# A SITE SUITABILITY ANALYSIS FOR AN INLAND PORT TO SERVICE THE PORTS OF LOS ANGELES AND LONG BEACH

By

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# Abstract

To alleviate some of the environmental and traffic concerns caused by the growth around the Ports of Los Angeles and Long Beach, research has begun on the establishment of a large inland port. An inland port (or dry port) stores cargo, transfers containers from drayage trucks to rail, and largely shifts seaport activities off-site (Roso, Woxenius, and Lumsden 2008). A location-allocation analysis has been conducted for the Los Angeles region to determine potential sites for an inland port in terms of distance from the seaports and reduction in vehicle miles traveled (truck VMTs) (Rahimi, Asef-Vaziri, and Harrison 2008). This study builds on this research by conducting a site suitability analysis (SSA). First, the study pre-screens numerous parcels for size and rail line proximity to limit the analysis to viable sites. Next the study investigates key siting decision variables in greater detail. These include rail line feasibility, parcel acreage, distance from schools, population density, and total truck VMT reduction. Using Arc GIS, the data were analyzed and transformed into scores to sum site desirability based on an even weighting of these criteria. Data for this study were obtained from multiple geographic information system (GIS) data warehouses including, Census.gov, egis3.lacounty.gov, ArcGIS Online, and the State of California Geoportal website. This study reaches three main conclusions. First, a site suitability analysis is needed when it comes to analyzing a multitude of variables and selecting a proper site for an inland port in an urban setting. Secondly, there are possible sites where an inland port can be placed and connected via rail that will minimize overall truck VMTs in the region. Lastly, although many sites scored high on some of the criteria, no one site stands out as optimal, according to the criteria chosen, for a heavy industrial facility, such as an inland port, in the Southern California region.

# Chapter 1: Introduction

This chapter provides an overview of the growth of the shipping industry, inland port development, and transportation networks. The current structure of the Southern California industrial and transportation system is explored. The concept of a site suitability analysis (SSA) as a means of placing an inland port is also described. Issues surrounding industrial development in an urban environment are discussed along with the usefulness of an SSA to address these issues and find optimal locations for an inland port in the region.

## 1.1 Containerization and the Growth of the Shipping Industry

Container shipping appeared in the United States in 1968 when the International Organization of Standards (ISO) began standardizing container dimensions for shipping, creating four specific standards: R-668, R-790, R-1161, and R-1897 (ISO 2011) (Roso, Woxenius, and Lumsden 2008). This sharply reduced manual labor on docks making cargo movement much more efficient and viable. This led to a shift from transporting small amounts of cargo by truck to shipping large amounts of cargo by truck, rail, and ship. This increase eventually put strain on seaport land-use and operations in urban regions (Walter 2004). This issue, in many cases, may be resolvable by connecting the seaport to a land-based facility. Shifting activities at the seaport to an inland port and transferring cargo via rail can lead to a more cost-efficient and effective transportation network.

The upsurge in cargo has also led to increasing automation of the transloading process. Transloading is moving cargo from one mode of transportation to another, which often occurs at the ports and at intermodal transfer facilities (ITFs). There are seven ITFs in the Southern California region, four in operation by Union Pacific Railroad and the remaining three by

Burlington Northern/Santa Fe Railroad (BNSF) (Polar Inertia 2005). The idea of an inland port is similar to this, except the majority of transloading, as well as storage, logistics matters, and other seaport-related activities would happen in the same place—the inland port. This would reduce the need of multiple ITFs throughout the region and lower congestion in the port areas.

According to Roso (2012), the benefits to having a distant or mid-range inland port include: less congestion, increased capacity, direct loading from ship to train, interface with the hinterland (seaport service region), opening up seaside land-use opportunities in the area of the seaport, less time in congested road terminals, improved seaport access, and regional development (Roso 2012). The downside to an inland port, as with any industrial facility, is the increase in potential pollution and congestion in and surrounding the area chosen. This leads to the necessity and usefulness of a site suitability analysis.

## 1.2 SSA for Site Selection

An SSA could help with these issues by providing an in depth analysis on the possible areas and giving the decision-makers the ability to compare each site according to selected variables. With a SSA, the possibility of one or two optimal sites may arise or even the possibility of showing that there is no best site for an inland port. It can also show the benefits or drawbacks of specific factors as it pertains to an inland port. For example, there is a possibility that removing congestion from the port complex may not give a net benefit for public health.

No previous studies include a SSA of an inland port in the Los Angeles region; though, one study uses location-allocation to define the optimal general areas in which to locate inland ports servicing both the Port of Los Angeles (POLA) and the Port of Long Beach (POLB) (Rahimi, Asef-Vaziri, and Harrison 2008). This study concludes that further incorporation of a

GIS-based algorithm into a location analysis that would involve variables such as emission exposure and distance to schools (Rahimi, Asef-Vaziri, and Harrison 2008). A SSA can address considerations such as those mentioned above as well as, parcel size, population density near the potential site, and the feasibility of access for connecting to the port via rail. Literature suggests that inland port sustainable development is feasible through proper planning (Kozawa, Fruin, and Winer 2009). This study conducts a site suitability analysis to determine if integrating an inland port into the Southern California region is possible.

The primary motivation for this study is to show that integrating vehicle miles traveled and diesel fuel emissions from container movement in a dense urban setting into freight routing optimization is feasible. In providing an analysis for a suitable inland port site, informing policy makers about more sustainable options for port development could reduce truck emissions and improve the region's transportation network altogether.

Alleviating the air pollution problems prevalent in the port area would improve the quality of life in the cities surrounding the ports. Compliance with Proposition 65 has increased the awareness of the harsh pollutants derived from port activities. The importance of reducing these pollutants, especially those that cause cancer and reproductive harm is much more pressing now that there are policies backing major change (Peterson 2011). Incorporating a proxy measure of by including population density near prospective sites, as well exposure of sensitive populations (such as school age children) will help in determining most suitable sites to minimize the impacts of air pollution.

## 1.3 Study Area

This study focuses on five counties in Southern California. Rahimi et al. (2008) refers to the Five County region as comprising of Los Angeles, Ventura, Orange, Riverside, and San Bernardino County.

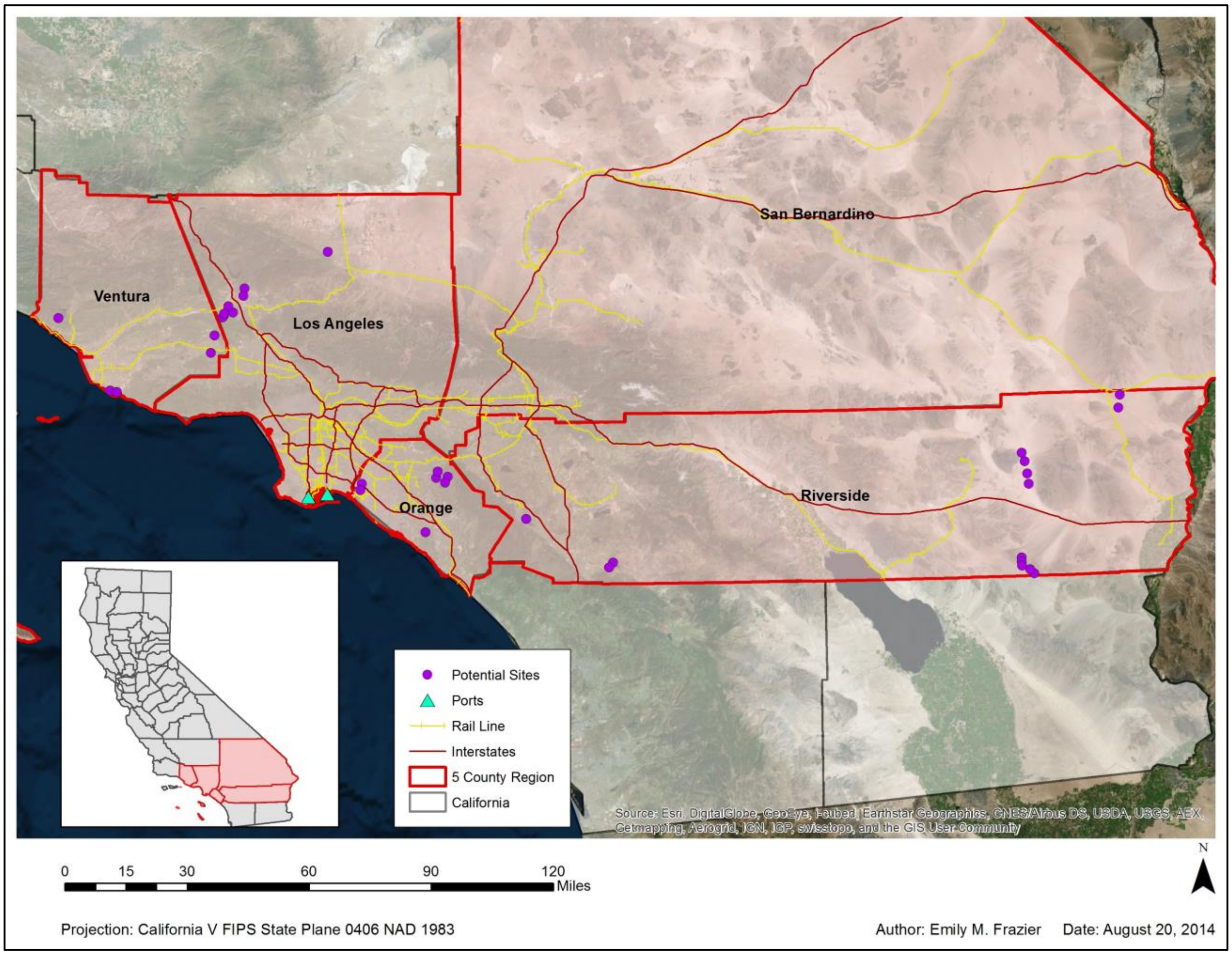


**Figure 1 Five-County Region of Southern California**

There are two ports located in the region: the Port of Los Angeles (POLA) and the Port of Long Beach (POLB)—indicated from left to right in the above map. For over a century, both POLA and POLB have been vital in shaping the cities surrounding them. These ports not only serve the five county region of Southern California, but also provide services to the entire nation.

POLA and POLB are the busiest ports in the United States and among the busiest in the world (AAPA 2013).

Los Angeles County is the most populous county in the nation with a population of over 10.4 million residents (US Census Bureau 2013) with more than a quarter of California's total population of 39.3 million residents. If Los Angeles County, along with its 88 cities, were a nation—it would have the world's 19$^{th}$ largest economy (LA County 2008). Los Angeles County covers a total of 4,084 square miles. Orange County is the sixth most populated county in the nation with roughly 3.1 million residents (US Census Bureau 2013). Measuring 948 square miles, it is also the smallest county in California. There are 34 cities in the county, three of which have populations surpassing 200,000 residents (Orange County Government 2014).

Riverside County is located in the southeastern portion of Southern California, covering a total of 7,303 square miles. It has an estimated population of 2.3 million (US Census Bureau 2013), with a fast-growing economy. The county comprises of 28 cities and is mostly covered by desert (County of Riverside 2014). Ventura County, with its ten incorporated cities, is the least populous of the 5-County region with roughly 839,000 residents, most of which reside in the southern half of the county. Ventura County covers 2,208 square miles. Lastly, San Bernardino County is the largest of the region covering 20,105 square miles (US Census Bureau 2013). The county alone is larger than four of the smallest states in the United States combined. San Bernardino County has a population of 2.1 million residents (Board of Supervisors 2014).

With an increase in population comes the need to expand the region's goods movement capacity. In 2013 alone, POLA and POLB combined handled roughly 14.9 million TEUs (twenty-foot equivalent units)—a 37% increase from 2012, more than one-third of the United

States' 43.1 million. Hobart Yard, a 245-acre intermodal rail yard located in the City of Commerce, California, handles much of the activity from the ports. These activities are burdensome on the area's current transportation system and its environment. An inland port outside of the heavily industrialized area of central Los Angeles County would help to relieve some of the environmental stress around Commerce and minimize some of the diesel truck traffic traveling to and from Hobart Yard. Because Hobart Yard is nearing handling more cargo as a distribution center than it was built for and continues to be a major contributor to the drayage truck traffic in the area, an inland port connected by rail will likely streamline the trans-loading process and decrease the need for so many trucks in this specific area (Meeks 2013). A SSA can help in determining the impact an inland port will have, especially on places such as Hobart Yard and cities currently strained with heavy industrial activity.

## 1.4 Document Structure

The organization of the remainder of this study is as follows. Chapter 2 discusses literature concerning inland port development and the process of a site suitability analysis (SSA). This chapter also details aspects of an optimal inland port covering: feasibility, proximity, and industrial pollution exposure. Chapter 3 identifies and describes methods used in the current study. A review of the results from the analysis are in Chapter 4. Lastly, Chapter 5 contextualizes the results and discusses what these results represent for future studies.

In the background of the current study, the process of a SSA is illustrated and defined. Inland port development as a whole is discussed along with current global examples of seaports in urban settings and existing inland ports. In addition, the Southern California transportation network including policies on the reduction of pollution and congestion are detailed. Lastly, there is an overview of aspects of an optimal inland port as stated by previous literature and reasoning behind the use of the variables chosen in the SSA.

The methodology of this study is separated into three parts. First, a prescreening process was used to create a manageable list of possible sites to be scored in the SSA. Then, the SSA is conducted with a list of specific variables to assist in determining the best site for an inland port. A sensitivity analysis is used to help weight the variables by importance in terms of financial and environmental costs.

The results chapter gives an overview of the outcomes of the methodology detailed above. The results for the prescreening, SSA, and sensitivity analysis are examined. The process of using weighted and un-weighted scores are examined in this section.

The outcomes of the analysis and the study as a whole are discussed in the final chapter of this study. The conclusions from the SSA and sensitivity analysis are illustrated and contextualized. Assumptions and limitations of the methods used for the current study are then discussed. To conclude, areas where future work can be done are explained.

# Chapter 2: Background

To understand the potential of an inland port (also referred to as a dry port) in the Southern California region a site suitability analysis (SSA) is required. No prior literature reviews the implementation of an SSA to determine the placement and potential of an inland port for the Southern California region, the United States, or globally. Much of the literature in the area of inland ports and transportation geography highlights the necessity of relieving congestion pressures at seaports, requirements for an optimal inland port, and the financial costs involved when placing an inland port in any region.

A location-allocation analysis, which focuses on the distance and vehicle miles travelled (truck VMTs) between origin and destination areas, has been conducted but is not sufficient to understand the factors involved when placing a large-scale inland port. To examine how an inland port would fit into Southern California's transportation and industrial setting, it is important to understand port development, the layout of the Southern California region, and an array of factors that contribute to industrial development.

Section 2.1 summarizes a site suitability analysis and its importance to this study. Section 2.2 highlights requirements for an inland port to service a high-density population and previous literature in this area. Section 2.3 details the Southern California transportation network and urban layout, lastly Section 2.4 summarizes variables necessary to consider for an ideal inland port, including: feasibility, proximity, and industrial pollution exposure.

## 2.1 Site Suitability Analysis

By investigating the best location for an inland port, an SSA (also referred to as a multi-criteria analysis) takes into account answering the question "where are appropriate locations (if any) for inland ports in the Southern California region?" This type of analysis applies a number of social and physical factors into defining the optimal site (or sites). When it comes to inland ports, multiple variables affect their proper implementation. Key factors include the necessity for inland port development to shift freight loads to more effective and environmentally friendly transportation modes (such as rail), relief of congestion in the neighborhoods surrounding the seaports, relief of congestion in the regions hosting the seaports, and enabling the improvement of logistics for the shippers involved (Roso, Woxenius, and Lumsden 2008).

Within ArcGIS, modeling and investigating a large number of factors all at once is possible. This way, sifting through and analyzing thousands of sites quickly then selecting a handful of sites for scoring is much less time consuming and much more efficient than completing the analysis manually.

Deriving information from multiple data layers using ArcGIS Spatial Analyst extension helps in determining whether the chosen site is the most suitable (ESRI 2013). Conducting an SSA is possible on both a small or large scale, from determining the best location for an elementary school in a residential community to finding the best location for a new airport in a region. For instance, in the case of the elementary school, inputting and analyzing spatial factors such as population density, average family size, crime rates, proximity to public transportation, and public safety facilities may help to determine optimal sites.

Figure 2 is a map of Riverside County K-12 schools with quarter-mile buffers and the locations of the potential inland port sites. This map conveys one aspect of a SSA.

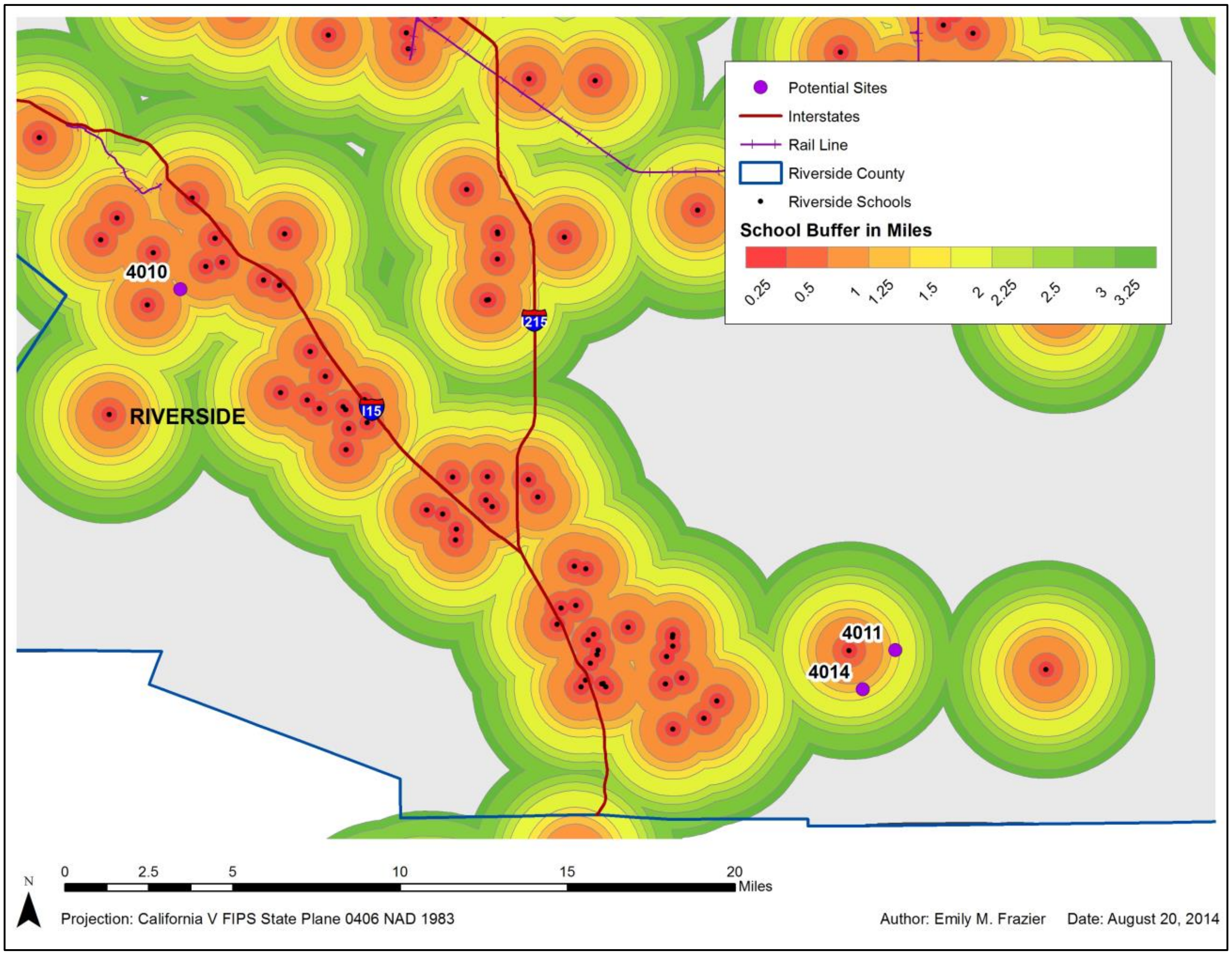


**Figure 2 Riverside County West School Buffers**

Using an SSA organizes the process of reviewing individual variables into a combination overlay of all of the variables. A downside to this process is the weighting aspect. Assigning weights to variables in an SSA are often subjective to the researcher and decision-makers, removing the public from the decision-making process entirely. A possible remedy would be public surveys for variables in which those directly affected could participate in determining what is most important—such as the environmental costs of a new industrial facility. With any decision, not everyone will be completely satisfied and a SSA will not fix this, but it is hoped what a SSA will lead to a better understanding of the process and factors going into the final-decision, making it, at the least, fair and complete (Malczewski 2004).

Another issue is that scores in SSA rely upon the quality of underlying science. A good example of this in this study is the issue of choosing a 'safe' distance for the inland port to be placed away from a school. Detailed research in terms of pollution effects on school-aged children and the spread of polluted air for specific sites would be necessary to score precisely for distances. This study uses distance buffers as a proxy for more specific scoring.

## 2.2: Inland Port Development

Effectiveness and efficiency are keys in the development of an inland port. In a region as heavily populated and heavily polluted as Southern California, sustainability should also be a major factor. It is important when developing an inland port to take into consideration the region's current rail network, industrial and logistics sites, and the potential sites for the new port (Bergqvist 2013).

China's large-scale economic growth and port development to support this growth have been a topic in the international trade community for the past decade (Zeng, et al. 2013). Developments in China's terminal areas face a number of challenges, similar to those in Southern California. A growing population, an expanding transportation sector, and a demand for a cleaner environment are all reasons both areas have been a renaissance in construction of goods movement infrastructure in when it comes to the current goods movement system. The idea of an inland port is somewhat new to China. However, China built its first inland port in the year 2002 (Zeng, et al. 2013). Since then, there have been 28 inland ports built by seaports (21 of which built and supported by Tianjin Port—the largest in Northern China), and 13 developed independently throughout China to improve the transportation system throughout the country (Zeng, et al. 2013) (Ministry of Transport of PR China 2014).

Zeng et al. (2013) detail the challenges and motivations behind inland port development in China. The first mentioned motivation is capacity and competition. Due to increased growth in population and increased volume in cargo being both imported and exported through the ports, there is a need for expansion. Taking this expansion off-site can help relieve congestion on the transportation network and free-up valuable land around the seaports. Another motivation for an inland port is a reduction in logistics costs. These include unstable fuel costs, driver and labor shortages, and economic instability within private shipping companies (Zeng, et al. 2013). Shifting from truck transport to rail transport would lower these types of costs in China as well as in Southern California. Zeng et al. (2013) do not give a complete analysis of what factors are necessary to mitigate many of the challenges they detail in their research, but discuss further potential research opportunities within the field such as the implementation of a dry (inland) port network (Notteboom and Rodrigue 2005) (Rahimi, Asef-Vaziri, and Harrison 2008).

Notteboom and Rodrigue (2005) discuss the evolution of a port network and introduce the idea of a port regionalization phase, which emphasizes the spatial development of existing seaport systems. Regionalization is a term used to describe spreading the reach of a seaport to the hinterland, not simply the port city. The port regionalization phase is led by two factors. The first are the local constraints which effect growth and efficiency around the port area. Often times, the immediate area at the seaport are restricted by space and competition from other industries such as tourism at beaches or private companies looking to build near the coast. Efficiency is limited when congestion hinders goods movement to and from the ports.

Second, the global changes which involve regional production systems and large consumption markets such as an increased demand for global imports or exports (Notteboom and Rodrigue 2005). The authors discuss deeply the idea of a port regionalization phase in port development and the necessity of organizing a transportation network that favors rail and interconnectivity between the seaports and inland facilities. Although Notteboom and Rodrigue (2005) do not discuss an analysis for specific locations, they highlight the need to consider spatial aspects of developing an inland port.

Bergqvist (2013) shows a site selected in Arriyadh, India for a proposed inland port. He illustrates a simple assessment of the current site as it compares to the new site using a binary selection process: either the site meets the criteria or it does not. His research fails to analyze any other site or to give any in depth reasoning for selecting the proposed site, aside from the fact that it may run along a new proposed rail line. Bergqvist's assessment is definitely a step in the right direction towards a full SSA, but excludes key details in analyzing necessary variables for an inland port.

Criteria for sites for inland port development, as derived from the mentioned studies, include the ability to integrate the facility into the current transportation network (Notteboom and Rodrigue 2005) and close proximity to railways. In addition, the capacity to take on large amounts of cargo requires a considerable site size (Zeng, et al. 2013), placement far from the seaport and well into the region to capitalize on the use of rail, and the ability for expansion around the site to coincide with a growing population and demand for goods movement (Bergqvist 2013). Proper implementation of these criteria involves an analysis able to take all of these factors and more into account when selecting a site.

## 2.3: Southern California Transportation Network

Currently, Los Angeles County is handling much of the cargo coming from the ports (City of Los Angeles 2013). Connecting POLA and POLB from the ports to the rest of the region are Interstate 710, Interstate 110, and the Alameda Corridor (POLB 2013). Figure 3 shows the Alameda Corridor and the nearby rail line ownership (ACTA 2014). Figure 4 shows a close-up of the port area and surrounding rail and roadway network. The Alameda Corridor is a length of railway in a subterranean trench extending from the ports to Downtown Los Angeles 20 miles north adjacent to Alameda Street. The creation of the Alameda Corridor was built in response to the increase in ground transportation from the port areas and it eliminates grade conflicts with roadways along its entire length (ACTA 2014).


**Figure 3 Alameda Corridor and Rail Line Ownership (ACTA 2014)**

The main part of the project, the Mid-Corridor Trench, carries freight through a ten-mile stretch separated from passenger trains and road traffic, meant to reduce congestion in the area approaching Downtown Los Angeles.  The benefits of having the Alameda Corridor in place include more efficient freight rail movements, reduced traffic congestion, improvements to the adjacent Alameda Street, less train emissions, reduced vehicle emissions at railroad crossings, and less noise pollution in the area as a result of the majority of the corridor being in a trench (ACTA 2014).

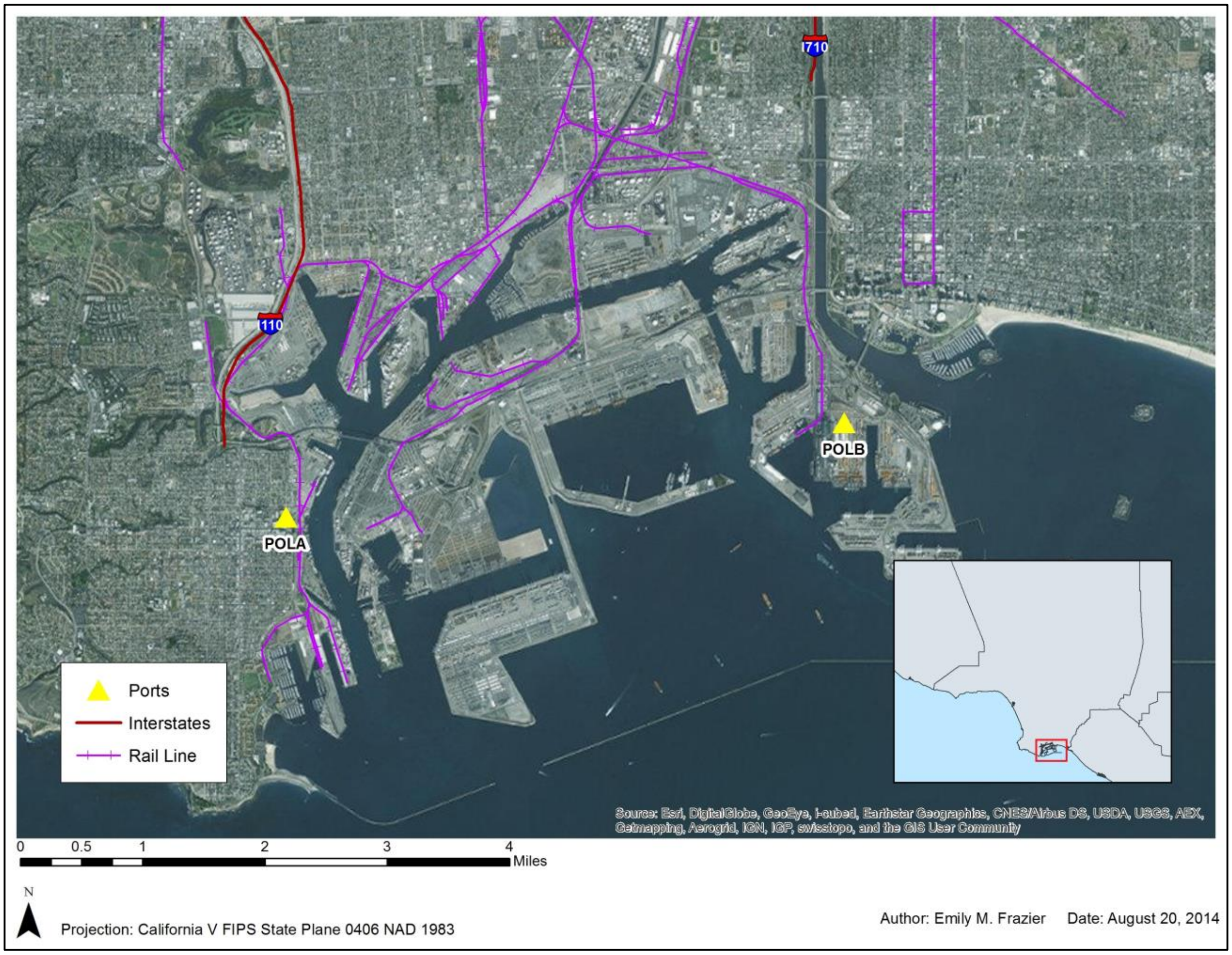


**Figure 4 Port of Los Angeles and Port of Long Beach**

The roads in and around the port are exceedingly congested.  This congestion leads to lower land-value, increased diesel truck emissions, and increased pollution overall.  Because a large amount of industrial and goods movement activity is already taking place in the cities of Commerce and Industry, the placement of an inland port somewhere else in the region to lighten the load is ideal. Similar to the challenges stated for China, the seaport area around POLA and POLB are restricted when it comes to space for industrial development.

The controversy around the implementation of the Southern California International Gateway (SCIG) Project is illustrative of the difficult issues of development in the seaport area. SCIG involves the construction of a new near-dock intermodal rail yard within four miles of the ports, connected to the Alameda Corridor. It is proposed that the construction of SCIG would eliminate 95% of the truck traffic between the ports and Hobart Yard and provide direct rail access to the Alameda Corridor—enabling Alameda Corridor to reach its full train capacity potential as a result (Los Angeles Harbor Department 2013). Having a near-dock rail yard to complement on-dock rail yards adds the logistical advantage of combining cargo from various marine terminals before shipping it via rail to the rest of the region.

The Los Angeles Harbor Department (2013) states "near-dock facilities are able to provide needed intermodal capacity with greatly reduced trucking impacts, compared to the more remote off-dock facilities… causing much intermodal cargo to be drayed over 20 miles to the rail yards near downtown Los Angeles (p. 27)". From this quote, one can infer the controversy surrounding trucks in the region and in the port area. If inland ports allowed the cargo to be loaded onto rail at the on-dock facilities, then there would not be a need for container trucks in the immediate area port at all. Even then, there would be less of a need for a near-dock facility since the cargo can be sent directly to an inland port for storage, service, further handling, maintenance, and trans-loading.

According to the Bay Area Council Economic Institute (2012), an assessment of SCIG shows the project is not yet necessary. The idea is that on-dock rail should be the main priority due to the current cargo load and potential growth of the seaports. The assessment defines two potential types of growth scenarios: low-growth at 4.3% and high growth. The first scenario concludes that existing on-dock rail will be adequate to handle the current cargo load in 2035. The high-growth scenario concludes that existing on-dock rail will not be adequate by 2035 but that this conclusion is overly optimistic since the estimated deficit would be nearly 1.8 million TEUs (in terms of handling capacity). Furthermore, it states that by that time, newer technology would open up the opportunity for a more efficient and cost-effective option than SCIG (Green LA Port Working Group 2012).

There are currently four on-dock rail yards at POLA owned by American President Lines Limited (APL), Maersk, Yang Ming (China) Shipping, and one owned jointly by Terminal Island Container Transfer Facility (TICTF), Evergreen, and Nippon Yusen Kaisha (NYK) Line (POLA 2014). POLA, transcontinental railroads, and its customers cooperatively design the on-dock rail yards. These rail yards connect to the Alameda Corridor and could be expected in the future to connect to an inland port for increased efficiency.

## 2.4: Variables to Determine Ideal Sites for Inland Ports

This section reviews the variables used in the methodology of the current study. Section 2.4.1 addresses the feasibility factor of placing an inland port along with connecting it by rail to the seaports. Section 2.4.2 details the issue of industrial pollution and exposure to sensitive populations, using schools and dense populations as a proxy for this.

### *2.4.1 Feasibility*

Efficient use of an inland port is its connection to a seaport by rail. Because POLA and POLB have existing on-dock and near-dock rail yards, connecting the current system to an extended network will save on costs and increase overall effectiveness. Finding a site near an existing rail line would be the ideal. This way the decision-makers would only need to invest in a rail spur (a rail line connection) to the inland port instead of building a new line altogether. The distance variable indicates the geodesic distance in miles from the nearest rail line to the potential site. If this is the case, then the shorter the distance from an existing line to a potential site, the cheaper.

Certain aspects of the terrain in the area contribute to the financial costs of connecting the seaports to an inland port by rail. The slope variable represents changes in terrain and elevation that would add to the total financial costs of building a rail line. Another obstacle is the number of roadway intersections the rail line may have to cross. When builders need to cross a road they can build a bridge over it, build a trench underneath it, or build through it and create street intersection with traffic controls in place, all of which add to the cost of labor, time, and finances, or create traffic safety concerns. Incorporating these variables into the SSA assists in evaluating the feasibility aspect of potentially building a rail line or connecting current lines with a rail spur.

### *2.4.2 Industrial Pollution Exposure and Proximity to Sensitive Populations*

Poor air quality is an issue that has been plaguing California for years. The Office of Environmental Health Hazard Assessment (OEHHA) and California Environmental Protection Agency (CalEPA) developed the CalEnviroScreen to evaluate air quality and pollution for the state of California (CalEPA 2013). The model determines scores for pollution burden (exposures and environmental effects) coupled with population characteristics (sensitive populations and socio-economic factors). The model combined the weights of the factors to determine the CalEnviroScreen score. The results of this model for the traffic density, diesel truck particulate matter, ozone pollution, and PM2.5 pollution, and toxic releases from facilities variable correspond closely to the industrial and transportation layout of the five county region. The state's growing population has led to a number of environmental problems including diesel particulate matter, traffic density, toxic release from facilities, PM2.5 pollution, and ozone pollution (as mentioned as study factors above). As it relates to this study, it is important not to burden an area with additional pollution, especially areas already heavily burdened with these environmental issues. Exploring this issue deeper requires analysis that is much more intensive than a SSA. Yet, to include this issue within the study, proximity to schools and dense populations are used as a proxy for per capita exposure and exposure of one sensitive population (children) to air pollution.

Interpreting population as an indicator of a high-demand service area is also a possibility (Henttu and Hilmola 2011). Although important, it is not used in this sense in the current study because the region in itself is populous enough to consider it high-demand, so exploring this further is not necessary for the SSA.

# Chapter 3: Methodology

Conducting a site suitability analysis involves gathering appropriate data for screening, scoring, and selecting sites. The foundation for this study is the Rahimi et al. (2008) model, which identifies transportation nodes (TNs) and traffic analysis zones (TAZs) shown in Figure 5 in section 3.2. The location-allocation analysis offers both a suggestion of general areas where it is optimal to place inland ports in the 5-county areas as well as underlying data and a formula to calculate truck VMT reductions by location.

Each parcel in the selected counties is pre-screened according to size (acreage) and proximity to existing rail lines. After that, sites were scored according to reduction in vehicle miles travelled (truck VMTs), distance from an existing rail line, the number of intersections crossed, slope of the land crossed, proximity to schools, and proximity to dense populations. With the application of the screening criteria, parcels were narrowed down from thousands to a manageable number of roughly thirty overall. After screening, sites were scored based on how closely they matched the ideal for each criterion. The goal was to identify five to ten high-scoring sites in the Southern California region for possible placement of an inland port.

Section 3.1 describes the typical process of conducting an SSA. Section 3.2 details the pre-screening process. Section 3.2 reviews the slope and intersection variables of the SSA. Section 3.3 details the screening for school proximity and population density, respectively. Finally, section 3.4 reviews the screening for truck VMT reduction as discussed in the Rahimi et al. (2008) study.

## 3.1 Site Suitability Analysis

A site suitability analysis (SSA) is typically used to evaluate the best location to build something or conduct a study. It can be used to predict risk areas for a number of issues such as fires or landslides. An SSA can also be used to identify where something may likely be found, such as an endangered species (Mitchell 2012). For this study an SSA is used to find the optimal location for an inland port facility to serve the five-county Southern California region. For an SSA, first the goal of the analysis is defined. The goal is often posed as a question like "where is the best location for an industrial facility?" or "what is the best path for a railroad connecting to distribution centers?" Secondly, the criteria for the SSA are defined. There is a combination of factors that are relevant to the question being answered. After criteria are defined, data are collected. For a GIS, the data will consist of various map layers. Next, a model is run with all of the data organized into the GIS. This produces a number of results that can be verified for validity. If errors were evident in the model, then the model can be modified and re-ran. Once the final results in an SSA are verified, then the analysis is documented to potentially be shared or revisited in the future. Finally, the results can be displayed using maps, tables, and/or charts for further interpretation or further analysis.

When it comes to attribute data for an SSA, there are four types: nominal, ordinal, interval, and ratio data. Nominal data describe variables by their name or type (categorical). Ordinal data describes values in high to low or first to last. Interval data is data also from low to high but the difference between each value on the scale is the same. For ratio data, there is a scale from zero to n (some number)—where zero represents a measurable number. For this SSA, the majority of the data was ratio data (distance, slope, intersection count, population, parcel size, and truck VMTs.) The school proximity variable was the only data represented as intervals. This leads to categorizing the data. Each of the variables represented as ratio data was converted into interval data using natural breaks (also referred to as Jenks.) Jenks are based on natural groupings within the data using this method of groupings helps in maximizing the differences in each class range.

The data in the current study were not weighted due to limitations mentioned in Section 2.1. Weighting data in an SSA can be done through ranking, rating, a trade-off analysis, or an analytic hierarchy process (Greene et al. 2011). Ranking the criteria orders then converts the ranks using a rank sum, reciprocal, or exponent. Rating uses a common scale to rate the criteria, for example, on a scale between zero and one. A trade-off analysis evaluates trade-offs between sets of criteria to determine values where both are considered equally important. Finally, an analytic hierarchy process equates criteria on a loose scale and then calculates relative weights based on total calculations of all of the ratios combined (Greene et al. 2011).

## 3.2 Data Collection and Pre-Screening

This study recovered and relied upon a set of 100 transportation nodes (TNs) that average origin and destination data for trucks in the Five County region of Southern California from the original Rahimi et al. (2011) report. Traffic analysis zones (TAZs) in the Rahimi et al (2008) study are areas that show high concentrations of truck destinations to distribution centers. The TAZs are based on a 2004 truck travel survey of where trucks were coming and going in the five-county region. Due to the widespread dispersion of trucks throughout the region, TAZs were combined (no more than five each) to create transportation nodes. TNs represent a single geographic point for the grouped TAZs. The TNs were used to calculate total truck VMTs from POLA and POLB to the central locations. It was determined in the Rahimi et al (2008) study that there were several areas which would optimally reduce truck VMTs by limiting long truck trips. A point was selected from each of the areas and Theissen polygons were created to show optimal areas where an inland port could be placed. These polygons are not related to County boundaries.

The original 100 TNs were overlain on top of the five counties by converting the TNs from a Universal Transverse Mercator (UTM) coordinate system to California V FIPS State Plane 0406 NAD 1983 using ESRI's ArcGIS. The TNs cover the counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura as seen in figure 5 below. The dots in figure 5 represent the 100 TNs. The various colors represent the regions demarcated with the Thiessen polygons mentioned above. The corresponding squares represent optimal inland port locations within each region according to the Rahimi et al (2008) study.

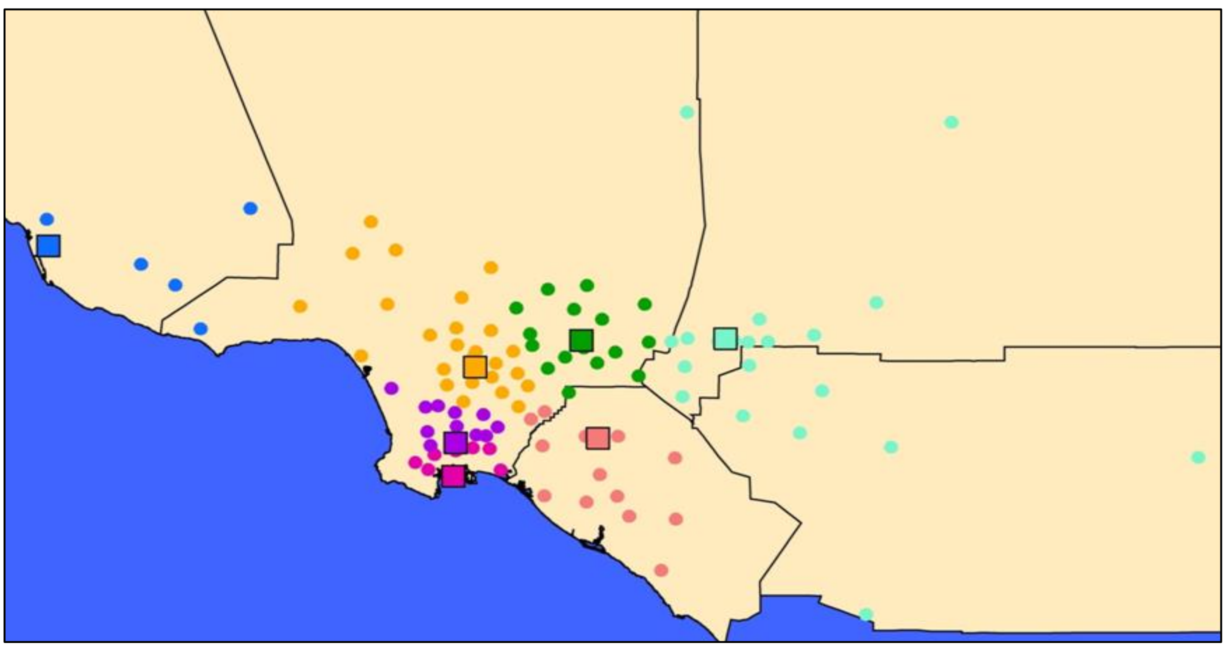

**Figure 5 Rahimi et al. (2008) Traffic Analysis Zones and Transportation Nodes for Southern California**

Data collection and organization for each county was done in ArcCatalog to create a geodatabase. The data for Orange County includes county parcel polygons, the county boundary line, and city polygons with labels. Much of the Orange County data was derived from the county's public works and information technology department (Orange County Government 2014). Data for Riverside County was obtained from the polylines, zoning data, city polygons, water bodies, parks, protected zones, farmland, schools, highways, airports, and major points of interest (County of Riverside 2014). The data for Los Angeles County was downloaded from the county's Enterprise GIS site and CalAtlas, which included city polygons, parcels, schools, hospitals, and other major points of interest (California Department of Technology 2014) (Los Angeles County Enterprise GIS 2014). Zoning data for Ventura County was not available through multiple searches, but base data for Ventura was downloaded from CalAtlas as well.

From this data, the study screened to identify land that was either industrial zoned or un-zoned. The next prescreening step was to check for the two necessary conditions for an inland port: large sites and proximity to rail lines. Thus, all the parcels were first filtered by size (acreage) and geodesic distance to existing rail lines. The objective was to find large parcels that met the size requirement, as opposed to a collection of small parcels, not only to simplify the process of purchasing land, but also to minimize potential costs of land. Persuading a single owner to agree to sell their land is less difficult than to convince multiple owners of multiple parcels to sell their land all at once. Implementing eminent domain (the ability of the government to expropriate private land for public use with reimbursement) would also be a possibility, but it would also be less problematic to gain ownership of one properly sized parcel than going through the process for gaining access to multiple small sized parcels.

Parcel size needs to be 10,000 acres to service a base population of three million residents (Leitner and Harrison 2001; Rahimi, Asef-Vaziri, and Harrison 2011). From this, the presumption is made that for every one million residents, 900 acres of land would be needed for an inland port.  A base population of three million residents within the region is necessary to make sure that the inland port would not decrease in efficiency due to its location in an under populated area (Leitner and Harrison 2001). The large number of consumers in the Los Angeles region makes it a good candidate for an inland port facility.  Table 1 below lists the ideal sizes for each county according to their population size as of 2010.  A simple filter is necessary to start, so a base of 900 acres for each county was used in order not to be overly restrictive in the initial sample of sites.

**Table 1 Ideal Inland Port Sizes for Corresponding Population**

| County | Population Size | Ideal Size (Acres) |
|---|---|---|
| ***Los Angeles*** | 9.9 million | 8910 |
| ***Orange*** | 3.1 million | 2790 |
| ***Riverside*** | 2.3 million | 2070 |
| ***San Bernardino*** | 2.1 million | 1890 |
| ***Ventura*** | .83 million | 747 |

The figures contained in Table 1 are calculated on a county basis and thus are an approximation.  In reality, inland ports in any of the surrounding counties would serve customers in L.A. County and perhaps in one or more of the other five counties in the L.A. region.  For example, cargo off-loaded from an inland port in Orange County could have final destinations in Orange County, Los Angeles County, and Riverside County.  A limitation of the current analysis is that the size of the markets for each of the locations identified by Rahimi et al. was not calculated to derive more specific parcel size.  However, in general, it is difficult to find parcels of even 900 acres, so the county-level approximation has not unduly restricted the candidate parcels selected for this analysis.

A parameter of five miles from the nearest rail line is used for all counties, except Riverside County, to screen for distance.  Some of the parcels in Riverside County were far from a rail line, but still under consideration due to their large size and their un-zoned designation.

These parcels were also a significant distance from the population—making them safer for industrial activity. The rail network was downloaded from 2013 TIGER/Line™ Shapefiles, and then clipped to the extent of each county (US Census Bureau 2013). A line was created from each of the potential site's centroids to the nearest point on the rail line. The geodesic (shortest possible) distance was measured in miles from the point to the rail line.

An exception was made for two points in Riverside County in which the nearest rail line was in the neighboring county of San Diego. Due to this, a line was drawn from those two points to the nearest rail line within the borders of Riverside County, which was over 20 miles away. Another exception was made in Northern Riverside County where the rail line had a distance of less than a tenth of a mile from the county border in the neighboring county of San Bernardino. Because the shortest distance to this rail line from the site centroid was 1.04 miles and the next nearest rail line was 2.75 miles away, a line was drawn to maintain the shortest distance.

*3.1.1 Establishing Point Data for Potential Sites*

After the initial three filters, each resulting parcel polygon was converted into a point using its centroid (center point of area). The resulting centroids along with their corresponding x, y coordinates and unique identifiers (FID) were displayed in a table in ArcMap. The distance from the 100 TNs to each of the centroids (potential sites) was determined using the Point Distance tool. This tool measures the distances from input point features to all of the points in the nearest features within an indicated search radius. A table was created with the distances between the two sets of points. Ventura County had a total of 5 potential sites, 7 in Orange County, 8 in Los Angeles County, and 14 within Riverside County resulting in a point distance table with 500, 700, 800, and 1400 entries respectively for each county (i.e. each point calculated against each of the 100 TNs).

## 3.2 Slope and Intersections

To determine the slope between the potential site centroids and the rail line, the lines were converted to a raster using the ArcGIS Feature to Raster tool using a one-degree digital elevation model (DEM) from the National Elevation Dataset (USGS 2014) (NIMA 2008). This tool converts features (such as points, lines, polylines, or polygons) into a raster dataset. The slope of each raster line was calculated using the slope tool and the overlay of ten-meter contour lines for the region. The slope tool calculates the maximum rate of change from each cell of a raster surface.

To determine the number of intersections made by the potential railroad, street layers for each county were added with the potential rail line layer. Each time the rail line crossed a primary or secondary road it was counted as one intersection. Dirt and unpaved roads were not counted as intersections.

## 3.3 School Proximity and Population

A layer showing K-12 schools for each of the five counties in the region was added to determine the score of the distance from the potential site to schools. Rings of concentric half-mile buffers (ten in total) were created using the Buffer tool in ArcMap to score the distance from the potential sites to a nearby school. If the site fell within one of the rings, it was scored accordingly to that ring's weight, (i.e. if it was within the first ring, it received a score of zero for being too close; if it was outside of the rings, it received a score of ten). The closer the site fell to a school, the lower its score for the school proximity variable. This was done for each of the counties.  An example map for Ventura County is shown below.  A table was created to show each of the sites and the score for the distance to a nearby school variable.

## 3.4 Truck VMT Reduction

Rahimi et al. (2011) show a potential reduction in truck VMTs with the initial placement of an inland port and the potential for additional reductions in truck VMTs with the subsequent placement of additional inland ports (see Figure 5 in section 3.2 and Figure 6 below).  Based on their analysis, six general areas in the 5-County region are identified.  These happen to sit in general in the counties of Los Angeles, Riverside, Orange, and Ventura.  However, potential sites should not be limited to these 4 counties.  Therefore, this study focuses on only those four counties that the areas are located in for the SSA (excluding San Bernardino County).  Not including San Bernardino County was a limitation of the current study and can be explored more in the future work.

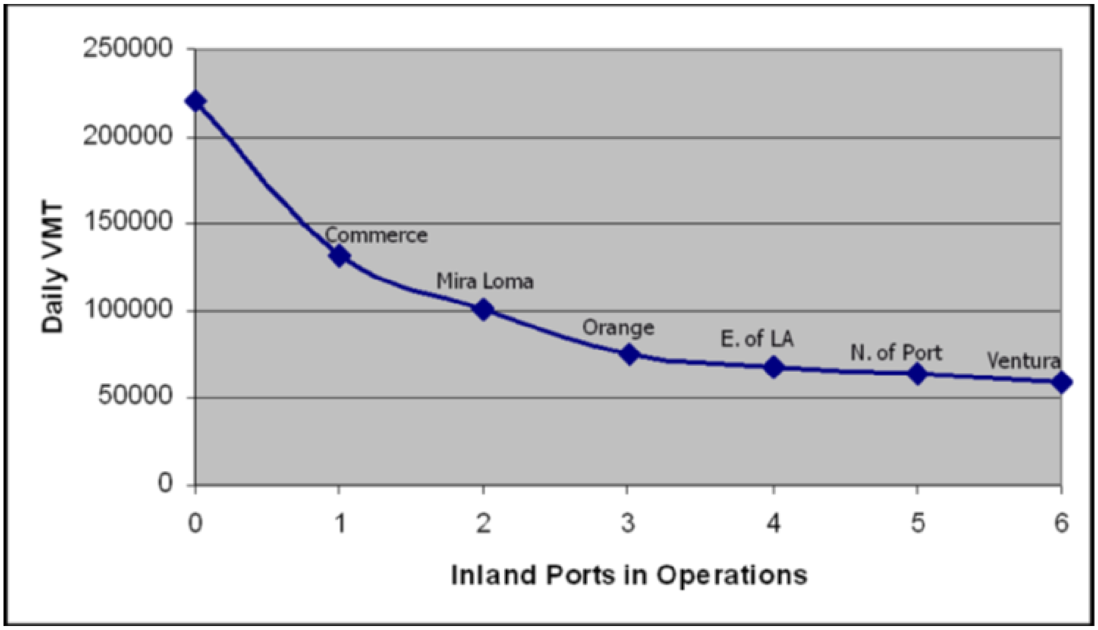


**Figure 6 Impact of Each Additional Inland Port (Rahimi et al. 2011 pg.44)**

The main goal of Rahimi et al. (2008) is to estimate the benefits gained from reduced truck VMT patterns using the placement of one or more inland ports (p. 362). To stay in line with this goal, during the screening step, Rahimi et al. (2008) completed an analysis to verify that none of the prospective sites would be likely to fall outside of the optimal truck VMT reduction areas identified for sites in each county. Truck VMT's were also incorporated into the SSA as a truck VMT variable for scoring after the candidate sites were identified.

During the screening step, the mean, range, average, and standard deviation was calculated for each site's geodesic distance measurements from the 100 TN's. These calculations were then used to conduct a difference of means test to find and compare the p-value between each site. The p-value determines the significance of the compared results. A difference of means test calculates how significant of a variance there is between a set of means. If the p-value from the test is greater than 0.05 (the null hypothesis), then the observations are highly probable to be the same, and in this case, are not likely to increase truck VMTs above the estimates in Rahimi et al.'s optimization model. None of the candidate sites located near the areas identified in Rahimi et al.'s study were significantly different than the mean of all sites in those areas.

## 3.5 Site Scoring

Once the potential sites had been selected and the variables were determined, scores had to be created for each of the sites. The scores for each site were determined using an overall percentage of the eight variables. Dividing the data for the majority of the variables was done in groups using natural breaks. The data is broken up into similar groups that maximize the differences between each class range (ESRI 2012). The final overall scores for the data were then converted into percentages.

### *3.5.1 Truck VMT Calculation and Scoring*

The truck VMT variable was scored using the following formula from the Rahimi et al. (2008) study:

$$Z = \sum_{i=0}^{m} w_i d(O, P_i)$$

In the equation, $i$ represents a TN. The number of TNs is denoted as $m$, the location of each TN is represented as $P_i$, and the weight of each TN is referred to as $w_i$. A choice of $O$ is a location for an inland port, and then $Z$ represents the optimal location for an inland port that minimizes the total cost of container movement (Rahimi, Asef-Vaziri, and Harrison 2008). The final truck VMT score for each of the sites were separated into groups using natural breaks, and then scored by group on a scale of one to ten. Table 2 below shows the range for each score and the number of sites in each score's range.

**Table 2 Truck VMT Variable Scores**

| VMT Score | VMT Range | Site Count |
|---|---|---|
| 10 | 66,127 - 84,572 | 2 |
| 9 | 130,955 - 151,513 | 4 |
| 8 | 189,530 - 316,288 | 5 |
| 7 | 322,039 | 1 |
| 6 | 476,970 - 655,636 | 6 |
| 5 | 768,794 - 863,280 | 4 |
| 4 | 1,022,141 - 1,721,156 | 5 |
| 3 | 2,189,936 - 2,372,887 | 3 |
| 2 | 2,901,952 - 3,359,700 | 2 |
| 1 | 13,630,112 - 15,146,058 | 2 |

### *3.5.2. Rail Feasibility Calculation and Scoring*

The rail feasibility score was comprised of three variables: distance from existing rail line score, intersection score, and slope score. The distance variable measures the geodesic distance between each potential site and the nearest existing rail line in miles. These distances were then separated into groups using natural breaks and scored on a scale of one to ten—with ten being close to an existing rail line and one being far from an existing rail line. Table 3 below displays the distance variable's scores and ranges.

**Table 3 Distance Variable Score and Range**

| Distance Score | Distance Range | Site Count |
|---|---|---|
| 10 | 0.01 - 0.45 | 2 |
| 9 | 1.05 - 1.47 | 3 |
| 8 | 1.67 - 1.96 | 3 |
| 7 | 2.30 - 2.36 | 4 |
| 6 | 2.88 - 3.09 | 4 |
| 5 | 3.85 - 4.50 | 6 |
| 4 | 5.72 | 1 |
| 3 | 12.32 - 15.20 | 5 |
| 2 | 16.05 - 19.12 | 4 |
| 1 | 21.34 - 22.70 | 2 |

The intersection score was based on the number of roads the potential rail line would cross between the site and the existing rail line. The higher the intersection count, the lower the final score for this variable. The data for this variable was also separated using natural breaks and then scored on a scale of one to ten. The scores and ranges for this variable are shown in Table 4 below.

**Table 4 Intersection Variable Score and Range**

| Intersection Score | Intersection Range | Site Count |
|---|---|---|
| 10 | 0 | 10 |
| 9 | 1 - 2 | 5 |
| 8 | 4 - 5 | 3 |
| 7 | 6 - 7 | 2 |
| 6 | 7 - 9 | 3 |
| 5 | 10 - 11 | 3 |
| 4 | 12 - 13 | 3 |
| 3 | 15 - 17 | 2 |
| 2 | 23 - 24 | 2 |
| 1 | 41 | 1 |

The slope score came from the slope of the potential rail line. This was based on the idea that the cost of building a rail line would increase with slope steepness. The slope of each raster intersected along a geodesic line created from each parcel centroid to a rail line was scored on a scale of one to ten with the data separated by natural breaks. The scores and ranges for the slope variable are shown in Table 5 below. The total score for rail line feasibility combined all three of these variables to get one score out of thirty.

**Table 5 Slope Variable Score and Range**

| Slope Score | Slope Range | Site Count |
|---|---|---|
| 10 | 0% | 10 |
| 9 | 1.1 - 1.4% | 6 |
| 8 | 4.10% | 1 |
| 7 | 5.0 - 5.1% | 3 |
| 6 | 5.6 - 5.9% | 2 |
| 5 | 6.7 - 7.3% | 2 |
| 4 | 8.1 - 8.6% | 4 |
| 3 | 9.3 - 10.5% | 4 |
| 2 | 12.9 - 14.0% | 2 |
| 1 | N/A | 0 |

### *3.5.3 School Proximity Calculation and Scoring*

The school proximity variable was scored based on quarter mile concentric buffers around schools in each county. If a potential site fell within one of the buffers it was scored accordingly. This was based on a scale of one to ten, a score of one was given if the site fell within the first buffer ring and a ten if it fell outside of the rings altogether (greater than 3.25 miles from a school). This score was the only variable not scored using Jenks natural breaks.

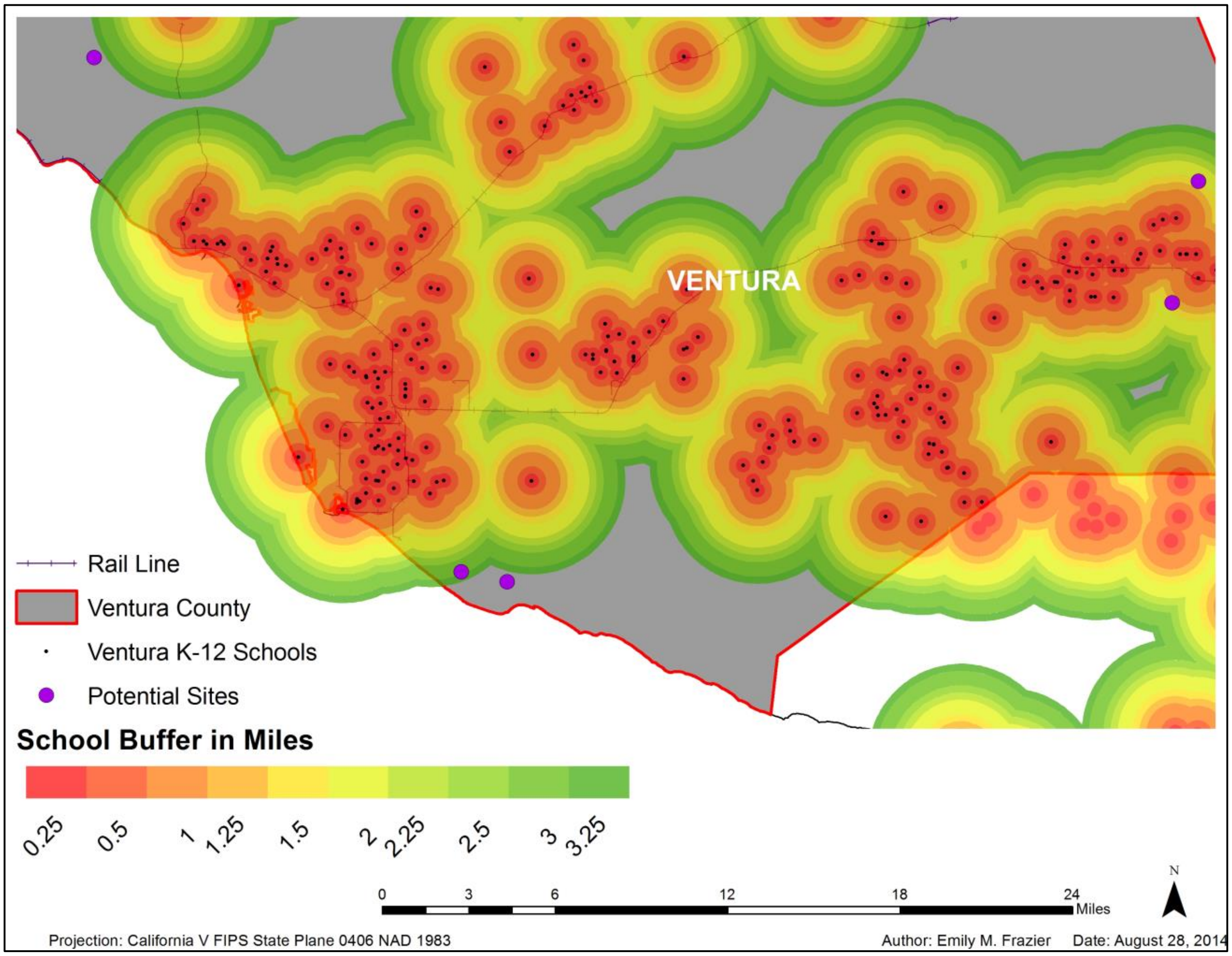


**Figure 7 Ventura County School Buffer**

*3.5.4. Population Density Calculation and Scoring*

The population density score was based on Census data derived from the census.gov website (US Census Bureau 2013). An arbitrary selection of a two-mile buffer range around each potential site was chosen and then overlain on top of the population data for each county. The data was then clipped using ArcMap's clipping tool to select only the data within the two-mile buffer range. The population data was normalized to account for the selected buffer size and from there the two-mile buffer population density around each potential site was produced. Below, Table 6 presents the population variable's scores and ranges. Natural breaks were used to score the sites in this variable. The high count of sites with a measurement of zero residents per square mile was due to those sites' location in desert areas or areas far from urban settings.

**Table 6 Population Scores and Range**

| Population Score | Population Range (residents per sq. mile) | Site Count |
|---|---|---|
| 10 | 0 | 15 |
| 9 | 0.001-7.497 | 1 |
| 8 | 7.498-19.12 | 2 |
| 7 | 19.13-123.7 | 2 |
| 6 | 123.8-323 | 5 |
| 5 | 323.1-401 | 0 |
| 4 | 401.1-420.6 | 2 |
| 3 | 420.7-1098 | 2 |
| 2 | 1099-1355 | 3 |
| 1 | 1356-3342 | 2 |

*3.5.5 Parcel Acreage Calculations and Scoring*

The parcel size score was based on the acreage of each individual parcel. The sizes as displayed in ArcMap had to be converted from square meters to acres using the calculate geometry tool in ArcMap. From there, the parcels were scored using natural breaks. Table 7 below displays the scores and ranges for the parcel size variable.

**Table 7 Parcel Size Scores and Range**

| Size Score | Size Range (in acres) | Site Count |
|---|---|---|
| 10 | 10,624 - 6,781 | 3 |
| 9 | 3,765 - 3,185 | 3 |
| 8 | 2,641 - 2,253 | 5 |
| 7 | 1,940 - 1,862 | 2 |
| 6 | 1,607 | 1 |
| 5 | 1,437 - 1,364 | 3 |
| 4 | 1,226 - 1,112 | 9 |
| 3 | 1,075 - 1,003 | 5 |
| 2 | 927 - 914 | 3 |
| 1 | N/A | 0 |

# Chapter 4: Results

The goal of this study is to identify and rank potential sites for the placement of an inland port in the Southern California region. This chapter examines the results of the SSA. Section 4.1 details the highest and lowest scoring sites overall and illustrates this with a series of maps. Section 4.2 documents some of the most influential variable results, including truck VMT reduction and rail line feasibility and section 4.3 discusses the scoring system and the issue of weighting.

## 4.1 Highest and Lowest Scoring Sites Overall

All of the sites in the region are shown in Figure 8 below along with their respective SSA scores. Close-ups of all of the sites by county can be found in the Appendix.

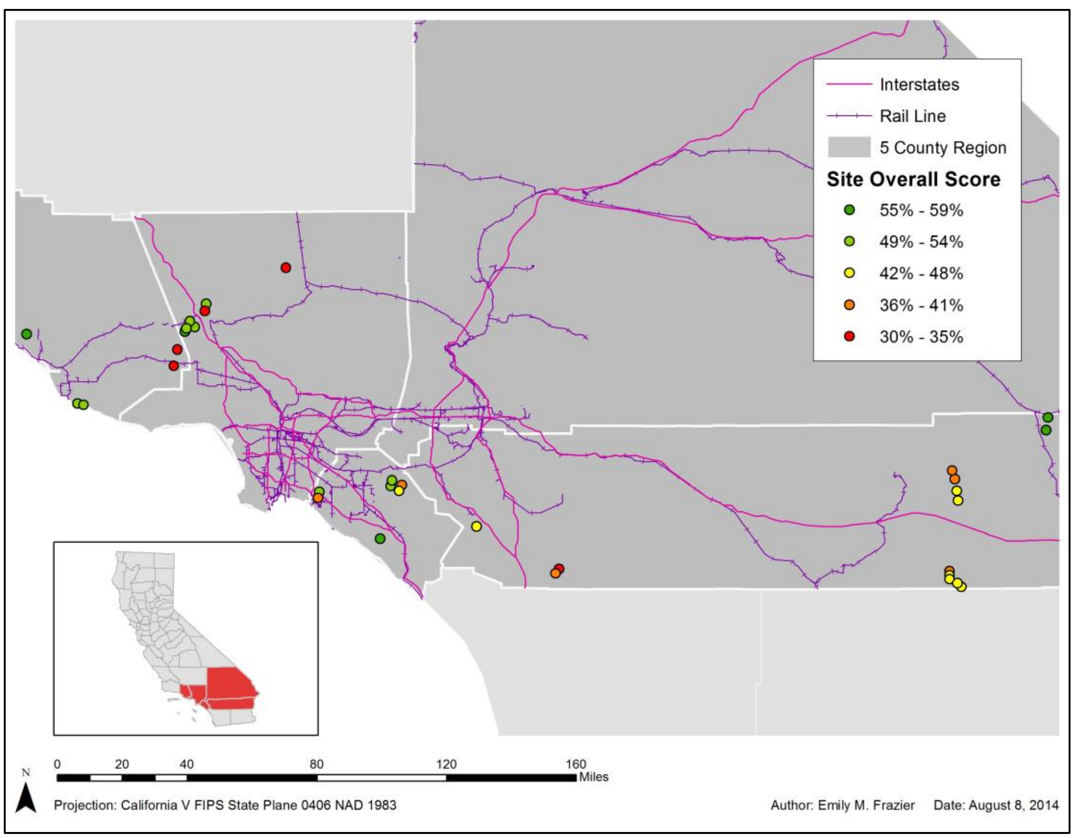


**Figure 8 All Potential Sites with Score Range**

Table 8 Final Overall Scores by County

| Point ID | County | Final Score |
|---|---|---|
| 4012 | Riverside | 59% |
| 3007 | Orange | 58% |
| 1001 | Ventura | 57% |
| 4013 | Riverside | 56% |
| 1004 | Ventura | 55% |
| 2006 | Los Angeles | 54% |
| 2002 | Los Angeles | 53% |
| 2004 | Los Angeles | 53% |
| 2003 | Los Angeles | 52% |
| 2007 | Los Angeles | 52% |
| 3002 | Orange | 52% |
| 1003 | Ventura | 51% |
| 3004 | Orange | 51% |
| 4001 | Riverside | 48% |
| 3003 | Orange | 47% |
| 4009 | Riverside | 46% |
| 3001 | Orange | 45% |
| 4002 | Riverside | 45% |
| 2001 | Los Angeles | 44% |
| 4006 | Riverside | 44% |
| 4008 | Riverside | 44% |
| 4005 | Riverside | 43% |
| 3005 | Orange | 42% |
| 4004 | Riverside | 41% |
| 4010 | Riverside | 41% |
| 4007 | Riverside | 39% |
| 3006 | Orange | 38% |
| 4003 | Riverside | 38% |
| 4014 | Riverside | 37% |
| 2005 | Los Angeles | 36% |
| 1002 | Ventura | 33% |
| 1005 | Ventura | 33% |
| 2008 | Los Angeles | 32% |
| 4011 | Riverside | 31% |

The scores for all of the variables were on a ten-point scale with natural breaks as a separator. Natural breaks are used to force the data into a set number of distinct groups. The overall scores were converted to percent for interpretation. A sensitivity analysis was attempted to show if there was a way to highlight the importance of certain variables over others. Weighting these variables was difficult and subjective. The decision to exclude weighted scores was made for this specific reason.

Due to their relatively high variance, the site scores for 'feasibility of rail line' and 'population density' variables contributed the most to the final score. The top three sites were in Riverside, Orange, and Ventura Counties with overall scores of 59%, 58%, and 57%, respectively. Close-up maps of the potential sites and their overall scores for each individual county are located in the Appendix.

The best site for the 'rail line feasibility' variable is site 3007 located in Orange County with an overall score of 58%. The lowest scoring site is site 4011 located in Riverside County with a score of 31%. The best sites for the 'distance from schools' variable are located in multiple counties. The lowest scoring sites were located within a half-mile (less than 3,000 feet) from a school. The best site for the 'parcel size' variable were sites 2007, 2006, and 2004 all located in Los Angeles County with sizes of 10,624 acres, 8,539 acres, and 6,781 acres respectively. The lowest scoring sites for this variable were 2005 at 915 acres and site 3001 in Orange County at 921 acres.

The population was measured by calculating the population density of a two-mile radius around potential sites. Some sites were located close together so the population density of a two-mile radius of the conglomerate of potential sites on those areas was used. All of the sites that scored high for this variable had nearby populations of zero residents. The lowest scoring sites for the population variable were located in Orange County (sites 3005 and 3006), both with population densities of over 3,000 residents per square mile. The scores and ranges for this variable are located in Table 4 below.

**Table 9 Population Variable Score and Range**

| Population Score | Population Range | Site Count |
|---|---|---|
| 10 | 0 | 15 |
| 9 | 0.001-7.497 | 1 |
| 8 | 7.498-19.12 | 2 |
| 7 | 19.13-123.7 | 2 |
| 6 | 123.8-323 | 5 |
| 5 | 323.1-401 | 0 |
| 4 | 401.1-420.6 | 2 |
| 3 | 420.7-1098 | 2 |
| 2 | 1099-1355 | 3 |
| 1 | 1356-3342 | 2 |

The best site for Los Angeles County is 2006. The worst site for Los Angeles County is 2008. The main contributing factor of this site's final score was the number of intersections crossing the potential rail line and its high population surrounding the site.

The best site for Orange County is 3007. The main contributing factor of this site's final score was distance to an existing rail line. The worst site for Orange County is 3006, which was due to the site's smaller size and population score. The best site for Riverside County is 4012, and this is also the best site overall. The main contributing factor of this site's final score was distance to an existing rail line. The worst site for Riverside County is 4011, which is also the worst site overall with a final score of 31%. The best site for Ventura County is 1001. The worst site for Ventura County is 1005 and 1002, both with an overall score of 33%; the main contributing factor of these sites' final scores was the population density variable and their small size.

## 4.2 Influential Variable Results

After reviewing the un-weighted results of the variable scores, the 'rail line feasibility' variable seemed to be determinative of the final score and site ranking. A sensitivity test was conducted by weighting every variable except the rail feasibility variable by two to see if there was a major difference in the overall score. Additionally, removing the feasibility score altogether had a similar effect on the sites that scored high for the truck VMT variable. This came to be a problem since the most important variable for this study is reducing truck VMTs. This score takes the weights used by the 100 TNs and the distance in miles between the 100 TNs and each potential site. This shows which sites were on average closer to areas where trucks made trips to most often.

The lower the weighted average distance for the site, the more suitable that site would be in regards to truck VMTs. To lower truck VMTs, the distance between the potential site and populated areas would have to lower as well. This is opposite in the case of the school variable. To raise the population density and school variable scores, the distance between the potential site and populated areas would correspondingly have to rise as well. The proximity to schools score is an important variable but it corresponds closely to population density and because many of the sites that were far from densely populated areas, many sites received favorable scores on this variable as well.

None of the sites scored higher than 60% overall, indicating the need to either reconsider some of the variables chosen or incorporate other variables that may contribute to a more in-depth SSA.

# Chapter 5: Discussion and Conclusion

In this study, a site suitability analysis was conducted to determine the feasibility of placing an inland port in the Southern California Region. Eight variables were used including: distance from the nearest rail line, number of intersections, slope, overall rail line feasibility, proximity to schools as a proxy for childhood exposure, parcel size, population, and vehicle miles travelled (VMTs). These variables provided a more comprehensive look at placing a large industrial facility in a predominantly urban region. It was determined that it is extremely difficult to score favorably on all of the chosen variables in a densely populated region. Many issues such as pollution caused by increased industrial activity and space necessary for expansion arose when analyzing final scores.

## 5.1 Assumptions and Limitations

With this study, a few assumptions had to be made to analyze and interpret the results and limitations had to be placed while conducting the SSA. The first assumption was of equal weighting. Each variable was weighted equally in the SSA to simply show how each factor scored overall. Some variables, such as the population or school proximity, may matter more to the public while variables like distance from an existing rail line (which has financial implications) may matter more to decision makers. Every variable had the potential of receiving subjective weights, but this method would not have been as straight forward as the one chosen.

Secondly, the basis of this study is not on a network analysis. Network analysis details specific aspects of travel such as particular roads trucks may or may not be able to use when carrying cargo, exact distances for truck VMTs based on the existing road network, and where rail pollution may occur when placing rail lines in the region. A network analysis would not use geodesic distances for calculations, instead, this type of analysis has the ability to show exact distances for travel on specified road networks giving a much more detailed view of truck VMTs. In addition, a network analysis could give a much more detailed view of the potential for the redistribution of truck and rail miles and resulting shifts in populations exposed to localized air pollution.

Restricting the pre-screen process to only a few large parcels to use in the SSA instead of an aggregation of many small parcels limited the potential site locations in the region. Although a conglomerate of parcels is a possibility, this study assumes this option is fixed. It is possible, however, to select multiple available parcels for industrial use with the idea of eminent domain in mind.

## 5.2 Future Work

Future studies and additional research can remedy some of the issues that arose while conducting this study and analyzing the SSA. By focusing on each of the assumptions and limitations, future work can improve upon this study.

Conducting a public survey is one way of solving the weighting issue. A survey would be able to ask questions specifically for the public in terms of what is most important to them when it comes to the placement of an industrial facility. Another survey can be made for decision makers that could detail what aspects are important when it comes to financial and labor costs or even preferred areas to build this type of facility. With the surveys, other variables that may not have been included in the current study's SSA can be added and some that may not be important to neither the public nor the decision makers can be left out altogether; this way, efforts and research centers on what matters most to placing an inland port in the Southern California region.

Conducting a network analysis for current truck travel as well as an analysis on potential rail line placement is an option for future work. This would give specific numbers in terms of distances and rail line length for decision makers to calculate precise costs. It would also give a more comprehensive look at the transportation network for the region and may make policy related decisions much easier when it comes to where things can and cannot be built in the region.

The idea of eminent domain being a more difficult option for decision makers was assumed for this study. Future work could take on the approach of selecting multiple parcels for acquisition to meet the ideal size requirement for an inland port. With this method, selecting an area further away from the population and considering expansion possibilities would be less problematic.

The current study's analysis excludes San Bernardino County and San Diego County. Although there were several transportation nodes in San Bernardino County as indicated by the Rahimi et al. (2008) study, excluding the county as a whole was due to the likelihood that placement of an inland port in that most of that county would not do much to reduce truck VMTs overall. Also, when it came to San Bernardino County, the amount of data was extensive and difficult to add to the existing analysis due to its size. In spite of these reasons, some areas of San Bernardino County are close enough to the Thiessen polygon's identified in the Rahimi et al. (2008) report that including it could lead to more possibilities for sites. Given the county's lower population density in some areas, it may be a practical option when it comes to protecting the population for industrial air pollution.

The Rahimi et al. (2008) study does not define San Diego County as being a part of the Southern California region. There is an implicit assumption that San Diego County has its own port and is not a part of the POLA-POLB service area. However, but according to the data obtained from the Rahimi et al. (2008) study, there is a significant amount of imports shipped out of POLA and POLB to cities in San Diego County. Including San Diego County will similarly open up opportunities for sites and even more possibilities for improving upon the transportation network since much of San Diego is well connected to the Los Angeles Metropolitan area.

Finally, addressing the pollution issue for the region is important when it comes to future industrial activity. Endresen et al. (2003) detail the types of emissions prevalent in international sea transportation and assess the environmental impacts of each. Reducing emissions of one pollutant may not be enough to improve air quality around the ports and the environment within the region. It is crucial to determine which pollutants are the most severe and what is involved in bringing about the greatest environmental improvements around the ports (Endresen et al. 2003). Doing this would require an in depth environmental analysis, which is not included in the current study. Further research is necessary to determine methods in which identifying these pollutants and reducing their overall impact is key.

## 5.3 Conclusion

This research and analysis for this study reaches three main conclusions. First, a site suitability analysis is needed when it comes to analyzing a multitude of variables and selecting a proper site for an inland port in an urban setting. There is no other effective way of addressing multiple variables all at once in a spatial manner that can conclusively determine proper (or improper) locations for industrial activity to take place. Conducting a SSA allows decision makers to review all possible effected factors when it comes to whether or not the region will benefit from an inland port as well as who and what will be effected by its placement.

Secondly, minimizing overall vehicle miles travelled in the region is possible with the placement of an inland port connected to the seaports via rail. There are places within the region that, if connected by rail, would help in reducing truck VMTs—which was a key point in the Rahimi et al. (2011) report. Knowing this, allows decision makers to take the additional step of evaluating the importance of improving upon the current transportation system with the environment and the public in mind. Simply making transportation and cargo movement easier on private companies is not always going to be enough.

Lastly, although many sites scored high in some of the variables, overall there is no optimal site—according to the variables chosen, for an inland port in the Southern California region. Further research in this area must be done because the population is continuously expanding and the need for a more efficient transportation system is only going to grow.

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# Appendix

## A 1.1 Maps of Potential Sites and Scores by County

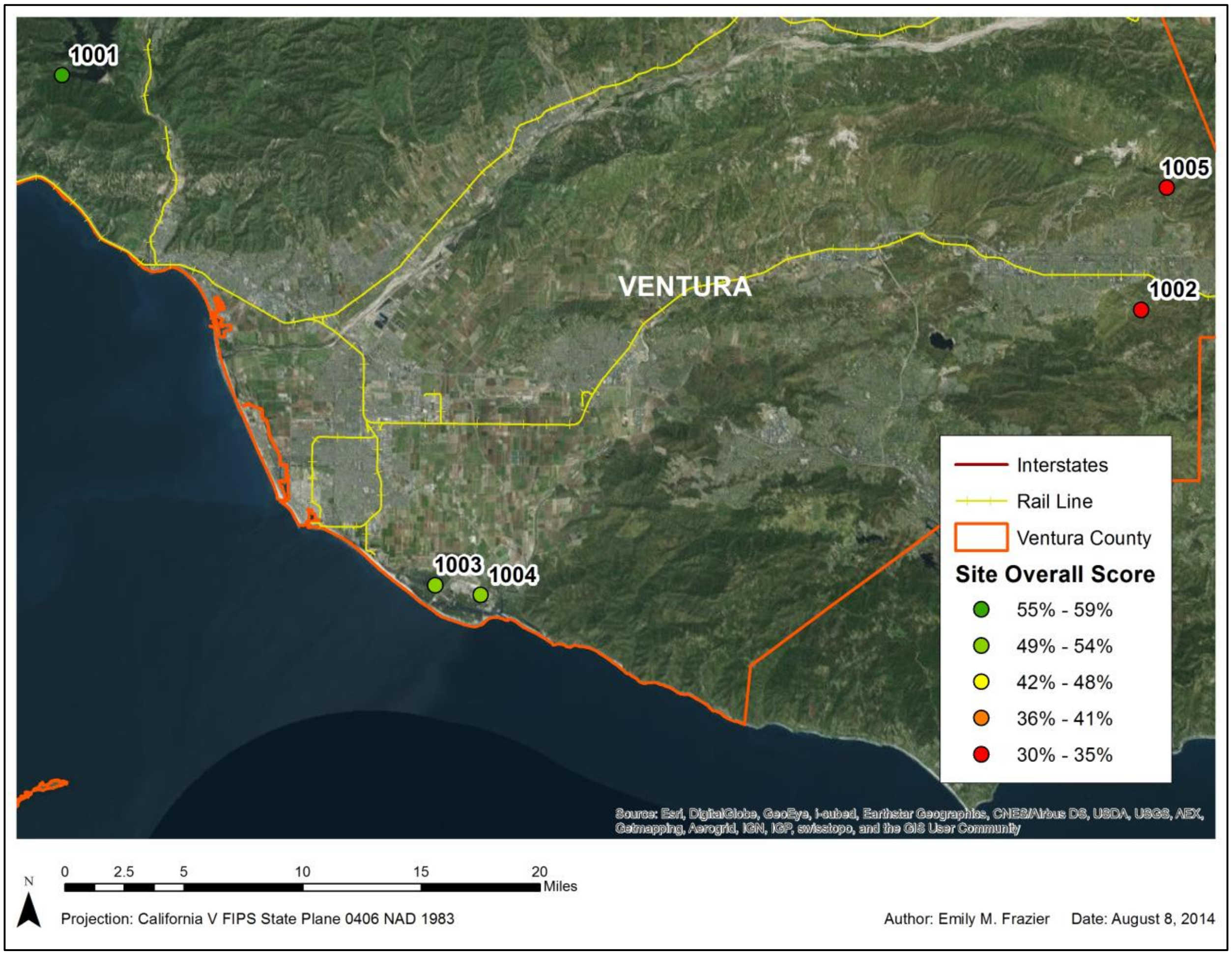


**Figure 9 Ventura County Potential Sites**

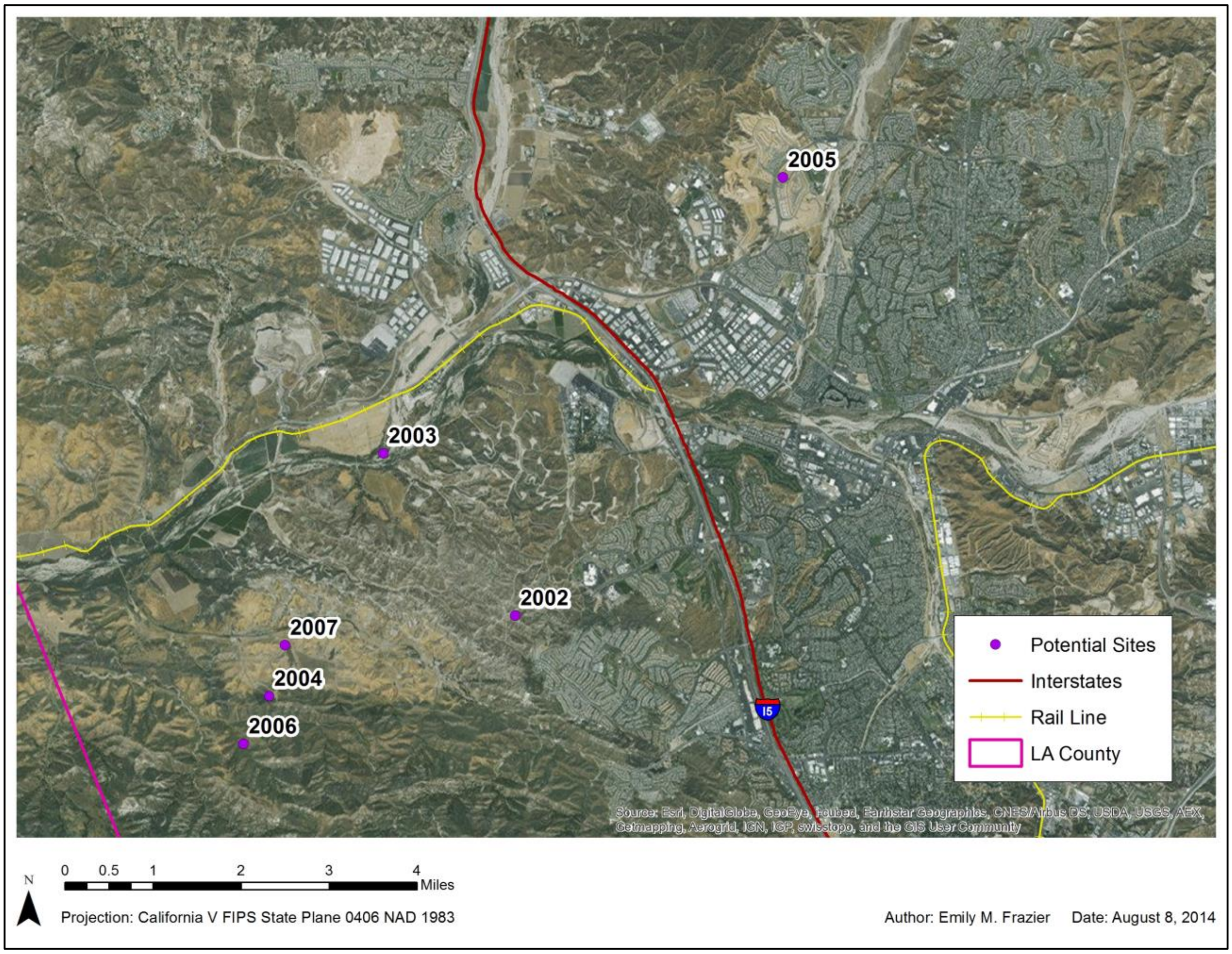


**Figure 10 Los Angeles County West Potential Sites**

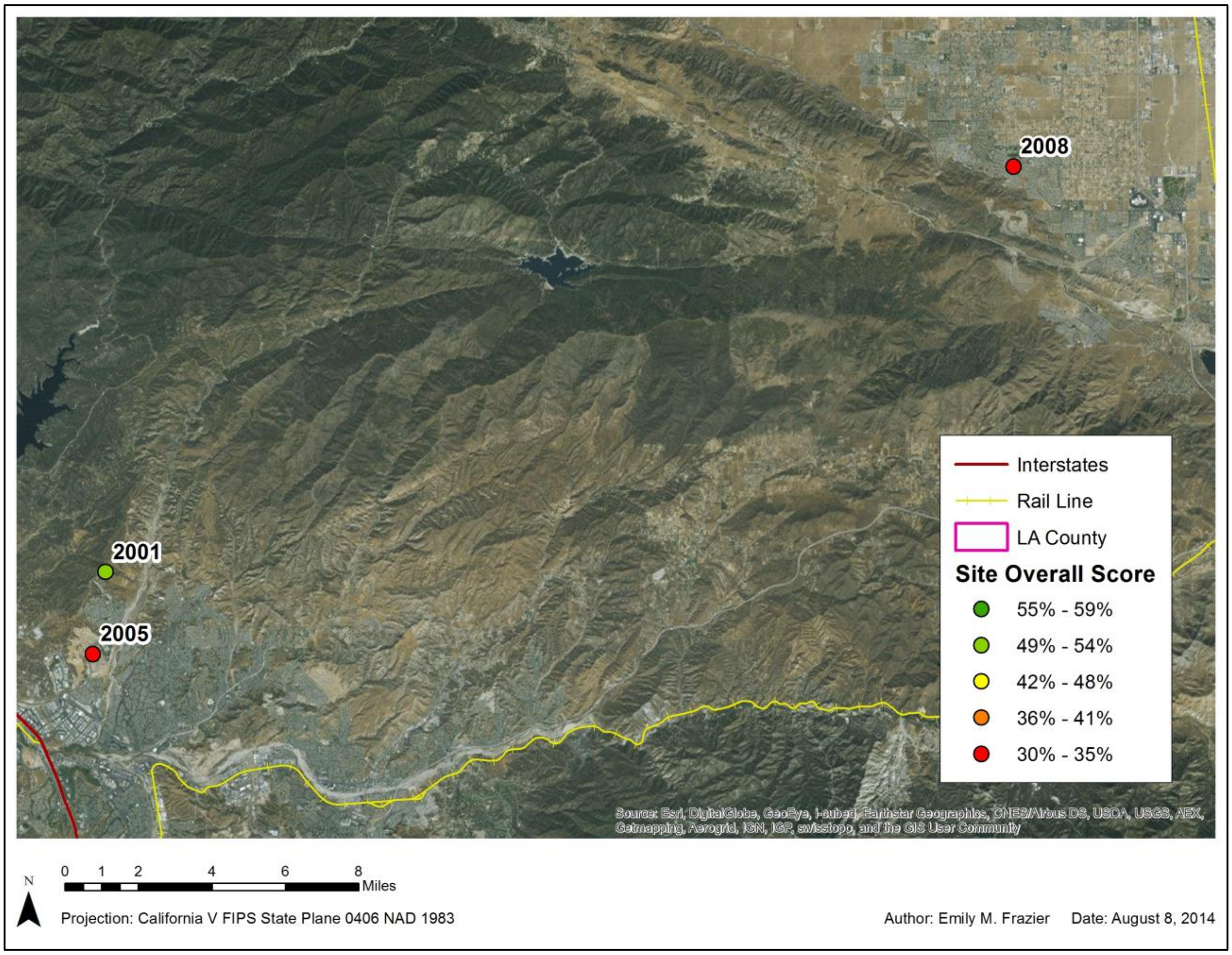


**Figure 11 Los Angeles County East Potential Sites**

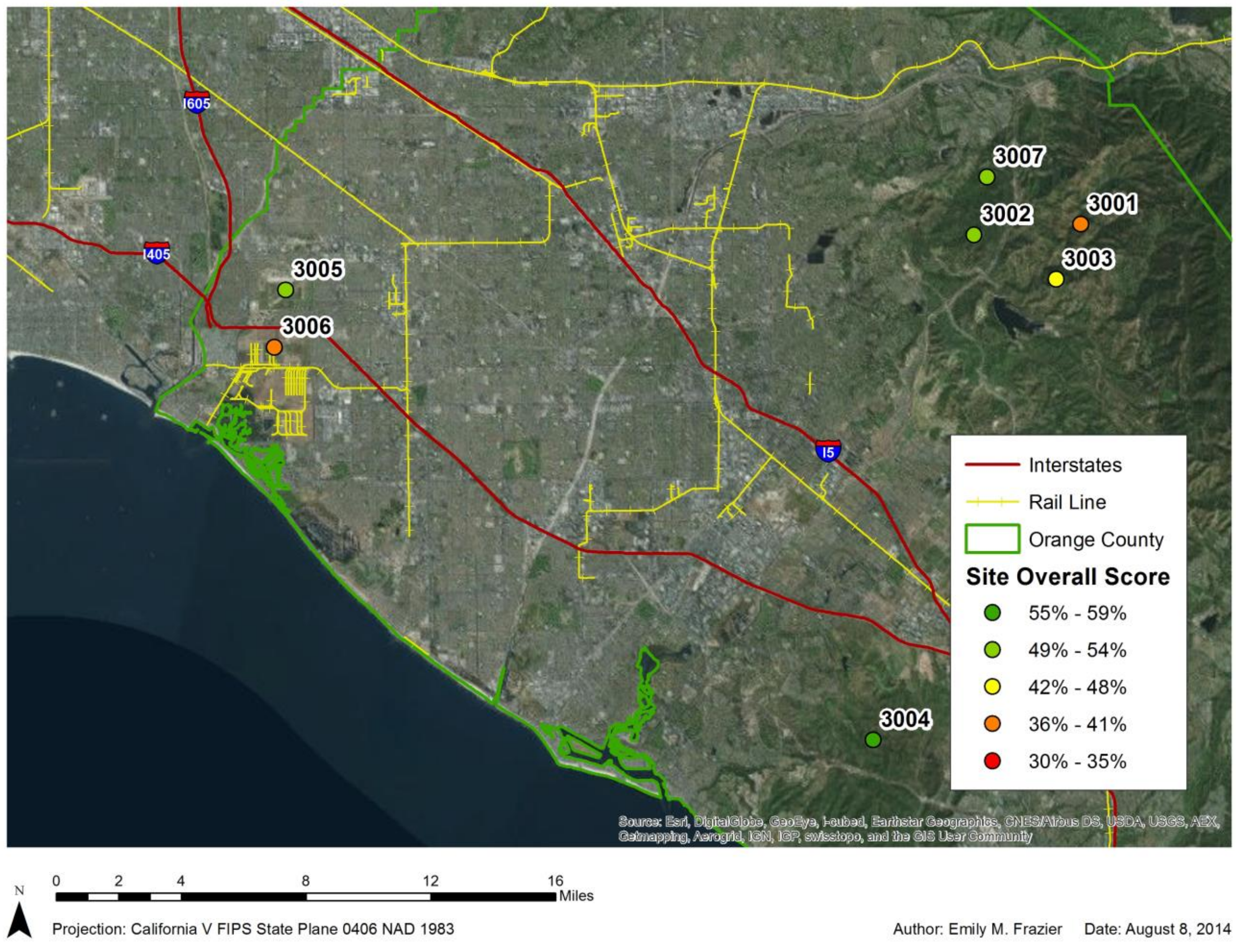


**Figure 12 Orange County Potential Sites**

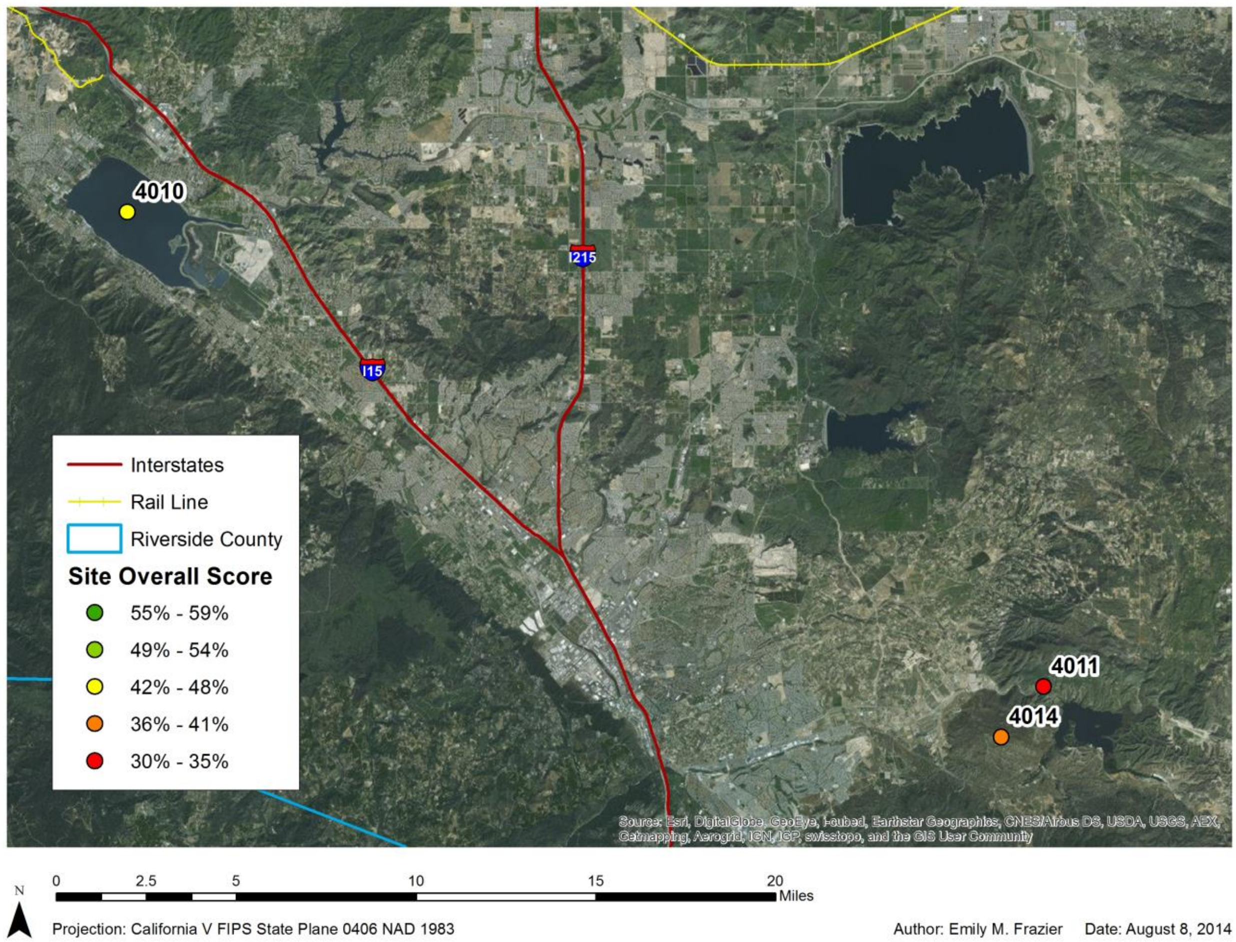


**Figure 13 Riverside County West Potential Sites**

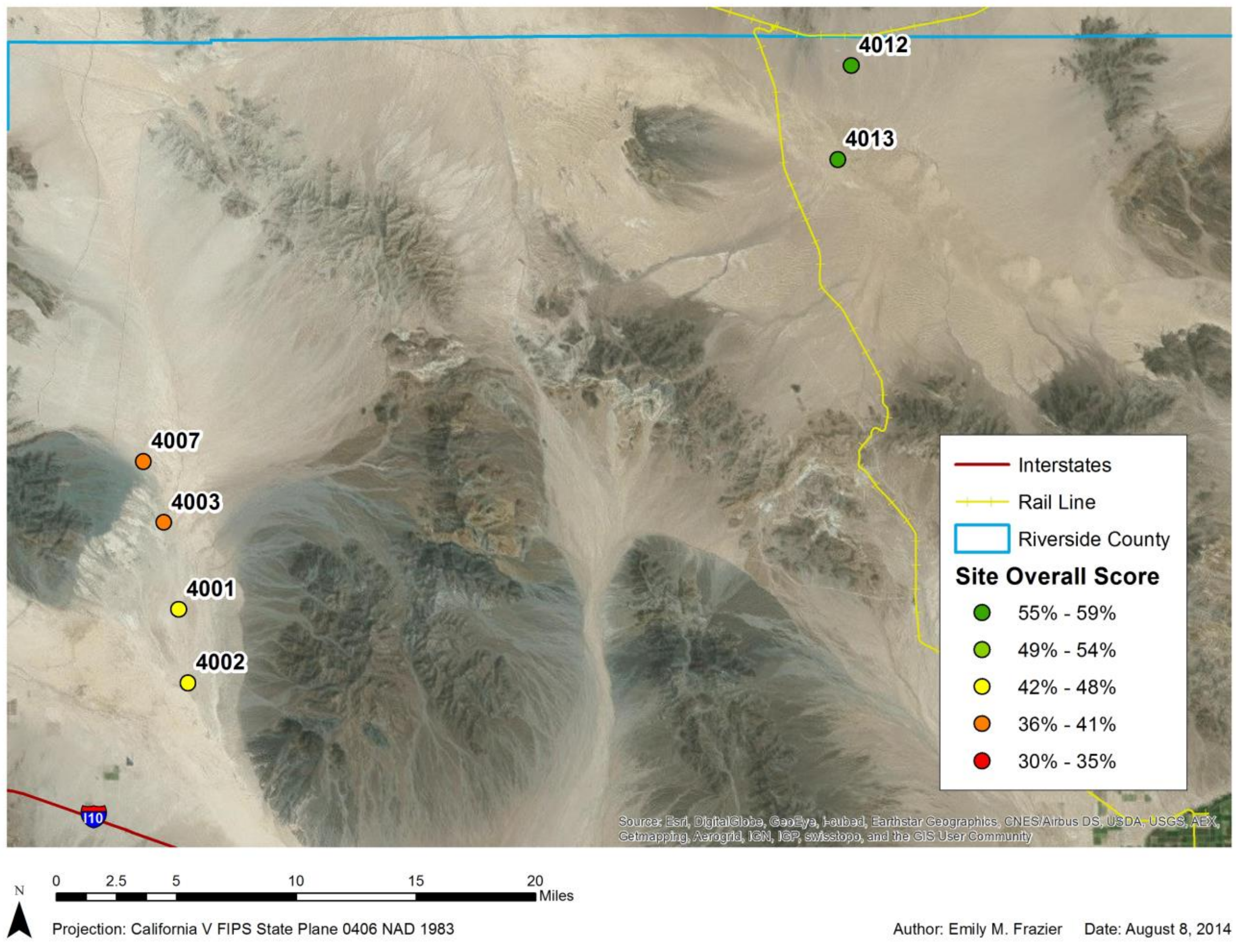


**Figure 14 Riverside County East Potential Sites**

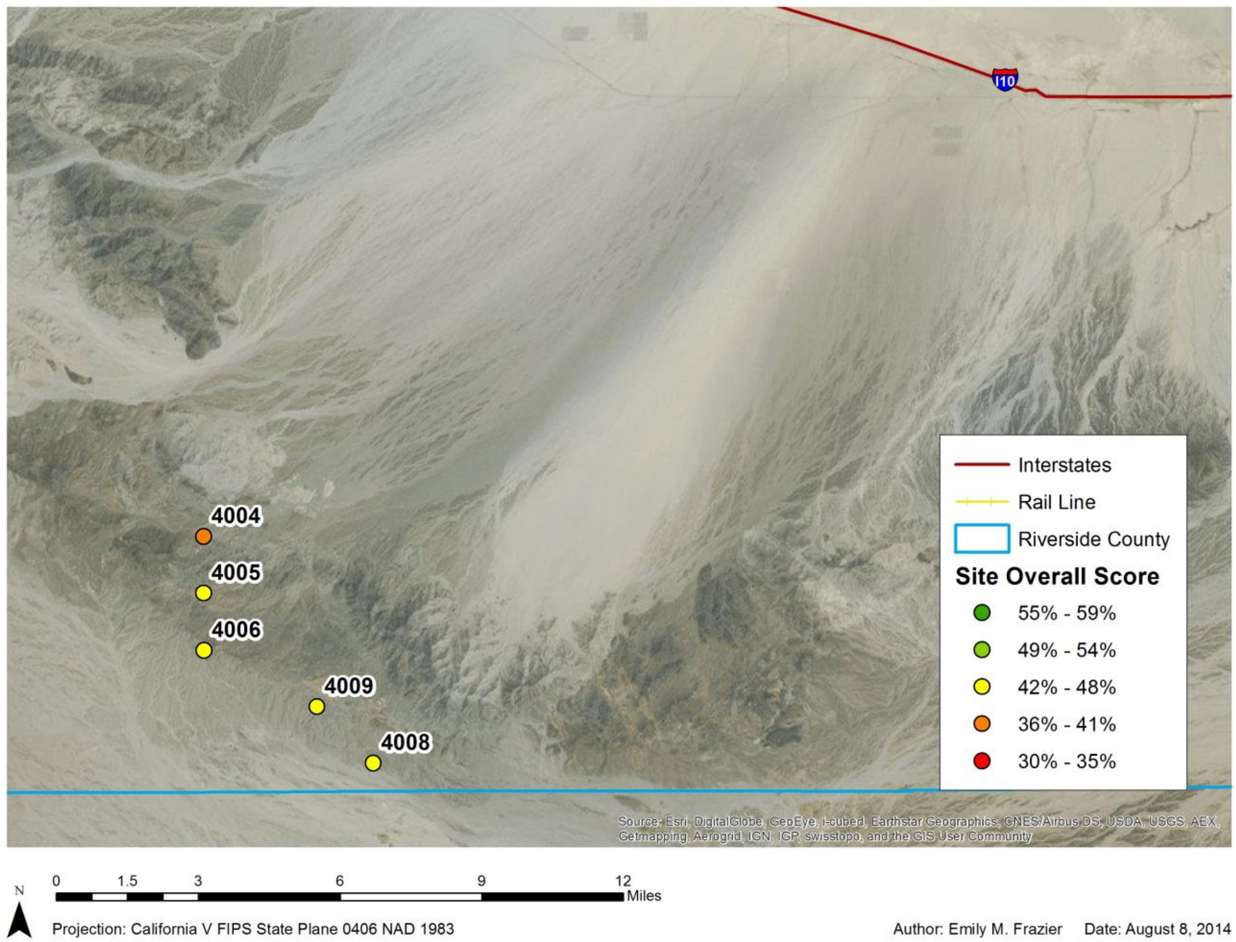


**Figure 15 Riverside County South East Potential Sites**

# A 1.2 Table of Final Variable Scores

**Table 10 Final Variable Scores**

| Point ID | County | Distance Score | Intersection Score | Slope Score | Proximity Score* | School Score | Size Score | Population Score | Truck VMT Score | **Total Score** |
|---|---|---|---|---|---|---|---|---|---|---|
| **4012** | Riverside | 9 | 9 | 10 | 28 | 10 | 8 | 10 | 3 | **59%** |
| **1001** | Ventura | 6 | 8 | 10 | 24 | 10 | 8 | 9 | 6 | **57%** |
| **1004** | Ventura | 5 | 8 | 9 | 22 | 10 | 8 | 7 | 8 | **55%** |
| **3007** | Orange | 10 | 10 | 10 | 30 | 5 | 4 | 10 | 9 | **58%** |
| **2006** | Los Angeles | 7 | 8 | 7 | 22 | 10 | 10 | 6 | 6 | **54%** |
| **4013** | Riverside | 8 | 10 | 10 | 28 | 10 | 4 | 10 | 4 | **56%** |
| **4001** | Riverside | 3 | 6 | 3 | 12 | 10 | 9 | 10 | 7 | **48%** |
| **2007** | Los Angeles | 8 | 9 | 5 | 22 | 10 | 10 | 6 | 4 | **52%** |
| **3002** | Orange | 5 | 10 | 7 | 22 | 8 | 9 | 10 | 3 | **52%** |
| **2002** | Los Angeles | 7 | 9 | 9 | 25 | 6 | 7 | 6 | 9 | **53%** |
| **2004** | Los Angeles | 8 | 9 | 8 | 25 | 10 | 10 | 6 | 2 | **53%** |
| **3004** | Orange | 4 | 10 | 7 | 21 | 10 | 7 | 4 | 9 | **51%** |
| **4009** | Riverside | 1 | 10 | 3 | 14 | 10 | 4 | 10 | 8 | **46%** |
| **4002** | Riverside | 3 | 5 | 4 | 12 | 10 | 9 | 10 | 4 | **45%** |
| **1003** | Ventura | 7 | 9 | 9 | 25 | 9 | 4 | 7 | 6 | **51%** |
| **3003** | Orange | 5 | 2 | 10 | 17 | 7 | 4 | 10 | 9 | **47%** |
| **2003** | Los Angeles | 10 | 10 | 9 | 29 | 8 | 6 | 6 | 3 | **52%** |
| **4006** | Riverside | 2 | 10 | 3 | 15 | 10 | 4 | 10 | 5 | **44%** |
| **4008** | Riverside | 1 | 10 | 4 | 15 | 10 | 4 | 10 | 5 | **44%** |
| **4005** | Riverside | 2 | 10 | 3 | 15 | 10 | 4 | 10 | 4 | **43%** |
| **3001** | Orange | 6 | 4 | 10 | 20 | 5 | 2 | 10 | 8 | **45%** |
| **2001** | Los Angeles | 5 | 4 | 9 | 18 | 9 | 5 | 2 | 10 | **44%** |
| **4004** | Riverside | 2 | 10 | 4 | 16 | 10 | 4 | 10 | 1 | **41%** |
| **4007** | Riverside | 3 | 7 | 2 | 12 | 10 | 3 | 10 | 4 | **39%** |
| **4010** | Riverside | 6 | 2 | 10 | 18 | 4 | 8 | 3 | 8 | **41%** |
| **4003** | Riverside | 3 | 7 | 2 | 12 | 10 | 5 | 10 | 1 | **38%** |
| **3005** | Orange | 5 | 6 | 10 | 21 | 7 | 3 | 1 | 10 | **42%** |
| **4014** | Riverside | 2 | 4 | 5 | 11 | 4 | 8 | 8 | 6 | **37%** |
| **3006** | Orange | 9 | 5 | 10 | 24 | 3 | 2 | 1 | 8 | **38%** |
| **4011** | Riverside | 3 | 3 | 4 | 10 | 5 | 3 | 8 | 5 | **31%** |
| **2005** | Los Angeles | 7 | 5 | 9 | 21 | 6 | 2 | 2 | 5 | **36%** |
| **1005** | Ventura | 6 | 3 | 6 | 15 | 5 | 3 | 4 | 6 | **33%** |
| **2008** | Los Angeles | 5 | 1 | 10 | 16 | 2 | 5 | 3 | 6 | **32%** |
| **1002** | Ventura | 9 | 6 | 6 | 21 | 5 | 3 | 2 | 2 | **33%** |

*Combined score of distance, intersection, and slope variables.

## A 1.3 Table of Potential Site Statistics

**Table 11 Final Site Statistics**

| Point ID | County | Distance | Intersections | Slope | Size | Population Density | Truck VMT |
|---|---|---|---|---|---|---|---|
| **1001** | Ventura | 3.08 | 4 | 0.0% | 2253 | 7.5 | 637,163 |
| **1002** | Ventura | 1.22 | 7 | 5.6% | 1056 | 1341.7 | 3,359,700 |
| **1003** | Ventura | 2.34 | 1 | 2.4% | 1158 | 123.7 | 655,637 |
| **1004** | Ventura | 3.94 | 5 | 2.1% | 2443 | 123.7 | 199,318 |
| **1005** | Ventura | 3.09 | 17 | 5.9% | 1049 | 420.6 | 476,971 |
| **2001** | Los Angeles | 3.85 | 13 | 1.4% | 1388 | 1355.2 | 84,573 |
| **2002** | Los Angeles | 2.36 | 2 | 2.0% | 1862 | 323.0 | 135,703 |
| **2003** | Los Angeles | 0.45 | 0 | 2.0% | 1607 | 323.0 | 2,372,888 |
| **2004** | Los Angeles | 1.96 | 2 | 4.1% | 8539 | 323.0 | 2,901,953 |
| **2005** | Los Angeles | 2.33 | 11 | 1.1% | 914 | 1355.2 | 768,795 |
| **2006** | Los Angeles | 2.30 | 4 | 5.1% | 6781 | 323.0 | 535,285 |
| **2007** | Los Angeles | 1.67 | 1 | 6.7% | 10624 | 323.0 | 1,022,141 |
| **2008** | Los Angeles | 4.50 | 41 | 0.0% | 1364 | 1023.4 | 505,971 |
| **3001** | Orange | 2.88 | 12 | 0.0% | 921 | 0.0 | 234,651 |
| **3002** | Orange | 4.20 | 0 | 5.0% | 3765 | 0.0 | 2,361,172 |
| **3003** | Orange | 4.50 | 24 | 0.0% | 1135 | 0.0 | 141,743 |
| **3004** | Orange | 5.72 | 0 | 5.0% | 1940 | 401.0 | 151,513 |
| **3005** | Orange | 4.07 | 8 | 0.0% | 1003 | 3341.6 | 66,128 |
| **3006** | Orange | 1.47 | 10 | 0.0% | 927 | 3341.6 | 239,182 |
| **3007** | Orange | 0.01 | 0 | 0.0% | 1226 | 0.0 | 130,956 |
| **4001** | Riverside | 13.05 | 9 | 10.0% | 3569 | 0.0 | 322,039 |
| **4002** | Riverside | 13.88 | 10 | 8.6% | 3185 | 0.0 | 1,548,284 |
| **4003** | Riverside | 12.56 | 6 | 12.9% | 1437 | 0.0 | 13,630,112 |
| **4004** | Riverside | 18.22 | 0 | 8.1% | 1112 | 0.0 | 15,146,059 |
| **4005** | Riverside | 18.65 | 0 | 10.5% | 1112 | 0.0 | 1,314,159 |
| **4006** | Riverside | 19.12 | 0 | 9.3% | 1120 | 0.0 | 776,267 |
| **4007** | Riverside | 12.32 | 7 | 14.0% | 1036 | 0.0 | 1,721,156 |
| **4008** | Riverside | 22.70 | 0 | 8.4% | 1112 | 0.0 | 863,280 |
| **4009** | Riverside | 21.34 | 0 | 9.5% | 1115 | 0.0 | 316,289 |
| **4010** | Riverside | 3.09 | 23 | 0.0% | 2384 | 1097.6 | 189,530 |
| **4011** | Riverside | 15.20 | 15 | 8.3% | 1075 | 19.1 | 774,240 |
| **4012** | Riverside | 1.05 | 1 | 0.0% | 2568 | 0.0 | 2,189,936 |
| **4013** | Riverside | 1.90 | 0 | 0.0% | 1128 | 0.0 | 1,168,021 |
| **4014** | Riverside | 16.05 | 13 | 7.3% | 2641 | 19.1 | 520,819 |