AN ASSESSMENT OF CENSUS 2000 COMMUTER PATTERNS
FOR THE PROMOTION OF COMMUTER RAIL IN
CALIFORNIA’S CENTRAL VALLEY

A Thesis
Presented
to the Faculty of
California State University, Chico

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Geography:
Rural and Town Planning Option

by
Devon Marlowe
Spring 2013
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DEDICATION

I dedicate this master’s thesis to my son, Joshua Marlowe, born in Chico in April 2010. It is my hope that Joshua’s fascination with trains will continue as a lifetime interest, and that California will build many more for him to enjoy.

“I’m driving a train! Choo-choo!” ~Joshua, age 2.
ACKNOWLEDGEMENTS

I would like to acknowledge the efforts of Dr. Nancy Carter and Dr. Kathryn Gray in the Statistics Department at California State University, Chico, for their assistance in running statistical reports, in the form of descriptive statistics, in SPSS.

I would like to acknowledge Mr. David Philhour in the Psychology Department at California State University, Chico, for his assistance with choosing the best statistical reports to run for analyses of linearity and uniformity among my study area commuting models. I am confident in my results thanks to Mr. Philhour and his expertise in the STATA program and in statistical methods.
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ABSTRACT

AN ASSESSMENT OF CENSUS 2000 COMMUTER PATTERNS FOR THE PROMOTION OF COMMUTER RAIL IN CALIFORNIA’S CENTRAL VALLEY

by

Devon Marlowe

Master of Arts in Geography: Rural and Town Planning Option California State University, Chico

Spring 2013

In the 2000’s, two commuter trains were built in the Western United States, the Front Runner in Utah and the Rail Runner in New Mexico. These two train systems connected adjacent metropolitan areas to each other and created a rail connection for all the cities and towns in their linear path. In California’s Central Valley (the Valley), like the two regions in Utah and New Mexico, a corridor of cities and towns has developed along a major highway (Highway 99), and this corridor forms a chain of contiguous metropolitan areas such as Sacramento, Stockton, and Modesto. This thesis explores whether the section of the Valley from Chico to Merced had a pattern of commuter origins and destinations collected for the 2000 census that would suggest it was equally suitable for a linear commuter rail system as the Utah and New Mexico study areas
showed in the 2000 census, which allowed their rail systems to be implemented in the following decade.

The Census 2000 contained comprehensive data on commuting statistics, based on origin and destination. This data was available at multiple levels of geography, such as county, tract, and block group. This presented an opportunity to conduct a spatial analysis to illustrate and statistically compare the commuting patterns in the three study areas, especially in the advent of California’s High Speed Rail initiative. Such analyses can help determine whether there is any similarity in commuting patterns in the three regions, and how they compare in terms of linearity (bearing).

In order to effectively promote rail, discussion should be made of rail’s advantages, what would encourage potential riders to switch modes from automobile to rail, what kind of developed landscape is conducive to rail startup, and what type of urban structure can develop at key destination stations once rail has been implemented. Considerations should be made about the type of data being used for this study, and its advantages over conventional sample data for this particular type of analysis.
CHAPTER I

INTRODUCTION

California’s Central Valley stretches for over 400 miles north to south, from Redding to Bakersfield. Within this long stretch, the Valley’s population is most heavily concentrated in a 120-mile stretch from Sacramento to Merced (Figure 1). Unlike some older and more populated urban centers on California’s coast, many of the communities in this inland region do not have rail transportation; therefore there are few instances of transit-oriented design (TOD). TOD is characterized by denser, mixed-use development in the immediate vicinity of a transit station, with decreasing density radiating from the transit station. There are already trains linking the San Francisco Bay Area to the Valley: the Altamont Commuter Express (ACE) train from Stockton and the Capitol Corridor (CC) from Sacramento. This existing network is logical, as these two Valley cities are two of the largest and closest to the San Francisco Bay Area, and the ACE and CC each utilize a natural passage through the Coast Range; the Delta and the Altamont Pass, respectively. There is, however, very little offered as an inter-regional public transportation system within the Valley. To address concerns of high fuel prices, air pollution, and outward development in the region, a transit-oriented connectivity of Valley cities is worth considering.

The Valley and its residents have been considered for a different mode of transportation, in the form of rail (i.e. California High Speed Rail), that can serve as an
alternative to the existing Highway 99 transportation corridor. One aspect of the Valley that could help make a commuter train successful and cost efficient is the linear arrangement of cities, towns, and general development. The Valley’s topography limits the number of major east-west corridors (Figures 1 and 2), so the morphology of the landscape development has been along a north-south corridor on the east side of the Valley. A commuter train that stops in the central business district of all major cities and selective towns would grant the Valley several benefits. First, it would offer commuters an alternative mode of transportation that would afford them a more relaxing commute. Second, it would augment the existing train system in Northern California, currently anchored in the San Francisco Bay Area instead of Sacramento. Stockton and Sacramento have the ACE and the CC, respectively, but there is no commuter rail connecting Sacramento with Stockton and other Valley cities. Third, it could increase the activities in the central business districts (CBD’s) of the communities through which it passes, as some neighborhoods around Salt Lake City have utilized TOD in the areas of their light rail stations (Brown and Werner 2009).

The purpose of this thesis is to study the idea of establishing commuter rail along the Highway 99 corridor, utilizing Sacramento, Stockton, and Modesto as its three anchor cities, and connecting them via rail to each other and to smaller cities and towns in the linear path. While there are other major cities in the Valley (such as Fresno and Bakersfield), Sacramento, Stockton, and Modesto are more proximate to each other and there needs to be a practical limit to the length of the study corridor. To determine the feasibility of this proposal, I will compare two existing commuter trains -- the Front Runner in Utah and The Rail Runner in New Mexico -- by analyzing the regional
Figure 1. California study area year 2000 population density.

Figure 2. California study area overview, tract to tract commuter count.

commuting patterns from an origin and destination perspective between the three regions. I have chosen these two particular commuter trains for comparison with the Valley situation for three reasons. First, the two train systems extend from one metropolitan area into at least one other adjacent metropolitan area, rather than being contained within a single metropolitan area. Second, the two trains were both built in the decade (2000-2010) following the vintage of the available census data, creating an opportunity to use the comprehensive commuter data from Census 2000 to illustrate the commuter patterns that immediately preceded the establishment of those two trains. Third, the other two trains serve regions that have a slightly smaller, not larger, population than the Valley study area (Table 1), meaning that any differences determined in the findings cannot be attributed to the comparative study areas having a larger population market.

Any discrepancies, therefore, should err on the side of conservatism. If less-populated regions can take the initiative of implementing commuter rail, then a larger study area like California’s should be worthy of consideration. The findings of the origin-destination analysis for intra-Valley travel patterns will determine an important variable to assess demand level for commuter rail for the Valley.

The layout of cities and towns and flat topography of the Valley provide a good opportunity to implement a commuter rail line to connect many of the Valley’s major cities. Using the city of Sacramento as the hub of the Valley line, Valley residents could be provided an opportunity to link up to the state capital city, Sacramento International Airport, and other existing rail systems (i.e. ACE and CC) without having to travel long distances by automobile. Commuters, whether daily or occasional commuters, would have a feasible, reasonable, and efficient means to travel to and from work without
Table 1: Population Counts of CBSA’s and Principal Cities in Study Areas

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<td>Albuquerque, NM</td>
<td>448,607</td>
<td>712,738</td>
<td>545,852</td>
<td>887,077</td>
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<tr>
<td>Santa Fe, NM</td>
<td>62,203</td>
<td>147,635</td>
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<tr>
<td>Ogden, UT</td>
<td>77,226</td>
<td>N/A^3</td>
<td>82,825</td>
<td>547,184</td>
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<td>Salt Lake City, UT</td>
<td>181,743</td>
<td>1,333,914</td>
<td>186,443</td>
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<td>Provo, UT</td>
<td>105,166</td>
<td>368,536</td>
<td>112,488</td>
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<td>Chico, CA</td>
<td>59,954</td>
<td>203,171</td>
<td>86,187</td>
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<td>Yuba City, CA</td>
<td>36,758^4</td>
<td>139,149</td>
<td>64,925</td>
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<td>Sacramento, CA</td>
<td>407,018</td>
<td>1,628,197</td>
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<td>Stockton, CA</td>
<td>243,771</td>
<td>563,598</td>
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<td>Modesto, CA</td>
<td>188,856</td>
<td>446,997</td>
<td>201,165</td>
<td>514,453</td>
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<tr>
<td>Merced, CA</td>
<td>63,893</td>
<td>210,554</td>
<td>78,958</td>
<td>255,793</td>
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Having to change their home or work location. Sacramento International Airport would benefit, provided there is a rail line or other public transit linking downtown Sacramento to the airport, since more residents of other Valley cities would opt for that airport and would not have to factor in long-term parking prices. Finally, the commuter train line could promote more interaction among all cities in the Valley.

A bill passed in 2008 is likely to result in more TOD in California cities.

Senate Bill 375 (SB 375) signed on September 30, 2008 by then-Governor Schwarzenegger is intended to reduce the need for automobile travel by encouraging

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^1 Some counties that belong to the CBSA may not have been included in the study area, if they were well outside the approximate proposed rail corridor.
^2 CBSA boundaries may have changed from 2000 to 2010, with counties being added or deleted from the CBSA.
^3 Ogden CBSA was included as part of the Salt Lake City CBSA in 2000, but was its own CBSA in 2010.
^4 (www.areaconnect.com 2000)
more concentrated, high-density residential communities, oriented around public transit systems. Most significantly, the bill relaxes California Environmental Quality Act (CEQA) requirements for housing projects which otherwise contribute to the reduction of greenhouse gases (Yamamura 2008). Such design would help improve the downtown areas of the cities and towns along a proposed rail route.

Throughout the United States, more metro areas are implementing some form of rail transportation to ease their commuting issues (lightrailnow.org). In large metro areas, such as Washington, DC and the San Francisco Bay Area, heavy rail and commuter rail have existed for several decades. Other smaller cities, such as Norfolk, VA; Charlotte, NC; and Sacramento, CA have recently introduced or are introducing light rail as a new way to get around town.5 It is an encouraging sign that more American cities are taking the initiative of finding alternative modes of transportation for commuting. There are very few inter-regional, from one core-based statistical area (CBSA) to another, rail systems in development. Although the California High-Speed

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5 The American Public Transportation Association (APTA) defines three modes of rail transit as follows: 1) **Commuter rail** (also called metropolitan rail, regional rail, or suburban rail) is an electric or diesel propelled railway for urban passenger train service consisting of local short distance travel operating between a central city and adjacent suburbs. Service must be operated on a regular basis by or under contract with a transit operator for the purpose of transporting passengers within urbanized areas, or between urbanized areas and outlying areas. Such rail service, using either locomotive hauled or self-propelled railroad passenger cars, is generally characterized by multi-trip tickets, specific station to station fares, railroad employment practices and usually only one or two stations in the central business district. Intercity rail service is excluded, except for that portion of such service that is operated by or under contract with a public transit agency for predominantly commuter services, which means that for any given trip segment (i.e., distance between any two stations), more than 50% of the average daily ridership travels on the train at least three times a week. 2) **Heavy rail** (metro, subway, rapid transit, or rapid rail) is an electric railway with the capacity for a heavy volume of traffic. It is characterized by high speed and rapid acceleration passenger rail cars operating singly or in multi-car trains on fixed rails; separate rights-of-way from which all other vehicular and foot traffic are excluded; sophisticated signaling, and high platform loading. If the service were converted to full automation with no onboard personnel, the service would be considered an automated guideway. 3) **Light rail** (streetcar, tramway, or trolley) is lightweight passenger rail cars operating singly (or in short, usually two-car, trains) on fixed rails in right-of-way that is not separated from other traffic for much of the way. Light rail vehicles are typically driven electrically with power being drawn from an overhead electric line via a trolley or a pantograph. (American Public Transportation Association. Mode of Service definitions)
Rail initiative is in early development, it is a larger scale rail system, the first of its kind in the United States, and is intended for longer distance travel than conventional commuter rail systems. Its high-speed prevents it from stopping at many of the towns along the route, therefore it does not serve as an appropriate example of inter-regional rail. The Utah and New Mexico commuter trains, however, are two examples of inter-regional rail and serve as ideal comparative case studies against the Valley situation.

Limitations

A study trying to establish the feasibility of commuter rail in the Valley is a very broad topic, and not practical to address all at once. Only selected factors will be addressed in this thesis in order to provide detail and relevance for recommended further study. Among the factors not to be addressed are right-of-way acquisitions and proposed routing. While the comparative commuter rail projects in Utah and New Mexico have utilized existing freight companies’ right-of-way and in some cases have built parallel tracks within existing freight rail right-of-way, any assessment of conditions with land use in the California study area is considered a separate study and will not be part of this analysis.

Another limitation is the availability of comprehensive data on commute statistics for the most recent census year. The 2010 Census did not collect data on commuter counts at the individual tract level as did the 2000 Census. In fact all censuses prior to Census 2000 did not collect such data, making the data from 2000 a unique opportunity for such an analysis. The purpose of this study, however, is to assess the commuter patterns that pre-existed both Utah’s Front Runner and New Mexico’s Rail
Runner, as they compare with the Valley’s commuting patterns from the same time period. While this does not give the most current estimates of commuter demand, it does effectively portray the level of demand that preceded the Utah and New Mexico commuter trains and allows one to surmise whether the Valley was at that same time an equally suitable location for commuter rail. The question to be answered is whether the Central Valley was as suitable for commuter rail as the other two areas prior to implementation.

Among the most challenging occurrences in the last decade that limits the value of such an assessment is the economic collapse of 2008. As a result of this economic downturn, many jobs have either disappeared or relocated, and this has affected commuter demand (Shilling 2012). The ACE train, for example, saw its annual ridership drop from 85,000 in 2008 to 54,000 in 2010, and is currently seeing only a 22 percent recovery at the fare box (Shilling 2012). Any data provided to fully reflect commuter demand in more recent years is not comprehensive like the Census 2000 and is instead limited to statistically significant samples, while the data for 2000 is comprehensive. With commuter data being inherently intricate and complicated, comprehensive data should offer an opportunity for a more thorough analysis.

Definition of the Study Area

The section of the Valley to be studied in this thesis is made up of several core-based statistical areas (CBSA’s): Chico, Yuba City, Sacramento, Stockton, Modesto, and Merced (Census 2000) (Figure 1). The CBSA is the designated geographic unit that
defines a principal city and its suburbs and outlying areas. Table 1 serves as a population comparison of the three study areas’ principal cities and CBSA’s that they include, in full or in part. While it could be argued that Placer, El Dorado, and Yolo Counties should be included as part of the California study area since they are part of the Sacramento CBSA, they will instead be excluded because they would create too much east-west bias against the assessment of that study area’s north-south linearity.

Since this comprehensive data constitutes the numbers needed to make a comparison between the three regions, they can each be illustrated in a spatial perspective to determine the answers to several important questions that need to be asked. First, do the Valley’s most travelled commuting origins/destinations (irrespective of roads) occur in a generally linear pattern, as does the general development in the Highway 99 corridor? Second, are the most common linear bearings parallel to the corridor overall? Third, where are the most heavily-travelled origin-destination routes in terms of origin tract and destination tract? Fourth, how similar or dissimilar are the patterns between the three regions?

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6 CBSA’s are defined at the county level, thus contain at least one full county, and may incorporate multiple counties if the outlying counties contain sufficient commuting statistics and cultural ties to the central city of the CBSA. Two or more contiguous CBSA’s can conglomerate into a Combined Statistical Area (CSA). This can happen if collectively they constitute a large metropolitan region with more than one core city as its base, and also demonstrate sufficient commuting, economic, and regional identification ties with each other. For example, the San Francisco Bay Area’s CSA includes the constituent CBSA’s of San Francisco/Oakland CBSA and San Jose CBSA, among others. In the section of the Valley being studied for this thesis, there is only one CSA, officially termed the Sacramento-Aden-Arcade-Yuba City, CA-NV CSA. It includes the Sacramento CBSA and the Yuba City CBSA. The Chico, Stockton, Modesto, and Merced CBSA’s are stand-alone CBSA’s, with no associated CSA. CBSA’s are defined by the Office of Management and Budget, a division of the United States Census Bureau, and can be revised at any time. Counties may be added or deleted periodically from a CBSA’s geography area.
CHAPTER II

BACKGROUND

For commuter rail to be effective, it must be able to draw in its ridership from users of other modes of transportation, primarily the automobile. Doing so would funnel the commuters from an expansive network of roads into a single-line commuter rail, causing them to pass through the same points or stations along the line. It logically follows that in order to make a prediction of how commuters would perceive the efficacy of this rail mode and how likely they would be to use it, commute patterns from an origin-destination perspective would be relevant, and whether these patterns have a linear relationship that is conducive to choosing a linear rail line. In this section, I will discuss what factors should be in place to encourage mode shift to rail ridership, what role rail plays in alleviating the phenomenon of sprawl, and what are the difficulties of gathering data on commuter counts to assess demand. This section will also mention jobs-housing imbalance and excess commuting. These two concepts are relevant to the study method that I use, because the journey-to-work data and the choice of geography for data aggregation (i.e. tract) in a linear analysis affect the findings of excess commuting levels.

Switching Modes to Rail

Several factors, other than distance to work, affect commuters’ mode choice. Mode switch is greatly affected by time of day. One significant variable that is often
overlooked is the temporal factor, or trip timing. Most transportation demand models do not employ the temporal factor of travel (Habib et al. 2009, Qian and Zhang 2011). Transit becomes a less desirable option during off-peak times due to frequency of service, while automobile travel becomes more desirable during off hours due to less congested roads (Habib et al. 2009). Other transportation options factor in as well. The delay on the roads, the price of fuel, the frequency and reliability of the transit service, and the flexibility of work schedule are all factors that influence commuters’ mode choice, particularly between rail and privately owned vehicles (POV’s). Cervero (2006) states that mode-choice models often carry a degree of misspecification. While they may include trip attributes, they frequently overlook place attributes such as land use (i.e. the depeaking factor) to predict which mode of transportation commuters will use. Qian and Zhang (2011) contend that when the capacity of the roads is expanded, traffic on the road will increase and transit use will decrease. Conversely, if the capacity of the road remains fixed and the share of carpoolers is increased, transit will increase. An increase in fuel prices would initially result in single drivers switching to carpooling, but past a certain threshold would cause more drivers, whether single drivers or carpoolers, to switch to transit (Qian and Zhang 2011). Each of these permutations increases the complexity of demand and mode-share modeling.

While gathering data of commuter count and direction does tell a story and provide a basis from which to project ridership, it is ultimately what goes on in the mind of each commuter in their decision-making process that will collectively make or break the attainment of the projected ridership numbers. This consideration alludes to a limitation of the conclusiveness of this study: while a comparison made of commuting
patterns between the three study areas can offer much value, various complexities that are unique to each study area, and households within the study area should be acknowledged as well. The goal for transit promoters is to affect commuters’ choices in switching modes. Proximity to transit stations, both at home and at work, would be a good start in determining the appropriate households for mode switch, but other factors weigh in more heavily than station proximity. Travel time by train becomes more competitive with travel by POV as the home-to-work travel distance increases (Vijayakumar, El-Geneidy, and Patterson 2011). Debrezion, Pels, and Rietveld (2009) lists two factors that influence the commuter’s choice of rail station: 1) the accessibility of the station and 2) the rail services provided at the station. The former includes interface between modes, i.e. parking spots and bicycle racks. This factor also is dependent on the time of day, as each new parking space at a transit station can attract anywhere from 0.6 to 2.2 new riders, depending on the time of the commute (Vijayakumar, El-Geneidy, and Patterson 2011). The latter includes factors such as frequency of train service and directness of the train service to other locations in the rail network. In a rail network with multiple lines, some station-to-station origin-destination combinations may require one or more transfers thus reducing efficiency to travel by rail. However, for a single-line commuter rail, there is no network per se, but simply a string of stations along the same line. The focus then becomes station accessibility. Proper design of interface between arrival mode and departing on rail, and the reverse at the end of the day is key to encouraging commuters to switch modes from POV’s. This means that there must be a smooth transition between arrival mode at the station and boarding the train. The distance people are willing to travel to get to a transit station rather than drive the entire route to their workplace is
influenced by several factors. With regard to those who drive to the station, parking provisions and time of day (influencing road traffic conditions) are important. For those who walk to the station, individual and household characteristics influence the distance people are willing to walk. Therefore the distance decay is not equal in every direction, as the demand around transit stations is not equally distributed. The challenge of the distance decay model is that household characteristics are more significant than distance from a station in assessing the likelihood that rail will be utilized by particular households (Vijayakumar, El-Geneidy, and Patterson 2011). Still, other factors need to be in place to effectively bring about mode shift. Some suggestions to help increase mode shift include: 1) employers provide benefits to workers for using transit, 2) transit authorities promote the use and benefits of transit, and 3) local governments and planners provide incentives to builders that support TOD, including limiting the provision of parking (Lindsey et al. 2010). Feebates and rebates, such as taxes on gasoline and vouchers to commuters to cover fees for using rail, respectively, are examples of these suggestions. These incentives would be helpful, yet the propensity for the commuter to use the automobile remains great, and without major changes in infrastructure and land-use patterns, the implementation of mode-switching will remain challenging.

When it comes to mode choice, another consideration is the commuters’ perception of the value of time spent while in transit. Although some commuters may prefer the privacy of their own automobiles, preferences may change if the utility of time in transportation is deemed productive. Lyons, Jayn, and Holley (2007) discusses the perceived utility of time spent in rail transit, and how that perceived utility varies among the different categories of rail travelers. More than three-quarters of the survey
respondents said they made good use of their time spent on the train (Lyons, Jayn, and Holley 2007). This makes a mode switch sound appealing for some riders.

Surveying and Demand Modeling

In medium-sized metropolitan areas, commuters are more likely to utilize various modes of transportation than their large city counterparts (Sakano and Benjamin 2011). Therefore, in medium-sized metropolitan areas, such as Sacramento, ridership in a transit system is expected to be occasional more than consistent. While Qian and Zhang (2011) assert that commuters may switch back and forth between modes as conditions change (i.e. cost of fuel, road conditions), Sakano and Benjamin (2011) state that commuters’ choice of mode will vary based on their own needs if planned for multiple days at a time. For instance, if a commuter is only planning their transportation to and from work for one day at a time, they will likely choose a particular mode based on their primary activity for the day. However, if the same commuter plans for the entire week, they may plan to utilize various modes of transportation throughout the week. Which mode is chosen each day would depend on what primary and secondary activities need to fit into their schedule for the week. Moreover, the depeaking effect occurs when mixed land uses exist in the vicinity of the rail station (Cervero 2006; Cervero and Duncan 2006). This means that placing certain types of facilities near the work destinations, such as a shopping center or fitness center, may give the commuter reason to alternate the arrival and departure time around the work vicinity. Many travel models do not account for the depeaking effects of mixed-land uses (Cervero 2006). Consequently, the task for planners to model the projected demand for a proposed transit system is difficult, because
there are external and internal factors influencing the decision made by the individual commuter.

For the reasons outlined above, surveys using samples meant to be representative of the whole population are sometimes problematic. It is not always possible to conduct survey campaigns that draw random samples at a reasonable cost. This is particularly true for determining interurban travel patterns, for several reasons. First, in a string of multiple cities and towns, the population is concentrated in multiple centers that are distant from each other. Therefore, secondly, the trip frequency between such places is significantly less than the trips made within a single urban entity. That means that many of those surveyed, except for frequent inter-city commuters, will have to have a clean record of inter-city trips that occurred some time ago. Such an information gap is more likely to generate errors. Finally, many of those trips made outside a single urban area may not be relevant to the study area itself and thus irrelevant to the analyst (Monzon and Rodriguez-Dapena 2006). Surveys themselves contain weaknesses (Monzon and Rodriguez-Dapena 2006; Qian and Zhang 2011; Sakano and Benjamin 2007). Therefore the use of comprehensive data, as it is available, is superior, particularly to determine the scope of excess commuting and assess linearity.

Collectively we have the issues of sample size representation, interurban commuting patterns, and surveys that generate the same projections for each day of the week. Together these issues serve to limit the value of the results of surveys to accurately project the demand for a fixed mode of transit, thus project ridership. There is the problem of drawing random, properly representative samples through surveys (Monzon and Rodriguez-Dapena 2006), while many of these surveys are too aggregated and do not
look at the individual neighborhood (Zolnik 2012). The demand around potential stations is not equal because there is the issue of individual household characteristics to consider (Vijayakumar, El-Geneidy, and Patterson 2011), while a commuter’s mode preferences, at least in a mid-sized metro area or smaller, are likely to change between one day of the week and another (Sakano and Benjamin 2011). With these issues, multiple forms of evidence are required to better assess the demand and potential for rail ridership. Comprehensive data such as that provided by the Census, rather than survey data, will offer a more complete portrayal.

Urban Structure and Developed Landscape

A key aspect of rail to be studied is in what type of developed landscape a switch of mode choices will occur, in the event of rail implementation. Loukaitou-Sideris (2010) contends that good planning and proper zoning as an antecedent to rail implementation is necessary for good mixed-use neighborhoods to develop in the station vicinity. Additionally, how the development of transit-adjacent design takes shape is influenced by the role that particular location plays relative to the study area served overall. Whether the station serves primarily as an origin station or a destination station influences the station’s immediate surroundings. Renne (2009) contrasts three Bay Area cities with regard to the layout of the areas that surround each of their rail stations, and states that the layout is influenced by the proportion of riders who arrive at the station by various modes. A station in which a majority of the riders arrive as pedestrians, such as the Berkeley, CA Bay Area Rapid Transit (BART) station, is more likely to generate TOD than a station in which more riders arrive by automobile, such as the Fremont, CA
BART station (Renne 2009). Those commuters who switch from car to rail are likely to live in an area farther from the city center. For the people who live closer to the city center, their mode switch is likely to be from bus to rail.

In Bahm-Snow and Kahn’s (2005) study, Sacramento was among cities with a lower savings of commute time, approximately 2,000 aggregate commuting hours saved per day by mode switching. This is a modest number compared to Washington, DC’s 50,000 aggregate hours saved per day (Baum-Snow and Kahn 2005). However, it should also be noted that Sacramento’s current rail transit is light rail, a relatively slow form of rail transit, while their continuous population density is comparably light compared to Washington, DC. Therefore the opportunity to save many per capita commuting hours is not as high as in those larger metro areas. Because commuter rail is a faster type of rail with longer distance between stops, it is primarily the car drivers around the outlying areas and second-cities to Sacramento who will be afforded this viable new transportation mode. It is to a much lesser extent those living in the center-city who might normally ride a bus or light rail for a relatively short distance. Since most new public transit users generated from a new addition of rail will be those living far from the city centers, who otherwise would commute by car, a commuter rail that serves those outlying areas is a good option to increase the Sacramento region’s market share of transit users. With Sacramento being a mid-sized metropolitan area and since the majority of the riders on a proposed commuter train would be non-urban residents, plentiful parking at the stations would be necessary to draw the mode-switchers from auto to rail.

Van der Ryn and Calthorpe (1986) contend that transit cannot efficiently serve areas of lower population density, and even at a residential density of six housing units
per acre, a 67-percent subsidy is required to sustain the system. For transit to be efficient in terms of environment, economy, and energy usage, it must be limited to serving areas of higher density. In neighborhood densities of at least 18 units per acre with transit lines leading to significant commercial zones, transit is superior to the automobile in terms of cost and energy usage. However, even at that density, it will exceed the auto in service level or efficiency only if roads and parking infrastructure are given less than full priority, meaning that planners give significant consideration and resources to alternative transportation modes. Land-uses that make transit a real competitor to the automobile are rare in most metropolitan areas (Van der Ryn and Calthorpe 1986). However, Vijayakumar, El-Geneidy, and Patterson (2011) state that with respect to commuter rail, an important portion of trips to rail stations is by car. Between reducing vehicle miles travelled (VMT) and thus offsetting carbon emissions, park-and-ride facilities have a positive effect on the regional environment (Vijayakumar, El-Geneidy, and Patterson 2011).

One of the components of the concept of smart growth is reducing sprawl and promoting TOD. Kunstler (1993) characterizes sprawl in several ways, but mainly as the segregation of land use zoning into massive homogenous areas of tract housing and minimalls, thereby creating great distances between different areas where daily routines (e.g. working, shopping, living, and recreating) are practiced (Kunstler 1993). Past studies suggest that suburban residents spend more money on transportation than urban residents (Sultana and Weber 2007; Zolnik 2012). For the specific transportation need of commuting to and from work, the comparison from past studies is again similar (Zolnik 2012). Sultana and Weber (2007) compared the relationship between the presence of
sprawling development and commuting time. These authors conclude that those people with the longest average commute time to work lived in a sprawling suburban area and commuted to a denser, urban area. Even though sprawling areas are usually afforded faster roads, there is a significant correlation between those living in areas of sprawl and those having a long time or distance commute from home to work. Average miles driven and commute times are significantly longer for those living in sprawling areas (Sultana and Weber 2007). While Sultana and Weber indicate a pattern between segregation of land uses and greater commuting costs (i.e. travel time, fuel costs), Zolnik (2012) states that we should be careful in drawing conclusions of such studies for two main reasons. First, these studies are aggregate in nature, meaning that they represent Core Based Statistical Areas (CBSA’s) overall, not individual tracts within CBSA’s. Secondly, it should not be assumed that the results of the comparisons are attributable to sprawl, when in fact they could be attributed to the types of people who live in such areas and their personal preferences. Therefore, studies on this topic suggest that the research is generally inconclusive, as there is nothing to indicate that any measures of sprawl contribute significantly to private vehicle commuting costs. The ecological fallacy states that there is a “fallacy of assuming that associations computed from group means or group proportions are valid estimates of the associations that would be obtained from individual data” (Zolnik 2012). These associations Zolnik refers to are especially vulnerable to misinterpretation when there is an aggregation bias. It seems reasonable to predict that people who live in more outlying areas are going to have a longer average commute time to a more centralized business area than their urban counterparts. However, it is inconclusive whether their commuting costs are actually more. We should
be especially cautious about superimposing the conclusions of one individual study area onto another study area that may have very different dynamics, especially if there is an aggregation bias in the study and if the study is based on limited survey data.

If sprawl does actually contribute to longer commuting times and/or commuting costs, then what effect would rail transit have on alleviating these issues? It is difficult to answer that question for two reasons. First, results should be studied on a case-by-case basis (Zolnik 2012). For example, what proved effective in metropolitan Washington, DC may not be effective in metropolitan Sacramento. Because different urban centers have different dynamics, they should not be treated the same. This supports the method of comparing study areas that have optimally similar population counts and city dispersions throughout the regions, as do Sacramento, Salt Lake City, and Albuquerque (Table 1). Still, even with a prudent choice in comparative study areas, caution should be used when drawing conclusions. Second, the people who live in the neighborhoods studied may have different conditions that affect their choices, such as demographics, wages, existing infrastructure, and cultural preferences (Vijayakumar, El-Geneidy, and Patterson 2011; Zolnik 2012).

While sprawl is a phenomenon that occurs in many places, there is not a tremendous difference in the commuting times or monetary costs between sprawling areas and more densely populated, mixed use areas. However, there is a correlation between rail transit and smarter, mixed-use design or TOD (Belzer and Autler 2002). Consumers’ quality of life is generally better if they have choices such as what mode of transportation to use, how far they want to travel for work and daily activities, how much time they spend in their cars, and how they want to utilize their time in transit.
Jobs-Housing Imbalance and Excess Commuting

Jobs-housing imbalance correlates with excess commuting (Suzuki and Lee 2012), and commuter rail is a mode of transit that can address excess commuting if the commute patterns are sufficiently linear. While rail transit, and particularly a commuter train, will not change a majority of the developed landscape from an auto-superior zone into a more urban setting, it will help to build up, and not build out, certain neighborhoods at centralized locations.

There is a correlation between longer commuting time and jobs-housing imbalance, and a better jobs-housing balance correlates with shorter average commutes (Giuliano and Small 1993, Horner 2002, Horner and Murray 2003). The jobs-housing balance is defined as the relative locations of jobs with respect to housing in a given area, and CBD’s tend to have more jobs than housing (Horner 2004). An enhancement of Valley CBD’s from the commuter train may extend the linear fashion of employment concentration. However, TOD and CBD enhancement is better known for creating mixed-use neighborhoods, not necessarily high employment concentration. The jobs-housing imbalance would likely remain for the most part, which contributes to excess commuting. To the extent that resulting TOD may redistribute a few employment centers into a more poly-nucleic region in the Valley, smaller communities could see a few new jobs created as a result of the need for more services in the vicinity of the commuter train stations. Ryan (2005) discusses a San Diego area study in 1996 to determine the importance of locating offices close to freeways versus light rail systems. For amenity-oriented firms, proximity to rail was important, and when access to the CBD and other
secondary centers is available, highway access becomes less important (Ryan 2005). Passenger rail could increase office developers’ preferences for locating employment centers near passenger rail.

Excess commuting is defined as the difference between the theoretical minimum commute distance and the observed average commute distance (Ma and Banister 2007; Murphy 2009; Suzuki and Lee 2012). More heterogeneity among home and work locations in an urban study area equates with a better jobs-housing balance. This means that for a given concentrated work destination, people who work there would live in relatively close proximity rather than scattered throughout the entire region. This would mean a lower minimum average commute, and better jobs-housing balance (Horner and Murray 2003). The attainment of a theoretical minimum commute distance throughout a region is not realistic because it would involve massive reassignment of home and work locations, thereby reducing all excess commutes to a minimum. However, rail can help address this jobs-housing imbalance if the commute patterns are sufficiently linear and parallel to the proposed rail corridor.

The concept of excess commuting has been studied from different angles; such as the effect of urban structure, using a monocentric model, the heterogeneity of households in the area studied, investigating the minimum commute calculation, and calculating a theoretical maximum commute (Hamilton 1982; Horner 2002; Layman and Horner 2010). The extents of excess determined were significantly influenced by the Modifiable Areal Unit Problem (MAUP) (Suzuki and Lee 2012). This refers to the geographic area (size of the geounit) that is used when aggregating the individual commute data into a summable level of geography. For instance, choosing ZIP codes as
the summable level, which are generally larger than tracts, would result in less accurate conclusions because of what is known as aggregation bias (Suzuki and Lee 2012). If using small enough geographic levels of data aggregation, three study areas can be effectively compared, using commuter counts, bearings and commute distance for each origin-destination combination. The Census 2000 offers journey-to-work data with commuter counts at the Census tract level as well as the block group level. The choice of tract, since it is a relatively small level of geography, will keep the aggregation bias to a minimum.
CHAPTER III

METHODOLOGY

For this thesis, I compared the commuter patterns of the Valley with the commuter patterns in two other regions that implemented a commuter train in the 2000-2010 decade. The two commuter trains I chose to compare their regions’ commute patterns with the Valley’s are Utah’s Front Runner and New Mexico’s Rail Runner. These particular trains were chosen because they are two of the few inter-regional commuter trains in the United States, and the three regions are similar in population counts of principal cities along the rail corridors (Table 1). Most relevant is the origin/destination commuting counts and spatial patterns of commuting among the three study areas. Commuting patterns will be analyzed and discussed, and the results from the three study areas will be compared and contrasted.

Design of the Investigation

The specific purpose of this thesis is to illustrate the year 2000 commuter patterns for the three study regions and statistically compare them. In order to analyze the linearity of the commuter patterns objectively, I will take the existing Census 2000 commuter data at the tract level in its raw form and bring it into a GIS system to illustrate the origin-destination demand, in the form of a spider map (Figures 2 through 10). This means having a straight line connecting every possible combination of origin/destination
Census tracts and the commuter count associated with each unique pair of tracts, and looking for linear patterns and gaps within the study area map, amid a plethora of lines. The result will be that all three study areas in the three states will have a visual spatial illustration of the commuter demand that existed in the time shortly before the Utah or New Mexico trains were implemented. With the spider map, each of the many lines connecting origin and destination tracts will have commuter count, distance, and bearing information associated with it. Each line will be weighted according to its commuter count, and the bearings of travel that each commuter is making will be collectively analyzed in several statistical analyses.

The GIS uses the latitude-longitude coordinates of the centroid of the tract as the point of either origin or destination. The limitation of this becomes apparent mainly in the rural, and therefore geographically larger, tracts because it creates an illusion that the centroid is the exact point of origin and/or destination, when in fact it represents the aggregation of all origin/destination points within that tract’s geographic area. This can potentially distort the distance and bearing variables. The effect, however, on the spider maps and the statistical analyses that reflect distance and bearing is minimal, since the vast majority of the tracts in the three study areas are in more heavily populated areas. Thus, those tracts in the populated areas are relatively small in geographic size with little variation among the actual origin/destination points.

Data Description

While traffic counts on major roads such as Highway 99, the main thoroughfare through the Valley, can be informative, such information does not include
more relevant details such as origin and destination counts. Census 2000, however, does provide data at the tract level for commuter counts of origins and destinations from one tract to another. Since the data was collected for the 2000 Census, it reflects the commuting and the origin and destination statistics down to the tract level for the study areas in Utah and New Mexico before the commuter trains were established. The data in its raw form represents the one-way commuter count and is not counting each passenger twice.

Census 2000 put out data on commuter counts from one geographic unit (geounit) to another, based on the geounit where one lives in and the geounit where one works. This type of data is further broken down to smaller levels of geography, or geounits, such as tracts and block groups. I have chosen to use tract as the level of geography by which to study these commuter patterns for two reasons. First, their geographic size, at least in populated areas, is typically that of a walkable neighborhood. This makes for a meaningful analysis which identifies areas of concentration and allows any linear patterns to emerge. Secondly, it is reasonable to expect that many residents of a tract that is of particularly high demand would live close enough to a transit station to utilize it, if one were implemented in that tract. Block groups are a smaller subdivision of a Census tract, but their size is too small to justify creating a map at that level for such relatively large study areas. Therefore Census tract is the level of geography that would yield results that are both informative and manageable.
Data Analysis Procedures

In order to compare and contrast the three study regions with regard to their demand level, illustrative maps and grouped statistical analyses were made. First, basic descriptive statistics were calculated to determine the means and modes of the spider line length and bearing variables, respectively, for each of the three study areas. Second, Levene’s test (StataCorp 2005) was employed for the three study areas collectively to compare the standard deviations of the bearing variable. Third, a Kruskal-Wallis test was conducted to assess the probability that the three study areas are similar ($p < 0.05$). The Levene’s test and Kruskal-Wallis test were weighted according to the commuter count associated with each spider line. Finally, a Wilcoxon (Mann-Whitney) test was conducted, also weighted according to the commuter count associated with each spider line, for each of the three possible pairs of study areas to determine which study area was driving the differences among the three.
CHAPTER IV

RESULTS AND DISCUSSION

Visually, the Utah study area is the best example of the three in that it contains generally solid commuting patterns throughout most of the corridor. At several points along the north-south corridor, there are instances of heavy (red line) commuting routes coming from tracts to the east. It is important to note that like California’s Central Valley and the adjacent Sierra Nevada foothills, Utah’s Wasatch Front is flanked by hills and mountains to the east. These foothills contain rural communities that are bedroom communities, requiring residents to commute to the more urban areas slightly to the west for employment (Figure 3). The Ogden to Salt Lake City sector is particularly heavily traveled, and the more southerly sector from Salt Lake City to Provo (Figure 4) is significantly traveled, albeit less than its northern counterpart (Figure 3). There seems to be more activity going shorter distances in the southern sector than there are going longer distances, but collectively they still add up to a fair amount of traffic continuously between those two cities. It is not surprising, from looking at these Utah maps, that the Front Runner North section was built (2008) before the Front Runner South (projected 2015 completion).

In New Mexico, we also see a heavy pattern of activity south of Albuquerque, all the way south to Belen (Figure 5). Like most principal cities in all three study areas (i.e. Sacramento, Salt Lake City, Albuquerque, Modesto, and Ogden), Santa Fe has a
Figure 3. Utah study area overview, tract to tract commuter count.

Figure 4. Utah study area south section, tract to tract commuter count.

Figure 5. New Mexico study area south section, tract to tract commuter count.

multitude of commuters traveling all conceivable directions to/from the central city (Figure 6). Since this study is about a commuter train, we are less concerned with intra-city commutes and instead want to focus on inter-city or inter-CBSA commutes, which are generally associated with longer commute distances. However, what is interesting about Santa Fe is that most do not seem to be traveling long distances to Santa Fe (such as from Albuquerque), yet there is one particular tract that has a fair amount of commuters going to that city (Figures 6 and 7). This is a geographically large and mostly rural tract, located about midway between Albuquerque and Santa Fe. This is the prime example of the limitation of the use of geographic centroids in the larger rural tracts. Many people are also commuting from this tract to the Albuquerque area. The illustrations suggest that, if not for this one tract, the Albuquerque and Santa Fe urban areas would be nearly self-contained with respect to commuting patterns. This one tract, however, seems to be the link that connects the two urban areas. In contrast, the southern section of that study area between Albuquerque and Belen experiences comparably heavier volumes of commuters (Figure 5). Again, it is not surprising that the first segment of the Rail Runner opened in this southern section (2006 for the southern section, 2008 for the northern section). Overall, the New Mexico totals are not as heavy as Utah’s, particularly in the northern half.

The California study area, like the other two, runs generally north to south, but covers more distance than the other two (Figure 2). Chico is the most northern city in the study area, and there is a significant travel path between Chico and Oroville and between Chico and Paradise (Figure 8). There are also high numbers of commuters to the Chico area from the foothill communities such as Concow, Magalia, and Forest Ranch
Figure 6. New Mexico study area north section, tract to tract commuter count.

Figure 7. New Mexico study area overview, tract to tract commuter count.

Figure 8. California study area north section, tract to tract commuter count.

(Figure 8). However, south of Oroville, the numbers abruptly drop, and there are very few commuters from Butte County even to Yuba City, and fewer to Sacramento (Figure 8). North of Sacramento, the Sacramento Valley is less densely populated and the cities are fewer and farther between. There are more people living south of Sacramento than north of Sacramento, within the study area. This makes the California study area different from the other two study areas in Utah and New Mexico, in that the largest city is closer to one end of what would likely become one terminus of the rail line if implemented, rather than close to the middle of the line as is the case with Salt Lake City and Albuquerque. Although the study area extends as far north as Chico, the sparser population in the northern section of the study area means that Sacramento would likely remain the northern terminus of a linear rail line if one were established.

In contrast, the area from Sacramento to Merced presents a different situation (Figures 2, 9, and 10). There are a few important generalities to observe in this corridor. First, as in other areas previously mentioned, we see a number of instances of heavy traffic volumes coming into the corridor from the foothills to the east. These are from bedroom communities either in the Sierra foothills or along the eastern edge of the Valley (Figures 2, 8, 9, and 10). Second, unlike the other two study areas in Utah and New Mexico, we see a few gaps in traffic along this corridor. These gaps, however, tend to be rather short, approximately 5 or 10 miles before the traffic volume picks up again (Figures 9 and 10). Third, Sacramento is surprisingly self-contained, at least with respect to north-south commuting patterns (Figure 9). Stockton and especially Modesto, however, have elongated patterns of north-south commuters (Figures 9 and 10). For example, there is solid traffic pattern from Galt through Stockton and down to Manteca
Figure 9. California study area central section, tract to tract commuter count.

Figure 10. California study area south section, tract to tract commuter count.

before a brief break, and then further south starting in Salida (just north of Modesto) all the way to Merced there are generally solid line patterns (Figures 9 and 10). The further south we look, the longer the commutes become and the greater the frequency of inter-regional commutes (Figures 9 and 10). While the southern half of the California study area does not compare to Utah for solid traffic volume, it is at least a fair comparison with New Mexico. This map is very revealing, particularly since it was not anticipated that Merced would be an appropriate southern terminus, and that likely it would be Modesto instead. In fact, the corridor between Merced and Modesto appears to be the most appropriate grounds for further study of a commuter rail (Figure 10).

Of the three study areas, the Utah study area appears to be the best one for inter-regional commuter rail for one main reason: the Utah study area’s commuters appear to be commuting in a more linear pattern overall as illustrated in Figure 3.

Statistically, the three study areas have very similar mean commute distances when considering all commuters (Table 2). In all three study areas, we see a generally linear north-south pattern. The primary bearing peak in the California study area is approximately 180 degrees different from the average of the secondary and tertiary peaks, and the secondary and tertiary peaks are at adjoining bearing ranges (Table 3).

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Mean Commute Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>California’s Central Valley</td>
<td>8.5 miles</td>
</tr>
<tr>
<td>Utah’s Wasatch Front</td>
<td>8.6 miles</td>
</tr>
<tr>
<td>New Mexico’s Middle Rio Grande Valley</td>
<td>8.7 miles</td>
</tr>
</tbody>
</table>
In the Utah and New Mexico study areas, the primary and secondary peaks occur at adjoining bearing intervals, while the tertiary peak is roughly 180 degrees off from the secondary peak (Table 3).

When screening commuters to show only those who travel at least (≥) 10 miles to work, the order and bearing of the top three bearing ranges change only slightly (Tables 3 and 4). In each study area, since two of the three most common ranges are invariably adjacent ranges, we can say that all three areas contain bimodal bearing data that again supports a generally north-south pattern.
The linearity increases for all three study areas when the commute distances are screened to ten miles or more. These ranges collectively account for a higher percentage of all possible bearing ranges among the ≥10 mile commuters than among all commuters (Tables 5 and 6).

Table 5. Percentages in Top Three Bearing Ranges for All Commuters

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Total Commuters</th>
<th>Commuters in Top 3 Bearing Ranges</th>
<th>% of Total in Top 3 Bearing Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>859,988</td>
<td>187,000</td>
<td>21.7</td>
</tr>
<tr>
<td>Utah</td>
<td>702,906</td>
<td>232,000</td>
<td>33.0</td>
</tr>
<tr>
<td>New Mexico</td>
<td>333,346</td>
<td>69,000</td>
<td>20.7</td>
</tr>
</tbody>
</table>

Table 6. Percentages in Top Three Bearing Ranges For ≥ 10 Mile Commuters

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Total ≥10-mile Commuters</th>
<th>≥10-mile Commuters in Top 3 Bearing Ranges</th>
<th>% of Total in Top 3 Bearing Ranges</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>258,756</td>
<td>73,000</td>
<td>28.2</td>
</tr>
<tr>
<td>Utah</td>
<td>198,457</td>
<td>106,000</td>
<td>53.4</td>
</tr>
<tr>
<td>New Mexico</td>
<td>86,722</td>
<td>30,500</td>
<td>35.2</td>
</tr>
</tbody>
</table>

In the Utah study area, 53 percent of the ≥10 mile commuters fall into one of the top three bearing ranges, which collectively range from 340 degrees clockwise to 20 degrees (a radial interval of 40 degrees), and from 180 degrees to 200 degrees. This makes Utah the prime site among the three study areas for a north-south commuter rail line based on year 2000 commuter data, when assessing the strength of the linear relationship of the patterns. In California’s Central Valley, only 28 percent of the ≥10 mile commuters are within that study area’s top three bearing ranges, which again range
from 340 clockwise to 20 degrees, and from 180 degrees to 200 degrees. In New Mexico, 35 percent of the ≥10 mile commuters are within the top three bearing ranges. These three bearing ranges go from 0 to 40 degrees for the first two, and a nearly opposite 180 to 200 degrees for the third. This suggests that there are more commuters going in the general direction of Albuquerque to Santa Fe than vice-versa. The overall numbers, however, for the New Mexico study area are significantly lower than those for the Utah or California study areas. Two aspects of the California study area differ from the Utah study area besides the lower percentage of commuters in the top bearing ranges. First, the California study area is spread out across a greater distance than the Utah study area and still does not manage to capture as many target commuters for linear rail. Second, the proposed corridor or string of cities along Highway 99 is not oriented as neatly north-south as the study corridor in Utah, yet the most common bearing values are in fact more north-south. The California study area corridor is skewed counter-clockwise from north, particularly in the more southern sections of the study area (Figure 2). This means that the most common commute bearings are not parallel to the bearings of the proposed rail course overall, making the Valley’s candidacy for commuter rail less viable than the Utah counterpart.

With Utah having the most pronounced linear commuter patterns, continuity of population density, and highest count of commuters in the top bearing ranges, it emerges as the best study area of the three for inter-regional commuter rail, when assessing demand using these methods. New Mexico has much lower commuter counts overall than Utah, and does not have as pronounced of a linear pattern as the Utah study area. New Mexico’s study area also does not have the continuity of population density as
Utah’s study area. The dominant bearings in the New Mexico study area, however, are in general parallel with that corridor overall. The California study area emerges as a middle value of the three when considering commuter counts in the top three bearing ranges, however it does not necessarily have the middle value in terms of linearity. It is further complicated by the fact that these commuter counts are gathered over a much longer corridor, and that the dominant commuter bearings are skewed from the bearings of the corridor overall. While the latter issue could be partially addressed by strategic placement of parking facilities to draw in riders from areas distant from their origin station, that challenge would likely remain.

Using the Levene’s test to assess the standard deviation of the absolute value of cosine of bearing degrees; we find that California has a standard deviation of 0.300, Utah has a standard deviation of 0.202, and New Mexico has a standard deviation of 0.280 (Table 7).

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>0.300</td>
</tr>
<tr>
<td>Utah</td>
<td>0.202</td>
</tr>
<tr>
<td>New Mexico</td>
<td>0.280</td>
</tr>
</tbody>
</table>

Since absolute value of cosine of bearing degrees is used to compensate for the issue of means of circular degrees, the possible value for each bearing in the analysis is between 0 and 1. The standard deviation for California is 30 percent of the possible range, the standard deviation for New Mexico is 28 percent of the possible range, and the standard deviation of Utah is only 20 percent of the possible range. Therefore we can infer that Utah’s commuter patterns are the most linear, followed by New Mexico, and
lastly California. While this is informative, running the Kruskal-Wallis test further
indicates that the three study areas bear no similarities in their patterns at all ($p < 0.0001$).

Additionally, a Wilcoxon (Mann-Whitney) Test for comparison of two study
areas at a time also indicates that there are no similarities between the patterns in any two
study areas ($p < 0.0001$) (Table 8).

<table>
<thead>
<tr>
<th>Pair of Study Areas</th>
<th>$p$-value</th>
</tr>
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<td>California vs. Utah</td>
<td>0.0000</td>
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<td>California vs. New Mexico</td>
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<tr>
<td>Utah vs. New Mexico</td>
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</table>

Finally, a radar polar chart clearly shows that Utah has a dominant pattern of linearity,
followed by New Mexico, and least of all California (Figure 11). The numbers on the $y$-
axis indicate the percentage of all $\geq 10$-mile commuters (target commuters) who
commute from home to work in the bearing indicated on the radar polar chart. The Utah
study area shows a well-defined north-south pattern. The highest percentage of those
target commuters, approximately 7.5 percent, travel from home to work at a bearing of 0
to 6 degrees, or nearly due north. The second most common bearing among the target
commuters in Utah is nearly due south at 180.1 to 186 degrees, for which approximately
5.5 percent of the target commuters travel that bearing. The New Mexico study area
shows a predominant percentage of target commuters who travel in a north-northeast
direction, 6.5 percent at 18.1 to 24 degrees and another 3.5 percent at 42.1 to 48 degrees.
Also, there are 3.2 percent of the target commuters in New Mexico who travel generally
south at 174.1 to 180 degrees. In California, the highest percentage of target commuters
are tied at only 3.3 percent for 0 to 6 degrees and 180.1 to 186 degrees, and secondarily at
Figure 11. Radar polar chart for commute bearings by percentage of ≥ 10 mile commuters.

2.7 percent for 240.1 to 246 degrees. While this does show that more commuters are traveling north-south that any other bearing, the percentages for those bearings or any other bearings are not as strong as the percentages of the dominant bearings in Utah or New Mexico. The California study area also has a higher percentage of target commuters traveling from the Sierra foothills to the Valley corridor, a direction generally perpendicular to the path a train would take if implemented.
CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

In this study, an opportunity presented itself in which the Census 2000 provided comprehensive data on commuting statistics at various levels of geography, at the start of the same decade in which two inter-regional commuter trains were built in the Western United States, one in Utah and another in New Mexico. This setup of events provided the framework to investigate and answer the question: Did California’s Central Valley region have a favorably comparable pattern of commuter origins and destinations with Utah’s Wasatch Front region and New Mexico’s Middle Rio Grande Valley region, so that it was an equally suitable location for implementation of commuter rail?

While the three study areas do show a generally north-south pattern with a majority of their commuter routes, further statistical analysis shows that they should not all be treated the same, as they are each truly unique. The California study area has more of a variety of bearings, rather than a well-pronounced linear dominance like that of Utah. New Mexico has the middle value of linearity, with a primary north-northeast and southbound concentration with some secondary spikes in other directions. California has its highest percentages of commuters going north or south, but these percentages are significantly lower than the highest bearing percentages in the other two study areas. The California study area, when compared to the other two, has a higher percentage of
commuters traveling in a direction generally perpendicular to the route a commuter train would take, therefore these people do not represent potential ridership. The California study area contains more people, and more commuters, than the other two, which it could be argued might compensate for the relative lack of linearity. This point is countered, however, by the fact that the data was gathered over a geographically larger study area, which stretches from Chico to Merced. Also, unlike the other two study areas, California’s Central Valley’s most commonly occurring bearings are skewed from the main course of the corridor overall, complicating the suitability for commuter rail based on these findings.

In the year 2000, at the beginning of the decade in which the Front Runner in Utah and the Rail Runner in New Mexico were built, the California study area did not have a commuting pattern structure similar enough to the other two study areas to emulate Utah’s or New Mexico’s suitability for commuter rail implementation. However, one limitation of this study is that commuter patterns can change significantly over time, so this conclusion should not be superimposed to project demand since 2000. The availability of such comprehensive commuter data is limited, which is unfortunate because comprehensive data, when current, enables transportation planners to evaluate demand through patterns that are very complex and varied. The fact that the three study areas showed such lack of similarity is indicative of the fact that the details of such patterns are inherently intricate.

For future reference, decennial censuses should collect information on origin and destination commuter counts, as conducted in Census 2000. Unfortunately this was not the case for Census 2010. This kind of comprehensive data proves useful for
transportation planners to project demand, particularly for planners involved in the complex field of commuter railroad planning.
REFERENCES


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