages of development to assesses whether each segment is over or under performing. The objective of this research is to understand the current rail performance of Metro and provide insight as to how Metro can more accurately predict rail ridership. The findings are that more than half rail segments, especially heavy rail, missed their ridership projections. This research investigates factors that influence the ridership of Metro Lines, including population and job density, route alignment, and the use of federal funding. The project also compares Metro light and heavy rail with the performance of other regional rail networks. Rail ridership between 2014 and 2018 is also presented to focus attention on the recent past. The study seeks to understand Metro rail system ridership performance as it moves into a new era of expansion.

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CHAPTER 1: INTRODUCTION

Over the course of the next decade, Los Angeles County Metropolitan Transportation Authority, commonly known as Metro, will spend over ten and a half billion dollars on rail projects throughout Los Angeles County (Metro, 2019b). Due severe traffic congestion and public support for rail transit, Metro plans to expand its light and heavy rail network by more than thirty-nine miles, spending billions of dollars to enhance this system (Tinoco, 2017). To help finance these projects, voters have approved multiple tax measures to provide new transportation modes. In 2008 voters approved Measure R, a ½ cent sales tax with just over two-thirds of the required vote for approval (Chiland, 2016). In 2016, 72 percent of voters approved Measure M, a sales tax measure set to generate $120 billion over 40 years to expand rail, rapid bus, and bike networks (Bliss, 2019). With two voter approved tax measures in place over the last ten years, it is important to hold such agencies accountable.

While rail networks are becoming more popular in metropolitan areas, it is important to ensure that decisions on these projects are made on realistic assessments of ridership and that these projects are performing as promised. In order to receive funding for major public transit projects, transportation agency must comply with local, state, and federal laws and policies. In most cases, an environmental impact report (EIR) presents alternatives and recommendation for the projects. Accurate ridership projections of these public transit developments are essential in providing input into project use, performance, and feasibility. Ridership projections provide essential information that decision makers can use in prioritizing projects. By looking at these rail networks through a ridership lens, the research assesses whether or not the network is performing the way Metro and these tax measures intended it to.

Ridership decline in major metropolitan areas is a growing concern for transportation planners. A recent study on transit in urban environments noted the decline in ridership in more than twenty major metropolitan areas in the United States. (O'Toole, 2018) This research looked at varying urban settings and assessed transit ridership, both bus and rail, which noted declines in nearly every mode of public transit. This is very concerning as the federal, state, and local governments spend more than $50 billion a year subsidizing public transit, yet transit ridership has declined in every year between 2014 and 2018 (O'Toole, 2018). This study also concluded a decline in public transit ridership for Los Angeles by more than 20% since 2008. As ridership decline persists, it is important to consider the ridership forecasts upon which project decisions are made.

The decline in rail transit ridership in recent years encourages further investigation into public transit trends in the greater Los Angeles region. While Los Angeles in known for having a car culture, Los Angeles transit agencies have attempted to change that perception. Metro builds and runs the primary public transportation system in Los Angeles County. It was formed in 1993 from a merger of the Southern California Rapid Transit District and the Los Angeles County Transportation Commission. It is chartered under state law as a regional transportation planning agency. Metro directly plans and manages bus, light rail, heavy rail and bus rapid transit services. It provides financial assistance and guides planning for rail and freeway projects within Los

Angeles County. It also assists twenty-seven local transit agencies as well as access paratransit services. (Simon, 1998)

Metro Rail is currently made up of four light rail lines (Blue, Gold, Green, and Expo) and two heavy rail lines (Red and Purple). Light rail is typically defined as a type of urban passenger transportation service that utilizes electrically propelled trains, operating primarily at surface level either over exclusive rights-of way or over public streets. Light rail typically operates between 35-50 miles per hour, with two to three cars per train. Heavy rail utilizes electrically propelled trains of cars operating over fully grade-separated rights-of-way. Heavy rail is typically envisioned as high-capacity, semiautomated trains of four to ten cars powered by electricity from a third rail. Because heavy rail systems require an exclusive, completely grade-separated alignment, Heavy rail typically operates at a faster speed than light rail, while transporting more passengers at a time (Siler, 2009). As seen in Figure 1.1, most of the system has a hub at the Metro headquarters at Union Station. Downtown Los Angeles is immediately west of the headquarters and station. As of Spring 2019, the rail network is made up of 93 stations, and 98 miles of services (Metro, 2019a). Recently, the Expo Line celebrated reaching its 2030 ridership projection goal. However, in that same article, the author noted the significant decline in ridership for much of the remaining rail network operated by Metro (Barragan, 2017a). As tax payers in Los Angeles County continue fund rail projects for the region, it is important to ensure accountability with future lines.

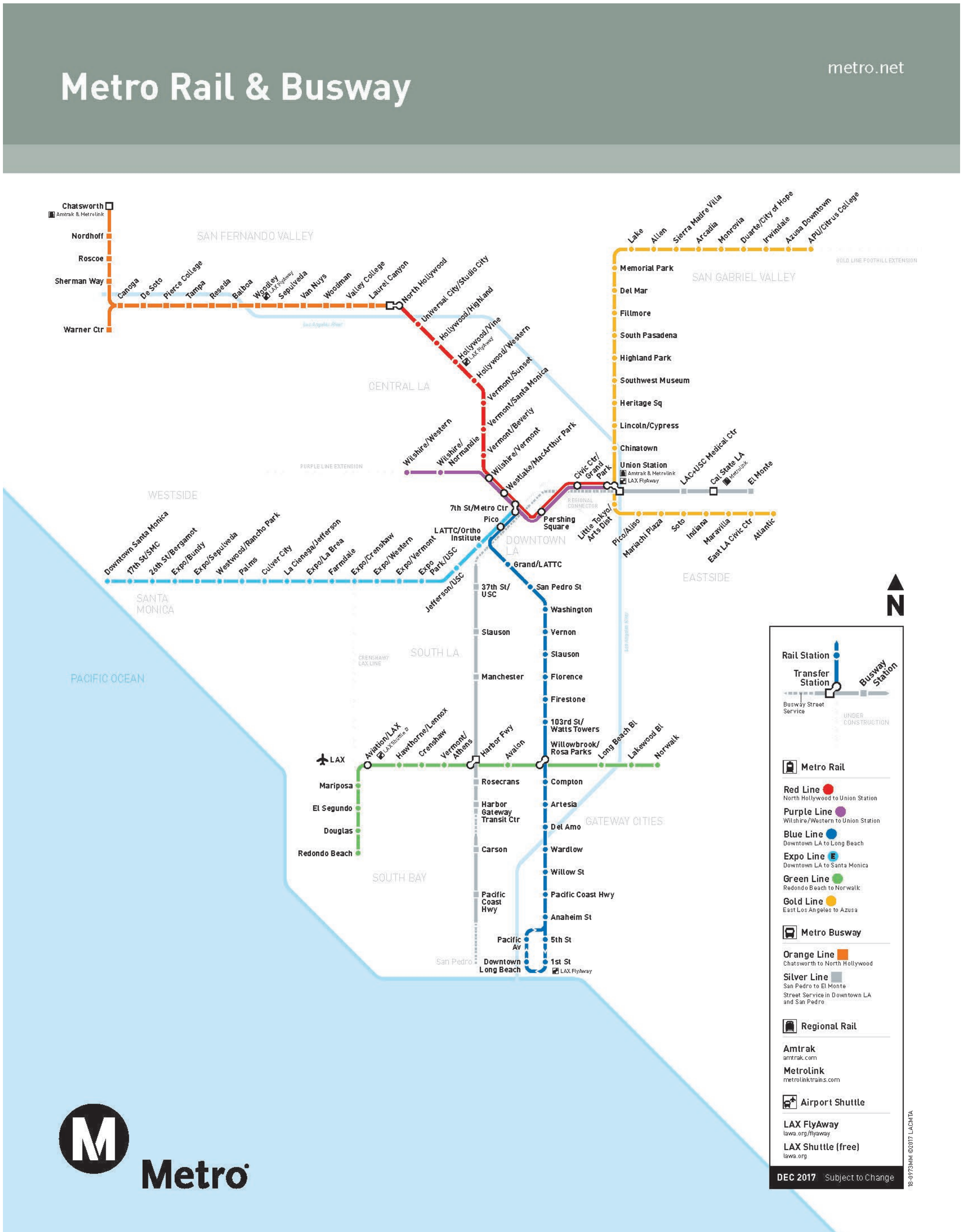


Figure 1.1 Metro Rail Map - June 2018 Source: (Metro, 2018)

While future projects rely heavily on ridership projections, the question remains, how has Metro's ridership projection performed when compared to actual rail ridership for the existing rail network? It is important to look back at past projections before proceeding with more investment. This study examines the current network of heavy and light rail in Metro's regional system, which was developed in fourteen segments. Ridership projections are assembled for each of these segments in the overall network. The study uses station-level average weekday ridership statistics and aggregates them to the line segment to allow for an appropriate analysis. The core comparison is predicted versus actual ridership.

The research question assessed in this thesis is the following: Is Los Angeles County Metropolitan Transportation Authority rail system meeting its projected average weekday light and heavy rail ridership goals? This inquiry has the following implications:

- It provides decision makers with information about whether ridership models provide accurate predictions
- It provides the general public with information on the consistency or discrepancy of projected rail ridership and actual rail ridership. Any discrepancy affects the efficiency and effectiveness of providing appropriate public transit to areas within Los Angeles County
- It provides a basis on which other studies may be patterned to further research concerning projecting rail ridership.

While financial performance, capital and operating cost, is also important and the subject of critical scrutiny, it is not the focus of this research.

The following chapters explain the research. The literature review explores historical research on this topic. The literature develops a framework that guides the methodology. The third chapter describes the study area. Since the unit of analysis is segments of constructed heavy and light rail in Metro's network, individual profiles of each segment are developed to better understand the system as a whole. It is in this chapter that ridership projections for each segment are introduced.

The fourth chapter of his study emphasizes the methodology of the research. A framework for how the data was collected, analyzed, and incorporated into the study is introduced. The fifth chapter, results, focuses on what the methodology produced. Following that chapter is the discussion and conclusion chapter. This section identifies the primary research findings and identify areas of further analysis. The remaining sections include the references, where sources for the data and literature are incorporated, as well as the appendices that provide much of the data.

CHAPTER 2: LITERATURE REVIEW

The literature review is divided into four main parts. The first section is *Forecasting Rail Ridership* and discusses current and historical forecasting processes, and what role they play in decision making. The second section is called *Optimism in Ridership Forecasting* and outlines the effects projections have on urban frameworks and metropolitan areas. The third part of the literature review focuses on ridership as a *Measurement of Performance*. The final section is entitled *Funding Rail Projects* and looks at studies focused on capital rail projects funded through public taxes.

Forecasting Rail Ridership

In 2007, Martin Wachs chaired a committee with the Transportation Research Board to assess the state of the practice in metropolitan area travel forecasting. The committee evaluated the state of the practice in travel demand forecasting and detected deficiencies in travel forecasting models, while recognizing obstacles for better practice, and developed strategies that are needed to ensure the use of applicable technical approaches (Transportation Research Board, 2007, p. 2). Travel forecasting models are used to study proposed transportation projects, where major investments are utilized to serve the public's needs for future travel and economic development. These models are utilized to evaluate the travel impacts of project alternatives. Outputs from these models also further predict air pollutants due to automobiles, trucks, and buses as well as the air quality impacts of the planned transportation development (Transportation Research Board, 2007, p. 15). These travel forecasting models intend to produce reliable forecasts that would allow elected officials to evaluate competing alternatives and make informed decisions about investments of public funds.

The research concluded that a majority of metropolitan areas with a population greater than one million people utilize the four-step travel demand model (Transportation Research Board, 2007, p. 48). The first step of the model is trip generation, which typically estimates the number of trips that originate and are destined to each Traffic Analysis Zone (TAZ). This step identifies how many trips are generated from a TAZ. The next step in the process is the trip distribution. It is in this stage that the model identifies matches between origins and destinations within a region. The third step is mode choice and highlights what type of travel mode is utilized for each trip. The last step is trip assignment in which the model identifies which route the trip will potentially take (Gonzalez, 2015).

Travel demand modeling allows public and private agencies to derive ridership projections of rail projects through various outputs. The information produced from the model identify trends through corridors and areas tested. With this information accounted for, transportation authorities can develop projected ridership of specific developments as a measure of alternative performance. This factor is important as ridership is a component used for alternative evaluation.

While the four-step travel demand model is utilized in standard transportation practice, it has come under scrutiny for its output accuracy. In 2001, Zhou and Kockelman investigated the stability of transportation demand model outputs by quantifying the variability in model inputs, such as trip generation rates, and simulating the propagation of their differences through a sequence of demand models over a 25-zone network. The results suggest that uncertainty is likely to compound itself, over a series of models. Mispredictions in the early stages of the four-step model appeared to amplify across the later stages. The research suggested that the four step travel demand model should consider improvements to address the inconsistencies and variation of the model outputs (Zhao & Kockelman, 2002).

Over the last three decades, the Federal Transit Authority has taken a greater interest in the accuracy of travel forecasts, as they are typically used to evaluate projects competing for federal grant funding. Two of the key factors utilized to evaluate competing projects for federal grant funding are projected ridership and associated benefits (Transportation Research Board, 2007, p. 37). Since many metropolitan regions apply and compete for grants, the Federal Transit Authority established a standard for fair grant funding procedure:

The agency carefully reviews the travel forecasting procedures employed to ensure that they are free of factors that would bias the results. In addition, SAFETEA-LU established a requirement that projects receiving funding under the New Starts program be the subject of before-and-after studies. Those studies are to document how the ridership achieved under the project compares with the forecasts made during project planning, thus establishing a formal and regular process for retrospective analysis of travel forecasts for major transit projects. FTA intends that the data collected and analyses performed in these studies contribute to improved travel forecasting procedures (Transportation Research Board, 2007, p. 37).Since the inception of mass transit, researchers have investigated economic risk of public transportation as there are concerns for public policy and management, including risk assessment, sound empirical basis for projects, and cost-effectiveness. Bent Flyvbjerg's research presented evidence that assessed effective economic risk assessment and management of urban rail projects. His research included benchmarking of individual or groups of projects. The research this thesis focused on was his interest in the Copenhagen Metro from "Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure (Flyvbjerg, 2007).

Flyvbjerg, and other professionals, are interested in identifying the economic risk of projects, as many projects are evolving into mega projects. Flyvbjerg's research was influenced by a study conducted on management of construction firms around the world. This interest of risk and megaprojects is described in the following way:

> Projects have grown larger over time, and increased size implies higher economic risks. A recent survey of top management in 25 of the largest construction firms in the world showed that executives see managing and pricing risk as one of their key challenges, and 63 percent of respondents said it was their biggest issue. Executives cited poor forecasting, poor risk identification, and cost escalation as the three top reasons for reduced profit margins (KPMG, 2005).

Throughout the past few decades, urban rail projects have become more like megaprojects as these systems get larger. While the system of urban rail grows, so does the risk. Flyvbjerg’s study analyzed a variety of rail projects and the risks associated with it (Flyvbjerg, 2007). He describes this risk as the following:

> "Urban rail" is here defined as rail in an urban area, including both heavy and light rail, which may be underground, at level, or elevated. "Risk" in urban rail projects is defined as downside uncertainty regarding costs and ridership. Urban rail projects are compared to other types of transportation infrastructure projects in order to test for differences (2007, p. 5).

While Flybjerg incorporated cost as an element of determining risk in much of his research, the focus of this study is on ridership. Furthur analysis of this research could investigate the economic risk associated with LA Metro’s projects

The approach developed is proposed as a model for other types of policies and projects in order to improve economic and financial risk assessment and management in policy and planning. His research highlights the economic risks of urban rail projects. This research is imperative to reflect upon as it suggests there are economic and managerial issues associated with current urban rail project development.

Flyvbjerg concluded that key policy recommendation for legislators and citizens should come from independent studies. Legislators and citizens should not trust the budgets, ridership forecasts, and cost-benefit analyses produced by project promoters and planners of urban rail. While his conclusion informs of a structured policy recommendation, Flyvbjerg’s study can inform a framework for this LA Metro study and should be considered when developing the methodology for this research.

Another article that influences the research design comes from Don Pickrell's study of urban rail transit projects. He found substantial errors in forecasting ridership and costs for the ten rail transit projects reviewed in the report, which suggests the possibility that more accurate forecasts would have led decision-makers to select projects other than those reviewed in this report. This study examines the accuracy of forecasts prepared for ten major capital improvement projects in nine urban areas during 1971-1987. The ridership results are as follows:

> None of the nine projects for which a forecast of rail ridership was available has achieved a level of actual ridership that approaches this forecast. While rail ridership in Washington is closest to that forecast, its 1986 level was still 28% below that originally projected for the size of rail system (approximately 60 miles) operated during that year. As discussed previously, however, the closeness of this comparison is probably aided by significant population and employment growth during the nine-year delay between the anticipated and actual years when Washington's rail system reached this extent. In contrast, rail ridership currently appears to be somewhat less than half of that initially forecast in Baltimore and Portland, and from 66% to 85% below its forecast level for six of the other projects reviewed (Pickrell, 1989, p. 63).

He continues to state inaccuracies as attributed to metropolitan areas where bus services are operating:

> Forecasts of total transit ridership with these projects in operation were

> slightly more accurate than those of rail ridership. This probably occurred partly because much of the bus service operating in these urban areas at the time these forecasts were prepared was unaffected by their decisions to construct rail lines. As a result, more accurate forecasts of ridership on these relatively stable services may have partly offset errors in projecting ridership in travel corridors where new rail lines replaced bus services. Nevertheless, four of the seven urban areas for which forecast and actual total transit ridership can be compared have attained less than half of the projected levels of total transit use with their rail projects in operation (Pickrell, 1989, p. 64).

The study examines why actual costs and ridership differed so markedly from their forecast values. It focuses on the accuracy of projections made available to local decision-makers at the time when the choice among alternative projects was actually made. The study compares forecast and actual values for four types of measures: Ridership, Capital costs and financing, Operating and maintenance costs, and Cost-effectiveness. A major finding that came from his research identified accuracy of forecasted capital costs and operating expenses. His research noted that predicting these expenses are varied and unrefined. Improved accuracy of forecasted operating expenses and capital costs, while increasing the financial consequences for local transit agencies for accepting unrealistically low-cost projections could improve the accuracy of cost projections. He also concluded with recommendations to improve the accuracy of forecasts. His four recommendations are:

1) Bringing the forecasting “horizon” closer to the present.
    a. In regards to LA Metro, their horizon years from opening segment dates range from 7 years (Gold Line Initial Segment) to 18 years (Expo Line Initial Segment).
2) Developing procedures that allow the effect on forecasts of projected future values of specific individual causal factors to be isolated and highlighted for critical examination by interested observers, including those who are not necessarily familiar with the technical procedures used to develop forecasts.
3) Conducting sensitivity analyses for validating forecasting models and for examining the effects of alternative assumptions affecting cost and ridership projections.
4) Checking the realism of construction and operating cost forecasts, ridership forecasts, and inputs to these forecasts, by comparing them to the record established by previous projects and by soliciting expert review of their reliability (Pickrell, 1989, p. 69).

This review of past forecasting errors highlights the origins of the discrepancy between forecast and actual performance of these projects. Through observing historical forecasting errors, studies can make recommendations to improve the reliability of forecasts for future projects. By doing so, better urban transportation investment decisions can be incorporated into the urban and regional framework (Pickrell, 1989).

Optimism in Ridership Forecasting

For more than fifty years, travel demand forecasting has come under criticism for a variety of issues. Many researchers have found conceptual problems in the conventional forecasting models (McGillivray, 1972). Others have complained that the context in which these models are used is open to certain ethical dilemmas (Wachs, 1982). Lastly, many researchers have challenged the forecasts produced by travel demand models (Wohl, 1976). Gordon and Willson agreed with these challenges, which influenced their decision to continue research on the subject. Little was known about how the demand for transit trips interacted with city descriptors as well as with characteristics of the population and transit system referents (Gordon & Willson, 1984, p. 135).

Their research in 1984 looked at international light-rail transit systems in a cross-sectional method. They utilized a demand test as a function of transport system, city, and population attributes. All tests confirm the standard hypotheses at high levels of significance. High levels of explanatory power support the notion of model transferability. One of their most significant findings is as follows:

> This study makes the point that certain simple relationships between city, population, transportation system descriptors and light-rail transit demand are remarkably stable over a diverse international cross-section of cities. Certainly, much work remains to be done since many of our predictor variables can be replaced by more specific indicators of settlement patterns, economic well-being, and transit system performance. Nevertheless, we confess to being astonished by the strong statistical associations that have

> been found. At this point it is possible to say that there is quite a bit which is transferable (Gordon & Willson, 1984, pp. 138–139).

The models developed in this paper are used to predict demand for new LRT systems now being installed in North American cities. Their model outputs suggest that the official forecasts are very optimistic (Gordon & Willson, 1984).

Ridership as a Measurement of Performance

Ridership performance is one way to understand how light rail and heavy rail is performing. A recent study explored the current performance of Light Rail services in Australia and compared it with Light Rail in the USA. Comparisons are made based on ridership and service effectiveness and scale of operations (Currie & De Gruyter, 2016, p. 298).

Their research explored issues regarding regulatory structures that govern performance. Public and private sector operations have contrasting regulatory structures using a range of forms of performance based contracting and competitive tendering. The study identifies that, in general, operations of all systems have grown as has ridership however significant reductions in service effectiveness (ridership per vkm) have occurred in US contexts here public sector operations have dominated. The implication is increases in public subsidies per trip.

When comparing the two country's light rail transit systems, the authors noted a few differences in operation. For example, much of Australia's Light Rail is operated by private agencies, excluding the Adelaide Light Rail. In their analysis, they noted that almost all of the United States Light Rail systems used in this study are operated and procured entirely by State and City Government agencies, while being operated as part of public sector organizations (Currie & De Gruyter, 2016, p. 299). This was an interesting component to their study as the two country's light rail transit systems are operated by different agencies.

The Light Rail Transit performance analysis had the following approach:

> The analysis aims to contrast performance of Light Rail systems over time between systems using competitive tendering/performance contracting approaches with those using public sector based operations. Two analyses are undertaken; firstly a review of the performance of Australian based systems and secondly an aggregate assessment of the Australian systems as a whole against performance of US based operations (2016, p. 300).

Their analysis of the Australian and United States Light Rail Transit systems provided the following performance trends:

> Both US and Australian ridership has grown substantially between 2006 and 2011 (24% Australia; 17% US). US growth kept pace with Australian growth up to 2009 but faltered in 2010 then resumed growth. Service levels have grown in both nations, but they have grown substantially more in the USA (26%) compared to Australia with only a 4% increase in growth. The outcomes of these trends are a dramatic contrast in productivity (service effectiveness) outcomes; a substantive rise in Australia (20%) compared to an 8% fall in the US (2016, p. 302).

Their results implied a considerable relative improvement in ridership productivity of systems that were operated under competitive contracts compared to those with public sector-based operations. In every case their research analyzed, competitive contracts improved performance over time while public sector-based operations declined ridership productivity (Currie & De Gruyter, 2016, p. 302). While much of their research focused on performance based off operational system, it integrated a narrative for the importance of ridership as a performance metric. This is integral to this current research as ridership projection and actual ridership is at the forefront of measuring segment performance.

Funding Rail Expansion

The last part of the literature review focuses on funding rail ride expansion. This gives insight into whether societal views of ridership match the performance of the system. Los Angeles voters, as well as other cities, have approved locally sourced tax increases to help fund capital projects focused in transportation improvements and expansion (Chiland, 2016). While local taxes are funding the growth of these public transit networks, it is important to reflect on how they are performing.

In 2018, Jessica Saab conducted research on Los Angeles and Atlanta, Georgia, both of which implemented voter-approved local transportation sales taxes (LTSTs) with a dedicated transit component. As transportation agencies struggle to find permanent and lucrative funding sources, the LTST has emerged as a politically expedient and publicly popular funding method, capable of great returns at a marginal increase (Saab, 2018, p. 51).

For the tax increases to be approved, transportation agencies must modify their priorities to sway voters, transit users and car drivers alike, that the changes made can have long-term effects on equitable access to transportation. Her research involved two case studies of recent large-scale transit development plans funded by LTSTs in two cities that have had historically distinct responses to previous transit development efforts.

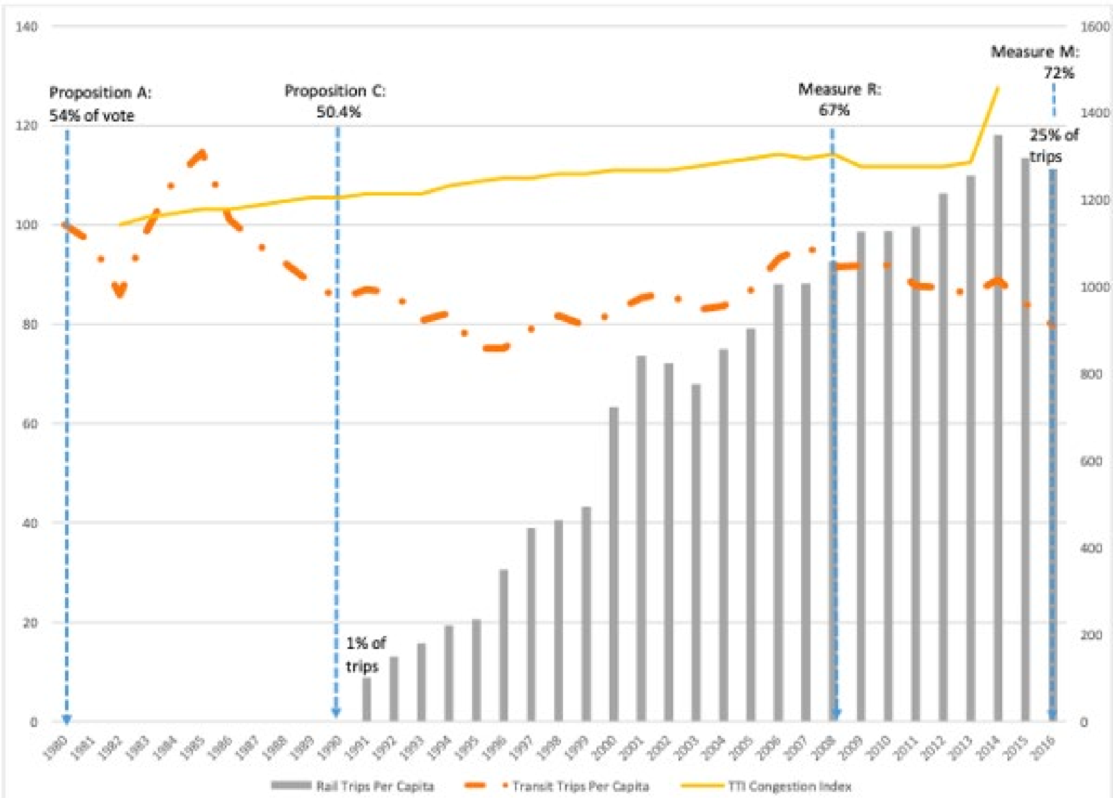
The methodology of her study is as follows:

> To examine the differences in their transportation agencies' strategic decision-making, I reviewed numerous journal articles, newspaper articles, reports, and websites on their agencies' transportation plans. Included were advocacy group reports, community organization reports, and comments on online forums, articles, and agency platforms. To determine the effects of the sales tax-funded transit plans on equity, I reviewed approved projects, their ridership (if constructed already), and agency relations with their existing customers. I also reviewed how LTSTs are presented and campaigned, and the burden they produce on those of least-income. Determining the enhancement or diminishment of equity involved a combination of information that I attempted to keep consistent across both case studies (Saab, 2018, p. 65).

Through analysis of the measures, the routes and systems proposed, and the response from the public, the transportation agencies' strategies are assessed, and conclusions are made for how LTST plans can be made more equitable (Saab, 2018). She concluded that democratic processes provide a thoughtful opportunity for local control, consensus, and equity improvement, but two of LTST measures' pitfalls weaken their effectiveness and fairness: their need to appeal to a wider regional audience of non-transit riders, and the dependence on the inequitable sales tax (Saab, 2018, p. 86).

Other research regarding tax measures funding public transportation networks come from the University of California, Los Angeles Luskin School of Public Affairs. Professor Michael Manville investigated how Measure "M" could transform urban mobility in Los Angeles. Manville conducted two surveys, one was a survey of 1,450 LA County adults who completed a telephone or online survey, which was completed during the 2016 election. The second survey was an "intercept survey", developed to catch the underrepresented population of LA County that typically utilize public transit and disproportionately wouldn't have access to online or telephone resources. With this survey, Manville chose five of the busiest transit stops in the system and administered a paper survey in person (Manville, 2019, p. 34).

This research was integral to understanding the views towards Measure “M” as it highlights that many people support funding transit projects, but don’t typically utilize them. Figure 2.1 shows that while there has been multiple voter approved tax increases



Sources: National Transit Database, US Census, Texas Transportation Institute. Base years are set to 100. Trips are unlinked passenger trips. The TTI congestion index has seen its methodology change periodically, although it is designed to be consistent. A post-2013 methodological change, however, may account for the notable congestion spike.

Figure 2.1 Trends in transit ridership, traffic congestion and ballot successes in Los Angeles County, 1980-2016. The brief spike in transit ridership in the 1980s was driven by significant, temporary fare cuts.(Manville, 2019, p. 13)

to fund transit projects, transit trips per capita do not demonstrate the same enthusiasm.

Manville considered the motivations behind those that supported or opposed Measure “M”. Manville’s conclusion addresses a challenging idea: Angelinos have consistently voted to fund transit, but consistently declined to ride it (Manville, 2019, p. 65). Manville concludes the following:

> Linking transit to Democratic identity is powerful politically, but its political power arises precisely because it divorces transit from the realm of material self-interest, and especially from the realm of personal transportation. When transit becomes a box that Democrats will reliably check, it gains votes. Similarly, linking rail transit to traffic reduction strongly implies that transit will benefit people in their role as drivers. This again is powerful politically; regions like Los Angeles have far more drivers than transit riders, and as this report has shown, drivers are much more likely to vote. But a vote for transit motivated by a desire to continue driving also suggests that as transit service expands travel behavior will not change. Adding to all this, of course, is that the typical Measure M supporter has few of the hallmarks of a transit rider: he or she owns vehicles and has access to parking at home or work (Manville, 2019, p. 66).

The literature provided insight into the complexity of forecasting, optimism and deficiencies in model forecasting, the importance of ridership as a performance metric, and where societal views in Los Angeles fits contextually with urban rail networks. While considerable evaluation of performance and ridership play a large role in the methodology of this research, intrinsic views of rail transit assist with framing the position of the thesis.

CHAPTER 3: STUDY AREA PROFILES

This chapter provides insight on the expansive rail network of Metro. It introduces the segments and lines in chronological order from operational date. This narrative outlines the motivations, alignment, and projections for each segment in the Metro network and in this study. With insight into historical factors that developed the network, this research can have a stronger basis of the existing conditions.

The study area for this research includes the heavy and light rail systems of LA Metro. Since ridership projections are utilized for individual segments of construction, the Metro rail network is divided into segments of construction. For example, the Gold Line was constructed in three segments: the Initial Segment, the East Side Extension, and the Foothill Extension. Ridership projections are developed for each individual segment which feed into the methodology of comparing actual and projected rail ridership.

The overall study area includes fourteen rail segments: three Blue Line segments, one Red/Purple Line segment, one Purple Line segment, two Red Line segments, one Green Line segment, three Gold Line segments, and three Expo Line segments. Figure 1.1 in Chapter 1 identifies the current alignment of the Metro Rail System, while Table 3.1 describes the simplified breakdown of each line. The following descriptions give an introductory overview and geospatial reference to each segment. Each map includes Metro line and station data pulled from Metro's Geographical Information System Database (Thai, 2015). To better understand the area surrounding the line segment, a one-mile buffer surrounds the specific line being discussed.

Line	Rail Type	Opening Date	Number of Stations	Miles of Track	Average Weekday Boardings (FY 2018)	Trips per Mile (FY 2018)
Blue Line Initial Segment	Light	7/14/1990	17	19.1	51,672	3,040
Blue Line Long Beach Loop	Light	9/1/1990	4	2.2	5,018	1,255
Blue Line To Financial District	Light	2/15/1991	1	0.7	12,937	12,937
Red/Purple Line (MOS-1)	Heavy	1/30/1993	5	4.4	78,441	15,688
Green Line	Light	8/12/1995	14	20	31,577	2,256
Purple Line (MOS-2A)	Heavy	7/13/1996	3	2	8,044	2,681
Red Line (MOS - 2B)	Heavy	6/12/1999	5	4.7	23,620	4,724
Red Line (MOS - 3)	Heavy	6/24/2000	3	6.3	28,053	9,351
Gold Line Initial Segment	Light	7/26/2003	13	13.7	34,050	2,619
Gold Line East Side Extension	Light	11/15/2009	8	6	10,874	1,359
Expo Line Initial Segment	Light	4/28/2012	10	7.6	34,279	3,428
Expo Line Culver City Extension	Light	6/20/2012	2	1	7,262	3,631
Gold Line Foothill Extension	Light	3/5/2016	6	11.5	6,509	1,085
Expo Line Santa Monica Extension	Light	5/20/2016	7	6.6	19,002	2,715
Light Rail Totals			**82**	**88.4**	**213,180**	**2,411**
Heavy Rail Totals			**16**	**17.4**	**138,158**	**7,940**
Total:			**98**	**105.8**	**351,338**	**3,320**

Table 3. 1 Breakdown of Metro's rail network, average weekday boardings.

Los Angeles Public Transit, A Brief History

Prior to the modern rail network and automobile era, Southern California had an extensive electric rail network. By 1911, the Pacific Electric Railway Company operated more than a thousand miles of track throughout Los Angeles and the surrounding communities (Demoro, 1986). While highest ridership was noted in the first two decades of the 20th century, the introduction of the automobile quickly diminished operations and instituted massive ridership decline. As most Red Line Cars are at grade crossings, automobile congestion grew, while the average speed of the electric rail dropped (Adams, 1986).

By the 1930s, automobiles became the main mode of transportation, further diminishing demand for the once expansive network. On April 9th, 1961, the interurban Los Angeles to Long Beach passenger rail line completed the final trip of the Red Cars for Pacific Electric Railway Company (Demoro, 1986). At this point, freeway construction was in full swing, expanding the road network, developing a mostly bus only public transportation system ("PE Bus Franchise Transfer Gets Ok," 1953). Aside from commuter rail, buses provided the public transportation system for nearly four decades.

With the auto centric region continually expanding, Los Angeles County Board of Supervisors councilmember Kenneth Hahn fought to bring back a new method of traversing the county. Through hard work and dedication to his community of South Los Angeles, Hahn was able to bring the dream of a light rail to Southern California (Reft, 2015). While then Los Angeles Mayor Bob Ward favored a heavy rail subway along Vermont, the cost, both operating and maintenance, made the route infeasible. Through political pressure, Hahn was able to navigate a route utilizing mostly freight right-of-ways, ultimately providing a much more feasible alternative as it came with reduced cost of land acquisition and minimal displacement (Elkind, 2014). With the help of Hahn, and other local officials, the Blue Line was fully funded by the 1980 voter approved Proposition “A” sales tax measure that was dedicated to transportation funding (Metro, 2017). The cost of the entire Blue Line was $877 million dollars.

Blue Line Initial Segment

The Initial segment of the Blue Line opened on July 14, 1990 (Trinidad, 2014). This segment of light rail, commonly known as the Mid-Corridor segment, provides rail transit services from the northern portions of Long Beach to the Southwestern region of Downtown Los Angeles. Alternative MC-1, see Figure 3.1, was recommended for construction in the Final Environmental Impact Report in 1985 (Parsons Brinckerhoff/Kaiser Engineers, 1985).This segment added 17 stations, 19.1 miles of track, and anticipated an average weekday ridership of 40,452 by the year 2000 (Parsons Brinckerhoff/Kaiser Engineers, 1985). The Initial Segment of the Blue Line is mostly made up of an at-grade alignment, however, roughly 1.5 miles of track is elevated as this private right of way cuts through more densely populated areas. (Parsons Brinckerhoff/Kaiser Engineers, 1985).

The route mostly follows the historical Red Line and freight right-of-way since it was already a low-density industrial corridor (Reft, 2015). When the Blue Line began operation in 1990, it was projected to have a daily ridership of 5,000 (Byrnes, 2014). The line performed better than expected with daily ridership reaching 32,000 by the end of the first year of service (Curiel, 1991).

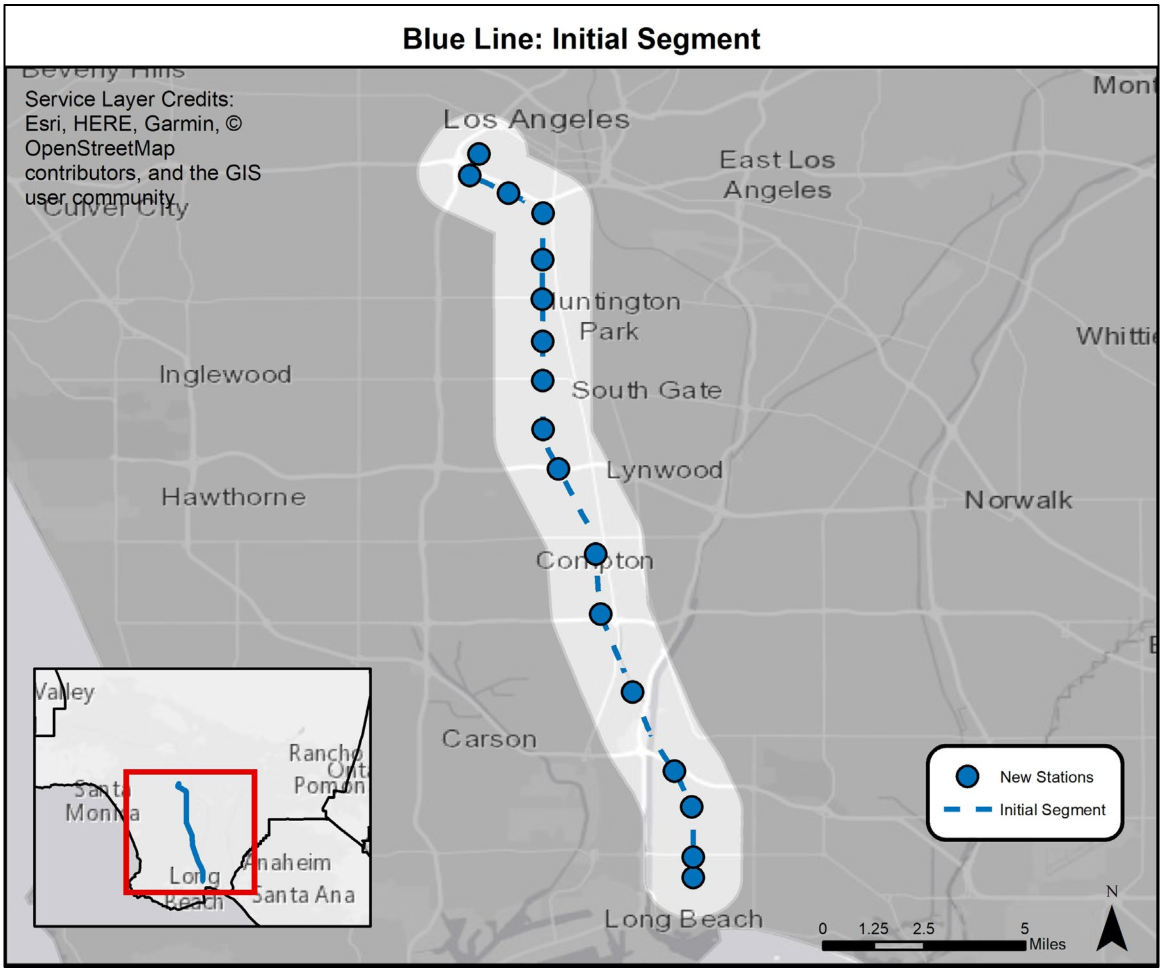


Figure 3.1- Blue Line Initial Segment. Map created by author. GIS data provided by: Metro (Thai, 2015)

Blue Line Long Beach Loop

A few months after the Blue Line Initial Segment opened, the Long Beach Loop Segment was operational. Opening on September 1, 1990, the second segment of Metro's Blue Line connected the city of Long Beach with the communities of South-Central Los Angeles (Fiore, 1990). This segment added four more stations and just over two miles of track to the Blue Line system. The constructed alignment was alternative LB-5 and can be seen in Figure 3.2. This segment runs at-grade throughout the median of Long Beach Boulevard and Pacific Avenue (Parsons Brinckerhoff/Kaiser Engineers, 1985, pp. II–40). Unlike many rail system termini, the Long Beach Loop splits the two tracks and creates a loop, minimizing wait times for trains to change directions. This portion of the Blue Line was projected to have 3,769 average weekday riders by 2000 (Parsons Brinckerhoff/Kaiser Engineers, 1985, pp. II–39).

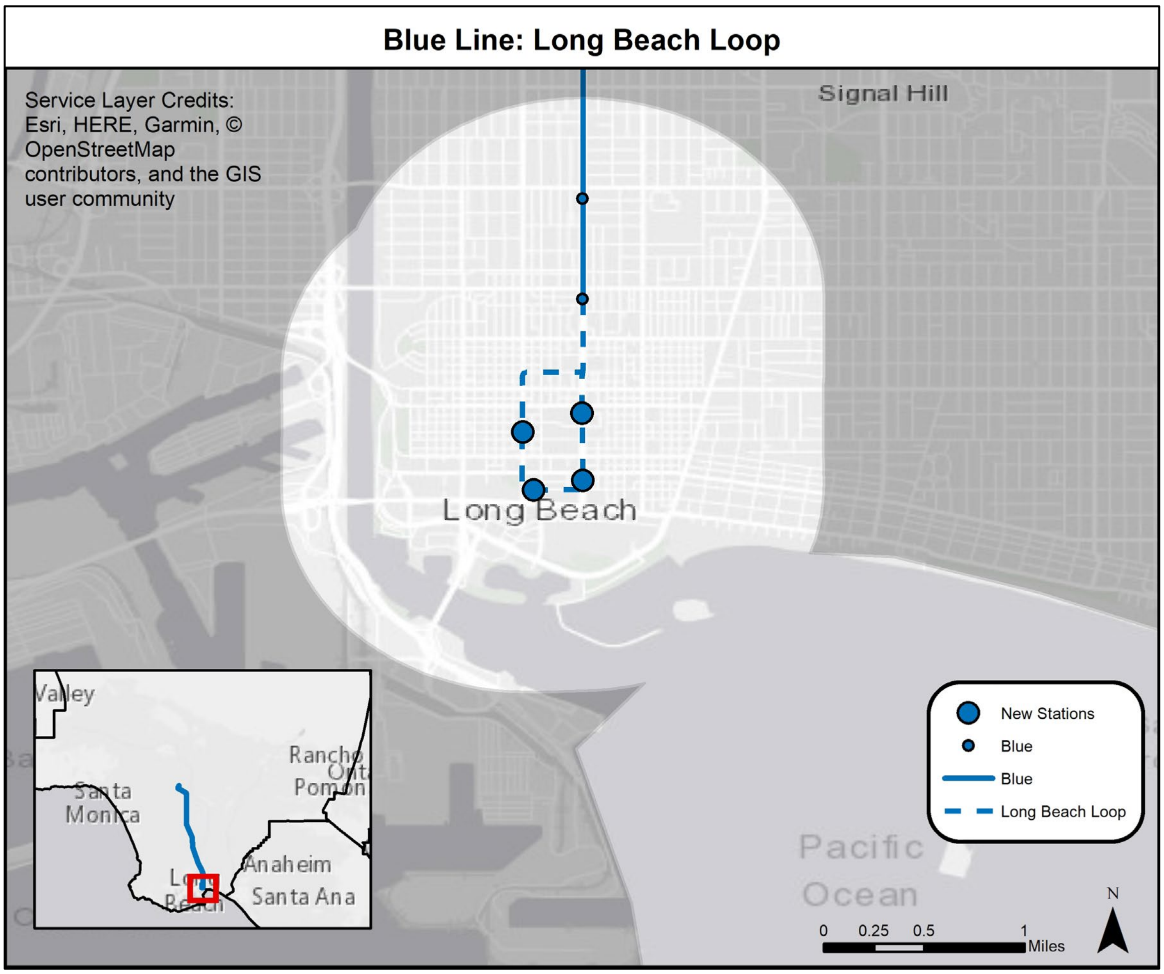


Figure 3.2 Blue Line Long Beach Loop Segment. Map created by author. GIS data provided by: Metro (Thai, 2015)

Blue Line to Financial District

The third and final segment of the Blue Line opened on February 15, 1991. The Financial District segment was final element that connected Long Beach to Downtown

Los Angeles. This segmented added one underground station, and .7 miles of mostly underground track. With the final stage operational, the Blue Line reached a length of twenty-two miles with twenty-two station (R. B. Taylor, 1991). This segment, alternative LA-2, was recommended for construction in the Final Environmental impact report in 1985 (Parsons Brinckerhoff/Kaiser Engineers, 1985, pp. II–48). The projected rail ridership was 10,481 average week day riders by 2000 (Parsons Brinckerhoff/Kaiser Engineers, 1985, pp. II–15).

Blue Line: Financial District

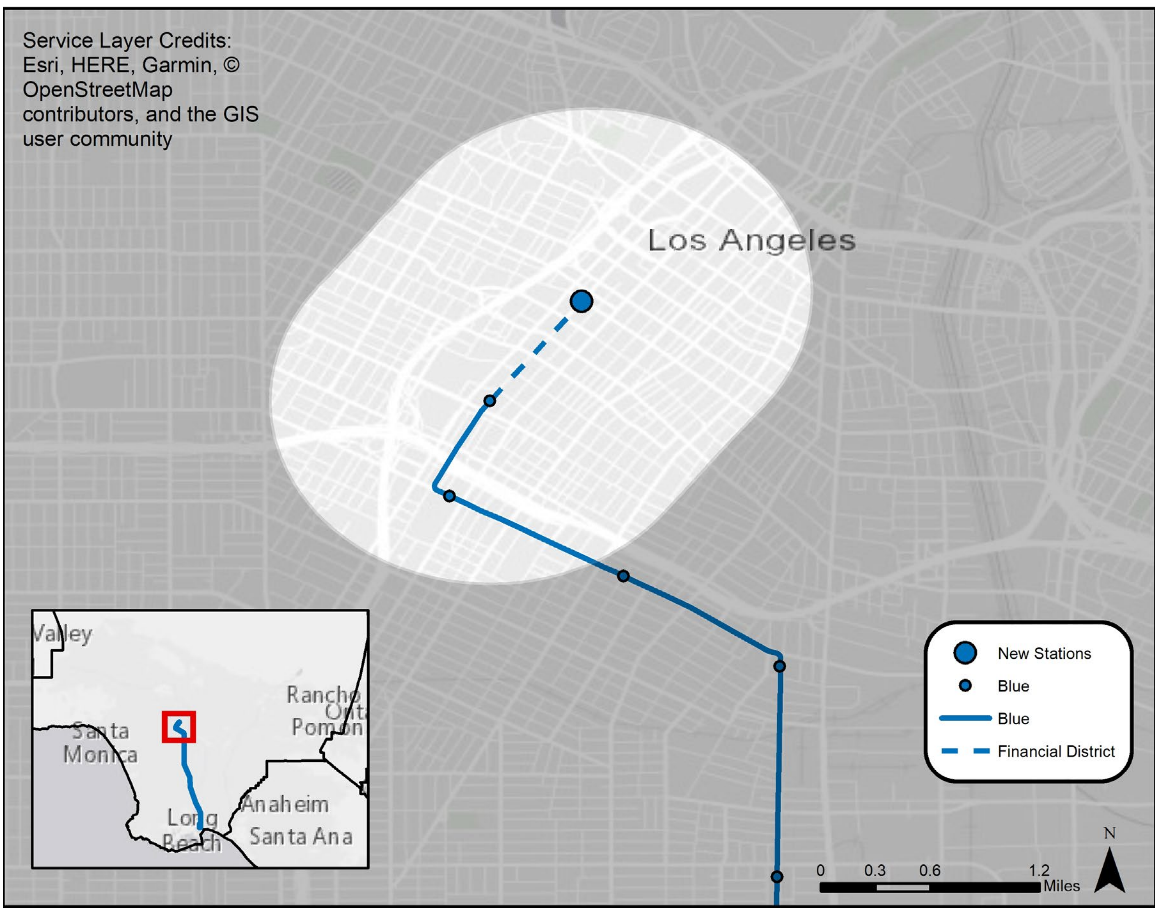


Figure 3.3 Blue Line Financial District Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

Red and Purple Line: MOS-1

The next major rail construction project was the subway that connected Downtown Los Angeles, the Blue Line, and Union Station. On January 30, 1993, Metro opened the first segment of the Red and Purple Lines. MOS-1 was the first heavy rail project completed by Metro (Reinhold, 1993). Five stations were constructed with four and a half miles of underground track. It was called the Red and Purple line as the network would split in different directions with MOS-2A (Purple) and MOS-2B (Red) (Southern California Rapid Transit District & Urban Mass Transportation Administration, 1989). This first subway segment cost roughly $1.5 billion dollars, with 48% coming from federal grants and the rest from Proposition "A" and other local funds. (United States General Accounting Office, 1996). Figure 3.3 illustrates the alignment of the route that projected 197,853 average weekday riders by 2000 (Southern California Rapid Transit District & Urban Mass Transportation Administration, 1989, pp. 2-1–47).

Red & Purple Line: MOS-1

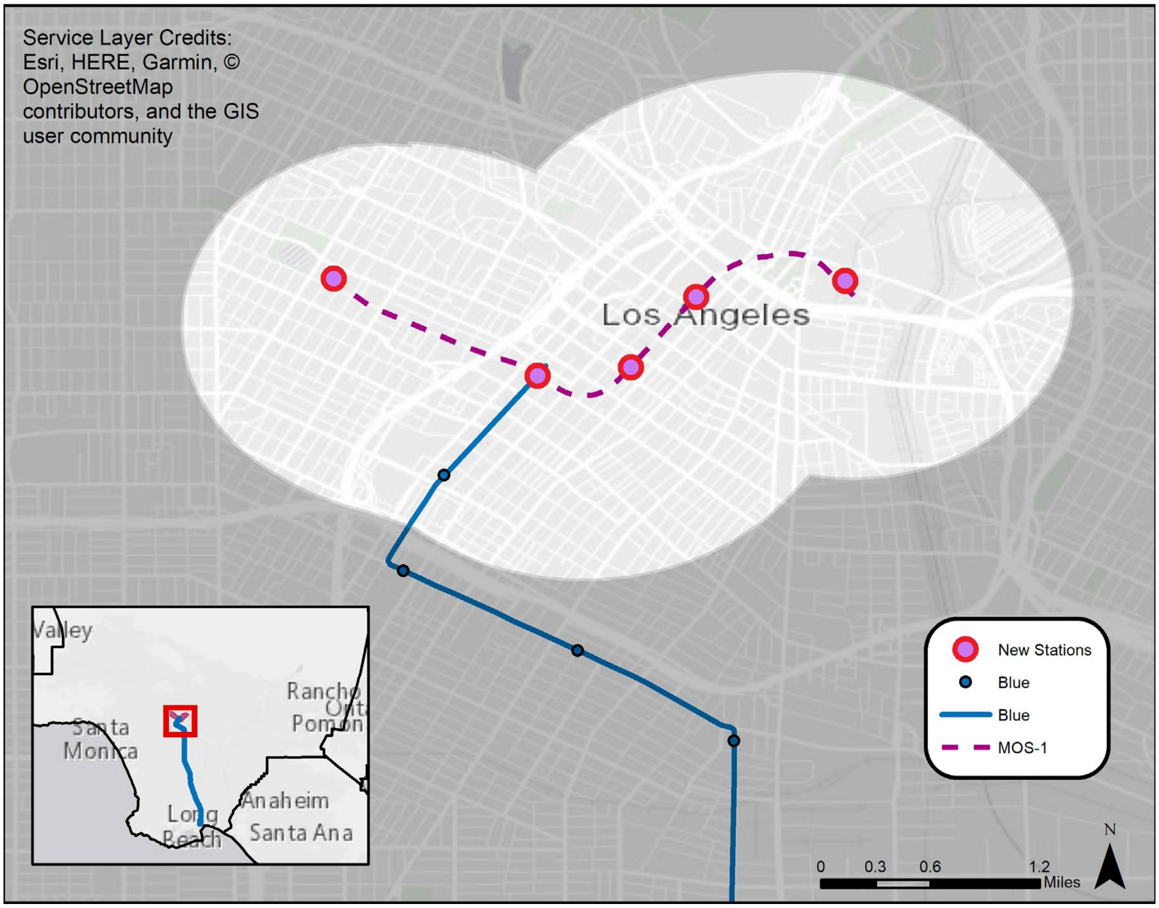


Figure 3.4 Red/Purple Line MOS-1 Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

Green Line

Metro's second light rail line opened on August 12th, 1995 connecting Norwalk to Redondo Beach (Rasmussen, 1995). The Green Line was developed as part of the Century Freeway (105 Freeway) project as a precondition included in the consent decree signed by Caltrans in 1979 (Ferrell, Carroll, Appleyard, Reinke, & Ashiabor, 2011, p. 109). The Century Freeway cut through mostly low-income minority communities in South Los Angeles. In 1972, communities members teamed up with the Sierra Club and the NAACP to bring the displacement concerns in front of a judge and halt the project construction. After several years of litigation, all parties signed a consent decree that would allow the project to continue, under modifications including the addition of a light rail (Ferrell et al., 2011, p. 110).

Construction began in 1987 and wrapped up in 1995 costing $718 million dollars (Mieger & Chu, 2007). The Green Line intended to connect on the east to the commuter rail (Metrolink) station in Norwalk, and the Los Angeles International Airport (LAX) to the west. However, the Green Line alignment was cut short on the east side and never made it to the Metrolink Station (Ferrell et al., 2011, p. 110). Construction towards LAX began, but was permanently halted by the Federal Aviation Administration over fear that the overhead lines would interfere with airplane landing paths (Maddaus, 2008). The western alignment moved south to connect with the aerospace and defense industry in El Segundo. However much of that industry left the area after the Cold War ended (Ferrell et al., 2011, p. 110).

The mostly aerial final alignment added fourteen stations and twenty miles of fully grade-separated light rail to the Metro network, see Figure 3.5. Over sixteen miles of track and nine stations are located within the median of the Century Freeway (Ferrell et al., 2011, p. 110). The Green Line was projected to have 35,000 average weekday riders by 2006 (Mieger & Chu, 2007). With the lack of connections to major activity centers, inadequate project justification, and poor design of freeway median stations, the Green Line is known as *The Train to Nowhere*. However, extensions are currently being studied to connect the Green Line with the City of Torrance to the west (Khanna, n.d.).

Green Line

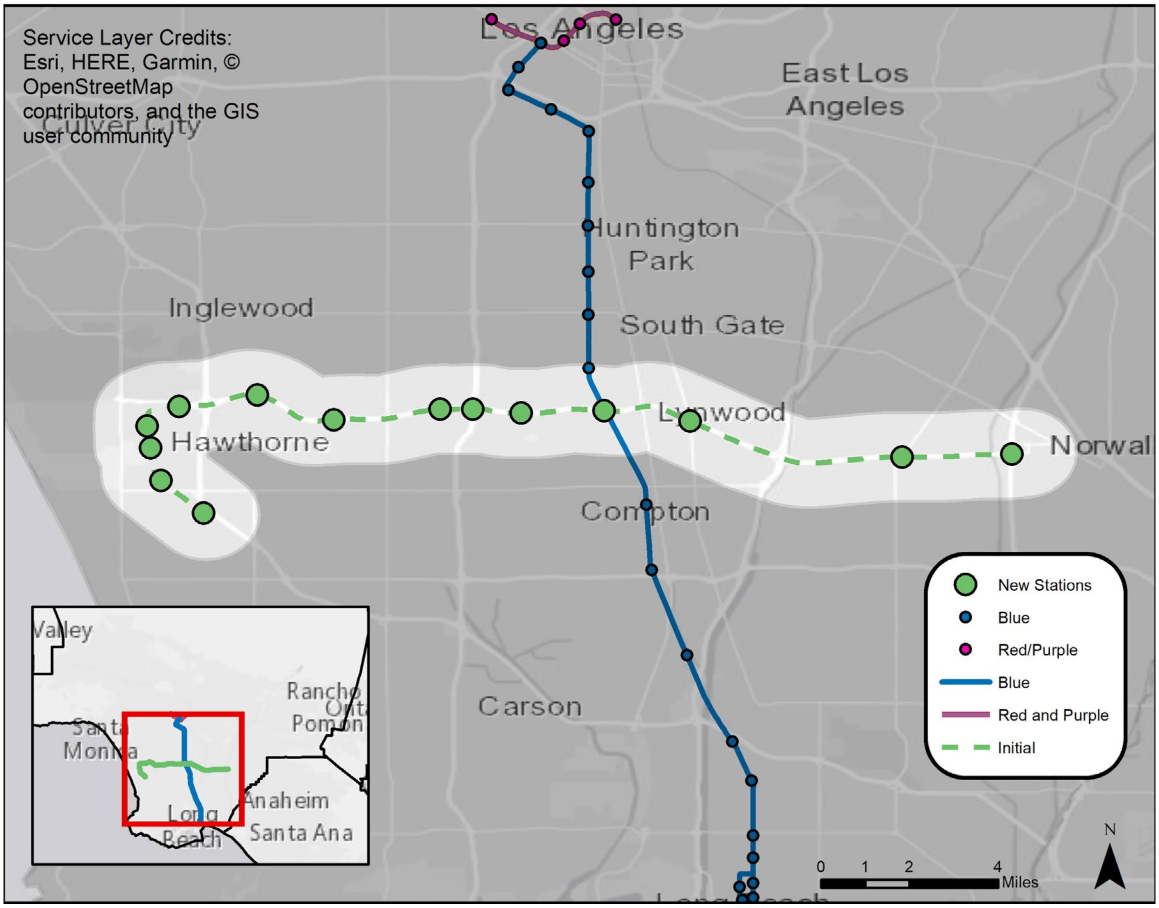


Figure 3.5 Green Line Map created by author. GIS data provided by: Metro (Thai, 2015)

Purple Line: MOS-2A

The west extension of the Red and Purple Line or MOS-2A, is commonly known as just the Purple line opened on July 13, 1996. This segment added two miles of heavy rail track and three new stations as shown in Figure 3.6 (Hong, 1996). The line was projected to have 22,088 average weekday riders by 2000 (Southern California Rapid Transit District & Urban Mass Transportation Administration, 1989, pp. 2-1–41). MOS-2A and MOS -2B cost roughly $1.64 billion dollars, with 44% ($722 Million) coming from federal grants and funds (United States General Accounting Office, 1996). The Purple

Line Extension to Westwood is currently under construction. The project will add seven stations and nine miles of heavy rail track (Chiland, 2017). The now four billion dollar project is expected to open in 2026 (Metro, 2019b).

Purple Line: MOS-2A

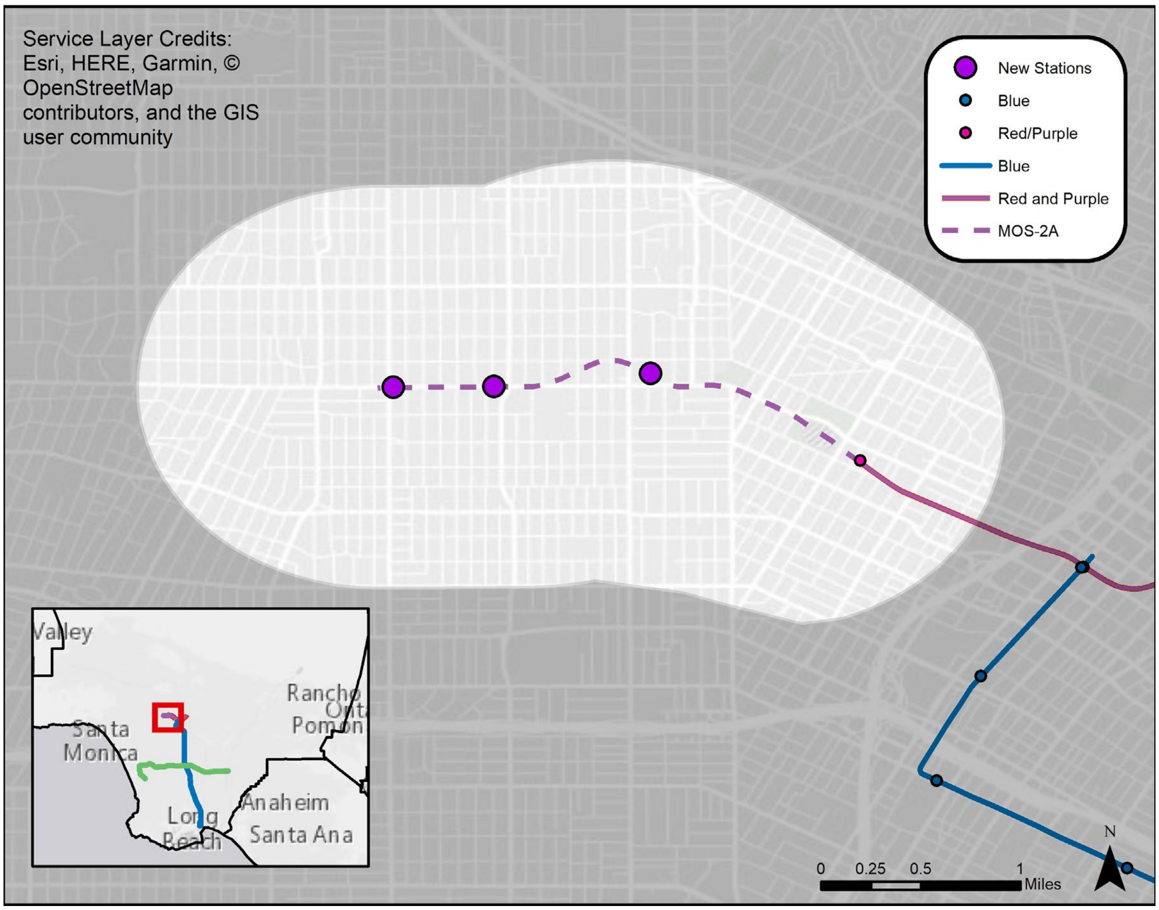


Figure 3.6 Purple Line MOS-2A Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

Red Line: MOS-2B

The Northern Extension of the Red Line, MOS-2B, opened on June 12th, 1999. The project connected Downtown Los Angeles and Union Station, with Hollywood, providing greater accessibility to the historic film district, as shown in Figure 3.7. This segment added 4.7 miles of underground heavy rail track with five new stations (Mitchell, 1999). MOS-2B was the middle segment that intends to connect Downtown Los Angeles with the San Fernando Valley. This segment of the line projected 39,479 average weekday riders by 2000 (Southern California Rapid Transit District & Urban Mass Transportation Administration, 1989, pp. 2-1–41).

Red Line: MOS-2B

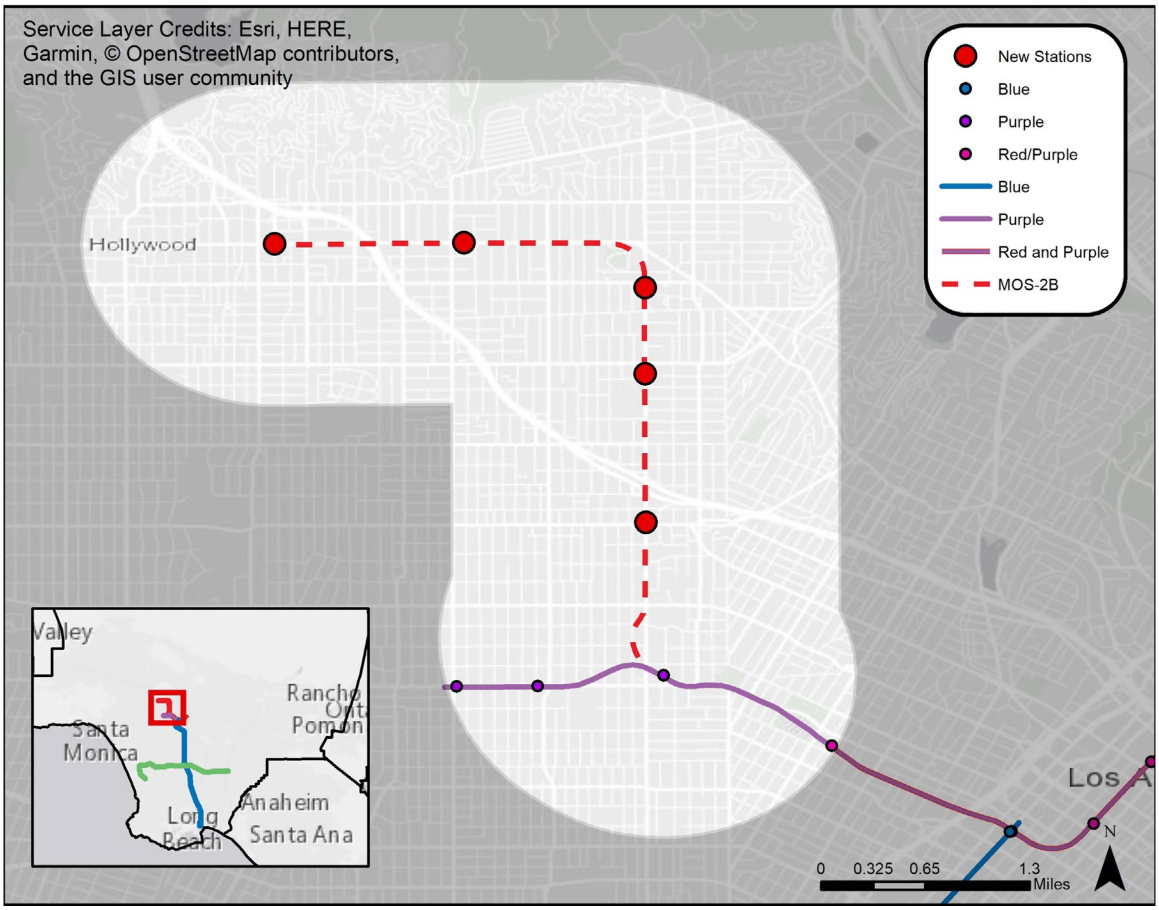


Figure 3.7 Red Line MOS-2B Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

Prior to this segment opening, the Red Line construction was heavily criticized as the price of the project increased, while the opening dates continued to be pushed back. Los Angeles County Supervisor Zev Yaroslavsky prepared the MTA Reform and

Accountability Act of 1998, which banned the use of Los Angeles County revenue from existing sales taxes for subway tunneling (Groves, 2006). This new proposition threatened the connection of the Blue Line to Union Station and the future Gold Line (Perez, 2003).

Red Line: MOS-3

The final segment of the Red Line, MOS-3, opened on June 24th, 2000. This project added 6.3 miles of track and three new stations to the system, see Figure 3.8. During construction there were claims of corruption and safety issues, including cost overruns and tunnel walls not meeting appropriate specified standards by law ("Los Angeles Asks," 1993). This portion of the Red Line was wrapped up in a legal battle over concerns that the project was awarded illegally. In fact, the litigation took longer to resolve than the construction of the actual project (*Kajima/Ray Wilson v. Los Angeles County Metropolitan Transportation Authority*, 2000). The discovery of over 2,000 fossils during construction slowed down the overall progress of the third and final segment of the Red Line(Littman & Wosk, 2000). Archaeologists were brought in to ensure preservation of historical fossils, some dating back to over 16.5 million years. MOS-3 was projected to carry 38,313 average weekday riders by 2000 (Southern California Rapid Transit District & Urban Mass Transportation Administration, 1989, pp. 2-1–41).

Red Line: MOS-3

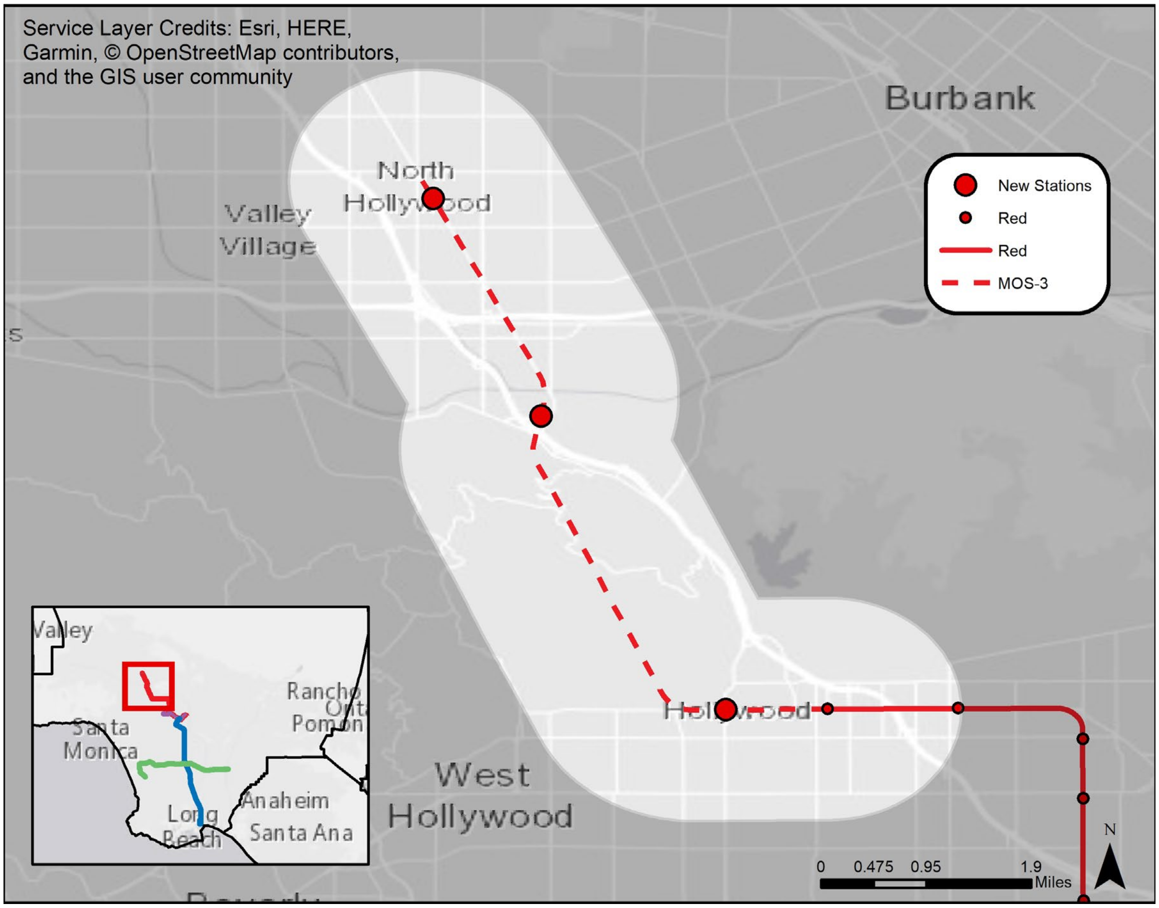


Figure 3. 8 Red Line MOS-3 Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

With prolonged construction, political, and operational issues regarding the heavy rail network of Metro, the Federal Transit Authority stepped in, in 1998 to complete an audit of the Red Line project. The Red Line project received more than $2.2 billion dollars in federal funding covering more than 48% of the total costs (Federal Transit Administration, 1998). The report outlined new ridership totals reducing the total heavy rail ridership from over 297,000 weekday riders down to 132,200, as seen in

Table 3.2. To stay consistent with the rest of the research, the ridership totals provided in the Final Supplemental Environmental Impact Report are analyzed, while the revised ridership numbers from the Federal Transit Authority are for reference only.

Red Line Project
COMPLETED AND ONGOING
SEGMENTS / EXTENSIONS

	Totals	MOS 1	MOS 2	North Hollywood
Miles of Track	17.4 miles	4.4 miles	6.7 miles	Hollywood 6.3 miles
Costs	$4.5 billion	$1.5 billion	$1.7 billion	$1.3 billion
Costs per Mile	$260 mill./mi.	$330 mill./mi.	$259 mill./mi.	$213 mill./mi.
Funding: Federal	$ 2.2 billion	$ 696 million	$ 722 million	$ 819 million
State/Local	$ 2.3 billion	$ 754 million	$1,014 million	$ 522 million
Completion Dates	May 2000	Opened 1993	June 1999	May 2000
Estimated Ridership	132,200	63,900	47,500	20,800

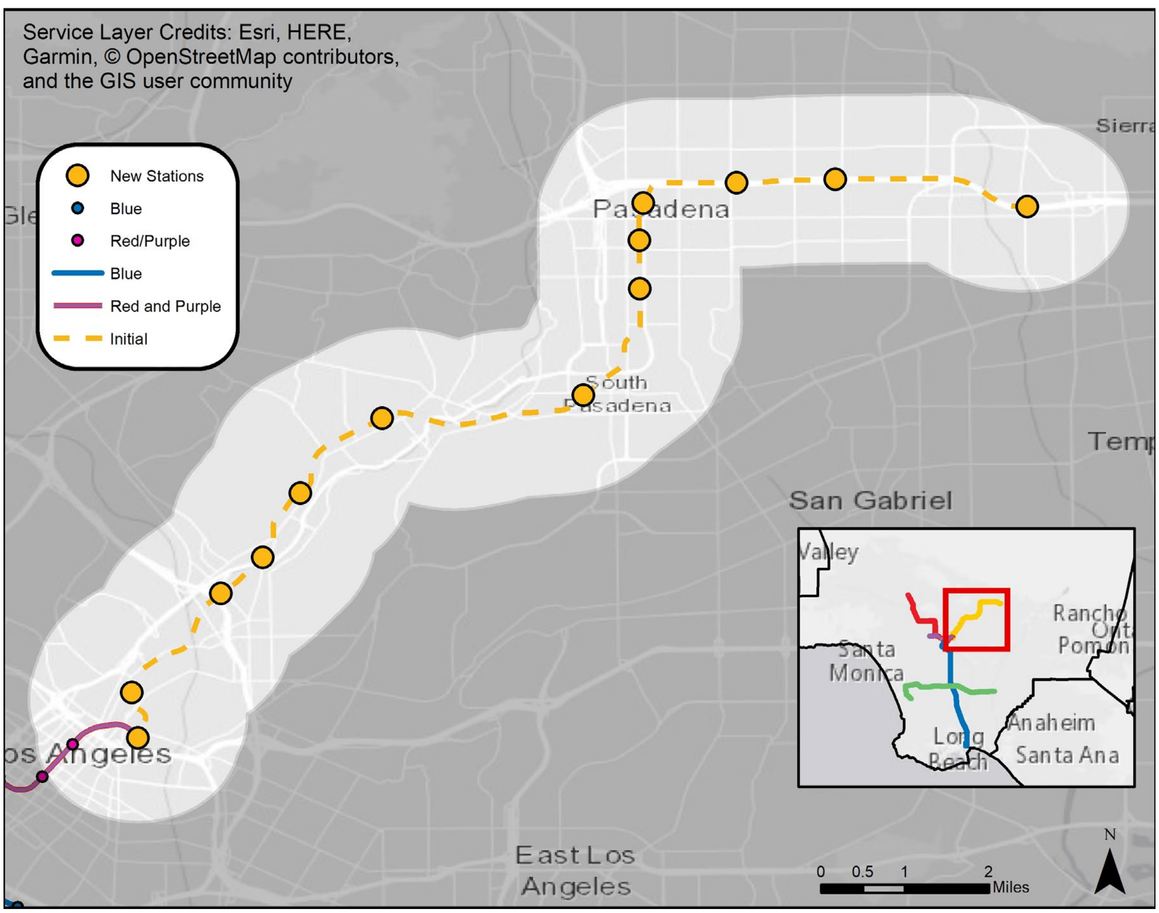
Table 3. 2 Red Line Project updates from the Federal Transit Authority (Federal Transit Administration, 1998, pg. 3)

Gold Line: Initial Segment

As part of a strategy to connect Pasadena to Los Angeles, the Initial Gold Line segment was recommended in the 1989 Final Environmental Impact Report (Bechtel Civl, Inc. et al., 1989). The Gold Line alignment mostly followed the former right-of-way of the Atchison, Topeka, and Santa Fe Railway (Rasmussen, 2003). The original plan called for tunneling to occur between the Blue Line terminus and Union Station, from where it would continue on to Pasadena. However, 1998 passage of the ballot measure banning the use of sales tax for subway tunneling denied Metro the funding required for that portion of the project (Groves, 2006). Congressman Adam Schiff authored a bill that created a separate authority to continue the work on the remainder of the Gold Line.

The mostly above ground line finally opened on July 26th, 2003 adding twelve stations, and nearly fourteen miles of light rail track (Streeter & Hymon, 2003). The $1.16 billion dollar project was funded through Proposition A and C funds. Figure 3.9 provides the track and station alignment. This extension northeast of Los Angeles projected approximately 68,200 average weekday riders by 2010 (Bechtel Civl, Inc. et al., 1989, pp. 3–22). The Regional Connector, projected to open in 2022, will allow the Gold Line to connect with the Blue Line like it was originally intended (Barragan, 2017b).

Gold Line: Initial Segment



Gold Line: Eastside Extension

While the Initial segment of the Gold Line was under construction, the East Side Extension was recommended to be developed through East Los Angeles. The project was originally considered in the early 1990s as an extension of the Metro Red Line subway from its eastern terminus at Union Station. However, funding limitations and a county-wide halt on subway construction led to the indefinite delay of the project. A major investment study (MIS) reevaluated options for the corridor, focusing on light rail and bus rapid transit alternatives (U.S. Department of Transportation, Federal Transit Administration & Los Angeles County Metropolitan Transportation Authority, 2002, p. 20). The line opened on November 15th, 2009 adding eight stations and six miles of track, 0.2 miles on an aerial bridge, 1.8 miles in twin sub-surface tunnels, and 4.0 miles in the center median of local streets (Bloomekatz & Becerra, 2009). The $899.1 million dollar project received $490.7 million (54.6% of total costs) in a full funding grant agreement(U.S. Department of Transportation, Federal Transit Administration & Los Angeles County Metropolitan Transportation Authority, 2002, p. 22). Figure 3.10 identifies the route alignment. This portion of the gold line projected an additional 16,000 average weekday riders by 2020 (U.S. Department of Transportation, Federal Transit Administration & Los Angeles County Metropolitan Transportation Authority, 2002, pp. 5–6).

Gold Line: Eastside Extension

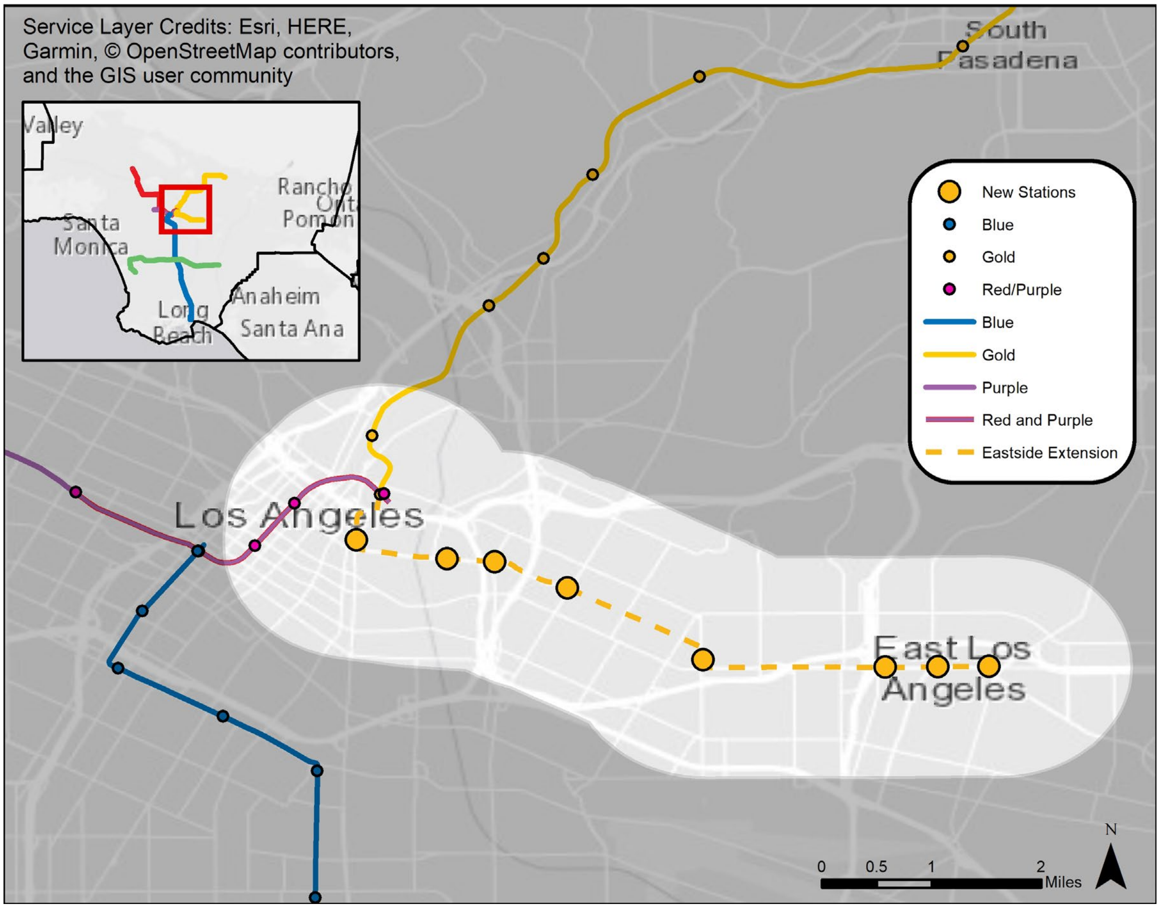


Figure 3. 10 Gold Line East Side Extension Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

Expo Line: Initial Segment

Metro's desire to expand out westward towards Santa Monica took its first step as the Initial Segment of the Expo Line opened on April 28th, 2012 (Bloomekatz, 2012a). The Expo Line followed the historic right-of-way of the Southern Pacific Railroad which transported freight and cargo from Santa Monica until it closed on March 11, 1988 (Morgenthaler, 1988). Friends 4 Expo Transit was created out of the concern that one of the last remaining intact rail corridors within Los Angeles County was going to be sold off haphazardly ("The Expo Line - Friends 4 Expo Transit," 2016). In 2003, an independent agency, the Exposition Metro Line Construction Authority, was given the authority to plan, design, and construct the line (Walker, 2007). The initial segment cost nearly $932 million dollars and was funded through Proposition A, Proposition C, state, and local funds (Walker, 2007).

The Expo Line, named after Exposition Park near Downtown Los Angeles, added eight stations and nearly eight miles of light rail track. The alignment is mostly at-grade, with some elevated, underground, and trenched sections. The project intended on connecting major economic and housing sectors on the Westside to Downtown Los

Angeles where the route connected at 7th and Metro Center Station. Figure 3.11 identifies how the new alignment fits into Downtown Los Angeles. According to the Final Environmental Impact Report, the Initial Segment of the Expo Line would add 36,412 average weekday riders in 2030 (AECOM, Cityworks Design, Inc., PBSJ, Inc., Lenax, &

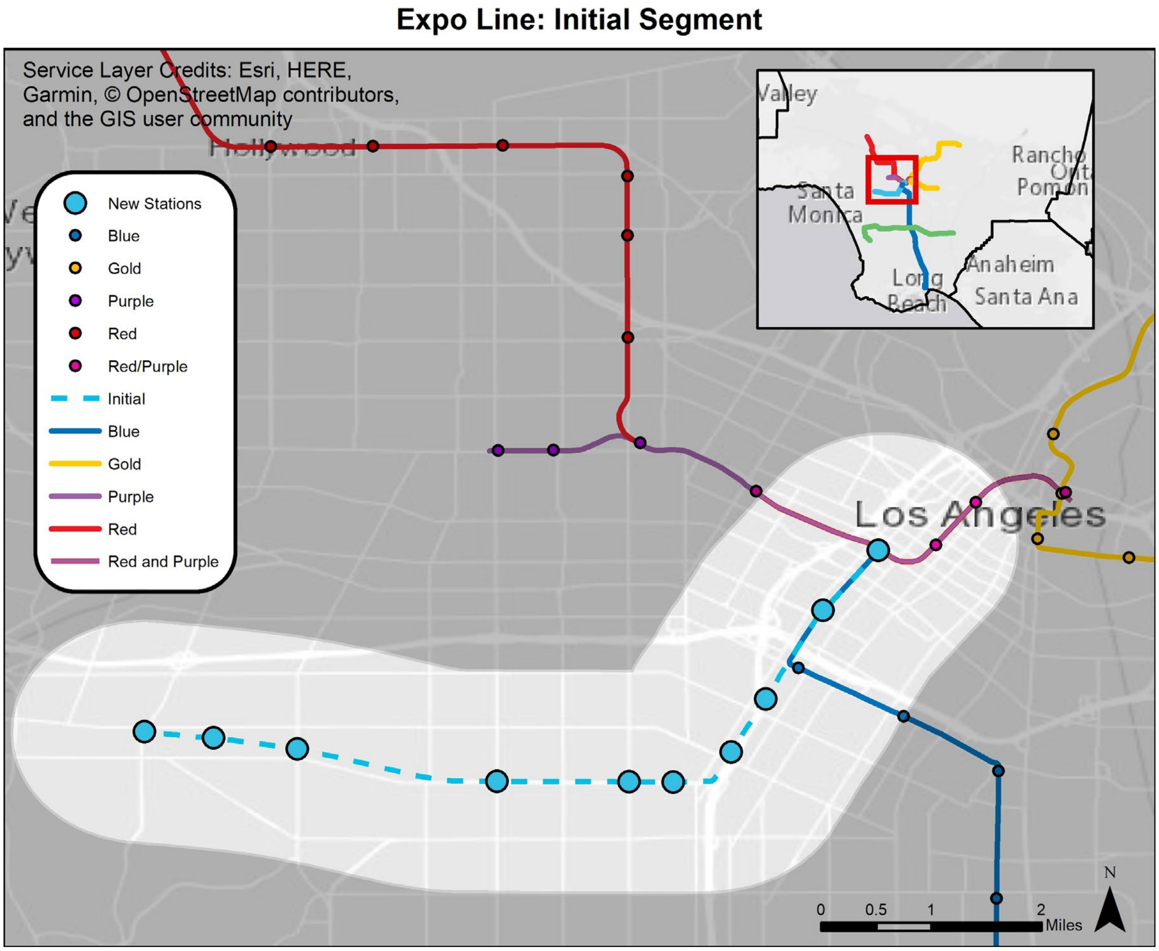


Figure 3. 11 Expo Line Initial Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

PSOMAS, 2009).

Expo Line: Culver City Extension

The second segment of the Expo Line opened up a few months later on June 20th, 2012, about a mile from the end of the Initial Segment (Bloomekatz, 2012b). The one mile and two station addition connected Culver City to the greater Metro Network. While the third phase of the extension was in limbo during the economic downturn in 2007, the second stage was enacted to ensure a connection to Culver City. Figure 3.12 highlights the new alignment. The Culver City Extension was projected to add 6,216 average weekday riders by 2030 (AECOM et al., 2009, pp. 7–12).

Expo Line: Culver City Extension

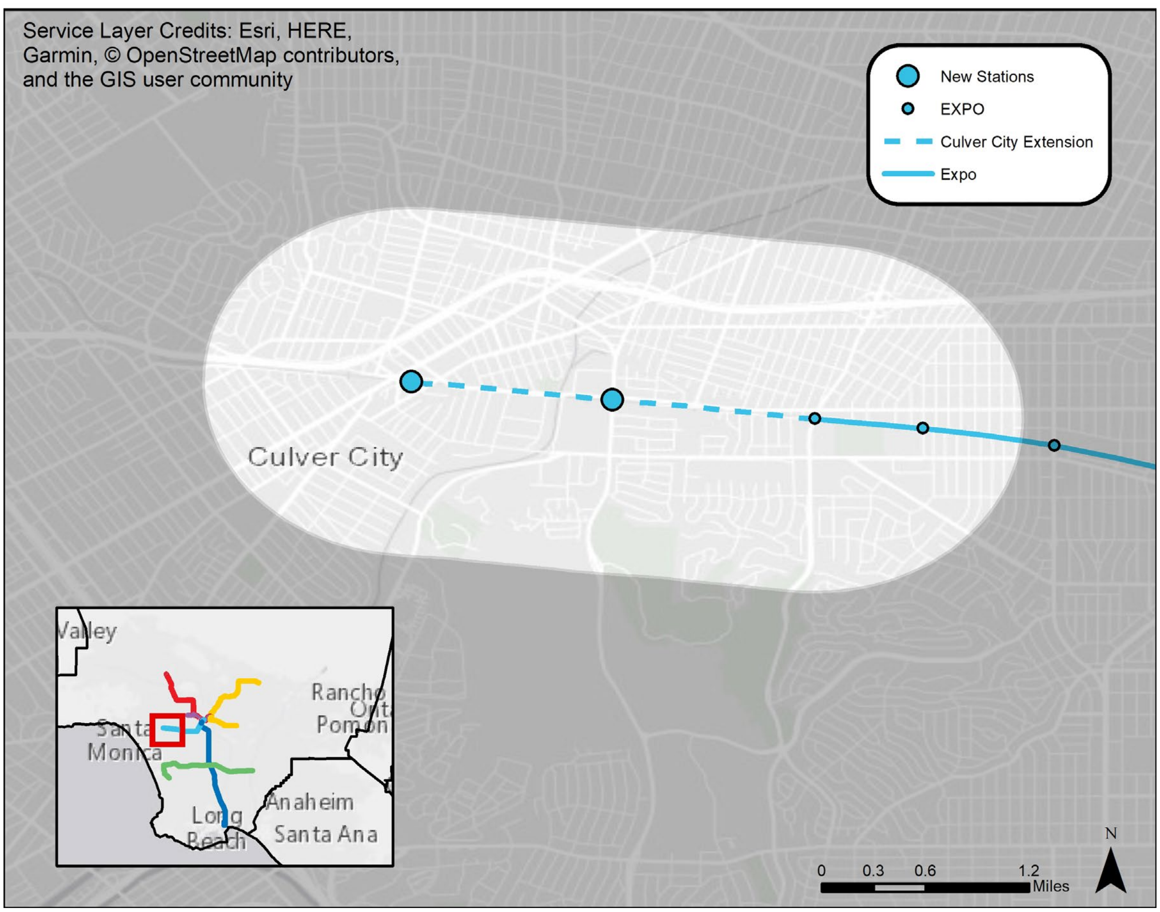


Figure 3. 12 Expo Line Culver City Extension Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

Gold Line: Foothill Extension

The Gold Line Foothill Extension continued to push light rail east, towards San Bernardino County. This portion followed the Atchison, Topeka, and Santa Fe railroad right-of-way. This segment of the Gold Line opened on March 5th, 2012. The mostly at-grade eleven-and-a-half-mile extension added six more stations along the north eastern extension of the Initial Segment (L. Nelson, 2016). The Foothill Extension cost roughly $735 million dollars, but was one of the first fully funded projections from Measure R, a voter approved half-cent sales tax (Metro, 2017). The Foothill Extension, as seen in Figure 3.13, connected the City of Azusa with the rest of the rail network. Metro

Gold Line: Foothill Extension

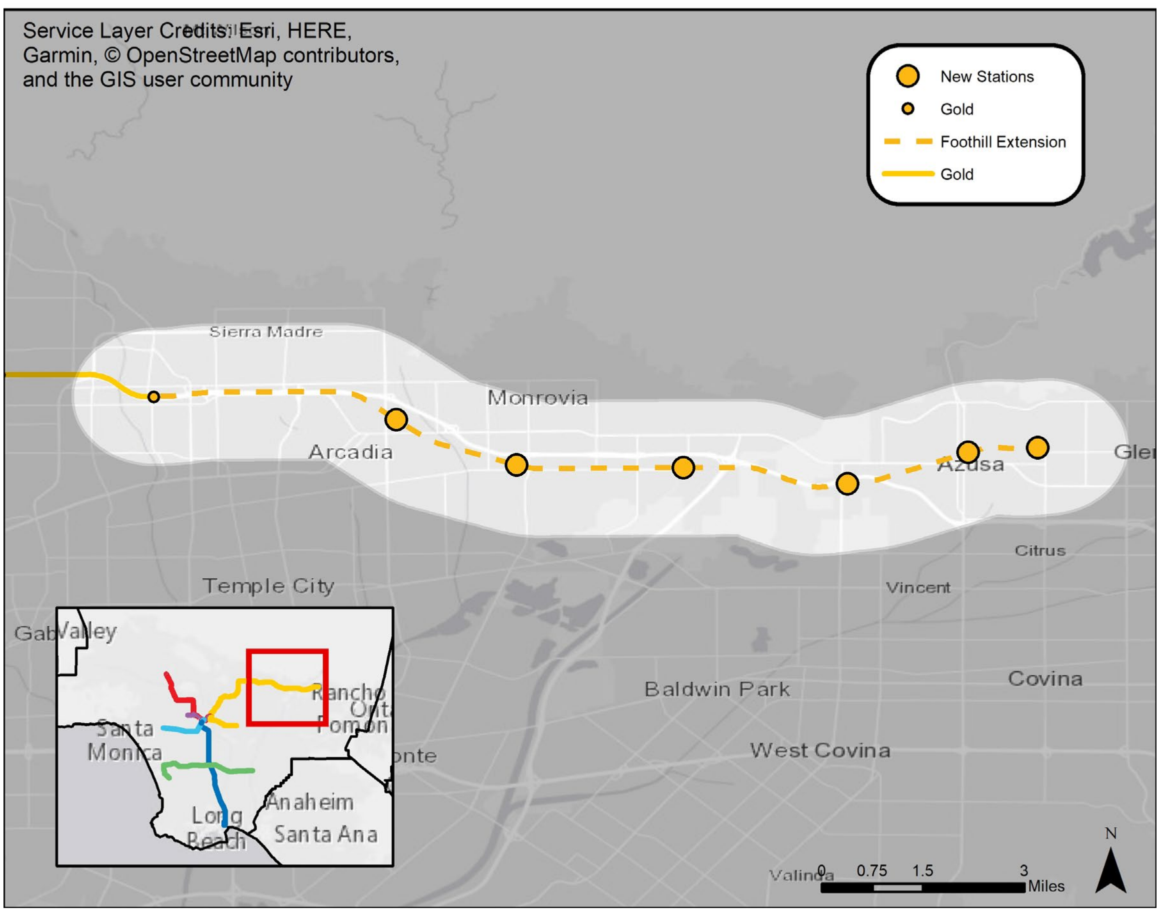


Figure 3. 13 Gold Line Foothill Extension Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

projected the Gold Line Foothill Extension would carry 13,600 passengers a day by 2035 (Scauzillo, 2016).

Expo Line: Santa Monica Extension

Metro conducted studies on the Expo Phase 2 between 2007 and 2009. They approved the project in 2010, with planned opening to Santa Monica in early 2016. The Expo Construction Authority officially handed over control of the Expo Phase II track to L.A. Metro for the county transit agency to begin pre-revenue train testing on January 15, 2016 (Islas, 2016). The Santa Monica Extension officially opened on May 20th, 2016. The new addition to the system included seven new stations, and more than six and a half miles of at-grade track (Hawthrone, 2016). The alignment, as seen in Figure 3.14, continued along the Southern Pacific Railroad right-of-way completing the connection between Downtown Los Angeles and Santa Monica (Morgenthaler, 1988). The $1.5 billion dollar extension was the second rail project to be fully funded through Measure R, avoiding financial criticisms unlike the initial segment of the (Metro, 2017). The Final Environmental Impact Report projected 23,092 average weekday riders by 2030 (AECOM et al., 2009).

Expo Line: Santa Monica Extension

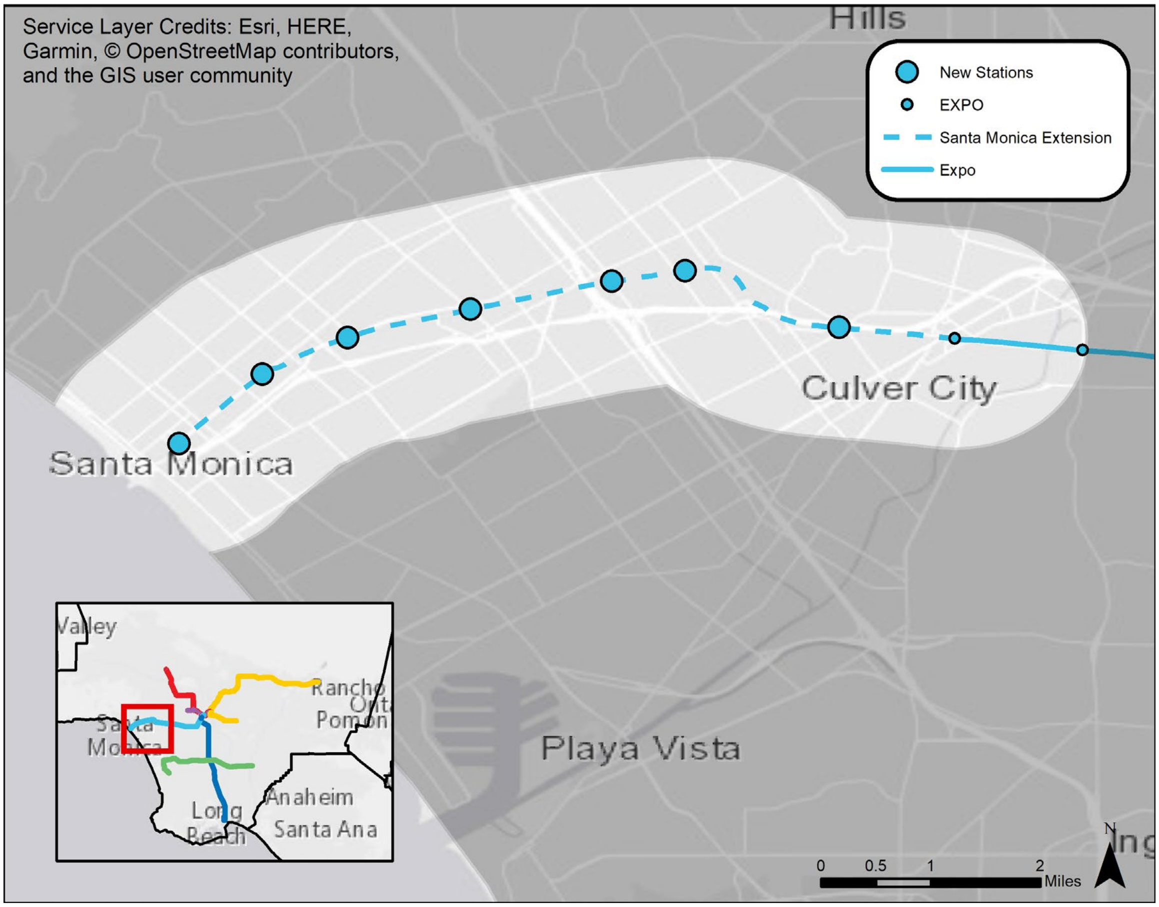


Figure 3.14 Expo Line Santa Monica Extension Segment Map created by author. GIS data provided by: Metro (Thai, 2015)

The rail network in Los Angeles has grown significantly over the past thirty years. The system is made up of four light rail lines and two subway networks that transport riders between ninety-three stations and ninety-eight miles of track. The Blue Line, Gold Line, and Expo Line follow historic freight rail right-of-ways, allowing for easily acquired land at a cheaper cost. However, most of these transit corridors are lined with low-density industrial land-uses with minimal existing housing developments along the way. When it comes to forecast ridership, Table 3.3 identifies the source of the forecast, who conducted it, and which model they utilized to execute it. This table provides insight into how and in what way the forecasts were completed.

Line	Segment	Source	Who Developed the Forecast	Model Type
Blue	Initial	(FEIR) – March 1985	Southern California Association of Governments/ PB-KE -1984	4-Step Model
Blue	Long Beach Loop	(FEIR) – March 1985	Southern California Association of Governments/ PB-KE -1984	4-Step Model
Blue	Financial District	(FEIR) – March 1985	Southern California Association of Governments/ PB-KE -1984	4-Step Model
Red & Purple	MOS-1	(SEIR) – July 1989	Schimpeler Corradino Associates SCRTD General Planning Consultant	Urban Transportation Planning System (UTPS) [Enhanced version supported by UMTA]
Green	Initial	Keith v. Volpe – Consent of Decree 1979	Metro	-
Purple	MOS-2A	(SEIR) – July 1989	Schimpeler Corradino Associates SCRTD General Planning Consultant	Urban Transportation Planning System (UTPS) [Enhanced version supported by UMTA]
Red	MOS-2B	(SEIR) – July 1989	Schimpeler Corradino Associates SCRTD General Planning Consultant	Urban Transportation Planning System (UTPS) [Enhanced version supported by UMTA]
Red	MOS-3	(SEIR) – July 1989	Schimpeler Corradino Associates SCRTD General Planning Consultant	Urban Transportation Planning System (UTPS) [Enhanced version supported by UMTA]
Gold	Initial	(FEIR) – November 1989	Los Angeles County Transportation Commission, 1989; Bechtel Civil, Inc., 1989.	4-Step Model
Gold	East Side Ext.	(FEIR) – January 2002	Metro	4-Step Model
Expo	Initial	(FEIR) – October 2005	Metro/FTA	Metro Transportation Demand Model, July 2004 and October 2004; MPA, 2005.
Expo	Culver City Ext.	(FEIR) – October 2005	Metro/FTA	Metro Transportation Demand Model, July 2004 and October 2004; MPA, 2005.
Gold	Foothill Ext.	(FEIR) – January 2012	Parsons Brinckerhoff, 2005	Metro Transportation Demand Model, 2005
Expo	Santa Monica Ext.	(FEIR) – December 2009	AECOM, SUMMIT Model, October 2008	Interim version of the Los Angeles County Metropolitan Transportation Authority’s Transportation Analysis Model

Table 3.3 Metro Forecasted Projection Data

Other findings in this section suggest that most of the heavy rail projects, as well as one light rail project, are partially funded through federal grants. This factor is important to consider as the research might find that ridership projections for projects funded by federal transportation grants are inflated. For example, the ridership projections for the Red and Purple heavy rail system indicate approximately 300,000 average weekday riders by the year 2000 (Southern California Rapid Transit District & Urban Mass Transportation Administration, 1989, pp. 2-1–41). This system alone is higher than any other projection among the other lines in the system. The following methodology assesses how the performance of the heavy rail and Gold Line Eastside Extension fair, as federal grants were utilized to construct those projects.

The rail network provides various alignments, unique station conditions, and fluctuating levels of construction that creates a diverse system. The chapter suggests that no two segments are the same as they were developed and constructed with varying intentions. This system provides a unique opportunity for ridership assessment, with varying factors to be considered in the process. The following chapters explores the experimental design of how this system is assessed.

CHAPTER 4: METHODOLOGY

This research compares actual rail ridership with projected rail ridership of Los Angeles Metro's light and heavy rail network. This section informs the reader of the varying data sources. In addition, the research design, methods, and limitations of this study is described in detail.

Actual Rail Ridership Data

Average weekday rail ridership data was collected through a public records request on November 21, 2018 from Metro. Station level boardings and alightings were provided for the following measures: the ridership of average daily, annual, Saturday, and Sunday. The fiscal years provided from Metro included the following years: 2001, 2003-2017. This research focuses on the boardings at each station. The station level data incorporates directional values for boarding, north, south, east, and west boardings depending on line alignment.

For this reason, the two numbers for each station are summarized so a singular boarding number is associated with each station. For example, in fiscal year 2017 the Monrovia Gold Line Station had an average weekday boarding of 171 riders heading north bound and 1,037 riders heading southbound. These two numbers are added together to derive a total weekday boarding of 1,208. This process is executed for each station for each year provided from Metro. That way, each station has a total boardings number for each year. For stations that had multiple lines, such as Union Station which has a station for the Gold Line, Red Line and Purple line, individual line boardings were provided from Metro. The station level data is aggregated to the line they are associated to and then cross referenced with the average weekday boarding by line numbers provided by Metro's Interactive ridership tool to ensure consistency (Metro, 2019c).

Station level boardings were not provided for fiscal year 1990-2000, 2002, and 2018. However, there is a way to calculate station level data based on station ridership data for the remaining sixteen years that Metro provided. This data provide information on the percentage of boardings by station by line. Once the average percentage of boarding by station by line is completed for each year, an average percentage of station boardings can be calculated. Once this is completed, the average weekday boarding by year and line is used to estimate station boardings. The average weekday ridership data by year and line was collected and displayed for 1991-2006 in "Los Angeles, California, Metro Green Line: Why are People Riding the Line to Nowhere?" (Mieger & Chu, 2007, p. 53). Their data was retrieved from Metro in the early 2000s. Average weekday boardings for fiscal year 2018 was provided in the first quarter of 2019 from Metro (Metro, 2019c), which complete the data set of station level boardings by year and line. With the station level data set in place, a variety of measures can be completed and assessed. This data is the basis of ridership comparisons throughout the research.

Since the ridership is analyzed based on the segment of construction, ridership numbers are aggregated to the specific segment they were built. The average weekday boardings by the fourteen segments discussed in Chapter 3 can be calculated since the station level data has been formatted in an appropriate manner.

Projected Rail Ridership Data

The ridership projection data set comes from the Environmental Impact Reports provided for each segment. Environmental Impact Reports (or EIRs) are reports to notify the public and public agency decision-makers of substantial environmental effects of future projects, identify possible ways to decrease or mitigate those effects, and describe reasonable alternatives to those projects. All of the segments of rail in Metro's transportation system had a "no-build" alternative that was tested against three to ten proposed alternatives, depending on location. Each alternative provides insight into environmental impacts and provides statistics such as ridership performance.

These documents give valuable insights into the planning process and decision making strategies as well as historical evidence that explains, in ways, the current context of the city (Los Angeles Public Library, 2012). Environmental Impact Reports help illustrate whether certain alternatives are worth the environmental impacts. Ridership projections for each segment were provided through various environmental impact reports over the past four decades.

In most cases, a projection year (horizon year) and ridership projection were provided. For example, the Green Line segment was projected to have a ridership of 35,000 average weekday riders by 2006. Beyond that projection year, ridership forecasts are not provided. Ridership scenarios are developed to estimate projected ridership beyond the projection year.

Another component of ridership projection is to estimate the annual rides between the year the segment opened and the horizon year. Opening year ridership projections were typically found in newspaper articles or online blog posts. Although not all segment openings had opening year projections, the initial findings are that opening year projections are roughly 60% of the horizon year projections. This information established the basis for how the projected ridership over time was developed. For segments that did not provide opening year projections, the 60% projected ridership is applied with an even growth distribution leading up to the horizon year.

Projected vs. Actual Ridership Comparison

Once the actual ridership data for each segment is compiled, and the projected ridership data is distributed, the comparison of the two elements begins. The initial comparison is a system-wide comparison. The research observes how actual rail ridership is performing compared to the projections of the system. Since each segment makes up the entire system, a similar comparison is conducted on each segment to understand the performance of each component. This analysis identifies segments that are performing at projection, overperforming, or underperforming. By identifying overperforming and underperforming segments, the research informs whether specific segments are carrying a bulk of the weight while other segments are underperforming.

Projected Ridership Scenarios

One element that the initial comparison, the literature, and the data collection identify is the absence of growth projections beyond the horizon year. While the projection year is an integral component of the EIR and measure of performance, research suggests the horizon year should be much closer to the opening date, with benchmark years as the line ages (Pickrell, 1989, p. 70). For example, the Green Line projected 35,000 average weekday riders by 2006. However, there was no growth projections beyond 2006. Growth scenarios are utilized to assume the growth forecast for projected rail ridership beyond the horizon year.

To analyze the data for 2018, four scenarios are developed. The first scenario is the no growth forecast. This scenario assumed growth is stagnant beyond the horizon year. The second scenario considers the Los Angeles County Population growth rate as a percentage and applies that percentage to the projected values of each segment, beyond the horizon year. The third scenario applies a standard one percent growth year after year to the projected ridership values beyond the horizon year. The last scenario applies a two percent growth year after year to the projected ridership values beyond the horizon years. Research that evaluated high performing rail networks argued that growth for twelve urban systems recorded an annual 1.5% growth rate year over year (Yoh, Haas, & Taylor, 2003, p. 119). 1% and 2% growth year over year was analyzed to study the range of these high performing systems. These growth scenarios are only applied to segments with horizon years before 2018. The intent of these scenarios is to assess how the projections could grow beyond the horizon year, giving a more accurate method of examining actual versus projected rail ridership.

Ridership and Density Regression

Housing and job densities play a major role when it comes to environmental impact reports and project performance. Travel demand models consider these factors when computing forecasted ridership (Gonzalez, 2015). A simple way to test whether or not there is correlation between the densities and the difference between actual versus projected ridership would be to take census tract data within a half mile of each station of each segment.

Using the U.S. Census Bureau, 2013-2017 American Community Survey 5-Year Estimates, census tract data for 2017 can be accessed and attributed to the data set. Using geographic information systems, the census tracts within a half mile of each station, by segment, is selected. This selection is exported and aggregated to determine a sum of job density and a sum of population density for each segment. This process is completed for all fourteen segments. Once completed the segment delta ridership (difference between actual versus projected ridership) for 2017 and the sum of job density per segment is plotted into a table. Excel is utilized to assess whether or not a correlation exists amongst the data.

What Does it All Mean?

Metro's rail network is made up of heavy and light rail. The next performance comparison is to compare rides per mile of the heavy rail system and the light rail system, with networks designated as quality performing system. This comparison evaluates Metro's light rail network with San Diego's light rail, commonly known as the San Diego Trolley. The heavy rail in Metro's network is compared with Bay Area Rapid Transit in San Francisco, commonly known as BART.

The miles of operational track by year is collected for the three systems throughout the data collection stage. Once that data set has been established, the total system average weekday ridership by year can be divided. This provides the number of rides per mile by a specific year. This process highlights how LA Metro's ride per mile compares with the two quality performing systems throughout the past three decades. This process also provides insight as to whether performance trends are similar among the rails systems.

Each segment of the network is assessed through ridership trends over the last five years, 2014-2018. National trends have identified a declining ridership trend for public transportation projects in recent years. This is important to understand as each segment can provide insight into what is occurring across the system on a spatial basis. This analysis identifies whether or not ridership trends are occurring similarly across all segments, or in specific areas.

Limitations

Author's Note: This study evaluates average weekday ridership as it is reflected under the current circumstances. Over the next few years, Metro will be phasing out the color names of the rail network and implement a new letter line nomenclature for the system (Chiland, 2018). This is in due part to the realignment of the overall network with the addition of the regional connector in Downtown Los Angeles (Barragan, 2017b). For example, the Initial and Foothill Extension segments of the Gold Line will connect with the Blue Line via the regional connector. This new alignment will be renamed the "A" Line. The segment projections utilized in this research did not account for the addition of the regional connector project. As the projections were designed for the specific alignment, the comparison of actual versus projected rail ridership can no longer be assessed once the regional connector is opened.

CHAPTER 5: ANALYSIS OF FORECAST AND ACTUAL RIDERSHIP

This study compares actual rail ridership with projected rail ridership for 14 segments of Metro's system. The results are broken down into five sections: projected versus actual ridership, projected ridership scenarios, ridership per mile comparisons, ridership and density, and Metro ridership trends. The intent of this chapter is to analyze Metro's rail network with a variety of attributes to fully understand how the system is performing. This chapter highlight the most profound findings of this research, while the appendixes illustrate the full data results.

Projected vs. Actual Ridership Comparison

This comparison of projected versus actual rail ridership shows the entire system is performing at about 66% of forecasted rides. As seen in Figure 5.1, the projected rail

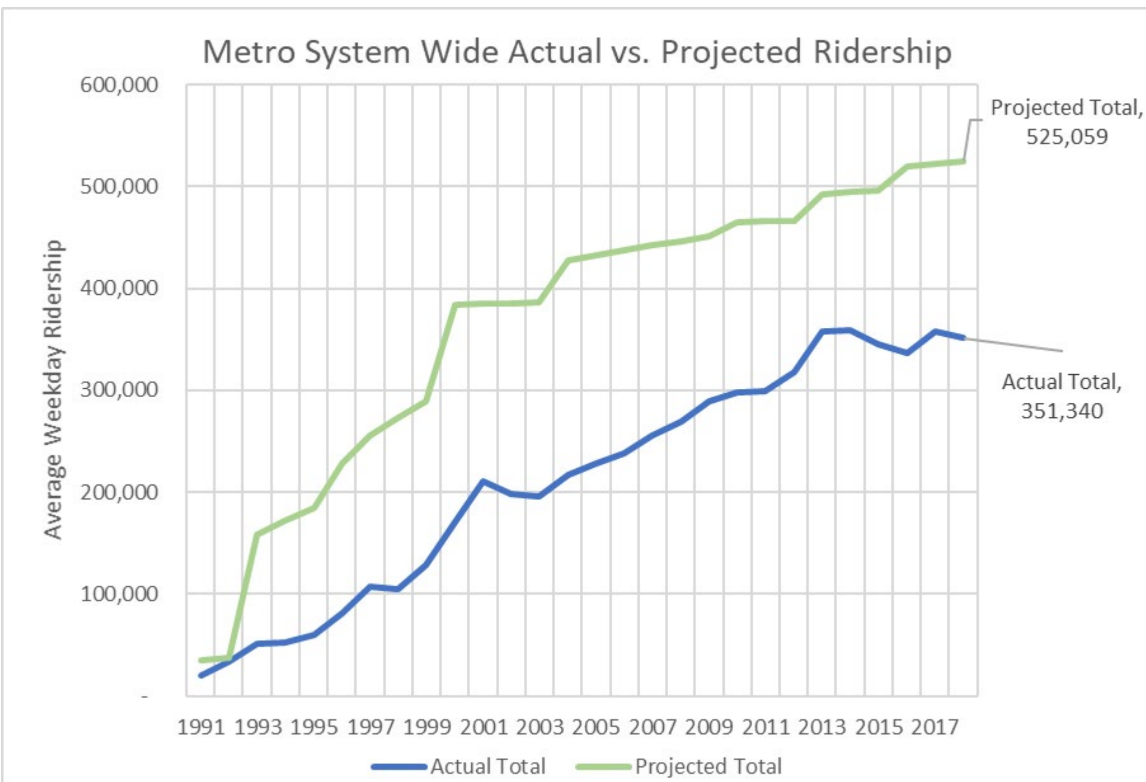


Figure 5. 1 Actual vs. Projected Rail Ridership of LA Metro

ridership was higher than the actual rail ridership for 21 of the 28 years evaluated. For fiscal year 2018, without growth adjustments beyond the various horizon years, combining the segment forecasts reveals that Metro projected a total of 525,059 average weekday riders. The actual amount of weekday riders for fiscal year 2018 was 351,340.

For fiscal year 2018, Metro's rail system missed its ridership projection by 173,719 weekday riders, meaning the system was only performing at 66.9% of its projected ridership. Metro's consideration for the projected rail ridership and with what occurred proves that the forecasting and modeling utilized for the segments were inconsistent and inaccurate. Further investigation into each line segment should be considered to see whether specific lines are underperforming while others are over performing. Figure 5.2 breaks down the segment performance by its horizon year. Table

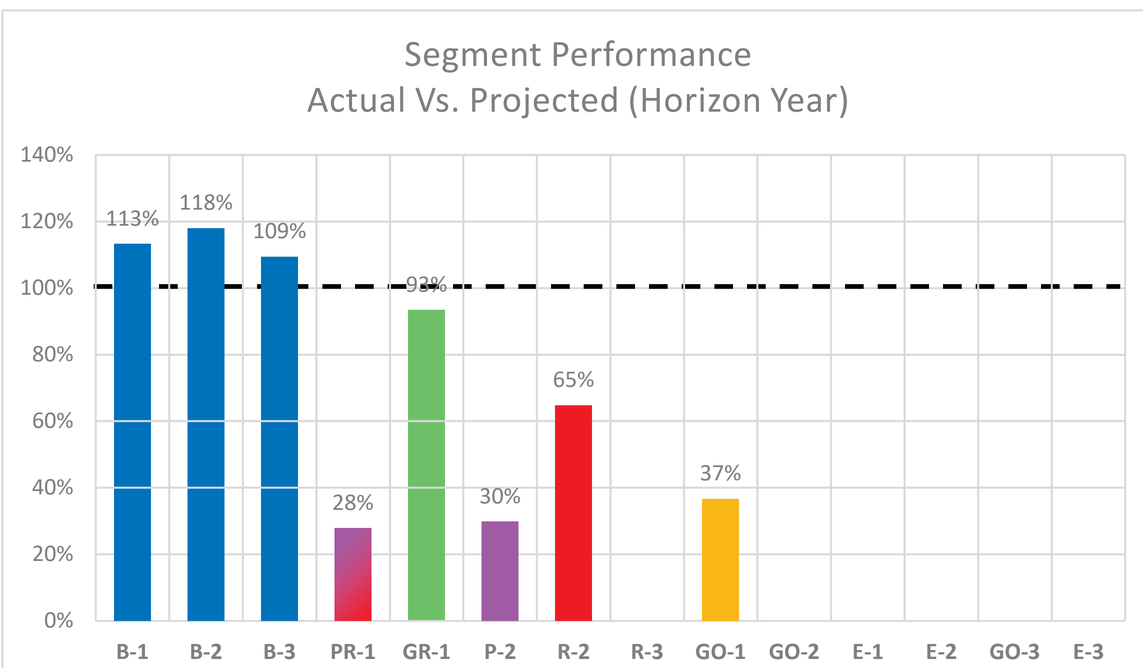


Figure 5. 2 Segment Performance by Horizon Year

5.1 identifies the numbers of average weekday riders and the projections made through the EIR. The table provides information regarding the specific horizon year for each segment, as most segments had varying horizon dates. Since the last five segments have not reached their horizon year, their performance is not applicable in Figure 5.2. The Blue Line segments are the only segments to reach their projections at the horizon year, while the other five segments were underperforming. The Red Line MOS-3 did not have

Segment	Horizon Year	Projection	Actual	% of Forecast
Blue Line: Initial Segment	2000	40,452	45,800	113%
Blue Line: Long Beach Loop	2000	3,769	4,447	118%
Blue Line: Financial District	2000	10,481	11,467	109%
Purple/Red: MOS-1	2000	197,853	55,011	28%
Green Line	2006	35,000	32,682	93%
Purple Line: MOS-2W	2000	22,088	6,578	30%
Red Line: MOS-2N	2000	39,479	25,543	65%
Red Line: MOS-3	2000	38,313	N/A	
Gold Line: Initial	2010	68,200	25,004	37%
Gold Line: East Side Extension	2020	16,000	N/A	
Expo Line: Initial	2030	36,412	N/A	
Expo Line: Culver City Extension	2030	6,216	N/A	
Gold Line: Foothill Extension	2030	13,600	N/A	
Expo Line: Santa Monica Extension	2030	23,092	N/A	
Total Light Rail		253,222	119,400	47%
Toal Heavy Rail		297,733	87,132	29%

Table 5. 1 Segment Performance by Horizon Year

an actual ridership for the horizon year as it was not operational for the year the ridership projection was developed.

To understand how the lines are performing across the same time span, a similar analysis was conducted during fiscal year 2018. Table 5.2 identifies the actual rail ridership for each segment in fiscal year 2018, as well as the projection for that same

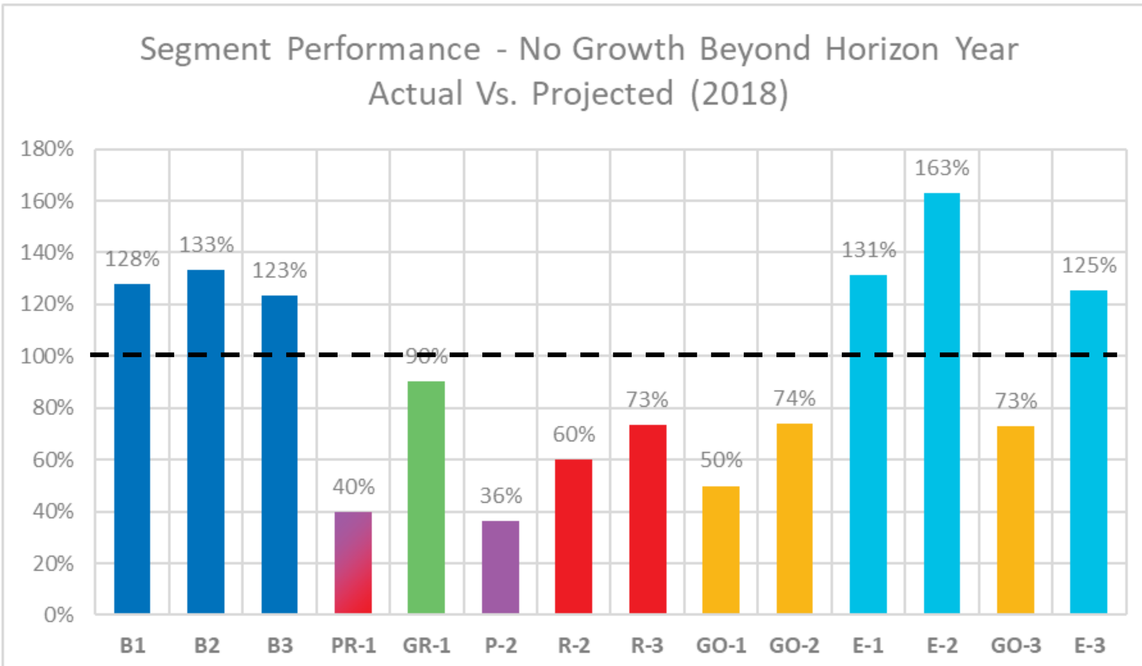


Figure 5. 3 Segment Performance for Fiscal Year 2018, no growth post-horizon year

year. Figure 5.3 focuses on the overall performance of the segments. For fiscal year 2018, the data shows that six of the segments are underperforming while eight of the segments are over performing. Three-fourths of those segments that are over performing, are doing so by more than 25% of performance. Meanwhile, five of the six underperforming segments are doing so with more than 25% of underperformance. While these tables and figures highlight the performance of the segments for Fiscal Year 2018, one thing that isn't considered is the projection the data is compared with. For example, in Figure 5.3, The Initial Blue Line segment is performing 28% better than its projection. However, the projection number is the same number as horizon year 2000. Since projections beyond the horizon year were not provided, it's hard to assess whether or not the performance is accurate as it should anticipate growth beyond the horizon year.

Segment	Projection	Actual	% of Forecast
Blue Line: Initial Segment (B-1)	40,452	51,672	128%
Blue Line: Long Beach Loop (B-2)	3,769	5,018	133%
Blue Line: Financial District (B-3)	10,481	12,937	123%
Purple/Red: MOS-1 (PR-1)	197,853	78,441	40%
Green Line (GR-1)	35,000	31,577	90%
Purple Line: MOS-2W (P-2)	22,088	8,044	36%
Red Line: MOS-2N (R-2)	39,479	23,620	60%
Red Line: MOS-3 (R-3)	38,313	28,053	73%
Gold Line: Initial (GO-1)	68,200	34,050	50%
Gold Line: East Side Extension (GO-2)	14,720	10,874	74%
Expo Line: Initial (E-1)	26,131	34,279	131%
Expo Line: Culver City Extension (E-2)	4,461	7,262	163%
Gold Line: Foothill Extension (GO-3)	8,937	6,509	73%
Expo Line: Santa Monica Extension (E-3)	15,175	19,002	125%
Total Light Rail	227,326	213,181	94%
Toal Heavy Rail	297,733	138,159	46%

Table 5. 2 Segment Performance for Fiscal year 2018 with no post-horizon year growth.

From the two comparisons, one of the biggest contributors to poor performance was the heavy rail system. The Red Line and Purple Line projected a combined total of 297,773 riders in 2018, while only 138,159 rides took place as seen in Table 5.2. The discrepancy between the projection and actual rail ridership should be a concern for Metro as they look towards the future of heavy rail extensions within the system. The question at hand is what caused such a discrepancy in the overall ridership projection.

Further investigation into the heavy rail system of Metro could provide new insight into how modeling and forecasting shouldn't be a copy-and-paste methodology.

Another issue that was identified in the process was projection beyond the horizon year. As illustrated in Figure 5.4, once the projected ridership reaches the horizon year (projection year), the first procedure kept in constant. This trend occurs in every segment that has reached the projection year. While no growth projections were

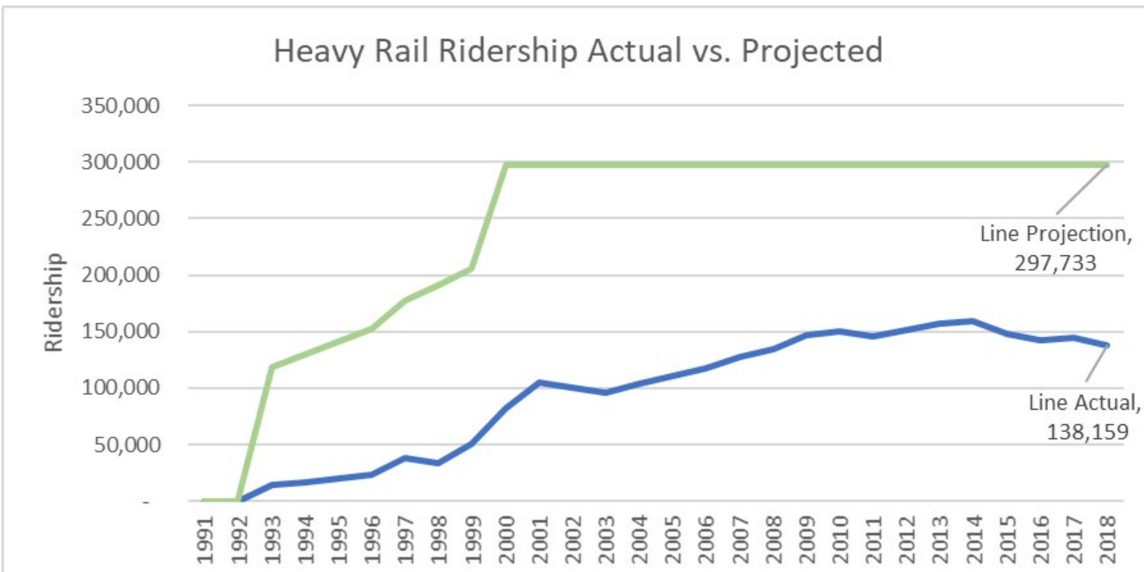


Figure 5. 4 Heavy Rail Ridership Comparison

made beyond the horizon years, while growth should still occur. This possibility encouraged further exploration of growth beyond the horizon year and is further discussed in the second segment of this chapter: *Projected Ridership Scenarios.* To assess an accurate comparison between a year of projected ridership and actual ridership, scenarios must be developed to assume growth beyond the horizon year of each segment. This study focuses on the segments that have already reached their horizon years. The three Expo Line Segments, the Gold Line Foothill Extension, and the

Gold Line East Side Extension are still incorporated in this section, but no scenario are applied as their projections are for 2020 and beyond.

Projected Ridership Scenarios

Due to the lack of projection beyond the horizon year, three ridership scenarios were developed to more accurately assess what occurs beyond the projection year. The first scenario considers the growth of Los Angeles County. In this scenario, the year over year growth percentage is applied to the projection number immediately beyond the horizon year for any given segment. Census data was collected from the census bureau to make accurate year over year growth projections (Given Place Media, 2019). Table 5.3 identifies the outcome of the projected growth numbers based off the historical county growth.

Segment	Projection	Actual	% of Forecast
Blue Line: Initial Segment (B-1)	43,676	51,672	118%
Blue Line: Long Beach Loop (B-2)	4,069	5,018	123%
Blue Line: Financial District (B-3)	11,316	12,937	114%
Purple/Red: MOS-1 (PR-1)	213,623	78,441	37%
Green Line (GR-1)	36,721	31,577	86%
Purple Line: MOS-2W (P-2)	23,848	8,044	34%
Red Line: MOS-2N (R-2)	42,626	23,620	55%
Red Line: MOS-3 (R-3)	41,367	28,053	68%
Gold Line: Initial (GO-1)	71,383	34,050	48%
Gold Line: East Side Extension (GO-2)	14,720	10,874	74%
Expo Line: Initial (E-1)	26,131	34,279	131%
Expo Line: Culver City Extension (E-2)	4,461	7,262	163%
Gold Line: Foothill Extension (GO-3)	8,937	6,509	73%
Expo Line: Santa Monica Extension (E-3)	15,175	19,002	125%
Total Light Rail	236,590	213,181	90%
Toal Heavy Rail	321,463	138,159	43%

Table 5. 3 Segment Performance Table with County Population Growth Projections

This scenario adjusted the projection to the trends based on the growth from the horizon year until 2018. This assumption leads the study to a more accurate depiction of what projections could look like beyond the projection year. This scenario shows that the over performance of the rail segments is not as high as they previously were since growth has been applied beyond the horizon year. As seen in Figure 5.5, six of the segments are still over performing based on their projected ridership, however only three are overperforming by more than 125%.

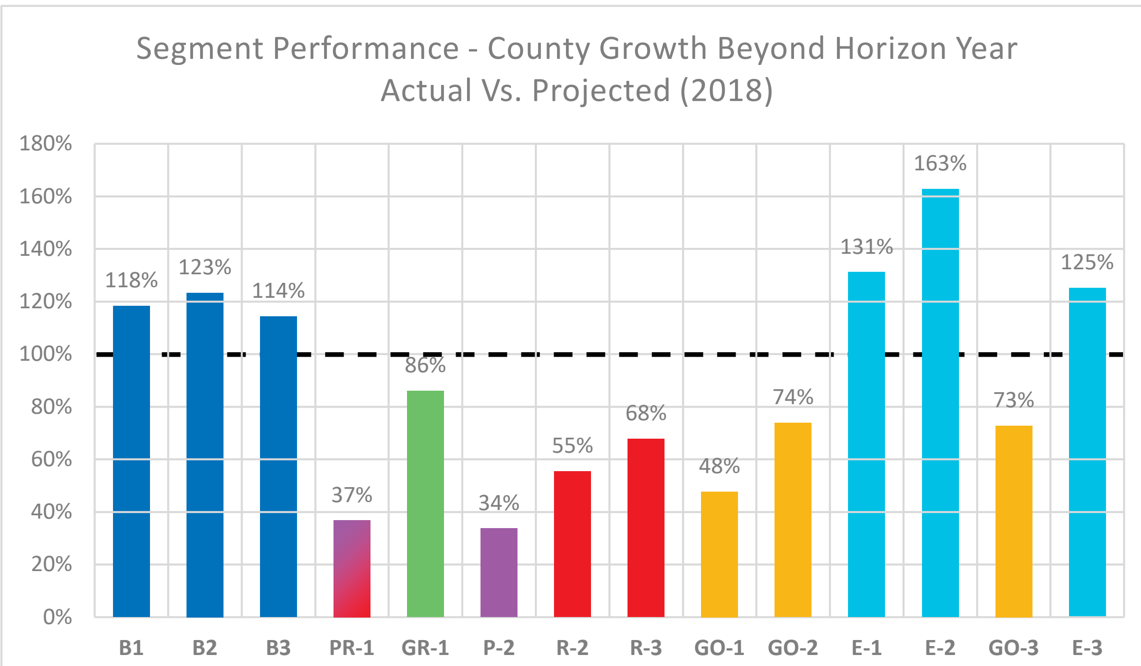
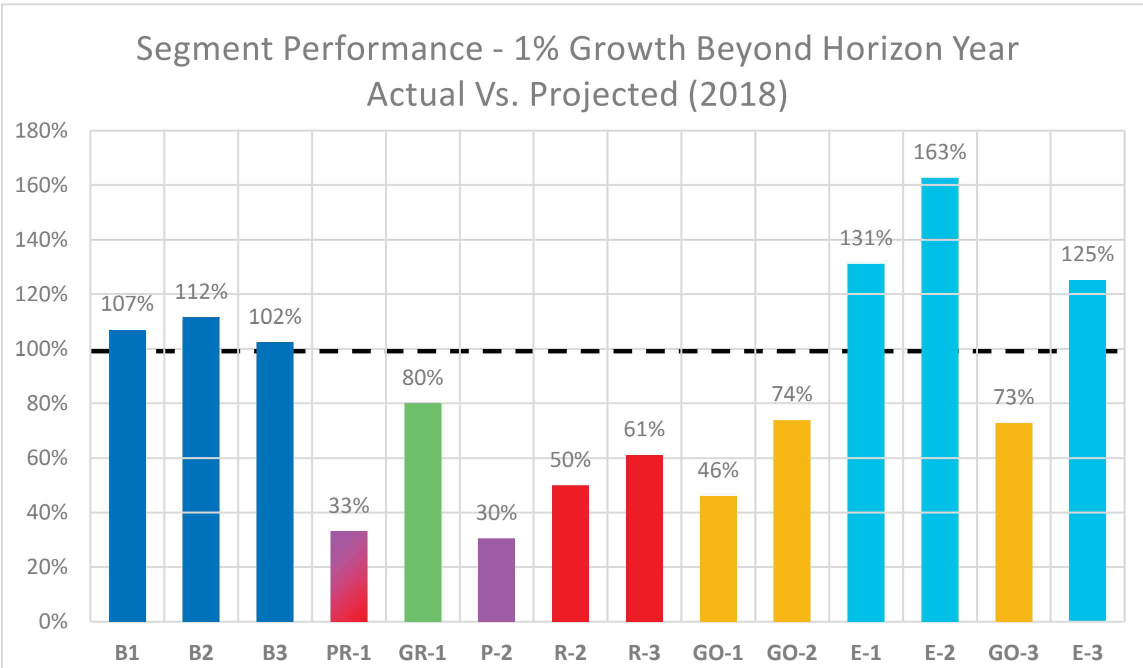


Figure 5. 5 Segment Performance based off County Growth Projections

The next scenario tested was a one percent growth, applied year over year for projections beyond the horizon year. For example, the horizon year for the Initial Blue Line segment projected 40,452 average weekday riders by 2000. For the year 2001, a 1%

growth was applied so the projection would now be 40,857 for 2001. The 1% growth would apply year after year for every year beyond the horizon year for each segment.

The projections and performance change with a 1% growth scenario, as seen in Figure 5.6, show that the only segments overperforming by more than 25% are the Expo Line segments. The heavy rail system is severely underperforming ranging between -



39% to -70% performance. However, the three blue line segments are over performing by a range of 2%-12%. The remaining eight lines are all underperforming by more than 20%. Table 5.4 illustrates the breakdown of how each segment compares with the 1% growth.

The last scenario tested was similar to the previous one. However, instead of applying a 1% growth, year over year, a 2% growth was applied. Table 5.5 identifies the new projections based on the 2% growth of each segment beyond the horizon year. The

Segment	Projection	Actual	% of Forecast
Blue Line: Initial Segment (B-1)	48,261	51,672	107%
Blue Line: Long Beach Loop (B-2)	4,497	5,018	112%
Blue Line: Financial District (B-3)	12,629	12,937	102%
Purple/Red: MOS-1 (PR-1)	236,661	78,441	33%
Green Line (GR-1)	39,439	31,577	80%
Purple Line: MOS-2W (P-2)	26,421	8,044	30%
Red Line: MOS-2N (R-2)	47,223	23,620	50%
Red Line: MOS-3 (R-3)	45,828	28,053	61%
Gold Line: Initial (GO-1)	73,851	34,050	46%
Gold Line: East Side Extension (GO-2)	14,720	10,874	74%
Expo Line: Initial (E-1)	26,131	34,279	131%
Expo Line: Culver City Extension (E-2)	4,461	7,262	163%
Gold Line: Foothill Extension (GO-3)	8,937	6,509	73%
Expo Line: Santa Monica Extension (E-3)	15,175	19,002	125%
Total Light Rail	248,100	213,181	86%
Toal Heavy Rail	356,133	138,159	39%

2% growth scenario presents a much more dramatic episode of projection adjustment. In this scenario, only four segments are overperforming their projected ridership. The remaining ten projections fall below the at performance grade with underperformance ranging from -7% to -57% as seen in Figure 5.7.

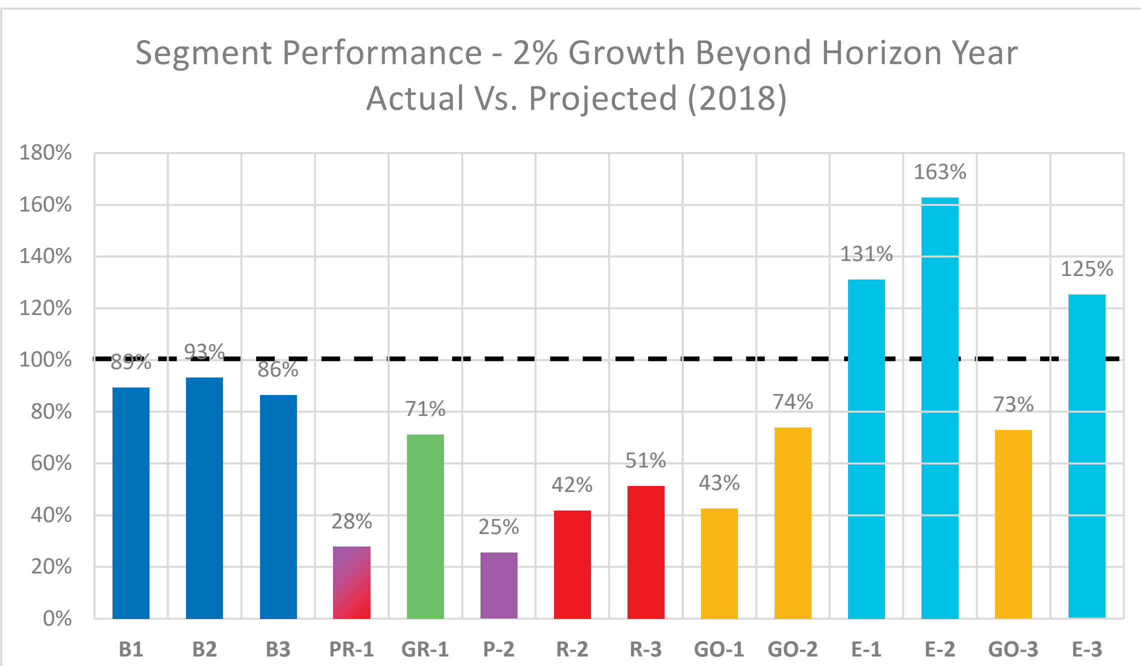


Figure 5. 7 Segment Performance with 2% Growth

Segment	Projection	Actual	% of Forecast
Blue Line: Initial Segment (B-1)	57,775	51,672	89%
Blue Line: Long Beach Loop (B-2)	5,383	5,018	93%
Blue Line: Financial District (B-3)	14,969	12,937	86%
Purple/Red: MOS-1 (PR-1)	282,583	78,441	28%
Green Line (GR-1)	44,388	31,577	71%
Purple Line: MOS-2W (P-2)	31,547	8,044	25%
Red Line: MOS-2N (R-2)	56,386	23,620	42%
Red Line: MOS-3 (R-3)	54,720	28,053	51%
Gold Line: Initial (GO-1)	79,907	34,050	43%
Gold Line: East Side Extension (GO-2)	14,720	10,874	74%
Expo Line: Initial (E-1)	26,131	34,279	131%
Expo Line: Culver City Extension (E-2)	4,461	7,262	163%
Gold Line: Foothill Extension (GO-3)	8,937	6,509	73%
Expo Line: Santa Monica Extension (E-3)	15,175	19,002	125%
Total Light Rail	271,847	213,181	78%
Toal Heavy Rail	425,236	138,159	32%

Table 5. 5 Segment Performance Table with 2% Growth

The three scenarios assessed for the projected ridership alterations presented varying conclusions. The county growth projection scenario presented a stronger metric of growth, since the growth was based on spatial context and reliable sources. These annual growth changes ranged from +.05% in 2008 and +.93% in 2002 (Given Place Media, 2019). While the county year over year projections varied, the standard 1% growth applied a simple assumption to the growth. The issue with doing this is that it doesn't necessarily respond to outside issues. The 2% growth scenario had a similar outcome where it applied a standard growth year over year which heavily influenced the performance. These scenarios presented a variety of outcomes, while introducing the idea of growth projections beyond the horizon year. As little supporting research exists on projecting beyond the horizon year, it should be considered when projecting rail ridership. As a measure of performance, at least bench mark years should be incorporated to evaluate performance before, during, and after the horizon year of ridership projections.

Ridership and Density Regression

Jobs and population are factors considered when projecting and forecasting rail ridership. Environmental Impact Reports utilize historical density data to analyze the viability of rail segments. Figure 5.8 highlights the average population and job density for census tracts within a half mile of each segment station of Metro’s network. The

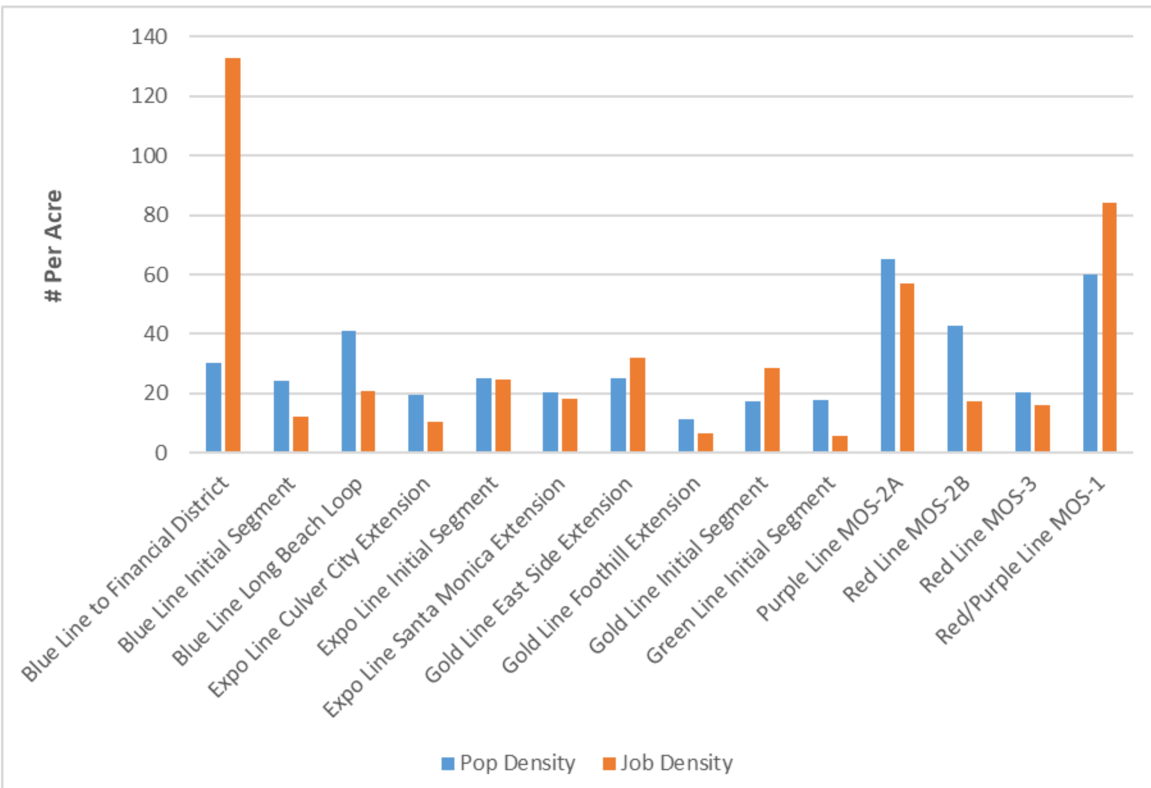


Figure 5. 8 Average Population and Job Density of Census Tracts within a Half Mile of Each Segment

graph suggests that higher densities are occurring along mostly heavy rail segments (MOS-2A, MOS-2B, MOS-1), as well as the Blue Line light rail segment to the Financial

District. These four segments are predominantly located within the downtown section of Los Angeles, which aligns well with the densities of the area.

The next assessment is to compare these densities, independent variables, with the dependent variable, inaccuracy of ridership, or delta ridership, of each segment. The population density regression model presents a positive correlation, meaning that as population density per acre increases, so does the likelihood of underperforming the projections. Table 5.6 identifies highlights that the population density regression presents statistically significant correlation with the delta density, recording a p-value of 0.00289

Regression Statistics	
Multiple R	0.732431313
R Square	0.536455628
Adjusted R Square	0.49782693
Standard Error	32.47497144
Observations	14

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	14646.0764	14646.0764	13.88748937	0.002891857
Residual	12	12655.48524	1054.62377		
Total	13	27301.56164			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.412126971	18.74249187	0.075343609	0.941182823
Pop Density	2.060267673	0.552855683	3.726592192	0.002891857

Table 5. 6 Population Density Regression Output

The same comparison was conducted on the job density of census tracts within a half mile of segment stations, which recorded similar results. In this similar comparison, a positive correlation exists. Similar to the population density regression, as job density per acre increases, the likelihood of missing a ridership projection increases. The regression output as seen in Table 5.7 suggests similar results as population density regression, however when it comes to the r-squares, the job density model is a much stronger model than the population density model. This implies that job density is a better factor than population density in terms of explaining the inaccuracy of the projection.

Regression Statistics	
Multiple R	0.950403196
R Square	0.903266235
Adjusted R Square	0.895205088
Standard Error	14.83515769
Observations	14

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	24660.57879	24660.57879	112.0518243	1.9302E-07
Residual	12	2640.982843	220.0819035		
Total	13	27301.56164			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	22.68584491	5.518487564	4.110880862	0.001443994
Job Density	1.221259689	0.115371505	10.58545343	1.9302E-07

The final regression model combined job and population density. Similar to the past two regressions, this model presented a similar correlation.. Normally, a 90% confidence level is an acceptable threshold for judging statistical significance. The combined density model presents a significant correlation with the dependent variable. Surprisingly, this presents a negative correlation, which is the opposite from other models. Furthermore, the r-square of this model is much smaller than the others. As seen in Table 5.8, these indicate that it is not a good idea to mix job and population together in order to analyze the accuracy of the projection. The reason why this happens is that majority of segments have one dominant factor, either population or job density. So, when you add up, one factor becomes dominant while the other does not effect on the independent variable.

Regression Statistics	
Multiple R	0.492631563
R Square	0.242685857
Adjusted R Square	0.179576345
Standard Error	41.50889338
Observations	14

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	6625.702883	6625.702883	3.845471936	0.073505639
Residual	12	20675.85875	1722.988229		
Total	13	27301.56164			

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	54.80488934	11.91277749	4.600513136	0.00061039
Ridership Delta	-0.000686019	0.000349833	-1.96098749	0.073505639

This assessment determined that a correlation exists between job and population density and the inaccuracy of projected ridership. However, the three regression models only had a sample size of fourteen, therefore an analysis with more samples is highly recommended. Further investigation on a station by station basis could present a stronger case for determining why and how the independent variables effect the inaccuracy of projected ridership.

What Does it All Mean?

The projected versus actual ridership assessment highlighted that Metro and their ridership modeling consultants significantly missed their projection, when the final numbers were assessed, as seen in Figure 5.1. While the ridership performance overall is performing at roughly 66.9% of the projected total, this study compared the system with peer light and heavy rail systems.

Metro's light rail network was compared with San Diego's Trolley, a light rail system that has received praise for its quality performance (Fudge, 2011). Rides per mile was the metric utilized to compare the two systems accurately. The miles of operational track per year was divided by the ridership of that same year. As seen in Figure 5.9, the light rail system of Los Angeles outperforms the San Diego Trolley for eight of the 28 years assessed. The San Diego Trolley performed at a higher rate than Metro's light rail between 1993 and 2008. Between 2009 and 2018 Metro and the San Diego Trolley varied in performance with the Trolley ending 2018 with 2,343 trips per mile. Meanwhile, Metro completed approximately 2,015 trips per mile. When compared with each other, Metro is typically not performing at the same rate as the San Diego Trolley,

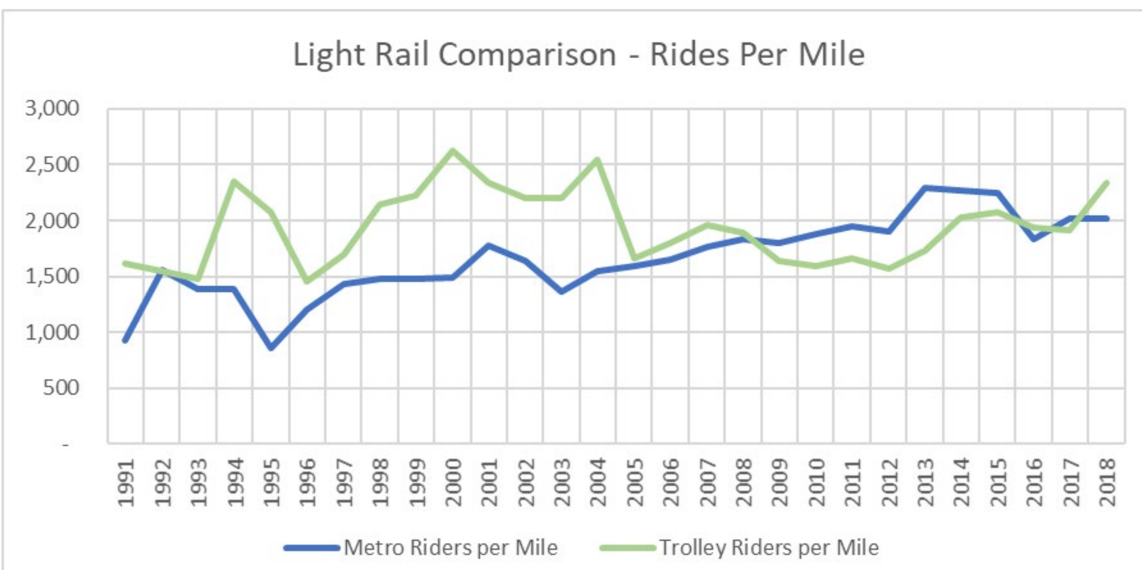


Figure 5. 9Light Rail Transit - Rides per Mile

however its ridership is responding to similar trends as seen in the San Diego Trolley riders per mile comparison.

The same comparison of heavy rail was completed that compared Metro Heavy Rail with the Bay Area Rapid Transit network in San Francisco. As seen in Figure 5.10, the heavy rail network in Los Angeles significantly underperforms when compared to the

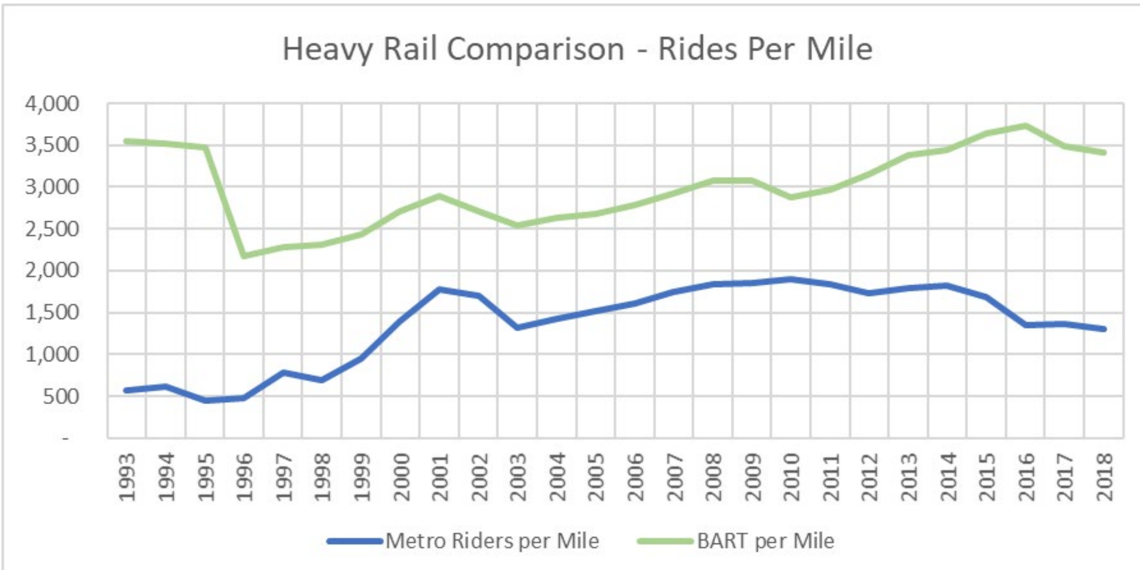


Figure 5. 10 Heavy Rail Transit - Rides Per Mile Comparison

similar network in San Francisco. Similar to that of the light rail comparison, the heavy rail comparison visualizes similar trends between 1997 and 2014 for the two systems, meaning that both systems are responding to outside attributes in a similar manner.

It should be noted that the BART Heavy Rail network has been in operation since the 1970s and thus developed a mature system, with a built environment that reflects a transit-oriented development. Further research could compare heavy rail networks that were opened around the same year, as it might suggest a different performance pattern.

What these two comparisons indicate is that while the Metro's light rail performs relatively close to similar performing systems, Metro's heavy rail significantly underperforms. Further research could be conducted on this area alone comparing Metro's rail network other networks from around the United States and internationally. This research could investigate factors as to why Metro's system is underperforming.

The last section of the results chapter looks to understand current ridership trends of Metro. National ridership trends show a decline in public transit users over the last five years (L. J. Nelson, 2017). While much of the research out there combines both bus and rail transit, this section focuses on rail transit only.

Metro's rail system shows a net decline in rides per mile by 767 over the last five years, as seen in Figure 5.11. This assessment shows that even with the addition of more than eighteen miles of track and thirteen new stations, overall ridership is still declining.

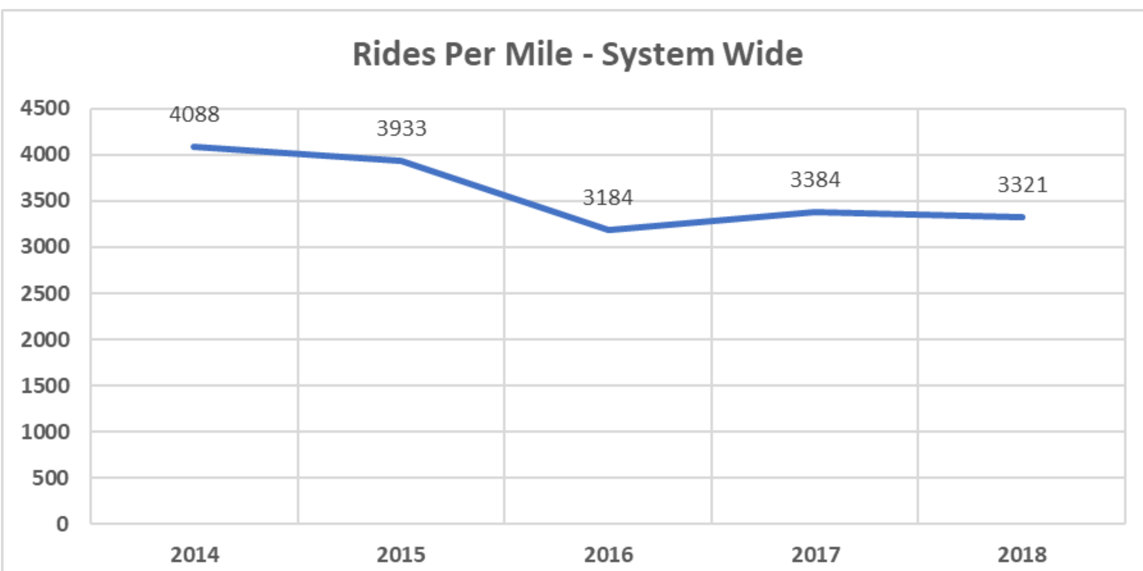


Figure 5.11 LA Metro Total Average Weekday Boardings - Last Five Years of All Rail

That calls into question whether additional miles of track create a more connected and utilized system.

To measure the system's performance without the adverse effects of the new lines that opened over the last few years, ridership was assessed as a whole without the Expo Line and Foothill Extension. This method of the analysis was selected as the new segments can impair the look of the system that has been operating over the past few decades. There is a significant decline in ridership over the last five years when you subtract the addition of the Expo Line and the Foothill Extension of the Gold Line, as seen in figure 5.12. The overall decline over the last five years for this data is 45,989 average weekday boardings. Without the Expo Line and Foothill Gold Line Extension, the

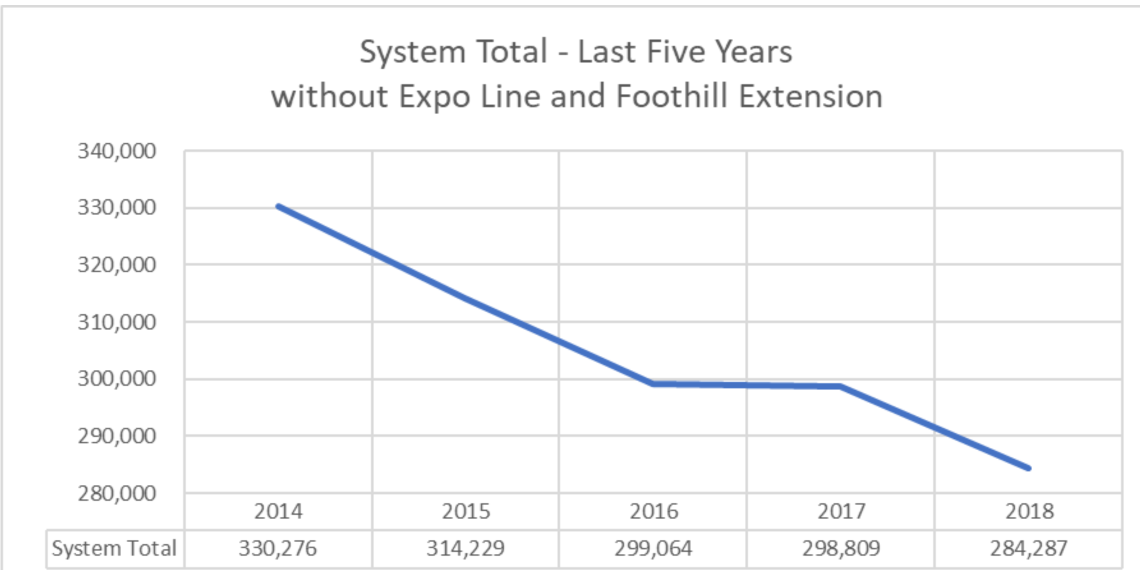


Figure 5. 92 Average Weekday Boardings without Expo Line and Gold Line Foothill Ext

Metro rail network declines by over 14% over the last five years. This type of trend should concern Metro as they look towards the future.

When individual lines are assessed, as seen in Figure 5.13 the Blue Line has seen the heaviest decline with a net loss of 20,019 average weekday boardings since 2013.

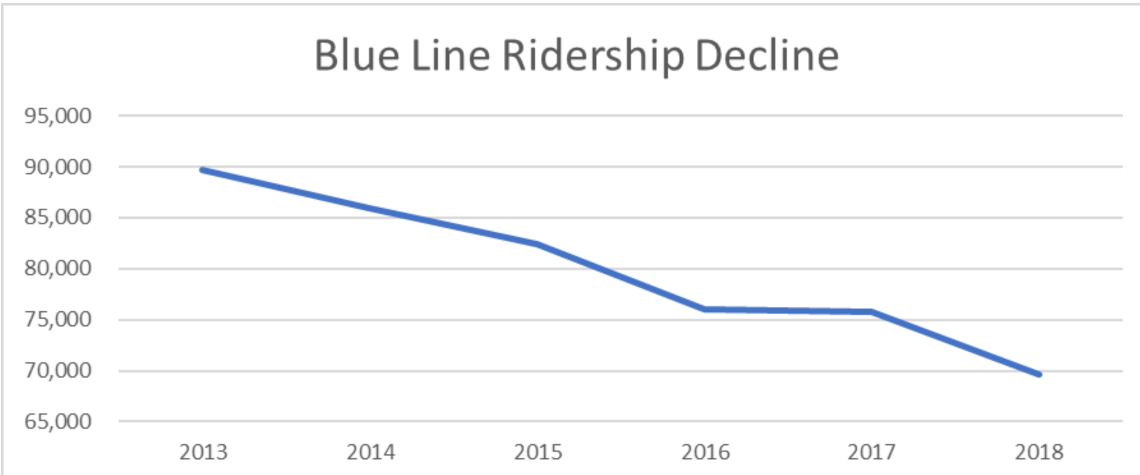


Figure 5. 103 Blue Line Ridership - Last Five Years

This was in part due to the fact that the line was running at maximum capacity and passengers were encouraged to utilize the Silver Line bus service to alleviate overcrowding. The heavy rail system has also observed a decline since 2013 as the total weekday boardings for the Red and Purple Line saw a net drop of 21,203, as seen in Figure 5.14.

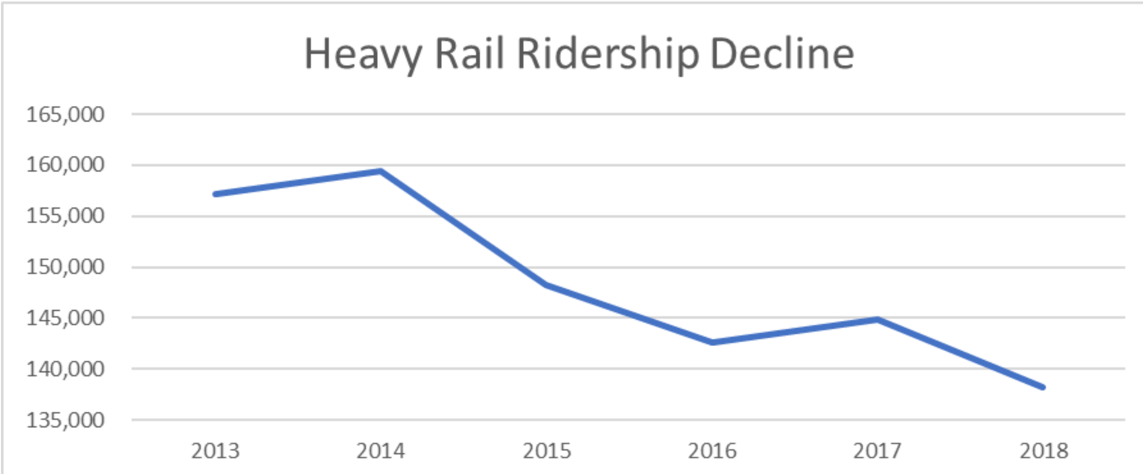


Figure 5. 114 Metro Heavy Rail Ridership - Last Five Years

The data suggest that declining ridership is a common theme for all rail segments of the Los Angeles Metro network, except for the newest additions. These new segments are still maturing into their optimal performance. The ridership over the past five years suggests that these newer lines are over performing and carrying the weight of the system, while the more established segments are dramatically declining. While Metro looks to the future of expansion, steps should be considered to ensure stability with aging segments to ensure efficiency and quality performance.

CHAPTER 6: POLICY DISCUSSION AND CONCLUSION

This research identified varying measures of performance of rail ridership for Metro. The actual versus projected ridership analysis suggested that Metro's projections, especially for heavy rail, were inaccurate with many discrepancies for the horizon year and beyond. The system in its entirety is performing at approximately 67% of the projected ridership, raising concerns of accuracy of the forecasted projections. The four lowest performing segments, all heavy rail, received more than three billion dollars in Federal grant funding. Metropolitan areas compete for Federal grant funding for major capital projects, such as public transit projects. Because of this, the authenticity of the forecasted ridership for the heavy rail segments in Los Angeles may be called into question. While Metro's heavy rail ridership indicates that the projected ridership numbers were above actual performance, further studies could research ridership of other major metropolitan areas to determine if this is a national trend.

The three scenarios used to depict ridership growth beyond the horizon years, highlighted how the projections system wide would grow. The county population growth scenario is the most applicable scenario as it models growth that occurred with a spatial association. The 1% and 2% year over year growth scenarios created a basis to explore how growth could occur, however, they do not correspond with what was actually happening within the region at the time.

The density and ridership correlation suggested that there was a positive correlation between degree of actual missed forecast. As job or population density increased, so did the likelihood actual ridership missing projected ridership. Further research could evaluate this assessment on a station by station basis. A greater sample size could interpret stronger results on the subject of correlation and causality.

In understanding what the findings mean, this research evaluated the performance of Metro light and heavy rail with quality performing systems. The analysis suggests that the light rail performed at or just below the other light rail networks, once the system matured, while Metro's heavy rail system is substantially underperforming when compared to other networks. This evaluation can be further investigated with additional heavy and light rail networks incorporated into the study. Metro's heavy rail network should be assessed with heavy rail lines that were constructed and matured around the same time. The current assessment could be criticized as BART was a well-developed mature system when heavy rail was introduced in Los Angeles.

Lastly, the ridership trends over the last five years should concern Metro as a decline is occurring among lines that have been operational prior to 2011. While Metro looks to future expansion, steps should be considered to ensure stability with aging segments to ensure efficiency and quality performance. Some research has even suggested that disinvestment in mature systems can negatively affect ridership of those lines over time (B. Taylor & Fink, 2003). Because of this research and the initial results of the last five years of Metro rail, further investigation should be considered to assess whether a correlation exists among investment of operations and maturing segments. Further exploration with all sections of these results is encouraged as each analysis can conclude with new findings.

With the interest of stronger ridership performance, Metro should consider some of the following recommendations. First and foremost, Metro should investigate a new standard of modeling and forecasting. While the standard method is developing a horizon year of ridership, Metro and consultants could consider incorporating benchmark years before and after the horizon year. That way, Metro can assess performance at an earlier stage, and strategize ways to mitigate issues early on. With additional benchmarking goals, ridership performance can integrate a structure to facilitate assist with long term rail planning.

The next recommendation is to consider the selection of rail alignment from a ridership standpoint. Much of the current system is built on an existing right of ways, as it was the most feasible way to develop. This causes limitations in the actual ridership as many of these rights of ways are lined with low-density corridors, freeways, or non-housing-oriented developments. Assembling the rail network with that strategy limits the ability for transit-oriented development or housing to occur near stations along the routes. By integrating future networks with housing rich communities, rail ridership could perform more appropriately.

As outlined in Advancing the State of the Practice, the four-step process could be drastically be improved to be encourage more accurate forecasting (Transportation Research Board, 2007, p. 91). Some of the recommendations include: Improved measures of arterial congestion, inclusion of both highway and transit travel in trip distribution, improved trip distribution models, and improved sensitivity testing. Other suggestions include improving the mode choice sub-models as this step is most important when it comes to predicting transit ridership. The most important of these improvements comes from the improved sensitivity testing.

> Models are used to project the responses of travelers and the transportation system to changes but have often been validated only on the basis of replication of observed conditions (Transportation Research Board, 2007, p. 92).

Improvements on transit demand model sensitivity, especially in a Southern California context, could greatly improve the accuracy of ridership projections.

Lastly, Metro should consider independent, third-party ridership modelers and forecasters to review projections throughout the Environmental Impact Report process. While many of the EIRs are conducted by local agencies, or Metro, it is important to encourage a non-biased system to ensure practicality and accurate ridership assessment. Furthermore, these steps should be considered as the current and future network are being funded and operated through public resources.

REFERENCES

Adams, C. (1986, January 10). Did General Motors destroy the LA mass transit system? Retrieved March 20, 2019, from The Straight Dope website: https://www.straightdope.com/columns/read/551/did-general-motors-destroy-the-la-mass-transit-system/

AECOM, Cityworks Design, Inc., PBSJ, Inc., Lenax, & PSOMAS. (2009). *Exposition Corridor Transit Project Phase 2: Final Environmental Impact Report* [Technical Background Report]. Retrieved from Exposition Metro Line Construction Authority website: http://www.buildexpo.org/phase2/Phase%202%20FEIR%20Documents/TBR%27s/TBR%20Expo%20Phase%202%20Ridership%20Results%20Final_Dec09.pdf

Barragan, B. (2017a, July 10). The Expo Line to Santa Monica reaches its 2030 ridership goal. Retrieved December 3, 2018, from Curbed LA website: https://la.curbed.com/2017/7/10/15948744/expo-line-reaches-2030-ridership-goal

Barragan, B. (2017b, September 18). Metro’s Regional Connector, explained. Retrieved January 10, 2019, from Curbed LA website: https://la.curbed.com/2017/9/18/16267632/regional-connector-metro-explained

Bechtel Civl, Inc., Michael Brandman Associates, Inc., DKS Associates, Inc., Walter V. Okitsu Engineering, Anil Verma Associates, Barrio Planners, … Ralph Stone and Company, Inc. (1989). *Revised Draft Environmental Impact Report Pasadena-Los Angeles Rail Transit Project* (Environmental Impact Report No. 88042713; p. 317). Retrieved from Los Angeles County Transportation Commission website: http://libraryarchives.metro.net/DPGTL/eirs/PasadenaBlueGold/1989Pasadena-LosAngelesFinalDraftEIR.pdf

Bliss, L. (2019, January 17). Los Angeles Loves Funding Transit, But Not Using It. Retrieved March 8, 2019, from CityLab website: https://www.citylab.com/transportation/2019/01/los-angeles-public-transportation-tax-measure-m-metro/580609/

Bloomekatz, A. (2012a, April 29). New Line, New Choices. *Los Angeles Times*.

Bloomekatz, A. (2012b, April 29). Officials, Riders Hail Culver City Rail Line Arrival. *Los Angeles Times*.

Bloomekatz, A., & Becerra, H. (2009, November 16). After decades of waiting, their trains have arrived. *Los Angeles Times*.

Byrnes, M. (2014, July 14). When Los Angeles' Blue Line Was New. Retrieved March 20, 2019, from CityLab website: http://www.citylab.com/commute/2014/07/when-las-blue-line-was-new/374421/

Chiland, E. (2016, June 2). Metro Report Shows How Measure R Has Changed LA. Retrieved March 8, 2019, from Curbed LA website: https://la.curbed.com/2016/6/2/11845368/metro-measure-r-data-ridership-transit

Chiland, E. (2017, January 13). What to know about the subway to the Westside. Retrieved March 13, 2019, from Curbed LA website: https://la.curbed.com/2017/1/13/14229338/purple-line-subway-extension-opening-date-wilshire

Chiland, E. (2018, December 7). Bye ‘Blue’ Line, Metro will rename rail lines using letters. Retrieved January 10, 2019, from Curbed LA website: https://la.curbed.com/2018/12/7/18129372/los-angeles-metro-train-names-letters-colors

Curiel, S. C. (1991). Los Angeles County Transportation Commission Joines SHPE Strategic Technical Employment Program (STEP). *Hispanic Engineer & IT*, (Autumn 1991), 56.

Currie, G., & De Gruyter, C. (2016). Exploring performance outcomes and regulatory contexts of Light Rail in Australia and the US. *Competition and Ownership in Land Passenger Transport (Selected Papers from the Thredbo 14 Conference)*, *59*, 297–303. doi: 10.1016/j.retrec.2016.07.012

Demoro, H. (1986). *California’s Electric Railways: An Illustrated Review* (1st ed.). Interurban Press.

Elkind, E. (2014). Railtown: The Fight for the Los Angeles Metrorail and the Future of the City. *Los Angeles: University of California Press*, 127.

Federal Transit Administration. (1998). *Mega Project Review of Los Angeles Metro Rail Red Line Project* (Audit Report No. TR-1998-154; p. 40). Retrieved from Department of Transportation website: https://www.oig.dot.gov/sites/default/files/tr1998154.pdf

Ferrell, C. E., Carroll, M., Appleyard, B., Reinke, D., & Ashiabor, S. (2011). *Reinventing the Urban Interstate: A New Paradigm for Multimodal Corridors*. Retrieved from http://www.trb.org/Publications/Blurbs/166013.aspx

Fiore, F. (1990, September 2). Blue Line Delivering. *Los Angeles Times*.

Flyvbjerg, B. (2007). Cost Overruns and Demand Shortfalls in Urban Rail and Other Infrastructure. *Transportation Planning and Technology*, *30*(1), 9–30. doi: 10.1080/03081060701207938

Fudge, T. (2011, September 2). San Diego Trolley Turns 30 Amid Praise And Higher Expectations. Retrieved May 6, 2019, from KPBS Public Media website: http://www.kpbs.org/news/2011/sep/02/san-diego-trolley-turns-30-amid-praise-and-higher-/

Given Place Media. (2019). Estimated Population for Los Angeles County, California. Retrieved March 24, 2019, from http://www.laalmanac.com/population/po04.php

Gonzalez, J. (2015). Regional Travel Demand Modeling at the BFCG: The Four-Step Travel Demand Model. Retrieved April 8, 2019, from Benton-Franklin Council of Governments website: http://bfcog.us/transportation/gismapping-modeling/regional-travel-demand-model/four-step-travel-demand-model/

Gordon, P., & Willson, R. (1984). *The determinants of light-rail transit demand—An international cross-sectional comparison* (Vol. 18). doi: 10.1016/0191-2607(84)90006-2

Groves, M. (2006). In a Reversal, Waxman Backs Westside Subway. *Greater West Los Angeles Area Business Monthly*, (January). Retrieved from https://web.archive.org/web/20070103195104/http://www.westlachamber.org/page_graphics/newspaper/back_issues/Jan06-GWLABusMthly.pdf

Hawthrone, C. (2016, May 21). L.A. has a ticket to connectedness. *Los Angeles Times*.

Hong, P. (1996, July 14). Riding the Rails. *Los Angeles Times*.

Islas, J. (2016, January 16). EXTRA: Metro Takes Control of Expo Line to Begin Pre-Revenue Service. Retrieved April 7, 2019, from Santa Monica Next website: http://www.santamonicanext.org/2016/01/extra-metro-takes-control-of-expo-line-to-begin-pre-revenue-service/

Kajima/Ray Wilson v. Los Angeles County Metropolitan Transportation Authority. , 2d 747 96 1 (Superior Court of Los Angeles County 2000).

Khanna, M. (n.d.). Green Line Extension to Torrance. Retrieved April 7, 2019, from https://www.metro.net/projects/green-line-extension/

KPMG. (2005). *Global Construction Survey 2005: Risk Taker, Profit Maker?* [Global Construction Analysis]. London: KPMG Building and Construction.

Littman, M., & Wosk, G. (2000, December 5). Encyclopedic Report Details Numerous Subway Fossil Finds. Retrieved April 7, 2019, from https://web.archive.org/web/20140325020508/https://www.metro.net/news/simple_pr/encyclopedic-report-details-numerous-subway-fossil/

Los Angeles Asks: Is Subway Safe? (1993, September 12). *The New York Times*. Retrieved from https://www.nytimes.com/1993/09/12/us/los-angeles-asks-is-subway-safe.html

Los Angeles Public Library. (2012). Environmental Impact Reports. Retrieved February 19, 2019, from /collections-resources/research-guides/environmental-impact-reports

Maddaus, G. (2008, January 9). Why Green Line stopped short of LAX. *Los Angeles Daily News*.

Manville, M. (2019). *Measure M and the Potential Transformation of Mobility in Los Angeles* (p. 94). Retrieved from TransitCenter, New York, New York website: http://www.its.ucla.edu/wp-content/uploads/sites/6/2019/01/Measure-M-and-the-Potential-Transformation-of-Mobility-in-Los-Angeles.pdf

McGillivray, R. (1972). Some problems in urban transportation models. *Traffic Quarterly*, 547–558.

Metro. (2017). Measure R | Proposition A. Retrieved April 3, 2019, from https://www.metro.net/projects/measurer/proposition_a/

Metro. (2019a). Facts at a Glance. Retrieved January 10, 2019, from Facts at a Glance website: https://www.metro.net/news/facts-glance/

Metro. (2019b). Metro Projects - In the Works - Project Tracker. Retrieved December 3, 2018, from https://www.metro.net/interactives/datatables/project/

Metro. (2019c). Metro Ridership. Retrieved January 19, 2019, from http://isotp.metro.net/MetroRidership/IndexRail.aspx

Mieger, D., & Chu, C. (2007). Los Angeles, California, Metro Green Line: Why Are People Riding the Line to Nowhere? *Transportation Research Record: Journal of the Transportation Research Board*, *2006*, 50–59. doi: 10.3141/2006-06

Mitchell, J. (1999, June 13). Tinseltown Connection Gets Riders' Thumbs Up. *Los Angeles Times*.

Morgenthaler, A. (1988, March 14). End of the Line: The Last Train Out of SM Blows a Final Whistle. *Santa Monica Outlook*.

Nelson, L. (2016, March 6). Thousands ride Gold Line Extension. *Los Angeles Times*.

Nelson, L. J. (2017, February 13). The Metro can take you farther than ever. Here's why ridership dropped — again. Retrieved March 10, 2019, from latimes.com website: https://www.latimes.com/local/lanow/la-me-ln-2016-metro-ridership-decline-20170209-story.html

O'Toole, R. (2018, November 8). Charting Public Transit's Decline. Retrieved March 10, 2019, from Cato Institute website: https://www.cato.org/publications/policy-analysis/charting-public-transits-decline

Parsons Brinckerhoff/Kaiser Engineers. (1985). *The Long Beach-Los Angeles Rail Transit Project* (Final Environmental Impact Report No. SCH No. 83091415; p. 481). Los Angeles County Transportation Commission.

PE Bus Franchise Transfer Gets Ok. (1953, July 8). *Los Angeles Times*. Retrieved from http://proxy.library.cpp.edu/login?url=https://search.proquest.com/docview/166511184?accountid=10357

Perez, P. (2003, July 26). “Potential Turning Point” for Southland. *Los Angeles Times*, p. 15.

Pickrell, D. H. (1989). *Urban rail transit projects : forecast versus actual ridership and costs. final report*. (UMTA-MA-08-9021-89-1). Retrieved from https://rosap.ntl.bts.gov/view/dot/10023

Rasmussen, C. (1995, August 12). Green Light for the Green Line. *Los Angeles Times*. Retrieved from http://articles.latimes.com/1995-08-12/news/mn-34233_1_green-line

Rasmussen, C. (2003, July 13). Pasadena’s Gold Line Will Travel a History-Laden Route. *Los Angeles Times*. Retrieved from https://www.latimes.com/archives/la-xpm-2003-jul-13-me-then13-story.html

Reft, R. (2015, February 26). A Clear Blue Vision: L.A. Light Rail Transit and Twenty Five Years of the Blue Line. Retrieved March 20, 2019, from KCET website: https://www.kcet.org/history-society/a-clear-blue-vision-la-light-rail-transit-and-twenty-five-years-of-the-blue-line

Reinhold, R. (1993, January 28). Subway in Los Angeles to Open in Modest Step. *New York Times*. Retrieved from https://www.nytimes.com/1993/01/28/us/subway-in-los-angeles-to-open-in-modest-step.html

Saab, J. (2018). Local Transportation Sales Taxes: Opportunities for Transit Equity in Los Angeles and Atlanta. *Journal of Politics & International Affairs*, *23*, 50–95.

Scauzillo, S. (2016, April 11). What we learned about new Gold Line train riders might surprise you. Retrieved January 12, 2019, from San Gabriel Valley Tribune website: http://www.sgvtribune.com/general-news/20160411/what-we-learned-about-new-gold-line-train-riders-might-surprise-you

Siler, N. (2009, May). Comparison of “Rail” transit modes. Retrieved May 5, 2019, from http://www.trainweb.org/kenrail/Rail_mode_defined.html

Simon, R. (1998, April 24). Quirky Perks of the MTA. *Los Angeles Times*. Retrieved from http://articles.latimes.com/1998/apr/24/local/me-46679

Southern California Rapid Transit District, & Urban Mass Transportation Administration. (1989). *Los Angeles Rail Rapid Transit Project* (p. 493) [Environmental Impact Report]. Retrieved from Southern California Rapid Transit District website: http://libraryarchives.metro.net/DPGTL/eirs/1989_Rail_Rapid_Transit_FinalSupplemental.pdf

Streeter, K., & Hymon, S. (2003, July 27). A Gold Glut. *Los Angeles Times*.

Taylor, B., & Fink, C. (2003). *The Factors Influencing Transit Ridership: A Review and Analysis of the Ridership Literature* (p. 18). Retrieved from UCLA Institute of Transportation Studies website: https://cloudfront.escholarship.org/dist/prd/content/qt3xk9j8m2/qt3xk9j8m2.pdf?t=mc3c7c

Taylor, R. B. (1991, February 16). After 35 Years, the Subway Makes a Comeback in L.A. *Los Angeles Times*.

Thai, A. (2015, July 15). Metro GIS Database [Transportation Agency]. Retrieved January 7, 2019, from Metro Developer website: https://developer.metro.net/introduction/gis-data/download-gis-data/

The Expo Line - Friends 4 Expo Transit. (2016). Retrieved April 7, 2019, from http://friends4expo.org/

Tinoco, M. (2017, August 4). The most anticipated transit projects opening in time for the 2028 LA Olympics. Retrieved December 3, 2018, from Curbed LA website: https://la.curbed.com/2017/8/4/16098474/olympics-transit-future-subway-rail

Transportation Research Board. (2007). *Metropolitan Travel Forecasting: Current Practice and Future Direction* (No. Special Report 288; p. 147). Retrieved from Transportation Research Board of the National Academies website: http://onlinepubs.trb.org/onlinepubs/sr/sr288.pdf

Trinidad, E. (2014, September 2). July 1990 - Rail Transit Returns To Southern California. Retrieved March 13, 2019, from KCET website: https://www.kcet.org/kcet-50th-anniversary/july-1990-rail-transit-returns-to-southern-california

United States General Accounting Office. (1996). *Los Angeles Red Line: Financing Decisions Could Affect This and Other Los Angeles County Rail Capital Projects* (Project Review No. GAO/RCED-96-147; p. 23). Retrieved from Resources, Community, and Economic Development Division website: https://www.gao.gov/assets/230/222792.pdf

U.S. Department of Transportation, Federal Transit Administration, & Los Angeles County Metropolitan Transportation Authority. (2002). *Los Angeles Eastside Corridor* [Environmental Impact Report]. Retrieved from http://media.metro.net/projects_studies/eastside/images/Chapter%205%20-%20Financial%20Analysis%20and%20Compar%20of%20Alts.pdf

Wachs, M. (1982). Ethical dilemmas in forecasting for public policy. *Public Management Forum*, (November/December 1982), 562–567.

Walker, G. (2007, September 13). Exposition light rail gets $314 million for Phase 1 from downtown to Culver City. Retrieved April 5, 2019, from The Argonaut website: https://argonautnews.com/exposition-light-rail-gets-314-million-for-phase-1-from-downtown-to-culver-city/

Wohl, M. (1976). *The Case for Rapid Transit: Before and After the Fact*. Presented at the Transportation Alterntatives for Southern California, University of Southern California.

Yoh, A., Haas, P., & Taylor, B. (2003). Understanding Transit Ridership Growth: Case Studies of Successful Transit Systems in the 1990s. *Transportation Research REcord*, *1835*((1)), 10. doi: 10.3141/1835-14

Zhao, Y., & Kockelman, K. M. (2002). The propagation of uncertainty through travel demand models: An exploratory analysis. *The Annals of Regional Science*, *36*(1), 145–163. doi: 10.1007/s001680200072

APPENDIX A – Average Weekday Ridership by Segment and Year

	Blue Line			Red/Purple Line	Green Line
Year	**Initial**	**Long Beach Loop**	**Financial District**	**MOS-1**	**Initial**
1991	15,059	1,462	3,770	-	-
1992	25,412	2,468	6,362	-	-
1993	27,127	2,634	6,792	14,990	-
1994	27,169	2,638	6,802	16,350	-
1995	29,402	2,855	7,361	20,700	-
1996	32,985	3,203	8,259	23,200	13,650
1997	37,197	3,612	9,313	34,421	19,000
1998	37,953	3,685	9,502	30,589	20,175
1999	39,660	3,851	9,930	45,714	25,175
2000	45,800	4,447	11,467	58,768	26,800
2001	54,951	4,526	12,785	63,181	33,350
2002	52,986	5,145	13,266	59,096	25,656
2003	51,202	4,298	12,198	55,011	32,365
2004	51,892	4,475	12,985	59,938	28,813
2005	52,399	4,971	13,319	63,818	30,333
2006	52,167	5,263	13,958	64,588	32,682
2007	53,717	5,906	14,680	71,502	35,686
2008	55,649	5,259	14,655	75,385	38,249
2009	57,465	5,764	16,120	83,138	39,632
2010	55,723	5,957	15,227	80,954	38,443
2011	58,211	5,963	14,904	80,390	40,047
2012	61,200	6,332	14,680	83,944	43,402
2013	67,813	6,958	14,875	88,320	44,824
2014	65,064	6,482	14,397	89,535	42,294
2015	61,543	6,128	14,725	85,301	40,027
2016	56,613	5,250	14,197	82,232	38,311
2017	56,366	5,324	14,107	87,137	33,503
2018	51,672	5,018	12,937	78,441	31,577

APPENDIX A – Average Weekday Ridership by Segment and Year

	Purple Line	Red Line		Gold Line	
Year	**MOS-2A**	**MOS-2B**	**MOS-3**	**Initial**	**Eastside Ext.**
1991	-	-	-	-	-
1992	-	-	-	-	-
1993	-	-	-	-	-
1994	-	-	-	-	-
1995	-	-	-	-	-
1996	-	-	-	-	-
1997	3,529	-	-	-	-
1998	3,136	-	-	-	-
1999	4,686	-	-	-	-
2000	6,024	17,708	-	-	-
2001	7,737	17,356	17,297	-	-
2002	6,699	16,780	18,099	-	-
2003	5,661	16,204	18,902	-	-
2004	6,044	17,345	21,009	14,877	-
2005	6,225	19,077	22,087	15,475	-
2006	6,578	21,174	24,819	16,599	-
2007	7,390	22,763	25,542	18,776	-
2008	8,058	22,522	28,700	20,514	-
2009	8,273	25,543	29,769	23,681	-
2010	8,403	28,666	31,968	25,004	8,068
2011	8,146	25,929	30,941	26,774	8,219
2012	8,850	27,051	31,882	30,851	10,227
2013	9,280	26,715	32,870	32,482	10,558
2014	9,027	27,445	33,354	31,596	11,082
2015	8,734	23,722	30,460	32,443	11,145
2016	7,965	23,062	29,313	31,960	10,161
2017	7,827	21,924	28,025	33,763	10,833
2018	8,044	23,620	28,053	34,050	10,874

APPENDIX A – Average Weekday Ridership by Segment and Year

	Expo Line		Gold Line	Expo Line
Year	**Initial**	**Culver City Ext.**	**Foothill Ext.**	**Santa Monica Ext.**
1991	-	-	-	-
1992	-	-	-	-
1993	-	-	-	-
1994	-	-	-	-
1995	-	-	-	-
1996	-	-	-	-
1997	-	-	-	-
1998	-	-	-	-
1999	-	-	-	-
2000	-	-	-	-
2001	-	-	-	-
2002	-	-	-	-
2003	-	-	-	-
2004	-	-	-	-
2005	-	-	-	-
2006	-	-	-	-
2007	-	-	-	-
2008	-	-	-	-
2009	-	-	-	-
2010	-	-	-	-
2011	-	-	-	-
2012	-	-	-	-
2013	18,707	4,608	-	-
2014	22,399	5,838	-	-
2015	24,198	6,473	-	-
2016	17,792	4,302	5,368	10,293
2017	30,303	5,565	7,265	16,108
2018	34,279	7,262	6,509	19,002