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MTI MINETA TRANSPORTATION INSTITUTE

Should State Land in Southern California Be Allocated to Warehousing Goods or Housing People? Analyzing Transportation, Climate, and Unintended Consequences of Supply Chain Solutions

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Report 23-35

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16. Abstract
In response to COVID-19 pandemic supply chain issues, the State of California issued Executive Order (EO) N-19-21 to use state land to increase warehousing capacity. This highlights a land-use paradox between economic and environmental goals: adding warehouse capacity increases climate pollution and traffic congestion around the ports and warehouses, while there is a deficit of affordable housing and high homeless rates in port-adjacent underserved communities. This study aims to inform regional policymakers and community stakeholders about these trade-offs by identifying current and future supply of and demand for warehousing and housing in Southern California through 2040. The study uses statistical analysis and forecasting, and evaluates across numerous scenarios the environmental impact of meeting demand for both with the Community LINE Source Model. Warehousing and housing are currently projected to be in high demand across Southern California in future decades, despite short-run adjustments in the post-pandemic period of inflation and net declines in population. Using state land for warehousing creates environmental justice concerns, as the number of air pollution hotspots increases even with electrifying trucking fleets, especially when compared against low-impact affordable housing developments. However, low-income housing demand appears to be positively correlated with unemployment, suggesting that the jobs provided by warehousing development might help to ameliorate that concern.

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Executive Summary

The COVID-19 pandemic revealed limitations in California's supply chain resiliency. In response, Executive Order (EO) N-19-21 proposed the use of state land to increase warehousing capacity. However, this revealed a land-use paradox between economic and environmental goals: adding warehouse capacity increases climate pollution and traffic congestion around ports and warehouses. It also raises questions about whether state land could be used for purposes of affordable housing and serving the homeless in port-adjacent underserved communities.

This study informs regional policy makers, transportation planners, community interest groups, and business stakeholders about the trade-offs between housing and warehousing when considering both economic and environmental impacts. It uses regression analysis, time-series forecasting, and literature review to estimate current and future supply and demand of warehousing and housing in Southern California through 2040 across a number of forecast scenarios. These projections are then used to evaluate the environmental impact of meeting demand across three key warehousing traffic pollution scenarios: (1) warehousing in the N-19-21 policy, (2) warehousing development to meet 2040 demand, and (3) warehousing development using state land at different levels and comparable scenarios for affordable housing development using the Community LINE Source Model, a community-based tool, to characterize roadway air pollution emissions.

This analysis finds that Los Angeles County and Orange County are expected to face supply shortfalls in four of the six scenarios we considered. The unmet demand for warehouses in Los Angeles County and Orange County will be mostly taken by Inland Empire (a metropolitan area consisting of Riverside and San Bernardino). Despite warehouse moratoria enacted by some Inland Empire cities, Inland Empire is expected to increase its share of warehouse space by 2% by 2040. Considering the impact of warehouse moratoria, the earliest time for aggregate warehouse demand exceeding supply in the Southern California Association of Governments (SCAG) region could fall in Q1 2028.

In terms of housing, a number of metrics suggest that California has a shortage of housing units overall and of affordable or low-income units. Despite recent State population declines, Southern California has a projected annual deficit of 120,000 housing units, based on a national regression of state-level housing per capita using 2040 county population projections. Over the past decade, new state-level housing development has averaged 73,000 overall and 10,000 affordable units. Low-income housing appears to be particularly influenced by the unemployment rate across Southern California regions, suggesting that focusing on employment opportunities is an effective approach to address this concern.

Looking at environmental impacts, we confirm prior environmental justice concerns that warehousing is often located close to disadvantaged communities, increasing the likelihood of pollution exposure and adverse health impacts for low-income and minority groups. Our analysis suggests that the pollution impacts of housing is minimal compared to warehousing across each of our scenarios.

Our analysis also confirms a trade-off between meeting warehousing demand, which often involves increased transportation and potential local air pollution "hotspots", and the simultaneous goal of decreasing local air pollution. Adding warehousing to areas where air pollution levels are currently relatively low—such as Ventura and Orange County—can significantly increase the number of air pollution hotspots. This raises important questions about where additional warehousing should be located to meet demand while also addressing environmental justice concerns. While electrifying trucking fleets would significantly reduce emissions and air pollution hotspots, using higher percentages of state land would make air quality worse.

There are numerous implications of the environmental impact analyses. The trade-off between meeting the demand for warehousing and decreasing local air pollution in terms of the number of hotspots warrants further exploration. For example, what are the specific factors that contribute to the trade-off, and how can we balance the need for warehousing with the need to protect our environment? Additionally, what are the potential long-term consequences of locating warehouses in areas that are already vulnerable? The answers to these questions should impact land-use, environmental, and transportation planning.

The environmental impacts of using higher percentages of state land for warehousing can be compared with the impacts of alternative strategies to resolve the short-term demand for warehousing. Other solutions can be explored in terms of air quality and other environmental factors. In terms of electrifying trucking fleets, the cost and infrastructure requirements of transitioning to electric trucking may also impact the overall demand for warehousing. Lastly, in terms of the role of environmental justice in warehousing location decisions, how the benefits and costs of warehousing can be fairly distributed across different communities can be explored further. For example, how can we ensure that communities that are already disproportionately affected by warehousing activities and associated air pollution are not further burdened by the addition of new warehouses?

1. Introduction

The COVID-19 pandemic revealed limitations in California's supply chain resiliency. In response, Executive Order (EO) N-19-21 proposed the use of state land to increase warehousing capacity. However, this revealed a land-use paradox between economic and environmental goals: adding warehouse capacity increases climate pollution and traffic congestion around ports and warehouses. It also raises questions about whether state land could be used for purposes of affordable housing and serving the homeless in port-adjacent underserved communities.

Land use is a critical component of economic development, and in post-industrial regions like Los Angeles, land-use paradoxes often emerge. Should city and transportation planners and regional development agencies support land use and zoning that promotes economic growth—increasing regional economic output, providing jobs to local workers, and increasing government tax revenues? Or should they allocate land resources in such a way as to protect environmental assets that benefit local residents and workers and improve the livability and marketability of those regions? These decisions are complicated and involve trade-offs with respect to uncertain outcomes.

This study looks at one such decision area: whether to use land for warehousing or housing. Both development types provide employment and economic benefits, along with increased transportation emissions. Warehousing is less resource intensive during the facility development phase and generates long-term job and economic benefits; however, the long-run transportation emissions are significant, with consequences for local communities in terms of adverse health impacts and climate change. Housing is more resource intensive during construction but generates long-term benefits to owners and regional benefits in terms of improved housing affordability. While long-term emissions and adverse community impacts are likely lower than in the case of warehousing, they are not insignificant, due to personal transportation and goods delivery to residences.

It is estimated that a half-million-square-foot warehouse brings 300 more truck trips per day to neighboring communities (Yuan, 2021), inducing substantial environmental externalities including traffic-related air pollution, noise, and greenhouse gas emissions (Dablanc et al., 2013). Warehouse location is correlated with toxic air contaminants (e.g., diesel particulate matter emissions) that cause detrimental human health problems (Dessouky et al., 2008), and disadvantaged communities are disproportionately exposed (Yuan, 2021). Local governments and environmental agencies (e.g., South Coast Air Quality Management District) have actively monitored and regulated air pollution related to warehousing activities (e.g., indirect source rule; Industrial Economics, Inc., 2020); however, more research is needed to evaluate potential traffic-related air quality impacts of increasing warehousing activities.

Amazon logistics began its footprint into Inland Empire (a metropolitan area consisting of Riverside and San Bernardino) in 2012, prompting a significant growth of warehouses in that region (De Lara, 2013). This has shifted the economy and primary workforce, from agriculture to warehouse logistics (Yuan, 2018a). Recently, communities within Inland Empire have organized a movement that has led the local government to place a moratorium on new production of warehouse space. The purpose of the moratorium is to provide time for local government officials to understand the implications of the increase of warehouses on the local community with respect to external impacts, such as pollution and traffic. Local city councils in Inland Empire announced initial regional moratoria in the Fall of 2022, which came after California Governor Gavin Newson signed Assembly Bill 701 (AB701), effective January 1, 2022. AB701 places limitations on production quotas and increases protections for warehouse workers. More recently, AB1000 was introduced this March 2023 by California Assembly Majority Leader Eloise Gómez Reyes. AB1000, also called the Good Neighbor Policy, provides specifications for the planning and construction of warehouse facilities. It allows local governments to approve warehouse development that are over 100,000 square feet when they are 1,000 feet from schools, homes, or day cares.

Furthermore, these state and local policies have advanced the work of community coalitions that are leading the charge of highlighting the unintended consequences of the extreme growth of warehouses in Southern California over the last decade.

1.1 Supply Chain Challenges during COVID

The COVID-19 pandemic caused severe disruptions to the global supply chain and to Californian warehousing and logistics. This section explores some of the causes of supply chain problems in recent years, which, in turn, explain why Governor Newsom's Executive Order N-19-21 was initiated in October 2021.

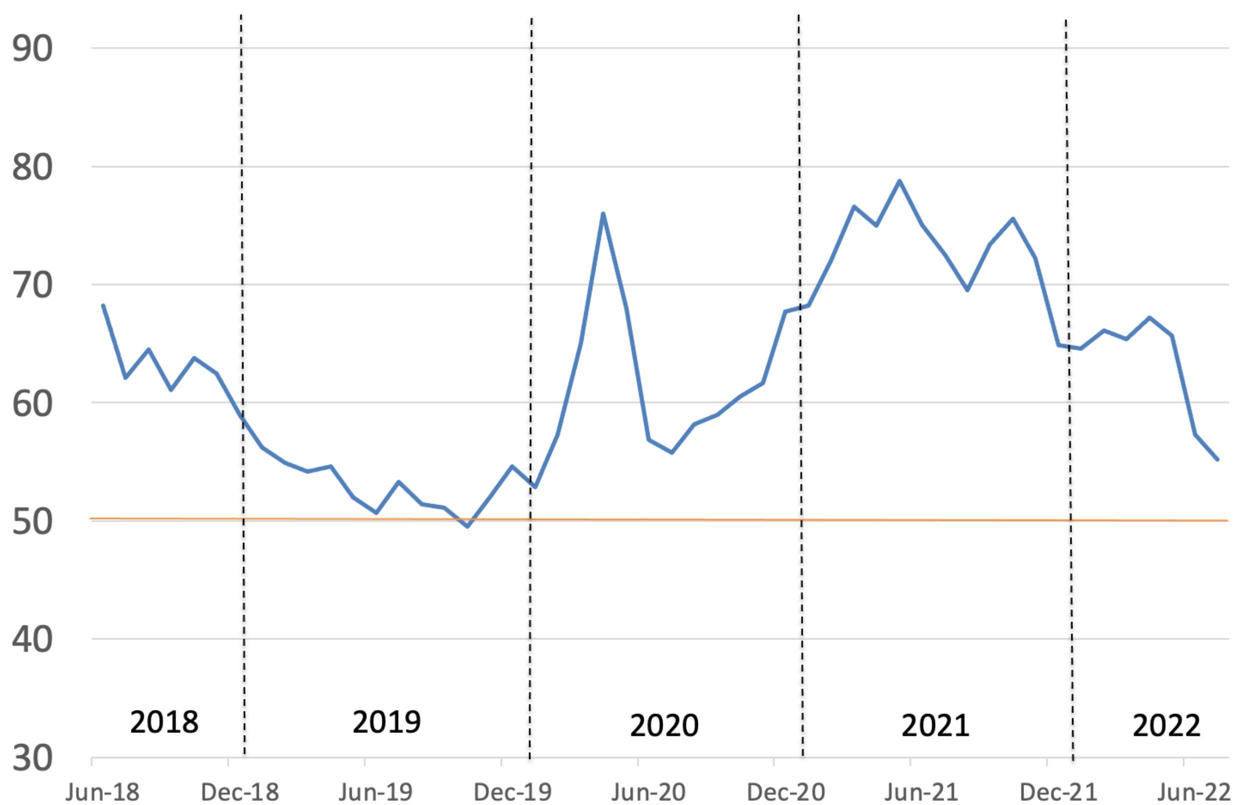
Since the first case of COVID-19 was officially reported in China in December 2019, the coronavirus has quickly spread worldwide, bringing global supply chains to a nearly complete pause. In 2020, most manufacturing industries faced declining demand and considerable operational constraints due to lockdowns and social distancing measures. The shipment value of the overall manufacturing industry decreased by 6.7% in 2020 over the previous year. With more people vaccinated and businesses reopening, the shipment value rebounded strongly in the first half of 2021. The shipment value of the first six months jumped 13.2% over the same period of 2020 (Martinez, et al., 2021). Several manufacturing industries showed strong growth, including miscellaneous products, petroleum and coal products, wood products, leather, metals, transportation equipment, machinery, and electrical equipment.

However, the gap between supply and demand in supply chains has significantly widened during the pandemic, leading to significant shipping delays. The rebound for container shipping began in July 2020 as Asian manufacturers returned to operations and e-commerce purchases increased as U.S. consumers stayed at home. Unexpected demand coupled with supply shortages during the pandemic prolonged suppliers' delivery times and raised prices. The suppliers' delivery times index, one component of the Purchasing Manager Index, is often watched by policymakers such as the

Federal Reserve to measure the imbalance between supply and demand, given its high correlation to inflation. Readings above 50 indicate that delivery times have become slower. After a manufacturer places an order for raw materials and components, the supplier uses its production capacity and inventory to fill the order. When the order is greater than its capacity and inventory, the delivery time will be longer because the supplier takes a longer time to fill the orders. Hence, longer supplier lead time implies that suppliers struggle to meet the demand for factory inputs and vice versa. Figure 1 shows that the suppliers' delivery times significantly slowed because of the pandemic in March 2020.

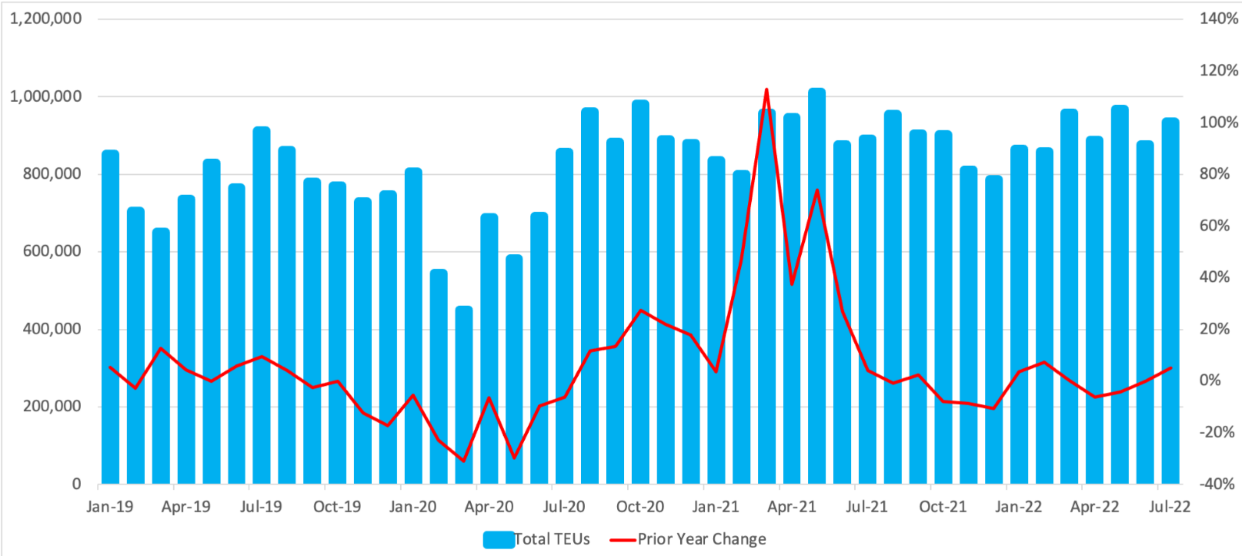
Then the second wave of supply chain congestion started in July 2020 and reached the severest level in May 2021. In the same month, the volumes (as measured in twenty-foot equivalent units (TEU)) at the Ports of Los Angeles (LA) and Long Beach reached a 110-year peak (see Figure 2). In the following 12 months, the trend of suppliers' delivery time reversed. While the delivery time is still longer than expected, the speed has gradually improved, implying a rebalancing of demand and supply.

Figure 1. Supplier Delivery Time Index, 2018–22



Source: Institute of Supply Management (ISM)

Figure 2. Port of LA Monthly TEU Count



Source: Port of Los Angeles

In addition to the long waiting line on the ocean, there are other factors leading to port congestion and shipping delays, including clogged railroads, truck driver shortage, near fully occupied warehouses, and chassis shortage.

- Clogged railroads: A shortage of rail workers, insufficient rail cars, and importers failing to pick up their goods cause cargo to pile up at the Port of LA.

- Truck driver shortage: It is challenging to attract, recruit, and retain drivers in the port because of low pay and poor working conditions.

- Near fully occupied warehouses: The unprecedented demand from overseas third-party logistics, logistics, and e-commerce tenants during the pandemic has taken most warehouse spaces in Southern California (SoCal). More analysis is available in the next section.

- Chassis shortage: There was a chassis shortage problem years before the pandemic. During COVID-19, the problem worsened. Because of unprecedented demand, clogged railroads, and insufficient warehouse spaces, chassis are being held longer before being returned when a retailer chooses to store goods in a container in the parking lot rather than unloading them into the warehouse.

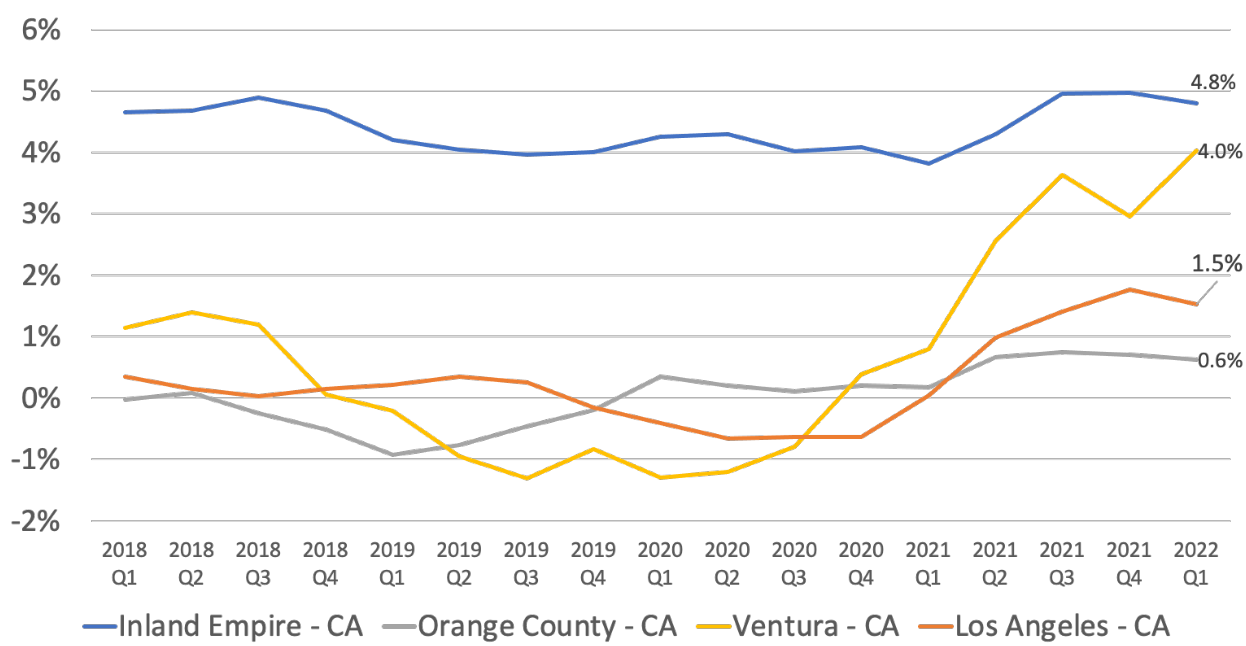
1.2 Forecasting Warehousing Demand and Supply in Southern California

Figures 3 and 4 and Table 1 report the demand growth and vacancy rates in the SoCal regions. Benefiting from the booming of e-commerce and land availability, Inland Empire has had the highest demand growth compared with other counties in the South Bay area in the past decade.

According to the CoStar database, before the pandemic, the growth of the occupied industrial warehouse spaces in Inland Empire was 4.7%, much higher than its growth in Q1 2018. From Q4 2020, the import surge led to strong demand for warehouses in the South Bay area. However, the inventory of warehouse spaces failed to accommodate the demand, leading to the lowest vacancy rate in the past 15 years. As shown in Figure 4 and Table 1, the vacancy rate went down significantly in 2021 and early 2022. The vacancy rate in Inland Empire dropped significantly from 5% in Q1 2018 to 1.3% in Q1 2022.

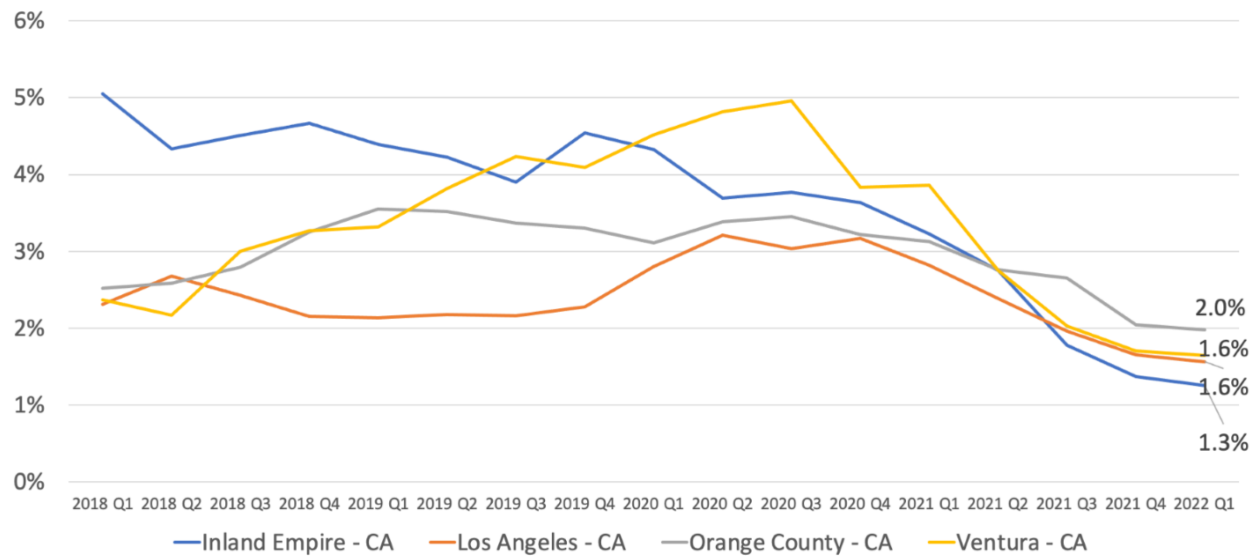
In the next four years, the low vacancy rates are expected to improve gradually due to the slowdown in demand. The main determinants of the economy will be the inflationary impact and policies, the war in Ukraine, and the diminution of the danger posed by COVID-19. CoStar's forecast for the vacancy rates, based on the Oxford Economics Baseline scenario published on March 22, 2022, is reported in Table 1.

Figure 3. Growth of Demand in SoCal Warehouse Spaces (by occupied sq ft)



Source: CoStar Database

Figure 4. Vacancy Rate by Region



Source: CoStar Database

Table 1. Vacancy Rate by Region

	Actual (Q1)					Forecast (Q1)			
	2018	2019	2020	2021	2022	2023	2024	2025	2026
Inland Empire	5.0%	4.4%	4.3%	3.2%	1.3%	2.3%	2.2%	2.5%	2.7%
Los Angeles	2.3%	2.1%	2.8%	2.8%	1.6%	1.5%	1.6%	1.7%	1.8%
Orange County	2.5%	3.5%	3.1%	3.1%	2.0%	1.9%	2.0%	2.1%	2.4%
Ventura	2.4%	3.3%	4.5%	3.9%	1.6%	1.9%	1.9%	2.3%	2.9%

Source: CoStar Database

The Southern California Association of Governments (SCAG) examined industrial warehousing in Southern California in 2018 and projected a supply shortfall in warehousing in 2029 that could reach 295 million square feet without considering the pandemic demand surge.

1.3 Housing Issues

While the warehousing sector is facing these issues, housing and homelessness are dominating the political agenda at the local and state level. The 2022 City of Los Angeles Mayoral Election was dominated by the issue of homelessness. High home prices have contributed to the County of Los Angeles losing population for the past five years, and for the state to experience its first declines in population since the 1800s (U.S. Census, 2023). Despite state directives, many California cities have been unwilling or unable to implement affordable housing targets.

In 2017, Governor Newsom campaigned on the pledge to see 3.5 million new housing units built by 2025 (Newsom, 2017). This was a bold campaign promise, given that the total California housing units at the time were 14 million. The 3.5 million figure equals the total number of housing units in Los Angeles County. The annual average number of housing units built in California since 1990 is an estimated 106,296 (CA DoF, 2021), which is 0.8% of the average total housing units during this period. It would therefore take 35 years to reach the Governor's target. Put another way, to achieve this target by 2025, 600,000 new units per year would be needed.

The number of new buildings across the state has fluctuated since 1990, reaching a peak of 205,328 new units in 2006 (1.6% of total units). Around 75% of these new units were single family homes. Recent home building has ticked up, with 156,939 new units built in 2020 (1.1% of total units), of which 52% were single family homes, reflecting a recent trend for more multiple-unit developments as available land has diminished.

In Los Angeles County, new units comprise a much lower proportion of total units compared to the state: 0.4% compared to 0.8%. This highlights the high level of development—and lack of available land—within the County. This is further highlighted by the lower rate of single-family home developments. If we compare to the state-level data above, in 2006, 54% of new units in Los Angeles County were single family homes (compared to 75% statewide), while in 2020, 30% of new units in Los Angeles County were single family homes (compared to 52% statewide).

California has the second least housing per capita and has the most homelessness in the United States—20% of Californians spend more than half of their income on rent (Bertran, 2019). Supportive housing can address this problem; the homeless population decreased by 11% as permanent supportive housing increased from 2007 to 2014 by 50% (Corinth, 2017).

EO N-06-19 proposes using surplus public land for affordable housing. While over 58,000 acres of city-owned land are available in Los Angeles (Walker, 2019), the suitability of these sites for affordable housing poses difficulties. Often, these public sites have increased environmental burden resulting from contamination from previous industrial or toxic use (Hickey & Sturtevan, 2015). These sites are disproportionately found in communities of color, which could potentially further increase the density of marginalized neighborhoods facing pollution and other burdens of industrialization. The 2022 California state budget identifies housing as a climate strategy, linking housing and climate goals, safeguarding natural and working lands, and reducing climate risk exposure while addressing homelessness.

In sum, land-use policies aiming to resolve warehousing gaps result in a complex dilemma characterized by the tension between economic interests and environmental goals linked to warehousing. Questions also remain on how best to understand and resolve the land-use paradox arising from the conflicting aims of increased warehousing and housing demands. This study explores how to prioritize the use of state lands while considering the needs of warehousing and housing, and associated climate and environmental impacts.

2. Literature Review

This literature review supports this report's analyses of warehousing and housing land use and environmental impacts in Southern California. The literature review starts with a broad perspective, exploring the land-use paradox between economic growth and environmental goals (Section 2.1), before focusing on warehousing and supply chains, the factors influencing warehousing location choices, changes during the COVID-19 pandemic, and policy solutions designed to address gaps in warehousing supply and demand (Section 2.2). Section 2.3 explores the intersection between warehousing, transportation systems, and various environmental issues. Section 2.4 focuses on housing, and related environmental and land-use issues impacting Southern California in particular. Each section reviews the current literature, identifies gaps within it, and sets up the analysis later in the report.

2.1 Land-Use Paradox between Economic Growth and Environmental Goals

The tension between economic growth and environmental protection is much studied within the fields of planning and environmental economics and policy. Protecting environmental assets by addressing negative externalities often involves costs to one or more stakeholders, even when aggregate social welfare is improved through market intervention. For example, when looking at climate change, global economic development has created negative externalities by raising the level of CO_2 and other greenhouse gases (GHG) in the atmosphere (Salari, Javid, & Noghanibehambari, 2021), thereby threatening human settlements and regional economies by increasing weather volatility and the incidence of costly natural disaster events. To address these externalities, International Energy Agency organizes all Organization for Economic Co-operation and Development countries have agreed to decrease GHG emissions and limit climate change through the 2015 Paris Climate Agreement. To achieve these targets, these countries will need to adopt an array of CO_2 emission mitigation strategies including shifting towards renewable energy generation and away from non-renewable energy sources due to their substantially higher GHG emissions (Cai, Sam, & Chang, 2018).

The trade-off between economic growth and environmental protection varies according to numerous factors. For example, the Environmental Kuznets Curve hypothesis suggests that the relationship between CO_2 emissions and economic growth is positive in pre-industrial societies, then levels off as industrial economies develop, and finally moves to a negative slope during the post-industrial phase (Isik, Ongan, & Özdemir, 2019). While there are limits to this hypothesis, the Los Angeles region is in many ways in the post-industrial phase and has seen significant emissions reduction—especially per dollar of output—as manufacturing has declined in prominence and transportation has become more energy efficient. These changes have been prompted by the roll out of environmental policies and laws such as the South Coast Air Quality Management District regulations of NO_x (nitric oxide and nitrogen dioxide) and SO_x (various sulfur oxides) emissions for stationary polluting facilities, and state laws such as the GHG emissions trading scheme, and the U.S. national corporate average fuel efficiency standards on vehicle emissions.

As discussed below, warehousing activities can contribute to climate change through production, distribution, and disposal phases in multiple complex aspects of the supply chain. The use of limited non-renewable energy resources for warehousing activities has exacerbated the ongoing climate crisis (Ghadge et al., 2020). In terms of mitigating contributions to climate change, sustainable designs for warehouses, freight trucks, and operation have been shown to be successful in decreasing GHG emissions, pollution, adverse health effects, and adverse environmental impacts on local communities (Oloruntobi et al., 2023).

Regarding housing, the 2022 California state budget identifies California housing as a climate strategy by linking housing and climate goals, identifying where to build housing, safeguarding natural and working lands, and reducing exposure to climate risk (California Department of Finance, 2022). These budget goals support the production of housing, elevating the importance of environmental impacts in development planning and of addressing homelessness. Development programs such as "Transit Oriented Communities", "Opportunity Zones", and "By-Right Development" have resulted in unintended consequences for marginalized communities, but they are the only tools available to affordable housing developers who seek to increase the housing stock. Los Angeles' inclusionary housing ordinances have limited the supply of affordable housing in certain neighborhoods (Jacobs, 2007). Los Angeles must plan for more than 450,000 units from 2021 to 2029, over 56,000 units per year.

2.2 Warehousing and Supply Chains

This section reviews the literature on warehousing and its role within broader supply chains, both in general and with respect to the Los Angeles region. It also examines the factors influencing location choices that are critical to land-use considerations.

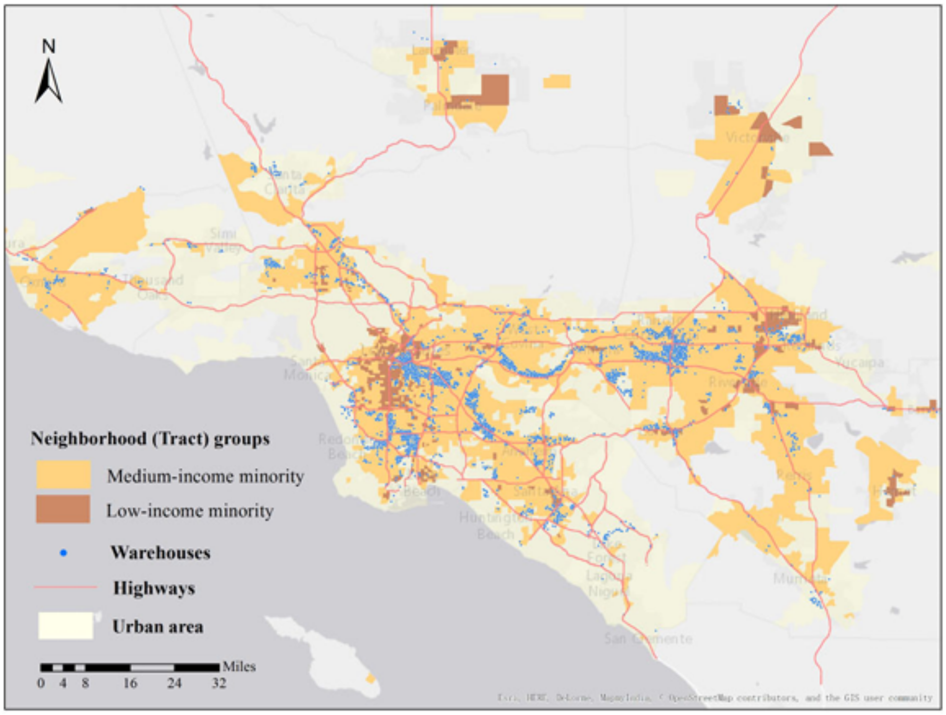
The storage of goods along trade routes has always been a paramount concern for societies and administrations throughout history. Warehousing is a fundamental element of supply chains, providing security for property rights and inventory management for trading entities (Mostafa et al., 2019).

In today's highly globalized supply chain networks, warehouses are often located in highly concentrated locations (Yuan, 2018a) due to agglomeration effects. These major "gateway" regions or "transport corridors" developed in tandem with major ports (e.g., Shanghai, Singapore, Ningbo-Zhoushan, Shenzhen, Guangzhou, Busan, Qingdao, Tianjin, Hong Kong, Los Angeles-Long Beach, Rotterdam, Jebel Ali, Antwerp), which require particular geographical conditions, substantial infrastructure investment, and efficient transportation connections to exporting industries or destination markets. Sophisticated logistics services develop around these public and private infrastructure investments to move goods to market at the lowest possible cost (Mason et al., 2003).

The sheer scale of goods passing through these ports and gateway regions is reflected in the massive stretches of land required for both ports and warehouses to store and manage goods. As Yuan (2018) highlights, the massive space required for modern high-tech warehouses tends to confine them to suburban locations, where land is cheaper. As discussed below, the concentration of warehousing in particular locations raises questions about the localized environmental impacts, and which communities are bearing the burden. And in connection with this project in particular, it raises questions about whether state land should be used to provide relief to supply chain congestion issues.

Warehousing in Los Angeles has received notable attention in academic literature. Dablanc et al. (2014) explore the rapid growth in warehousing in Los Angeles between 1998 and 2009 and find that this industry shifted substantially in its geographical distribution away from the urban center. Figure 5 shows the location of warehousing in the Los Angeles region in the 2010s—the "after" stage of the Dablanc et al. study—set against locations of highways, and low- and medium-income communities. Most of the new developments represented in Figure 5 are in the north-east area of urbanized Los Angeles, known as "Inland Empire", which has cheaper land on average than the coastal areas due to higher temperatures and further distances from employment centers. There was also a higher proportion of farmland and undeveloped land in this region. Figure 5 also highlights the importance of transportation infrastructure to warehouse location choice, as most warehouses are short distances from major highways.

Figure 5. Spatial Distribution of Warehouses and Selected Types of Neighborhoods in the Los Angeles Region



Source: Yuan (2018)

Despite the development of many large warehouses in suburban areas like Inland Empire—a trend that has continued in the years since the aforementioned article's publication (Baker, 2021)—demand for warehousing in the region continues to be high (Garland, 2021). This speaks in part to the unusual demand spikes caused by the COVID-19 pandemic, as well as increasing capacity at the Ports of Los Angeles and Long Beach.

A recent study by Ke and colleagues (2021) looks at California's freight system at a regional level, comparing its competitiveness with other states and trading regions in the United States. California's strengths lie with its ports, which continue to compete globally across numerous metrics. While California's airports and rail freight systems perform relatively well compared to other U.S. regions, two areas for comparative improvement are warehousing and highways. California's road systems are notoriously congested, especially in the areas around the Los Angeles ports. Transporting goods by truck from the Ports of Los Angeles and Long Beach to warehouses in Inland Empire and beyond requires drivers to navigate freeways already congested with commuter traffic. Warehouse developments in California face particularly high land and construction costs, especially in comparison to other states where demand for housing in particular is much lower.

Prior projects such as the Alameda Corridor railway have added capacity in recent decades. A similarly bold idea to create rail links to an inland port in Inland Empire would increase capacity and flows, reduce congestion and local pollution, and provide benefits to warehouses in that region. However, it would also require substantial investment and face significant practical and regulatory hurdles (Ke et al., 2021).

2.2.1 Factors Influencing Warehousing Location Choices

In the previous section, we explored some of the general factors that influence supply, demand, and warehousing location choices (as outlined in Yuan, 2108a, among other literature). However, numerous studies have identified these factors at a higher resolution (Cambridge Systematics, 2018; Jaller & Pineda, 2017; Kang, 2020; Ke et al., 2021; Uyanik et al., 2018; Yuan, 2018b; Yuan, 2021). In a study regarding logistics sprawl, i.e., the phenomenon of the relocation of logistics facilities towards suburban areas, Jaller and Pineda (2017) propose four categories for determining logistics sprawl, namely, land availability and affordability, accessibility to labor and supply chains, proximity to customers and transportation networks, and regulatory environment. Table 2 shows the factors and their definitions and rationales.

Table 2. Factors Determining Logistics Sprawl

Factors	**Definition**	**Rationale**
Land Available for Expansion	Space that can be acquired or existing space that can be converted to intensify usage or storage capacity onsite. Zoning can affect this factor (e.g., parking requirements onsite reduces storage capacity)	Flexibility to expand or contract depending on the state of business. The ability to expand onsite rather than purchasing or renting a separate facility
Number of Dock Doors (at warehouse facilities)	Number of dock doors	Appropriate amount of dock doors for operational needs
Proximity to Highways	On-road distance and travel time to highways	Ease of goods transportation by truck
Public Transit Availability	On-road distance and travel time to public transit	For workers (typically low-skilled) to get to work
Long Combination Vehicle Accessibility	Surrounding roads and facility's yard wide enough for long combination vehicles to maneuver	Infrastructures (e.g., large enough surrounding roads) available for operators to utilize long combination vehicles
Proximity to Airport	Distance and travel time by truck to airport	To take advantage of flight cut-off times for shipping materials and lower drayage costs
Proximity to Sea Port	Distance and travel time by truck to seaport	To reduce truck drayage cost and time
Proximity to Rail Intermodal Facility	Distance and travel time to rail intermodal facility	To reduce truck drayage cost and time
Ability to Operate 24/7	The ability to increase and decrease operation depending on the state of the economy	Increased control of operation
Trailer Parking/Truck Staging Areas	Land available for staging areas and outside storage	A reduction in the amount of floor space required by just-in-time firms is often offset by more land being required for outside storage, and staging areas
Telecommunication Systems	Communicative technologies between the warehouse, suppliers, and customers	Certain regions do not have good telecommunication systems—a major requirement in a modern economy

Factors	Definition	Rationale
Quality and Reliability of Modes	Quality of the transportation services between the warehouse, suppliers, and customers	Ability to have timely deliveries, delivery to the correct location, and undamaged goods
Access to Customers	Distance and time to deliver goods to customers	To allow for constant and punctual deliveries
Access to Suppliers	Distance and time to obtain goods from suppliers	Minimization of travel time and distance
Customer Population in Surrounding Area	Customer population in the surrounding area of the facility	Maximization of distribution zone and penetration of such zone
Spending Power of This Population	Income of the population in the surrounding area of the facility	Maximization of distribution zone and penetration of such zone
Distance from Competitors to Customers	Distance from competitors to customers	Competitive edge
Availability of Skilled Workers	Sales, administrative staff, trained forklift drivers, etc.	Necessary personnel
Availability of Unskilled Workers	Workers that would have to be trained before they can be operational	In case not enough skilled workers are hired
Pro-Business Regulatory Environment	How active municipalities are in attracting business through various incentives	Reduced cost and increased control of operation
Zoning and Construction Plan	Different development plans, implementations, and arrangements at alternative locations	Match between zoning and regulator's vision for construction and the vision of the firm
Land Costs/Tax Rates	Operating cost	Reduced operating cost
Proximity to Other Similar Businesses	Logistics campuses—where similar businesses are in the same complex	Logistics campuses are a way for companies to reduce costs
Labor Costs	Wages, salaries, etc.	Reduced operating cost
Transportation Costs	Fuel and equipment cost	Reduced cost of transporting goods
Handling Costs	Cost of goods storage	Reduced operating cost

Source: Jaller and Pineda (2017)

Uyanik, Tuzkaya, and Oğuztïmur (2018) review the literature on logistics centers' location selection problems. In exploring seven studies published between 1996 and 2014—which use a number of different methods including multivariate and logistic regression analysis, multicriteria analysis, and interviews—the authors identify a broad range of variables. In addition to those provided by Jaller and Pineda (2017), these variables include distance to large blue-collar worker pools, age of building, traffic congestion, distance to central business districts, and rents. The authors then group these into five key areas, namely, location, cost, cargo capacity/economic reflection, environment, and social factors. Building upon their classification scheme, Ke and colleagues (2021) use secondary data to operationalize the criteria above by the performance measures shown in Table 3.

Table 3. Measures for Location Decision Factors

Category	**Measures**
Location	1. Population of Closest Metropolis (millions, 2019)
	2. Distance to Nearest Port (miles)
	3. Distance to Nearest Airport (miles)
Cost	4. Wage of Workers (per hour, 2019)
	5. Land Cost (asking rent per square foot per year, Q2 2021)
	6. Electricity Cost (industrial, cents per kWh, 2020)
	7. Fuel Cost (diesel per gallon, 2020)
Cargo Capacity/Economic Reflection	8. Gross Domestic Product (GDP) of Closest Metropolis (millions of dollars, 2018)
	9. Connectors Between Major Intermodal Facilities (number of connectors, 2019)
	10. Highway Providing Reliable Travel Time (percentage, 2019)
Environment	11. Damage Costs Due to Hazardous Weather (millions of dollars, 2019)
	12. Air Quality Index (median AQI, 2019)
Social Factors	13. Unemployment Rate (percentage, 2019)
	14. Social Vulnerability Index (percentile, 2018)

Several recent studies focused on the Los Angeles region have provided insight into which of these factors is particularly relevant to our study. The 2018 SCAG report, conducted by Cambridge Systematics, evaluated how Southern California could accommodate future demand for warehouse space based on trends observed through literature review, stakeholder interviews, and data analysis. Its demand model considers five factors:

(1) Warehouse space inventory;

(2) The U.S. GDP growth forecast;

(3) The Ports of Los Angeles and Long Beach container volume forecast and the number of goods to be warehoused in the region;

(4) Cross-border trade flows that cross the land ports of entry in Imperial County and the number of goods to be warehoused in the region; and

(5) Warehousing space submarket assumptions.

The SCAG report provides an important first step in identifying which of these various factors is the most important. In what appears to be a bivariate model, they found a strong positive correlation between occupied warehousing space and national annual GDP between 2004 and 2014. As a result, GDP forecasts were used to estimate the overall warehousing space needs for Southern California through 2040. As will be explored below, our study aims to produce a more comprehensive forecasting model that includes and tests a broader range of factors, subject to data availability.

Kang (2020) provides an important case study examination of warehouse location choice in Los Angeles. This examination looks at warehouses built between 1951 and 2016 and identifies differences across time periods. Location choices for warehouses built prior to 1980 appear to be influenced more by the local market, labor considerations, and proximity to seaports and related intermodal facilities. In contrast, warehouses built after 2000 appear to have been influenced more by land prices and proximity to airports and related intermodal facilities.

Location choice has also been explored in the environmental justice literature. As will be discussed further below, there have been numerous studies exploring the relationship between location choice and minority and poor communities. In general, these studies aim to answer two levels of questions: (1) whether negative externalities from warehousing activity—such as transportation-related air and noise pollution, and disruption of ecosystems—are more likely to harm poor and minority communities than affluent and majority communities; and (2), if so, whether warehouse developers are choosing to locate close to these communities (at least in part) because they are there, or whether members of these communities are choosing to reside close to the warehouses (e.g. due to job opportunities).

Yuan (2018b) uses simultaneous equation modeling to explore these questions with data from Los Angeles from 2000 through to 2010 and finds that as the share of minority population increases, warehousing activity density then increases, but not vice versa. This suggests that warehouse developers are choosing to locate close to minority populations, and not the other way around. This finding appears to hold for the share of Latinx populations and Asian populations but not Black populations. In a later study, Yuan (2021) explores the relationship between warehouse location and the intersection of income and race/ethnicity. That study found that warehouses are also disproportionately located in low- and medium-income minority neighborhoods, but the relationship only holds for minorities, not for income.

2.2.2 Warehousing during the COVID-19 Pandemic

As highlighted in the introduction, the COVID-19 pandemic created numerous challenges for supply chains in general (McCrea, 2020). In Los Angeles, goods movement had already been disrupted by the Trump Administration's 2018 25% tariffs on Chinese imports. In anticipation of these tariffs, many importers brought goods in early, and filled up inventories, with demand slackening thereafter. These large inventories helped to meet increased household demand for goods during the early lockdown period, as consumers shifted spending away from in-person services and towards at-home products.

As the pandemic progressed into its second year, the demand surge continued and inventories dwindled, with the result that demand for imported goods increased further. Domestic manufacturing could meet some of this demand; however, domestic prices were increased due to supply shortfalls and closure of some facilities during lockdowns. Indeed, studies have shown that in Los Angeles County, warehouses were notable sites of COVID-19 outbreaks, leading to closures (Contreras et al., 2021). More aggressive lockdowns in East Asian manufacturing locations in particular (where numerous countries had implemented "zero COVID" policies) also constrained import activity and increased prices (McCrea, 2020). Moreover, when importers were able to move goods into the United States, they faced significant congestion at the Ports of Los Angeles and Long Beach, low vacancy rates at warehouses, and issues with freight rail systems. These compounded issues reached their peak in late 2021 and appear to have softened since due to the various measures described above. Magableh (2021) captures these issues in Figure 6 below, highlighting the importance of supply disruptions, demand volatility, and governments' responses.

Figure 6. Diagram of Factors Impacting Supply Chains During Pandemics

High-level

- Government responses
- Supply disruptions
- Demand volatility

Mid-level

- Industrial challenges
- Supply chain breakages
- Online shopping
- Delivery challenges
- Production pauses due to economic shutdowns
- Input source challenges

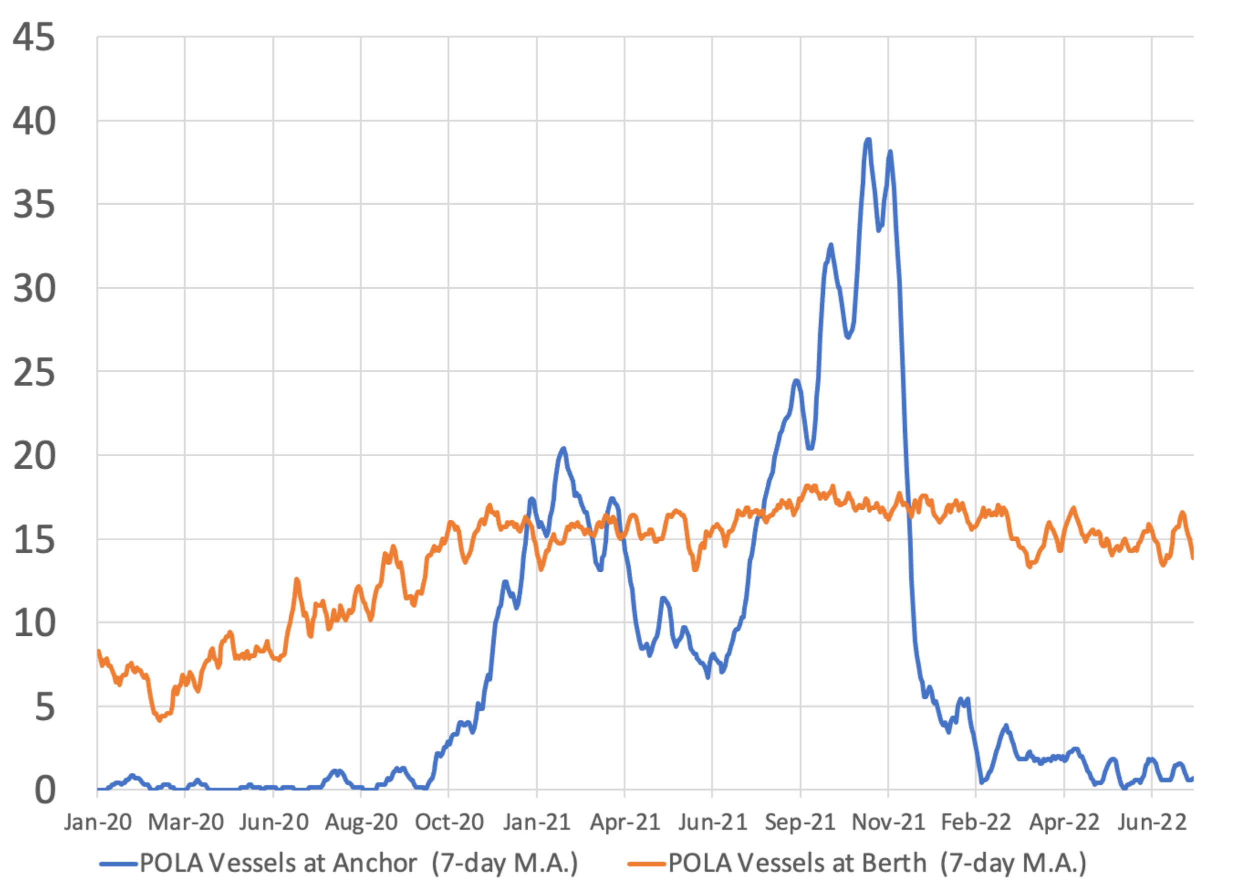
Base-level

- Long lead time, delivery and distribution delays
- Fluctuation and increase in product prices, especially downstream
- Delays to shipments, cargo un/loading at borders and ports
- Reduction in production/manufacturing capacity
- Information and communication challenges due to variations in technology and supply chain management systems
- Lack of planning for disruptions and risk and emergency management; lack of contingency planning
- Reduction in revenue and return on investment/profits
- Reduction in quality control

Adapted from Magableh (2021).

Port congestion plays a major role in shipping delays. Figure 7 uses the daily numbers of vessels at anchor and berth at the Port of LA (POLA) during 2021–2022 to show the dynamics of demand and supply. The orange line represents the number of vessels at berth, which indicates the utilized capacity of the port, and the blue line is the number of vessels anchored, which indicates the demand over capacity. It shows that the vessels waiting outside the port increased from October 2020 and peaked in November 2021.

Figure 7. Daily Vessel Activity at the Port of Los Angeles



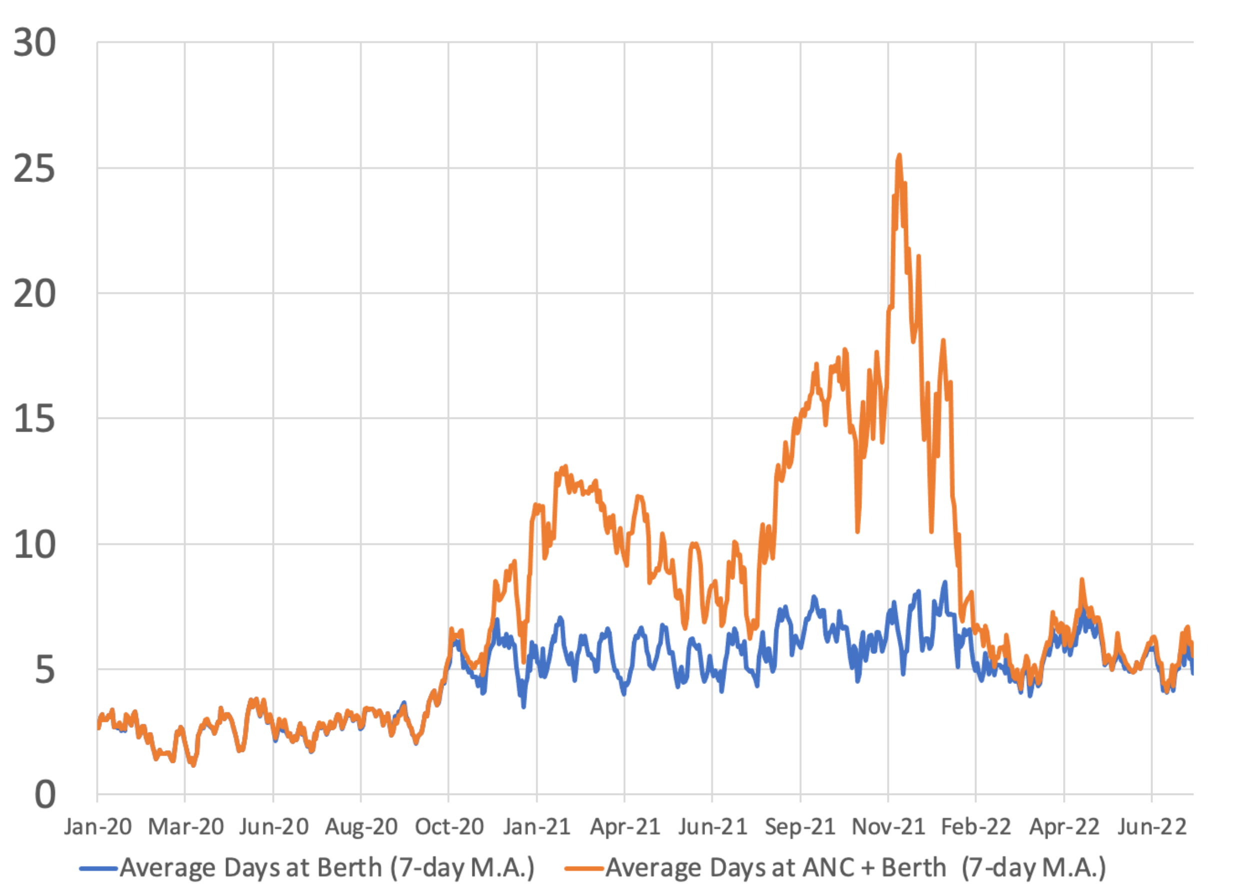
Source: Port of Los Angeles (POLA)

After President Joe Biden announced government intervention in the port operations in October 2021, the "nominal" waiting line shrank noticeably in December 2021 due to a few reasons. First, the ports at San Pedro had addressed some capacity constraints at their terminals and improved their efficiency. Second, the ports instituted a fine to discourage the practice of leaving containers lingering on the docks. Third, a new policy set by shipping trade groups encouraged incoming ships to wait in the open ocean rather than close to shore. Hence, the number of vessels anchored may not reflect the whole picture of the waiting vessels.

In addition, Shanghai in China started a four-month COVID lockdown in April–July 2022 and disrupted import and export shipments. The lockdown prompted carriers to increase blank sailings (canceled trips) to one-third of their transpacific destinations, including the U.S. west coast ports. The decrease in China's import and export cargo also contributed to relieving congestion at the ports at San Pedro.

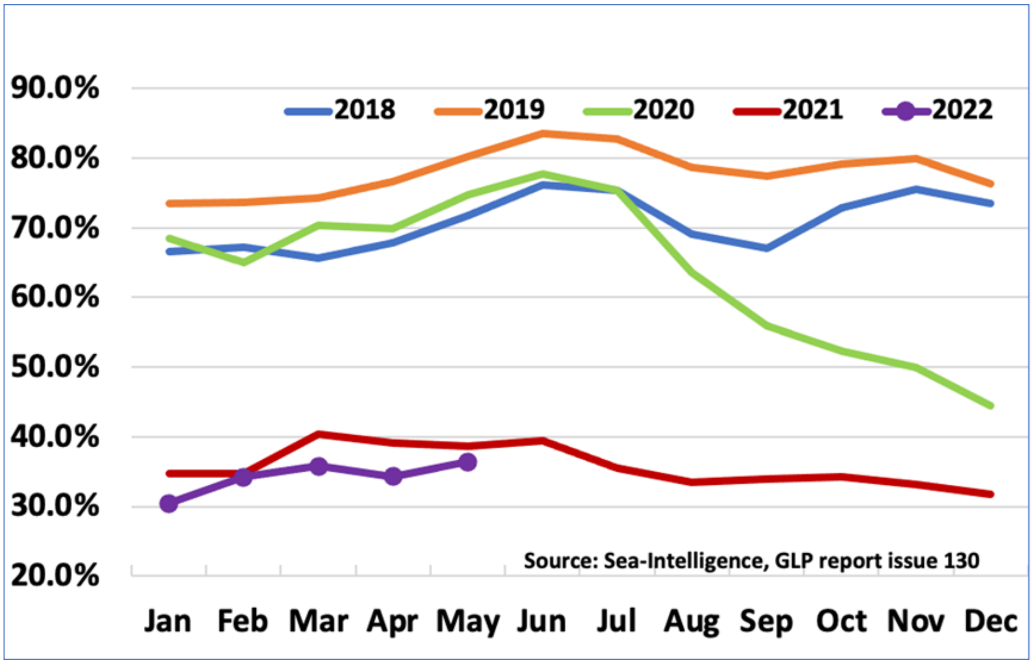
As a result, shipping delays significantly improved in early 2022. As shown in Figure 8, it took a boat roughly 25 days to secure a berth in November 2021. In June 2022, the waiting time was significantly reduced to 5 days, implying a 20-day shorter lead time in supply chains. The improvements in shipping delays occurred not only on the U.S. west coast but globally. According to Sea Intelligence, the global schedule reliability and global average delays for late vessels improved in early 2022, showing trends similar to the U.S. numbers (see Figures 9 and 10). Schedule reliability represents the likelihood that any given ship will adhere to its schedule, that is, that it will dock, unload, and depart on time. As the imbalance between demand and supply for ocean shipping narrowed, the ocean shipping cost per container dropped significantly in early 2022. Figure 11 reports historical freight rates by trade routes from Shanghai. In November 2021, firms paid $10,038 per 40-foot container from Shanghai to Los Angeles. The rate dropped to $6,985, a 30-percent decrease, in August 2022.

Figure 8. Average Days at Berth and Anchored at the Port of LA



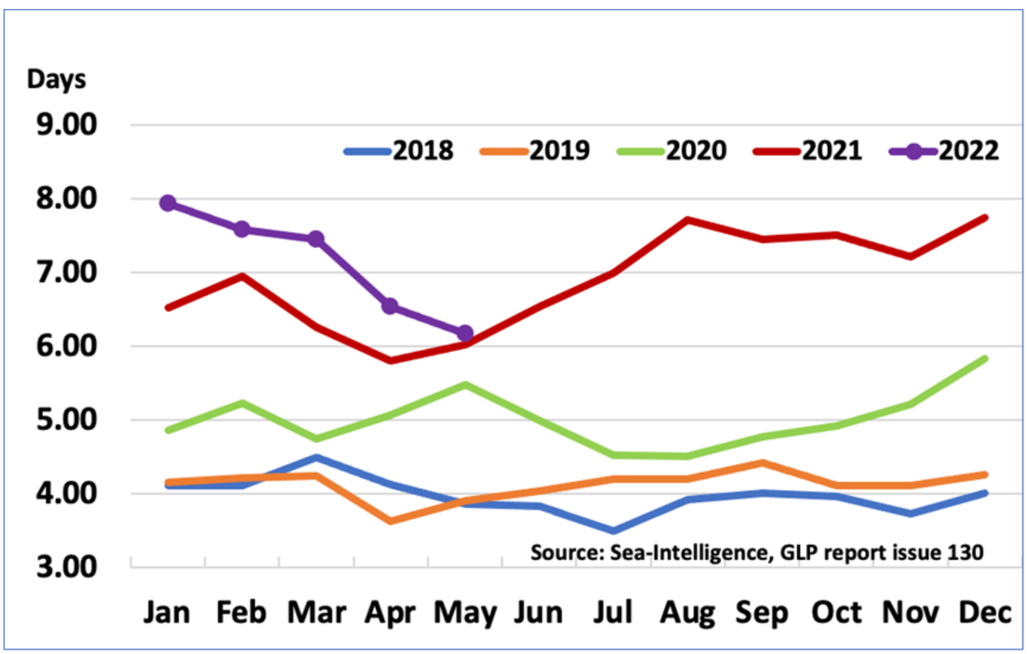
Source: Port of Los Angeles

Figure 9. Global Schedule Reliability



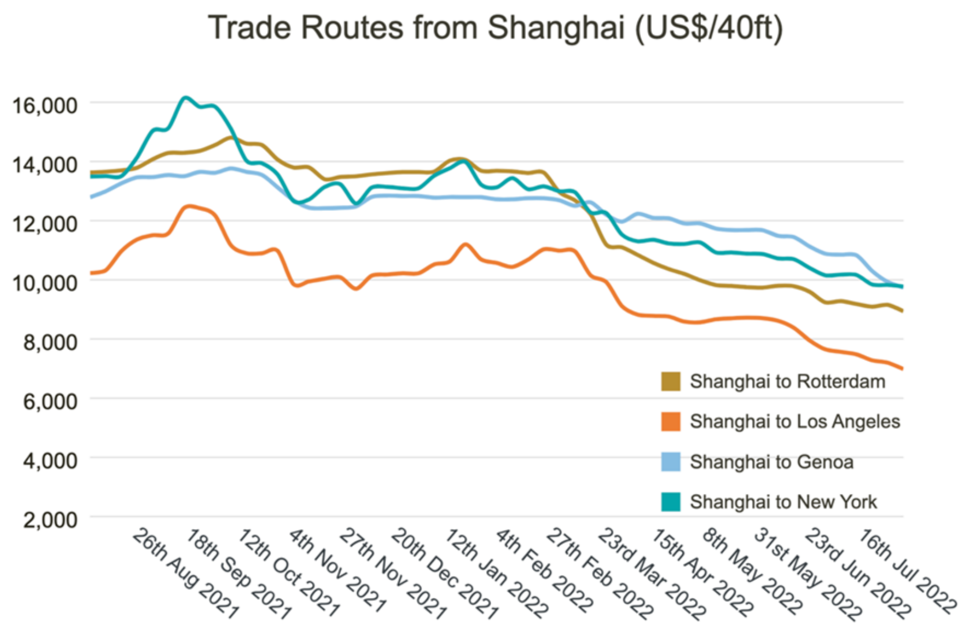
Source: Sea Intelligence

Figure 10. Global Average Delays for Late Vessel Arrivals



Source: Sea Intelligence

Figure 11. Freight Rate by Trade Routes from Shanghai



Source: World Container Index, Drewry Supply Chain Advisors

2.2.3 Solutions to Warehousing Supply and Demand Gaps

The "problem" here is not the gap between warehousing demand and supply per se, as prices resolve these gaps over time. Prices rise when warehousing is in short supply, leading supply chain managers to find solutions such as cheaper land for storage or alternative shipping routes through competitor regions such as port systems in the Pacific Northwest or the Southeast. In the longer term, higher prices also encourage building more warehousing within the region.

Instead, the problems related to warehousing that emerge are the ones that are of concern to regional planners, such as congestion in the regional supply chain system, pollution associated with warehousing and transportation activity, labor market issues, and workforce housing and transportation concerns, each of which can impact local communities, business profitability, and regional competitiveness.

There are creative solutions to increase the supply of storage in the short run, such as those included in N-19-21 that we focus on in this study. This policy as it relates to warehousing has resulted in quite a small area of land being allocated by the Department of General Services (DGS) for temporary storage of 20,000 containers:

- Lancaster Armory, 7.5 acres
- Palmdale Armory, 2.5 acres

- Stockton Armory, 1.8 acres
- Deuel Vocational Institution, Tracy, approx. 4.6 acres
- San Joaquin County Fairgrounds, 60 acres
- Antelope Valley Fairgrounds, approx. 41.3 acres (22 acres unavailable in May and Sept. during large events)

These facilities provide temporary outdoor storage, rather than permanent warehouses. For reference, the TEU-loaded imports for 2021 were 5,513,286 for the Port of LA, and 4,581,846 for the Port of Long Beach. Thus, the 20,000-container storage capacity at these facilities equals about 0.2% of annual loaded imports at the San Pedro ports. In other words, the policy's allocation of land for storage is unlikely to make a meaningful difference by itself, though it could contribute to broader port congestion along with other initiatives.

N-19-21 also includes the following efforts:

- "A strategic partnership between the California State Transportation Agency (CalSTA) and the U.S. Department of Transportation for up to $5 billion in loan financing to advance a comprehensive, statewide portfolio of freight, goods movement and supply chain resiliency projects.
- Issuing temporary permits allowing trucks to carry increased loads on state highway and interstate routes between the ports of Los Angeles, Long Beach, and other statewide ports to expedite transport of international commerce between ports and distribution centers.
- Doubling the Department of Motor Vehicles' capacity to conduct commercial driving tests to address the national shortage of workers in the industry.
- Securing a 22-acre pop-up site, in partnership with the California Department of Food and Agriculture and the U.S. Department of Agriculture, located at the Port of Oakland to assist agricultural exporters in storing products and getting them onto containers. This site is expected to be operational on March 1." (DGS, 2022)

Other short-run solutions have been implemented by ports, government officials, and companies alike to address port congestion and other supply chain issues, including additional fees for long-dwelling containers on docks (Mongelluzzo, 2021b), moving towards 24/7 operations at the ports (Port of Los Angeles, 2021), adding resources to the congested rail network (Littlejohn, 2022), and establishing a Presidential Emergency Board to engage in dispute resolution and contract negotiations for the rail workers' union (AAR, 2022).

There are a number of long-run solutions to address supply chain issues and improve regional competitiveness. Ke and colleagues (2021) used a combination of public data and expert interviews to create a balanced scorecard comparing the competitiveness of multiple U.S. regions across five key freight transportation segments (seaports, airports, highways, rail, and warehousing). This study found that Californian highways and warehouses required significant investments to address highway congestion and reduce the labor, land, fuel, and electricity costs in California that impact warehousing competitiveness. While California's seaports and airports both perform highly compared to other regions, investments to expand seaport container terminal and air cargo handling facilities, to increase automation, and to add intermodal connections could help to manage the flow of chassis, container trucks, and empty containers, and address the cargo backlogs and congestion at ports and warehouses. The report also recommends investing in inland ports to transport goods by rail directly to inland processing facilities.

There are currently three major projects in the pipeline that offer examples of what this study recommends. First, the Mojave Inland Port is planned to be operational by 2024 and will transport containers via rail along the Alameda corridor from the San Pedro ports to Kern County, 90 miles inland (Businesswire, 2022). Second, BNSF Railway plans to invest $1.5 billion in an intermodal complex in Barstow, California, which is 70 miles east of Mojave and connected via a rail line and highway. These facilities combined will help to get freight to market more quickly and ease congestion around the San Pedro ports (Shepardson, 2022). Third, the U.S. Department of Transportation is developing a digital tool called "Freight Logistics Optimization Works" to improve the processing of information on supply chain performance by node and region (Shepardson, 2022). Information plays a critical role in all transportation systems, and numerous institutions exist to provide information to large numbers of agents within these systems whether for air traffic control, rail timetables, google maps, or radio traffic reports. However, public live (i.e., frequently updated) information around freight system performance is limited, especially across the different transportation modes. The government can play an important role here, where private companies might have limited incentive to invest.

2.2.4 Gaps in the Literature

There is a growing body of work on the environmental justice dimensions of warehousing (Giuliano & O'Brien, 2007; Wu et al., 2009; Kozawa, Fruin, & Winer, 2009; Yang et al., 2021; Yuan, 2018a; Yuan, 2018b; Yuan, 2019a; Yuan, 2019b; Yuan, 2021). Numerous studies cover environmental justice problems associated with freight activities, focusing on seaports or freight corridors and the impacts to public health from freight truck emissions (Giuliano & O'Brien, 2007; Wu et al., 2009; Kozawa, Fruin, & Winer, 2009). Numerous studies by Quan Yuan (Yuan, 2018a; Yuan, 2018b; Yuan, 2019a; Yuan, 2019b; Yuan, 2021) have also explored air quality and health impacts from freight and warehousing, as well as accidents. This reflects trends in the broader environmental justice literature, which initially focused on toxic waste sites, then air quality, and later, urban green space, climate changes, transportation mobility, and flood threats (Yuan, 2021).

However, there remain numerous unexplored issues and areas for future research. Studies of pollution tend to assume that more warehousing causes more traffic, which then causes more localized pollution. Given this assumption, prior studies drew their conclusions from aggregate pollution levels by location rather than measuring the pollution of trucks in the freight industry specifically. Studies are underway to unpack these relationships and confirm the relationship between freight traffic and localized air pollution. Local government policy making and planning also play an important role in warehouse location choices and, hence, in environmental inequalities; this dynamic has yet to be explored in the literature (Yuan, 2021).

Other gaps in the literature concern the impact of warehousing on jobs and housing. While warehousing is likely to have an impact on environmental and public health, it also provides employment to local workers. Municipalities are likely to see the benefits of warehouse development in terms of local business and income tax, while also seeing some environmental harms highlighted and addressed through the California Environmental Quality Act process. Related to this, warehousing in the Los Angeles region is both creating demand for housing and competing with housing for land. While some of these dimensions are discussed in the literature, they are not explored in depth.

2.3 Climate and Environmental Impacts of Warehousing

2.3.1 Warehousing and Climate Change

Climate change describes a change in the state of the climate that persists over decades or longer (IPCC, 2000). Warehousing activities can contribute to climate change through production, distribution, and disposal phases in multiple complex aspects of the supply chain. The use of limited non-renewable energy resources for warehousing activities has exacerbated the ongoing climate crisis (Ghadge et al., 2020). One study found that less packaging materials would reduce the weight and volume of transported goods, thus reducing GHG (Ji et al., 2014). However, another study found that less packing could otherwise lead to more transport damage of goods and reverse transport, thereby resulting in more GHG emissions (Oglethorpe & Heron, 2010).

The choice of applying cross-docking practices and increasing vehicle capacity (Dadhich et al., 2015), localizing supply chains (Nieuwenhuis et al., 2012), reducing vehicle speed (Paksoy & Ozceylan, 2014), shifting to sustainable transportation modes (Jin et al., 2014), and collaborating with stakeholders (Ramanathan et al., 2014) could impact overall GHG emissions and reductions, as demonstrated by the findings of these studies. These findings reveal the relationship between warehousing activities and climate change, especially through GHG emissions.

A European simulated study concluded that most supply chain GHG emissions contributing to climate change were produced during road travel (57%) and in total constituted 23% of all total GHG emissions (World Economic Forum, 2009; OECD, 2010). Warehousing alters the urban landscape and the built environment due to the large spatial widths of the buildings. This leads to more severe urban heat island effects (Voogt, 2007). The architectural designs of warehouses also impact the intensity of urban heat islands and energy usage (Indrawati et al., 2018). For example, in Jakarta, Indonesia, increasing population, urbanization, and intensified land uses for economic development have led to temperature changes through the urban heat island effect with average temperatures increasing from 289°K–293°K in 2007 to ≥ 293°K in 2013, which further exacerbates air quality, environmental quality, and energy use problems (Putra et al., 2021). The spatial expansion of warehouses is likely to increase emissions and climate change effects at a higher rate than the warehouses' initial environmental reports suggest (Allison, 2020).

In terms of mitigating contributions to climate change, sustainable designs for warehouses, freight trucks, and operation have been shown to be successful in decreasing GHG emissions, pollution, adverse health effects, and adverse environmental impact on local communities in Indonesia. These serve as highly transferable methods for use in the United States (Indrawati et al., 2018). A small increase in costs to obtain more sustainable operation devices produces a large increase in emissions savings (Fichtinger et al., 2015).

2.3.2 Warehousing and Traffic

Empirical studies have found that introducing warehouses into an area contributes to a large increase in general traffic and congestion, especially in truck traffic. For example, a newly introduced warehouse increased truck flow significantly in Mott Haven, New York, alongside the increased traffic burden of a 10% to 40% increase in vehicles at the monitoring sites (Shearston et al., 2020).

Evaluations of the increase in Amazon Warehouses located in Inland Empire also reported increases in truck traffic (Allison, 2020). These impacts also exacerbate air quality problems and adversely affect local residents through increased accidents, congestion, noise pollution, wear and tear on local roads, and burdens in access to public transportation (Indrawati et al., 2018; Lindsey et al., 2014; Cidell, 2015). Major freight generators were highly associated with freight truck-related crashes in the Los Angeles region (Yang, 2021).

Two studies in Southern California have estimated the warehousing-related truck trip generation rates. A survey conducted for NAIOP Inland Empire found that the average truck trip generation rate was 0.3 truck trips per day per 1,000 square feet of warehousing; 70% of the trucks were five-plus-axle combination trucks (Kunzman Associates, 2011). The South Coast Air Quality Management District estimated the truck trip generation rate at 0.66 truck trips per day per 1,000 square feet of warehousing. This means that a one-million-square-feet warehouse brings about 660 daily truck trips to the region (South Coast Air Quality Management District, 2014). Heavy duty diesel trucks (HDDT) in association with the Port of Long Beach on the I-710 freeway average 1100 trucks per hour with peak hours of 2200 to 2600 trucks (CalTrans, 2006; Ntziachristos et al., 2007; Zhu et al., 2002). Street intersections in Wilmington and West Long Beach were observed to have an average of 660 HDDTs per hour (Houston et al., 2008).

It is claimed that warehouse locations are chosen with a strong consideration for transportation access for freight trucks, although empirical evidence has shown this factor to be insignificant (Yuan, 2018a). There is an increase in truck movement-related fatalities with the introduction of warehouses, that is, a 15% rise in suburban areas and a 17% rise in urban areas (Giuliano, 2013; McDonald et al., 2019). Greater attention within the planning process to factor freight truck travel routes based on the location of the warehouse has the potential to decrease freight-related accidents (Yang, 2021) and truck emissions (Yuan, 2018a).

2.3.3 Warehousing and Air Quality

The warehousing industry produces an immense amount of pollution that decreases air quality through the processes of operation and transportation (Fichtinger et al., 2015; Yang, 2018). With 66% of U.S. electricity powered by fossil fuels (EIA, 2014), operations of commonly inefficient warehouse heating, cooling, and lighting produce harmful emissions (Ries et al., 2017; Rai et al., 2010). Specifically, lighting alone accounts for a substantial portion of energy usage, with the United Kingdom Warehouse Association (2010) reporting it to be as high as 65%, while other sources, such as the Department of Energy and Climate Change (DECC, 2013), estimate it at around 29% of total energy consumption. The usage of alternative lighting equipment is a more sustainable option that would save between 80–90% of energy use (Ries et al., 2017) that likely comes from sources impacting air quality (e.g., fossil fuels).

The World Health Organization reported that an increase of black carbon by 10 $\mu g/m^3$ is associated with a notable 1.64% increase in child asthma hospitalizations (Quincey, 2007). Increasing warehousing activity has the potential to worsen air quality. An empirical study on a newly introduced warehouse in Motts Haven, South Bronx, showed significant increases in traffic, translating into a mean predicted increase of 0.003 $\mu g/m^3$ in black carbon. Although the increase of black carbon was small in comparison to the quantity that increases childhood asthma hospitalizations, any increase in black carbon is against community efforts to combat poor air quality (Shearston et al., 2020).

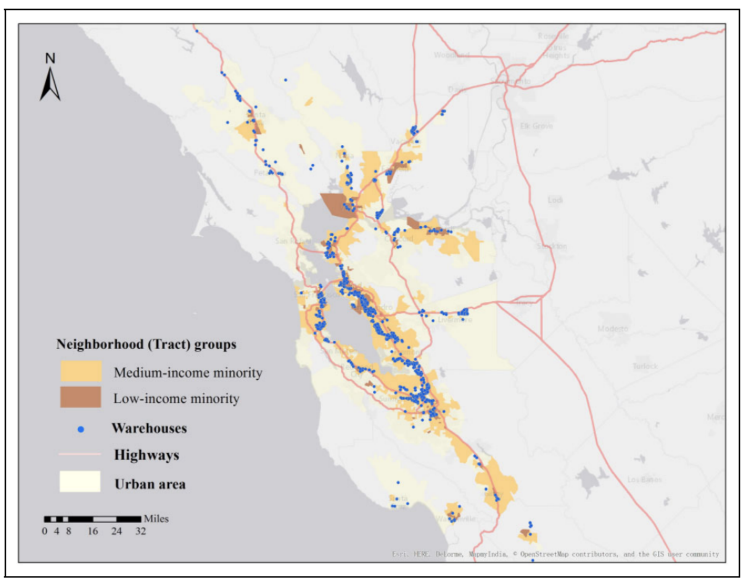
Freight trucks are particularly detrimental to air quality and because of their large contribution to supply chain emissions (57%), most warehousing research on environmental impacts focuses on freight transportation rather than operations (Fichtinger et al., 2015; Ries et al., 2017). Heavy duty trucks generate 51% of NO_x and 21% of PM_{10} (particulates that are 10 microns or less in diameter) out of all on-road emissions in the United States (US Environmental Protection Agency, 2014). North-central France has similar data, with freight trucks generating 59% of PM_{10}, 43% of SO_2, and 38% of NO_x of all on-road emissions (Dablanc, 2013). The introduction of more warehouses increases the amount of on-road freight trucks, thus exacerbating their contribution to these air pollutants, as well as traffic congestion across local communities (Shearston et al., 2020).

The few areas in the United States to implement a regulation in relation to these statistics of freight truck air quality impact include the "Clean Truck Program" of Los Angeles, which has been successful in air quality management due to continuous regulation (Dablanc et al., 2013). Impact fees disincentivize warehouses from producing an excess of environmental externalities, such as black carbon or excess particulate matter, but are rarely enforced (Yuan, 2019b). Proper initial environmental reports and continuous government regulation will help decrease warehouse air pollution.

2.3.4 Warehousing and Land Use

The most economically efficient land is chosen for warehouses and, because of this dynamic, warehouse facilities often settle in low- or medium-income minority neighborhoods. These areas have lower tax rates because land is considered to be undesirable. Other factors, such as accessibility to land, labor, and transportation, and the effects of agglomeration impact warehousing location choices (Allison, 2020; Jaller et al., 2020; Yuan, 2018a). An empirical study found access to transportation to be an insignificant factor when warehouses chose locations (Figure 12) and discovered proximity to minority communities to be a stronger factor (Yuan, 2019a). Some warehouses claimed that they often share land with minorities due to shared interests (e.g., access to transportation, inexpensive land, access to labor/work). However, there was a strong correlation in the direction of warehouses choosing land where minorities reside due to low- to medium-income minorities' lack of economic opportunity to compete (Yuan 2018a; Yuan 2018b).

Figure 12. Spatial Distribution of Warehouses and Selected Types of Neighborhoods in the San Francisco Region



Source: Yuan (2018a)

Local governments often offer financial incentives to warehouse developers to encourage them to use land in their regions for operations and expansion. These incentives can result in more relaxed regulations. It is important to note that fulfillment warehouses conducting transactions with customers are subject to sales tax, and the location choices of developers building these warehouses are often influenced by these economic factors. These findings indicate that warehouses are often situated on land considered 'undesirable,' which is frequently inhabited by low-income minority residents (Yuan, 2019b). While local governments typically prioritize the tax revenue and job opportunities that warehousing facilities can bring to the community, it's essential to note that the evolving nature of warehousing, with a significant portion of jobs now performed by robots, has reduced its impact on job opportunities (Yuan, 2019b; Cidell, 2011; Dablanc, 2014; Yuan, 2018a). Consequently, warehouses may not provide communities with as substantial an economic benefit in terms of employment as other land-use options might. This focus on economic benefits often overshadows considerations of increased environmental regulations for warehousing, as local governments do not commonly perceive warehousing as a significant environmental concern (Saha & Paterson, 2008).

The environmental externalities warehouses produce become increasingly concerning when close to neighborhoods. A city planner in Santa Fe explained that there were no policies in Santa Fe supporting or opposing warehousing, and any vacant land could be used for warehousing (Yuan, 2019b). Another planner in Carson, California acknowledged that if environmental land-use rules were not present in the land-use policy, warehouse presence and environmental impact would not be considered when making decisions (Yuan, 2019b). The lack of land-use policy and environmental awareness of decision-makers exacerbated the environmental issues with warehousing. The success of a warehouse often results in expansion, which leads to the increased concentration of warehouses in areas with already unequal and high distributions (Allison, 2020; Yuan, 2018b). Policy makers make long-lasting land-use decisions, which may not always align with community preferences or recommendations (Yuan, 2019a). Policy makers should be aware of warehousing's environmental impact, in and outside of highly vulnerable communities.

2.3.5 Warehousing and Environmental Justice

Warehouses reside in a variety of neighborhoods, but there is an empirically discernible pattern whereby they are disproportionately placed in low- to medium-income minority neighborhoods (Yuan, 2018b). In pursuit of economic advantages, warehouse developers look for low- to medium-income minority communities that have lower tax rates and accessibility to labor (Jaller et al., 2020). A study further evaluated minority populations and concluded warehousing intensified with the inflow of Asian and Latinx populations, but not with the inflow of Black populations (Yuan, 2018b). Studies on warehousing's relationship with ethnic populations are limited. The evidence for the relationship between warehouse locations and minority communities is strengthened through a simulation study showing the presence of minorities encourages warehouse expansion (Yuan, 2018b).

Warehousing development and expansion in neighborhoods is not considered an environmental threat by local governments despite community concerns about warehouses. An urban planner in Carson, California confirms that if land-use policy lacks rules for protecting the communities that warehouses disproportionately settle in, they will not be protected by urban planning decisions (Yuan, 2019b).

An analysis suggests that proximity to low- to medium-income minority populations is associated with a higher likelihood of experiencing poor air quality, health issues caused by environmental toxins, and other negative effects of warehousing, as seen in companies such as Amazon (Allison, 2020; Shearston et al., 2020). When warehouses are introduced into these neighborhoods, pollution multiplies. As shown in Table 4, San Bernardino County faces nine times as many high ozone days as adjacent counties, which could be explained by the newly introduced Amazon warehouses. The number of high ozone days appears to be positively correlated with each evaluated county's proportion of Latinx/Hispanic residents.

Table 4. Spatial Inequality in Southern California

Metropolitan Statistical Area (MSA)	Racial/ Ethnic Diversity	Ave. Age	Median Income	Poverty	Poorest Social Group	Primary Employment Sectors	High Ozone Days 2015-17
Riverside-San Bernardino-Ontario	Latinx/ Hispanic: 51% White: 29%	35	$62K	17%	Hispanic Women 25-34	Retail Trade: 13% Health Care: 13% Warehouse: 8%	SB: 161 Riv: 130
Los Angeles-Long Beach-Anaheim	Latinx/ Hispanic: 45% White: 29%	37	$70K	16%	Hispanic women 25-34	Health Care: 12% Retail Trade: 10% Manufacture: 10% Warehouse: 5%	LA: 119
Orange County	Latinx/ Hispanic: 34% White 40%	38	$86K	12%	White women 18-24	Manufacture: 13% Health Care: 12% Retail Trade: 10% Science-Tech: 10% Warehouse: 3%	OC: 18
San Diego-Carlsbad	Latinx/ Hispanic: 34% White: 45%	36	$76K	13%	Hispanic women 25-34	Health Care: 13% Retail Trade: 11% Science-Tech: 10% Warehouse: 3%	SD: 37

Source: Allison (2020)

These populations face pre-existing environmental burdens that warehousing further intensifies. A study evaluated that long-term exposure to $PM_{2.5}$ (particulates that are 2.5 microns or less in diameter) corresponds to a higher mortality rate in populations living in poverty and/or without a high school diploma. Mortality rates also increase in connection to $PM_{2.5}$ exposure when a city has a higher number of Black residents (Kioumourtzoglou et al., 2016; Shearston et al., 2020).

Neighborhoods with freeways experience a large amount of environmental pollution from freight truck routes. An empirical study assesses pollution levels in areas of impact, located less than 150 meters from freeways included in freight truck routes, relative to reference zones greater than 150 meters away (Kozawa et al., 2009). The pollutants black carbon, NO (Nitric Oxide), and UFP (Ultrafine Particles) were two times higher at impact zones than reference zones in the morning, and one and a half times higher in impact zones with changes in ratio attributed to wind displacement of the toxins towards adjacent communities in reference zones (Kozawa et al., 2009). Reference zones commonly had higher CO_2 concentrations due to wind displacement, showing that immediate and adjacent communities are affected by freight travel in the Los Angeles and Long Beach ports. Environmental reports should acknowledge this in order to better control air quality (Kozawa et al., 2009). Communities located on freight truck routes not near warehousing facilities should also be considered when planning to decrease environmental impacts.

2.3.6 Other Potential Overlooked Impacts of Warehousing

High numbers of heavy-duty trucks in neighborhoods lead to increases in truck accidents and road pavement damage. Accidents result from a combination of factors including land use, freight generators, economic attributes, road infrastructure, and road network variables. Freight truck impacts have the potential to harm pedestrians, bicyclists, and others. Accidents at night or in harsh weather conditions are more severe and disrupt the quality of life in neighborhoods containing freight truck routes. Road infrastructure often lacks the safety signals to prevent truck accidents and development of road safety should be considered when planning warehouses (Yang et al., 2021).

Although there is a strong pattern of warehousing located in low- to medium-income minority neighborhoods, other communities are also affected by warehousing pollution. Port-adjacent communities experience an increase in air pollutants because of wind displacement, despite not being in direct proximity to warehouses or ports (Kozawa et al., 2009).

Disruptive, distracting, and stressful warehousing activity noises create a noise burden that can lead to negative health effects. The average level of noise pollution in Motts Haven ranged between 63.7 to 75.0 dBA, which is within the average range of New York noise pollution levels (55.8–95.0 dBA). With the introduction of a new warehouse, there was a small predicted average noise increase of 0.06 dBA resulting from traffic increases. However, the average measurement does not account for the noise burdens of sudden sounds, such as freight truck horns at night or at unexpected times that may induce stress in the local community (Sheartson et al., 2020).

2.3.7 Warehousing Workforce Issues

Warehousing may be desirable economically for the jobs it provides, but jobs within this field often have low stability and low pay in comparison to other jobs. In Southern California, 60% of warehouse workers worked temporarily and without health benefits or stable hours (Yuan, 2019b).

Even if they work full-time, employees receive low wages. It was reported that the introduction of Amazon warehouses led to a 3% decrease in wages in areas that already commonly face socioeconomic disparities (Yuan, 2019b; The Economist, 2018).

Technological advances led to robots replacing 75% of warehouse jobs, creating a low job density in the industry (Yakowicz, 2017; Yuan 2019b). Warehousing job density in Southern California is 11 employees per acre, as opposed to retail with 22 employees per acre, heavy manufacturing with 33 employees per acre, or offices with 44 employees per acre (The Natelson Company, Inc., 2001). Local governments often make warehousing expansion decisions with the hope of creating job opportunities, but the low job density of warehouses may not allow for as many jobs as other industries could with the same amount of land (Yuan, 2019b).

2.4 Land Use and Housing

Housing development is determined by city zoning rules and processes. City processes vary depending on whether they follow a rule-based "By-Right" approach, whereby administrators approve or deny projects based on permitted parcel use, shape, and density requirements, or a "Discretionary" process whereby review boards, elected officials, city staff, and community hearings interact to create unique requirements for each project. Cities tend to sit on a spectrum between these two approaches and might follow different processes depending on the parcel type and size of the project under consideration (NMHC, 2019). Discretionary approaches open the door for "NIMBY" ("not in my backyard") tendencies among local residents, especially when projects might have adverse environmental impacts on the community.

While discretionary and other land-use restrictions provide an avenue for community input, they may also lead to declining housing affordability over time. Conversely, an easing of land-use restrictions may help to increase the housing supply which may eventually reduce housing prices. Having more people who could afford houses would reduce wealth inequality in society and improve the local quality of life (Albouy & Ehrlich, 2018). Households must save in order to purchase a house, so housing affordability constraints determine household spending. Households reduce their non-housing expenditures on necessities such as their food, education, and health to be qualified to be homeowners. Thus, housing affordability constraints have negative consequences on personal and social life in the long run (Acolin & Green, 2017). To address housing affordability concerns, policy makers have some tools to help people buy housing, such as first home buyer benefits, tax credits, easing regulations for builders, facilitating new constructions, and requiring builders to allocate some portion of their buildings for low-income households. However, rents and house prices have gradually increased due to tight planning regulations and increased costs of labor and materials in the construction industry (Anacker, 2019).

Economists, urban planners, environmentalists, and policy makers enact rules and define zoning classifications with the aim to help people afford housing. There are some zoning requirements—such as the number of required parking spaces for each unit, height of buildings, and minimum square footage)—that could be the main obstacles for new housing developments. However, there are some incentives in certain regions to encourage builders and developers to build housing. For example, Los Angeles' density bonus ordinance offers some incentives to developers who are qualified to build more units in the same lot size compared to the other areas. Thus, developers may be able to earn more profit with this specific incentive. Cities should have basic regulatory floor plan requirements while requiring builders and developers to provide public benefits if they are asking for exceptions and looking to build more affordable and low-income units in the same region. Although local policy makers determine land-use regulations, state governments can play an important role to provide those policy makers with short-run and long-run directions (Gabbe, 2018).

Exclusion zoning, known as redlining, is a series of zoning measures that creates a divide between urban and suburban areas (Serkin & Wellington, 2012). This divide has had a devastating impact on the quality of life of low-income communities (Silver, 1997). Having left generations of predominantly black and brown people with limited options to acquire stable housing (Pastor, Morello-Frosch, & Sadd, 2005), Los Angeles has led zoning efforts to define the zoning area for each area (commercial, industrial, and residential), being the first city in the nation to develop zoning ordinances in 1908 to preserve residential areas from the impact of industrialization (Silver, 1997). Since 1908, Los Angeles has continued to set regulatory standards for local land use with a series of zoning standards that comprise what can be defined as the racial zoning movement (Nardone, Anthony, Joey Chiang, & Jason Corburn, 2020). These practices have shaped areas of Los Angeles, leaving communities of color in neighborhoods that have experienced decades of disinvestment (Nardone, Chiang, & Corburn, 2020).

While redlining and other racial zoning policies are no longer explicit, recent policy initiatives such as "By-Right Development", "Up-Zoning", and "Opportunity Zones" might have consequences that disproportionately impact disadvantaged communities. At the very least, these measures spur changes in these communities that create winners and losers. "By-Right Development" follows rule-based zoning with review by administrators and avoids local community review. This approach allows developers to increase housing supply without potentially costly time delays (NMHC, 2019); however, removing community input from the review process might result in environmental impacts that negatively impact low-income communities and people of color.

"Up-Zoning" refers to city policy changes that increase zoning-allowable density by relaxing constraints on building height, bulk, and floor area ratios. On the one hand, these approaches can improve housing supply and hence affordability; however, empirical studies have found that "Up-Zoning" is associated with increased short-run property prices—possibly due to the improved development potential—and neighborhood gentrification (Davis, 2021). Pastor (2007) also reflects on the potential of "Up-Zoning" and upbuilding as planning strategies that can mitigate air quality and congestion.

“Opportunity Zones” were created through the 2017 Tax Cuts and Jobs Act to increase economic development in low-income communities with tax incentives. “Opportunity Zones” appear superficially to have increased investment, by an estimated $48 billion in 2018–20, which is concentrated in urban areas (Theodos et al., 2023). However, it is unclear whether this investment would not have occurred anyway, as it is concentrated in a specific type of tract where economic conditions were already favorable (Theodos et al., 2023). There are interesting racial dimensions here. Zones receiving investment appear to have lower shares of Black residents, yet higher shares of Latinx residents, compared to those not receiving investment (Theodos et al., 2023).

In neighborhoods throughout Los Angeles, developers use these tools to respond to the housing crisis. These policies furnish developers with tools within the zoning code to build at high density and near freeways (Barboza & Schleuss, 2017). Multi-family building permits are allowed in areas that are high traffic, and densely populated, and developers have an incentive to build in these areas of the city. These areas also have a high rate of homeless population (Barboza & Schleuss, 2017). The unintended consequences of increased housing in these neighborhoods places a burden on local communities.

With EO N-19-21 in mind, it can be instructive to consider whether using government land for affordable housing would be beneficial. There are over 58,000 acres of city-owned land in Los Angeles (Walker, 2019). Access to public land may provide an opportunity to meet the need for housing (Garde, 2016). However, even if city policy were to require affordable housing be built on available city-owned land, this may not increase the production of affordable housing. The housing market in Los Angeles is competitive and affordable housing developers are unfairly positioned with respect to market-rate developers. In most cases, the use of public land increases the amount of time a project takes to complete. Moreover, the use of the surplus land may have unintended consequences for developers regarding the geotechnical feasibility of the site. Often these public sites have increased environmental burden resulting from contamination from previous industrial or toxic use (Hickey & Sturtevan, 2015).

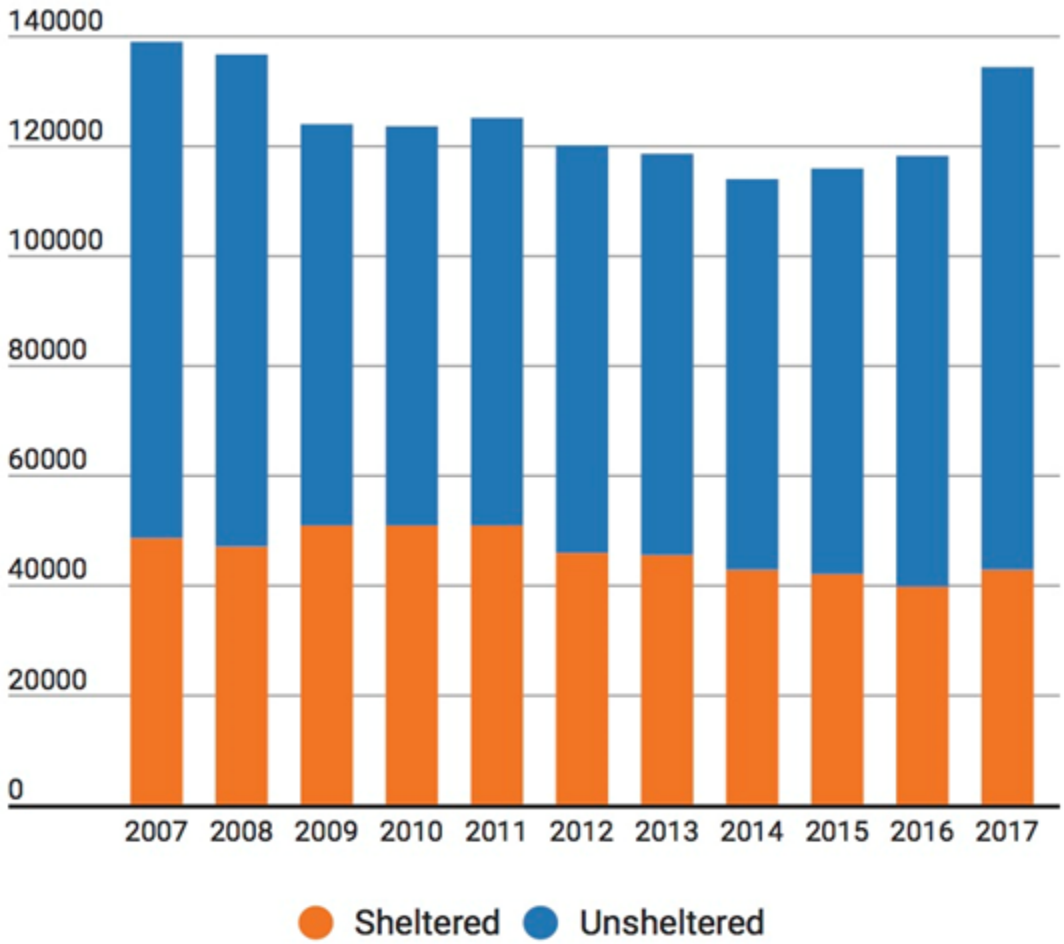
2.4.1 Housing Demand and Affordable Housing

Gong and Yao (2022) examined the impacts of demographic changes on the housing market. They showed that the urbanization rate had increased from 76% to 84% in the United States from 1970 to 2010. Thus, more people have moved from rural areas to metropolitan areas. This movement impacts housing prices. Their findings indicate that housing prices will keep growing by 4.42%–18.85% from 2010 to 2050 based on urbanization rates and the level of immigration (Gong & Yao, 2022). Choi and Jung (2017) used cross-country panel data to indicate that the active share of the population has statistically significant impacts on housing prices. They concluded that stable population growth would moderate housing-price growth and economic cycles (Choi & Jung, 2017).

Homelessness is caused by a lack of affordable houses, and is both a national and local concern and challenge in the United States. Los Angeles County has the largest population of homeless people in the United States. Los Angeles had an estimated 60,000 homeless individuals in 2019 (Chinchilla & Gabrielian, 2020), although this count only captures unsheltered populations, and does not account for those living in vehicles, in vulnerable housing situations—e.g., "couch surfers"—or those in temporary hostels or shelters. Many more people are at risk of being homeless in the metropolitan area due to the lack of affordable housing. Approximately 17 out of every 10,000 individuals are homeless in the United States. Shelter is a basic need and human right in each region. The homeless population has increased significantly in recent years due to rising unemployment and poverty rates. A high percentage of homeless people live in vehicles such as cars, vans, and recreational vehicles. Almost 25% of the homeless population in Seattle live in vehicles while in Los Angeles this rate is 50% (Giamarino, Brozen, & Blumenberg, 2022). The lowest number of homeless was reported in 2014, while the highest was in 2007. Almost two-thirds of homeless in California are sheltered and one-third are unsheltered. Homelessness is a statewide problem due to many reasons, such as high housing costs and a general lack of affordable housing. Understanding the geographical distribution of homelessness is important for policy makers to design effective policies in this regard. Figure 13 shows California's homeless population over the last decade, divided into sheltered and unsheltered (an unsheltered person has been found living on the street, parks, or other places not meant for human habitation).

Previous studies show that employment offers sufficient income to obtain housing. Homeless populations have high levels of unemployment (Axe, Childs, & Manion, 2020). Gould and Williams (2010) used a panel dataset from 1993 to 2001 from Missouri and showed that emergency sheltering is positively related to the unemployment rate.

Figure 13. Homelessness in California, 2007–17



Source: Department of Housing and Urban Development, 2023

Historical land-use policy has produced a housing crisis and has left areas of Los Angeles with minimal options to meet the needs of the current population (Whittemore, 2012). Land-use and housing policy have engendered issues of equity, access, and affordability throughout the state of California, which are further aggravated in Los Angeles (Silver, 1997).

3. Methodology

This study identifies and predicts current and future gaps between supply and demand for warehousing and housing in Southern California, explores land-use and zoning policies, and assesses multiple scenarios of environmental impacts, thus informing land-use strategies to address challenges in housing, warehousing, and the environment. Section 3.1 explains the study's warehousing supply and demand modeling process; Section 3.2 presents the study's housing analysis; and Section 3.3 presents the study's environmental impact analysis.

The project's analytical framework, as presented in Table 5, encompasses a comprehensive analysis of both the warehousing and housing sectors. For warehousing, the framework involves an in-depth examination of demand through 2040 using CoStar data, along with considerations of zoning and policy constraints. Emissions analysis for warehousing scenarios, including traffic generation and air pollution, is conducted under three distinct cases (see Table 5). In parallel, the housing aspect of the project involves an exploration of the housing deficit in California, an analysis of current housing stock and trends, and an evaluation of low-income housing supply. Additionally, housing zoning and policy issues are briefly outlined. Similar to the warehousing analysis, emissions assessments for housing scenarios, focusing on traffic and air pollution, are carried out for 2040 forecasts and in relation to meeting housing shortages within SCAG regions. This analytical framework provides a comprehensive basis for understanding the dynamics of both warehousing and housing sectors, aiding in informed decision-making and policy development.

Table 5. Project Analytical Framework

	Warehousing	Housing
Demand Analysis	Analysis of warehousing demand through 2040 using CoStar data.	Review of the literature on housing deficit in California; analysis of current housing stock and trends.
Supply Analysis	Analysis of warehousing supply through 2040 using CoStar data.	Analysis of low-income housing supply; review of affordable housing unit development trends and policy.
Zoning and Other Policy Constraints	Brief on warehousing zoning and policy issues.	Brief on housing and affordable housing zoning and policy issues.
Emissions Analysis (C-LINE) Case 1	Calculation of traffic generated from warehousing freight transport for N-19-21, and associated air pollution.	Calculation of traffic generated for the same area provided under the N-19-21, and associated air pollution.
Emissions Analysis (C-LINE) Case 2	Calculation of traffic generated for the 2040 forecast scenario of warehousing, and associated air pollution.	Calculation of traffic generated for the 2040 forecast scenario of housing, and associated air pollution.
Emissions Analysis (C-LINE) Case 3	Calculation of traffic generated if the warehousing shortage were met using available state lands, and associated air pollution, by region within SCAG.	Calculation of traffic generated if the housing shortage were met, and associated air pollution, by region within SCAG.

3.1 Warehousing Supply and Demand Modeling

SCAG is the nation's largest metropolitan planning organization, representing six counties (Imperial[1], Los Angeles, Orange, Riverside, San Bernardino, and Ventura), 191 cities, and more than 19 million residents. Figures 14, 16, and 17 report the share of inventory, demand growth, and vacancy rates in the SCAG region, respectively. Following the market definition of the CoStar database, the six counties were aggregated into four industrial markets: Los Angeles, Orange, Ventura, and Inland Empire (including Riverside and San Bernardino).

The LA industrial market, located in the center of the Southern California industrial market, is the largest county in the United States by most measures. Its warehouse inventory share in the SCAG region shrank from 52% in 2008 to 47% in 2022 (see Figure 14). The main reason for the share loss is a lack of available land. Its warehouse inventory growth has been less than 1% in the

[1] Because Imperial County is not included in the CoStar data, it is excluded from this study.

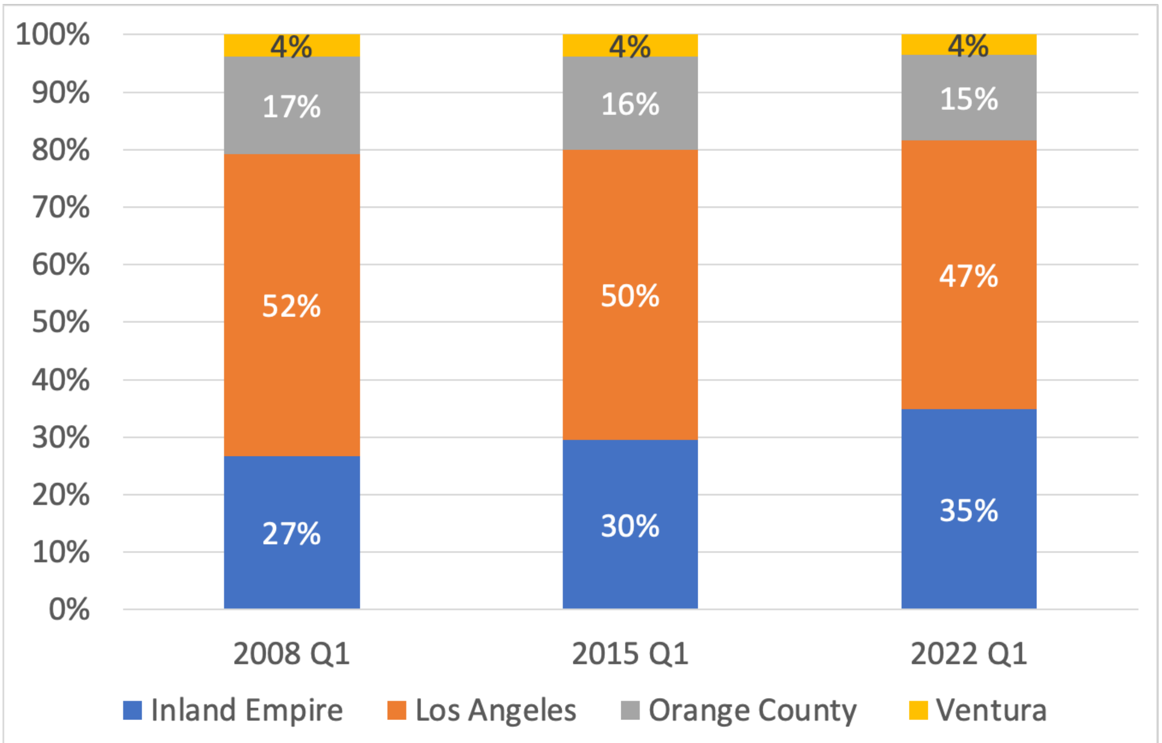
past two decades (see Figure 15). During the 2020–2021 pandemic period, elevated traffic at the Ports of LA and Long Beach resulted in the lowest vacancy rate in the United States (see Figures 16 and 17), and the rental rates, which have been increasing for over a decade, were pushed to new highs. High land costs and limited development sites constrain new construction. As a result, most inventory in LA is older and smaller than in many other industrial markets across the nation.

The Inland Empire (IE) industrial market has had the highest demand growth compared with other counties in the SCAG region due to higher land availability (see Figure 16). The growth in e-commerce and an increased effort to improve efficiency at the last mile of distribution made IE a popular location for industrial development. The presence of high-credit tenants, such as Amazon, Walmart, Target, and General Pacific, attracts institutional investors worldwide. Before the pandemic, the growth of warehouse demand in 2018 in IE was around 4.7%, much higher than the growth in the neighborhood in Q1 2019 onwards (see Figure 16). From Q4 2020, the pandemic-related import surge led to strong demand for warehouses. However, the inventory of warehouse spaces failed to accommodate the demand, leading to the lowest vacancy rate in the past 15 years. The vacancy rate in IE dropped significantly from 5% in Q1 2018 to 1.3% in Q1 2022 (see Figure 17).

Orange County's (OC) proximity to the ports and major paths into IE amid a dense population has reinforced its growth in recent years. With supply chain disruptions during the pandemic, e-commerce tenants look for warehouses to store goods, leading to a vacancy rate of 2% in Q1 2022, well below the 10-year average of 3.3%, and currently trending near an all-time low (see Figure 17). South OC, like Irvine and Irvine Spectrum, attracts high-tech tenant firms that have formed an incubator-type atmosphere among them. The electric vehicle ecosystem is also solidifying in OC, with recent signings by Tesla in Costa Mesa, Rivian Automotive in Tustin, and Fisker Automotive in La Palma. These firms are taking a mix of flex, manufacturing, and distribution space. Developers are building logistics-oriented infill projects to accommodate pent-up demand.

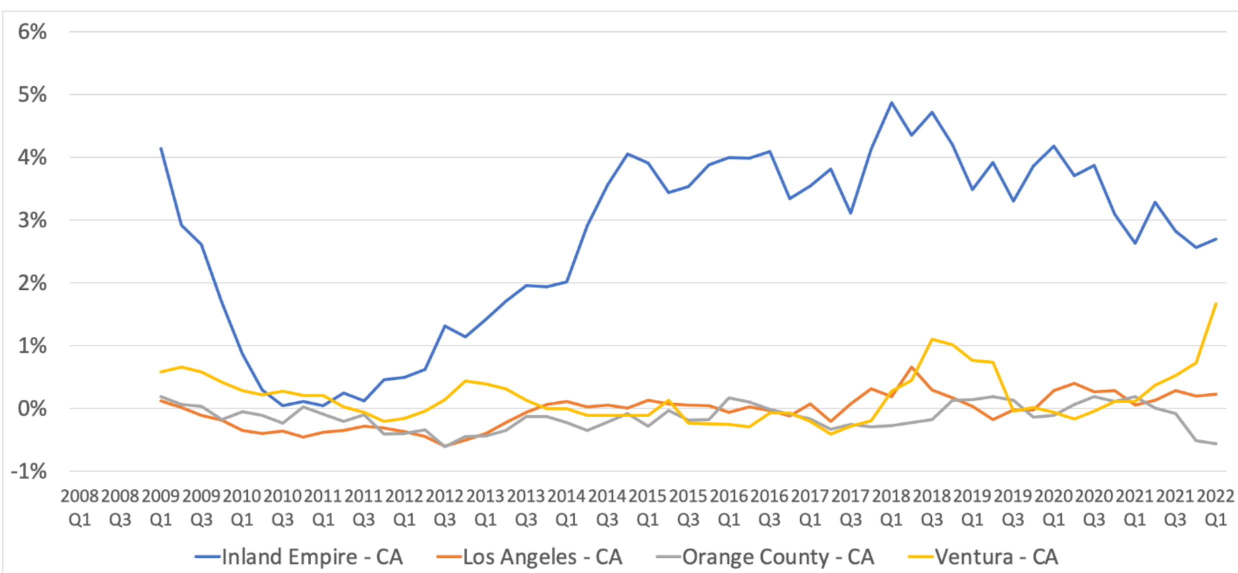
Ventura County has a strong connection to Port Hueneme and Amazon. Port Hueneme, located in the southern part of the metro, is one of the busiest ports in the nation, with specialties in automobiles, produce, and agriculture. It handles a significant portion of west coast roll-on roll-off cargos. Amazon has opened several fulfillment centers in the area and signed leases for more than 2.5 million square feet in the past couple of years. As a result of Amazon's activity and local industrial user demand, vacancy is trending at a historic low of 1.6% in Q1 2022 (see Figure 17).

Figure 14. Share of Warehouse Inventory in the SCAG Region



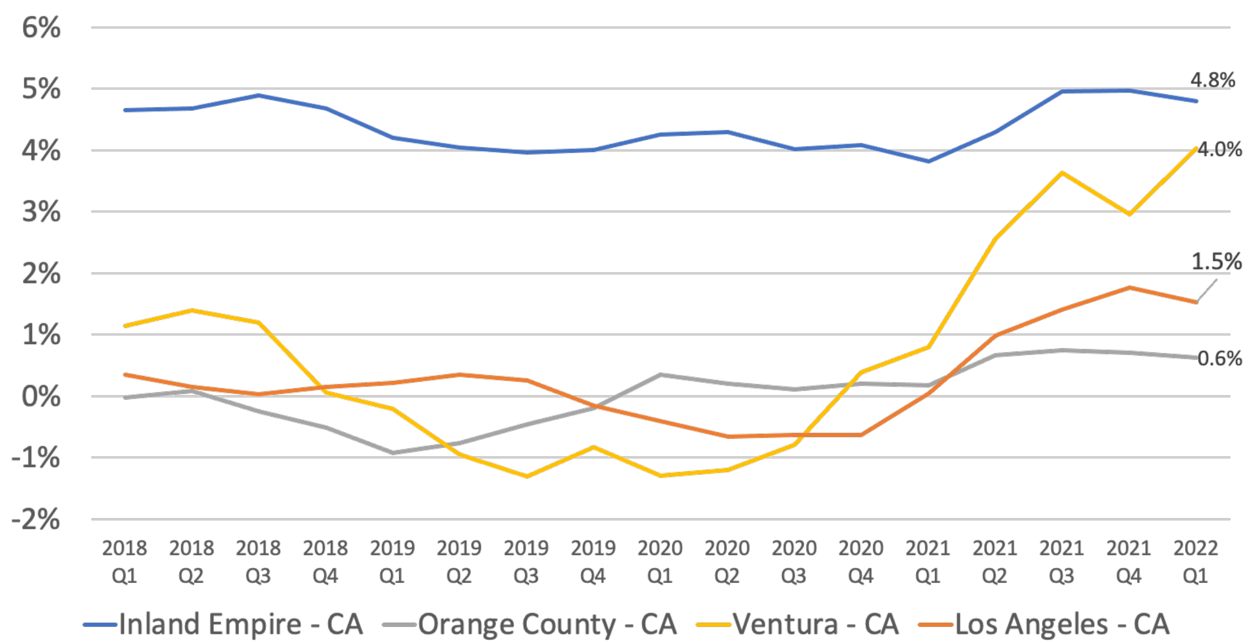
Source: CoStar Database

Figure 15. The Growth of Warehouse Inventory in the SCAG Region



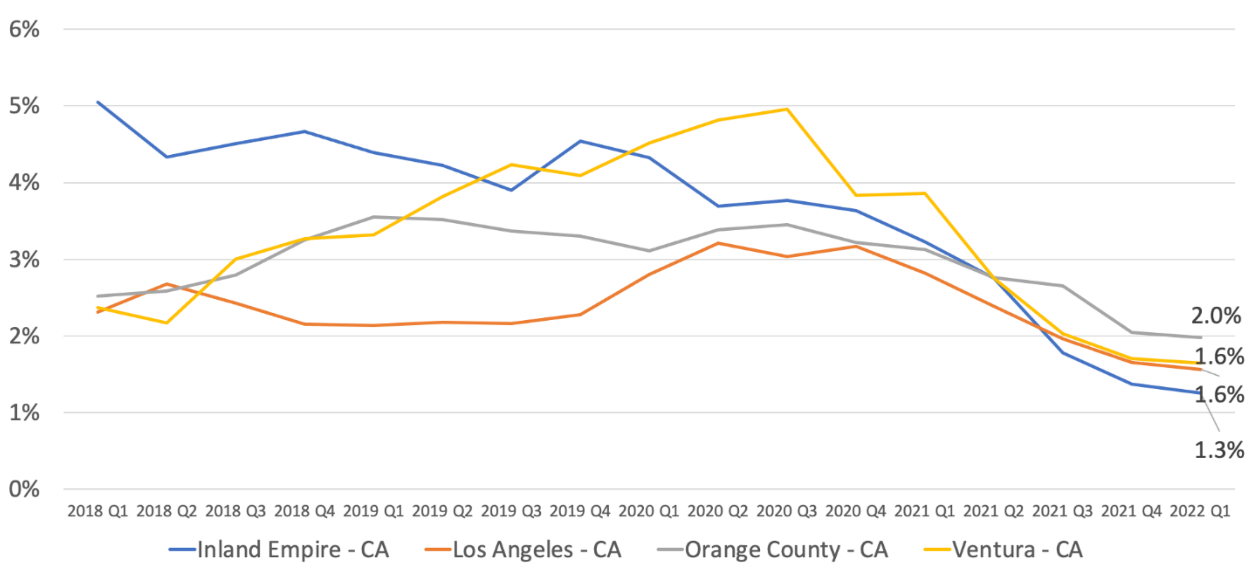
Source: CoStar Database

Figure 16. The Growth of Warehouse Demand in the SCAG Region



Source: CoStar Database

Figure 17. Vacancy Rate in the SCAG Region



Source: CoStar Database

3.1.1 Warehouse Supply Model Scenario 1: CoStar Base Case

This study uses the warehouse supply model developed by CoStar for the quarterly warehouse inventory forecast from 2022–2032. The forecast considers the construction plans over the next several years that developers will conceive, propose, start, and ultimately complete. The CoStar quarterly inventory forecast from Q4 2022 to Q4 2032 for Inland Empire (including Riverside County and San Bernardino County), Los Angeles County, Orange County, and Ventura County was downloaded in October 2022.

Equations 1-3 below explain the methodology CoStar uses to forecast inventory.

The starts model includes lagged change in rent and the lagged natural log of the vacancy, represented as:

$$\textit{Equation 1: } Start_t = f\,(\Delta Rent_{t-1},\ \ln Vac_{t-1})$$

where $Start_t$ is construction starts, $\Delta Rent_{t-1}$ is the percentage change in rents, and $\ln Vac_{t-1}$ is the lagged natural log of the vacancy rate.

The amount of construction underway can then be modeled by starting with the space underway today (the last historical date) and adding modeled starts and subtracting modeled deliveries, as in:

$$\textit{Equation 2: } Const_t = Const_{t-1} + Start_{st} - Deliv_t$$

where $Const_t$ is the amount of space underway at time t, $Const_{t-1}$ is the amount of space underway in the prior period, $Start_{st}$ is construction starts (from *Equation 1*), and $Deliv_t$ is modeled deliveries.

Deliveries are estimated by applying the historical average of deliveries as a share of space underway in each market, as in:

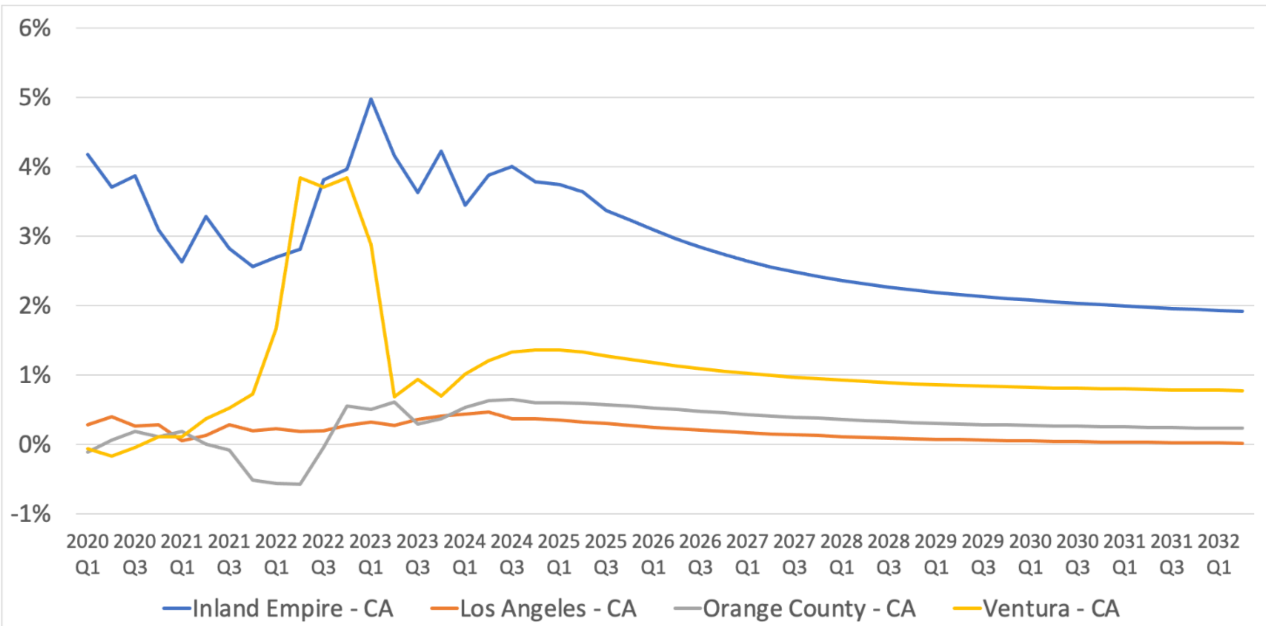
$$\textit{Equation 3: } Deliv_t = Const_t\,(\Sigma(Deliv_h/Const_h))$$

where $Deliv_t$ is the deliveries of new space at time t, $Const_t$ is the amount of space underway at time t, and h denotes historical periods.

Unlike the 2018 SCAG report (Cambridge Systematics, 2018) that assumes a constant supply constraint for 2018–2040, Co-Star's warehouse inventory forecast for 2022–2032 is dynamic and driven by rent, vacancy, and known and predicted construction projects. CoStar assumes that the number of constructions started depends on the demand, which is predicted based on the rent and vacancy rate in the last period. The supply differs by scenarios representing different assumptions on the factors that affect demand, including geopolitical tensions, supply chain efficiency, government policies, and the economy.

In this project, we aim to estimate the supply shortage from 2022–2040 and identify available state-owned properties to be allocated for warehousing construction. For the demand during 2022–2040, we developed our demand model (see Section 2.3) and forecasted the demand by county. For the supply or the warehouse inventory, we used CoStar's inventory forecast during 2022–2032 based on CoStar's Base Case. Then, we extended the forecast from 2033–2040 through the exponential smoothing method. Figure 18 and Table 6 present CoStar's forecasts for inventory growth by county during 2022–2032. It shows higher variability from 2022–2025 and becomes smooth afterward.

Figure 18. Forecast for Inventory Growth in the SCAG Region



Source: CoStar Database

Table 6. Forecast for Inventory Growth in the SCAG Region – Warehouse Supply Scenario 1

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Inland Empire	4.2%	2.6%	2.7%	5.0%	3.4%	3.7%	3.1%	2.6%	2.4%	2.2%	2.1%	2.0%	1.9%
Los Angeles	0.3%	0.1%	0.2%	0.3%	0.4%	0.4%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%
Orange County	-0.1%	0.2%	-0.6%	0.5%	0.5%	0.6%	0.5%	0.4%	0.4%	0.3%	0.3%	0.3%	0.2%
Ventura	-0.1%	0.1%	1.7%	2.9%	1.0%	1.4%	1.2%	1.0%	0.9%	0.9%	0.8%	0.7%	0.6%

Source: CoStar Database

3.1.2 Warehouse Supply Model Scenario 2: Inland Empire Warehousing Moratoria

Warehouses are typically centered in lower-income and minority communities. In Inland Empire, more than two-thirds of those living within half a mile of a large warehouse identify as Hispanic or Black, the populations of which account for 52% of the overall population in the region (Yeung & Saraiva, 2022). These populations often face increased rates of heart disease, asthma, and low birth weights, according to the South Coast Air Quality Management District, an air-pollution agency.

For these reasons, the residents in some Inland Empire cities pushed pause on new warehouse development (Yeung & Saraiva, 2022). In August 2022, the city council of Pomona sought to address pollution and its effects on residents by passing a measure to extend a temporary halt on new warehouse developments. This action follows similar freezes by Riverside, Colton, Chino, Norco, and Redlands over the past several years. These moratoria have allowed communities to explore emission-reduction initiatives, including proposals to redesign truck routes, restrict the size of warehouses, and rezone some neighborhoods to create warehouse districts.

Table 7 reports the city-level warehouse inventory in Inland Empire for Q3 2022. The areas affected by moratoria—which are bolded in Table 7—account for 26.6% of the warehouse inventory in Inland Empire. In Warehouse Supply – Scenario 2, we assume that these areas do not allow new development, leading to a 26.6% loss in the increase in the inventory supply from 2023 to 2040 as shown in Table 8.

Table 7. Warehouse Inventory in Inland Empire by City, Q3 2022

Geography Name	Inventory Square Feet	% of County Total	Vacancy Rate
Airport Area	232,165,043	33.1%	1.2%
Beaumont/Hemet	10,706,358	1.5%	1.0%
Chino/Chino Hills	**55,628,897**	**7.9%**	**0.8%**
Coachella Valley	16,615,642	2.4%	3.4%
Corona/Eastvale	37,003,556	5.3%	1.6%
Mojave River Valley	27,212,908	3.9%	3.1%
Moreno Valley/Perris	94,300,730	13.4%	1.3%
Redlands/Loma Linda	**31,660,475**	**4.5%**	**1.6%**
Riverside	**75,597,580**	**10.8%**	**3.9%**
South Riverside	**23,738,125**	**3.4%**	**7.2%**
San Bernardino	99,083,767	14.1%	0.5%
Twentynine Palms	416,459	0.1%	1.3%
Upland/Montclair	9,975,033	1.4%	2.3%

Source: CoStar Database

Table 8. Forecast for Inventory Growth in the SCAG Region – Warehouse Supply Scenario 2

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Inland Empire	4.2%	2.6%	2.7%	3.8%	2.6%	2.8%	2.4%	2.1%	1.8%	1.7%	1.6%	1.5%	1.5%
Los Angeles	0.3%	0.1%	0.2%	0.3%	0.4%	0.4%	0.3%	0.2%	0.1%	0.1%	0.1%	0.0%	0.0%
Orange County	-0.1%	0.2%	-0.6%	0.5%	0.5%	0.6%	0.5%	0.4%	0.4%	0.3%	0.3%	0.3%	0.2%
Ventura	-0.1%	0.1%	1.7%	2.9%	1.0%	1.4%	1.2%	1.0%	0.9%	0.9%	0.8%	0.7%	0.6%

3.1.3 Warehouse Demand Model

Jaller and Pineda (2017) indicate that the factors influencing logistics sprawl include land availability and affordability (e.g., land costs), proximity to customers and transportation networks, accessibility to labor and supply chains, and the regulatory environment (e.g., development requirements, incentives) and zoning plans found in the region. Uyanik et al. (2018) review the literature on logistics centers' location selection problems and summarize five criteria determining selection, namely: location, cost, environment, cargo capacity/economic reflection, and social factors. In this study, we propose that warehouse demand is a function of six factors, namely: proximity to the market, land availability, land affordability, labor availability, a social factor (described below), and an environmental factor (described below) (see Equation 4).

Equation 4: Warehouse Demand = f(proximity to market, land availability, land affordability, labor availability, social factor, and environmental factor)

We identify independent variables as proxies for the factors affecting warehouse demand. Warehouse demand (Demand), the dependent variable, is measured by occupied warehouse space in square feet. To measure proximity to the market, we chose the number of industrial and office jobs (Employment) and the taxable sales (Sales) in the county because they directly determine the demand for warehouse space. The delivered warehouse space (Delivered) is used to capture land availability. The unemployment rate (Unemployment), the ratio of people who search for employment in the county, is used to represent labor availability. Land affordability is measured by the average weekly wage in the transportation and warehousing industry (Wage), and the average rent of industrial property per square foot (Rent). The social factor chosen is the Centers for Disease Control and Prevention/Agency for Toxic Substances and Disease Registry Social Vulnerability Index (SVI), which evaluates a community's ability to prevent human suffering and financial loss in a disaster. The SVI ranks each tract on 15 social factors, including unemployment, minority status, and disability, and further groups them into four related themes. The overall tract summary ranking variable is used in this study. The environmental factor chosen is the weighted annual mean of $PM_{2.5}$ (Air Quality Index (AQI)). Table 9 summarizes the definitions and data sources of the variables for the warehouse demand model. There are 224 quarterly data points, which consist of 56 quarters during 2008–2021 for Inland Empire, Los Angeles, Orange, and Ventura.

Table 9. Variable Definitions

Factor	Variable	Definition and Logic	Source
Demand	Demand	Demand for warehouse measured by the occupied warehouse space in square feet.	CoStar
Proximity to Market	Employment	The number of total employees in the industrial sector and office-using employment.	CoStar
Proximity to Market	Sales	Taxable sales of goods and merchandise provided by the retailers engaged in business in California.	California Department of Tax and Fee Administration
Land Availability	Delivered	Total gross warehouse space delivered in the last quarter, implying the warehouse space changed from under construction to existing space.	CoStar
Labor Availability	Unemploy-ment	The unemployment rate represents the number of unemployed as a percentage of the labor force.	Bureau of Labor Statistics
Land Affordability	Wage	Average weekly wage in the transportation and warehousing industry.	Bureau of Labor Statistics
Land Affordability	Rent	Average monthly rent of industrial property per square foot.	CoStar
Social Factor	SVI	SVI uses U.S. Census data to rank each tract on 15 social factors, including poverty, lack of vehicle access, and crowded housing, and groups them into four related themes.	The Centers for Disease Control and Prevention
Environ-mental Factor	AQI	Air Quality Index is the weighted annual mean of $PM_{2.5}$.	Environmental Protection Agency

The ordinary least squares (OLS) regression model is displayed in Equation 5. Considering that the relationship between a dependent variable and independent variables could be nonlinear in parameters, this study adopts a log-log model that uses natural logs for both dependent and independent variables of the econometric specification. Using Inland Empire as a base case, three dummy variables are added for LA County, Orange County, and Ventura to control for the specific effect of each county. The regression coefficient for each dummy variable represents the specific effect of the county-level difference in warehouse demand between that county and Inland Empire.

Equation 5: $$ln(Demand_{it}) = b_0 + b_1\, ln(Employment_{it}) + b_2\, ln(Sales_{it}) + b_3\, ln(Delivered_{i(t-1)}) + b_4\, ln(Unemployment_{it}) + b_5\, ln(Wage_{it}) + b_6\, ln(Rent_{it}) + b_7\, ln(SVI_{it}) + b_8\, ln(AQI_{it}) + b_9\, LA_i + b_{10}\, OC_i + b_{11}\, VT_i + e_{it}$$

where i represents county i, while t represents period t.

3.2 Housing Analysis

Our analysis of housing data and issues in Southern California aims to provide a comparison to the warehousing analysis. We are interested in answering the question of whether particular tracts of state land in Southern California should be allocated to warehousing goods or housing people. As discussed above, one issue here is the forecast gap between supply and demand. In housing terms, this issue has been explored in numerous studies identifying the deficit of housing stock in California. In other words, these studies ask the question of how much housing is needed in California. Following an analysis of the housing deficit, we analyze the factors influencing the supply of low-income housing.

3.2.1 Housing Deficit Analysis

Section 5.3 below uses literature review and analysis of current housing stock and trends—overall and affordable housing—to explore the following questions: Do California and Los Angeles County need to build more housing? What are estimates of the number of affordable housing units based on? Are affordable housing and low-income units needed? Where are new houses most likely to be built? Answering these questions—and projecting the Southern California housing deficit and identifying affordable housing development trends—sets up the calculation of inputs for C-LINE modeling of comparable scenarios to those in the warehousing environmental impact analysis.

3.2.2 Low-Income Housing Analysis

This study uses both static and dynamic panel estimation models to estimate low-income units in four main counties. The static panel estimation models include cross-section pooled OLS models with various specifications. The dynamic estimation models include one-step and two-step system generalized method of moments (GMM) models with one lag or two lag. The general model to estimate low-income units demand depends mainly on the unemployment ratio as shown in Equation 6.

Equation 6: Low-Income Units = f (Unemployment, Rent, Sales)

This study uses the following static model (Equation 7) to estimate total low-income units based on the unemployment rate, market rent per unit, and market sale price per unit in each country from 2008 to 2019:

$$\text{Equation 7: } Low - Income\ Units_{it} = \beta_0 + \beta_1 Unemployment_{it} + \beta_2\ Market\ Rent\ Per\ Unit_{it} + \beta_3\ Market\ Sale\ Per\ Unit_{it} + \theta_i + \phi_t + \varepsilon_{it}$$

Low-income units are the total number of low-income units for county i in time t. β_0 is a constant term. Unemployment is the unemployment rate in a given region. The parameter Θ is the county-fixed effect and ϕ presents the time-fixed effect in the model. Finally, ε shows the standard error for the model.

3.3 Environmental Impact Analysis

An overview of our approach to the environmental impact analysis is presented in the last three rows in Table 5 ("Project Analytical Framework") above. Warehousing activities and associated heavy-duty diesel trucks create environmental externalities that often cluster in the SCAG region, especially across disadvantaged areas where low-income people of color often reside. With near-future possibilities of warehouse expansion on state land, air pollutant emissions issues and NIMBY issues arise. Understanding current environmental geospatial patterns of impact can clarify phenomena around warehouse land use and air quality impacts. Particularly, the evaluation of warehousing's land-use patterns is crucial to: (1) understanding land characteristics of areas with a high population of warehouses per county and the likelihood of expansion, and (2) evaluating warehouse developers' desire to locate in proximity to transportation, labor, and land resources.

We used geospatial tools (e.g., ArcGIS) to visually evaluate trends associated with warehousing land use and air quality exposure patterns. We identified warehousing locations using the CoStar database and obtained GIS data layers displaying disadvantaged areas and current air pollution data from CalEnviroScreen 4.0 (OEHHA, 2021). The intensity of each variable is presented in percentiles referencing a comparison of percentiles with all regions in California. We evaluated areas with warehouse clusters within the SCAG region to understand spatial patterns between warehouses and major variables (e.g., disadvantaged communities).

3.3.1 C-LINE Models

We used the C-LINE (Community LINE) Source Model, a community-based modeling tool developed by the U.S. Environmental Protection Agency (EPA) and the University of North Carolina (Barzyk et al., 2015), to examine different air pollution emissions in different scenarios of warehousing/housing developments. We focused on developing models for ambient $PM_{2.5}$ and NO_2 since they belong to the Criteria Air Pollutants regularly monitored and regulated by the U.S. EPA. This model enabled us to estimate local air quality impacts by modifying various input data, including traffic volume (e.g., annual average daily traffic) and fleet mix (e.g., light- and heavy-duty vehicles). We modeled the long-term (annual) air pollution impacts resulting from three cases based on the various scenarios of warehousing and housing developments shown below. All model estimates were made at the Census Block Group level to show neighborhood impacts.

3.3.2 Traffic Generation Rates

Since the C-LINE models relied on the input of traffic generation rates and fleet mix, we followed existing literature by adopting corresponding rates. For warehousing, we used a truck trip generation rate of 0.66 truck trips per day per 1,000 square feet of warehousing (South Coast Air Quality Management District, 2014). For housing, we mainly used the affordable housing traffic generation rate of 11 motorized vehicle trips per dwelling unit per day (Caltrans, 2018). We are aware that non-affordable housing traffic/emission impacts are higher (Howell et al., 2018).

We calculated final generated trucks by multiplying the traffic generation rates of warehousing with the added/estimated warehousing area for the three cases. We also calculated final generated motorized vehicles by multiplying the traffic generation rates of affordable housing with the corresponding added/estimated affordable housing area. For Case 1, we followed the permit of at least 30 units per acre to feasibly accommodate affordable housing need (City of Los Angeles, 2021). For Case 2, we used the average affordable share of total new units (2011–2021) in California (14.3%) as the rate of generated affordable housing (California Housing Partnership, 2023). For Case 3, we followed California's new housing goal of 40% as the rate of target affordable housing (The Mercury News, 2023).

The list of state land was retrieved from the Department of General Services in California. The associated traffic and truck volume data (e.g., Annual Average Daily Traffic) were retrieved from the SCAG website. All rates based on various scenarios were used to adjust the parameters (e.g., truck/passenger vehicle volumes) in the C-LINE model development process. Detailed scenarios under each case are shown below.

3.3.3 Estimation Analysis Cases

Emissions analysis case 1: estimating air pollution emissions generated by traffic from both warehousing freight transport and affordable housing for Executive Order N-19-21.

Emissions analysis case 2: estimating air pollution emissions generated by traffic for the 2040 forecast scenario of both warehousing and affordable housing. That is, if we fill in the shortage, what does that mean for air quality?

Emissions analysis case 3: estimating air pollution emissions generated by traffic if the warehousing shortage and affordable housing shortage were met using available state lands.

Emission Analysis Case 1

Case 1 is based on the effort of Executive Order N-19-21, which aims to strengthen the resilience of California's supply chains by promoting the use of state land/property. Since our study area focuses on the SCAG region, we developed the C-LINE models using the three sites (state property) identified to allow for storage of shipping containers (warehousing) to help alleviate congestion at California ports within the SCAG region (Department of General Services, 2022). We were also aware that California seeks to accelerate the market transition to Zero-Emission Vehicles (ZEV) with a particular focus on improving air quality and reducing climate change and health impacts (California Air Resources Board, 2022). We used three targets respectively set for 2027, 2030, and 2040 with regulated categories of the heavy-duty fleet set at 50% as the scenarios for our warehousing-related air pollution emission analysis; that is, we assume 50% of the heavy-duty fleet will be ZEVs.

State land based for the Department of General Services (DGS) sites (Lancaster and Palmdale, Figure 19):

- Lancaster and Palmdale (within the SCAG region): 3 sites (2,234,628 sq ft).
- The same ZEV scenarios with identified state property.

Zero Emission Vehicles:

- Regulated categories of heavy-duty fleet (~50%).
- In 2027, 10% fleet into ZEV, results in 10% * 50% = 5% ZEV.
- In 2030, 25% fleet into ZEV, results in 25% * 50% = 12.5% ZEV.
- In 2040, 100% fleet into ZEV, results in 100% * 50% = 50% ZEV.

Figure 19. Site Images of Lancaster and Palmdale N-19-21 Locations (3 sites)

Scenarios based on state land usage and ZEV adoption rate:

- Scenario 1: added vs. base. "Added" refers to the scenario in which we used all the identified state land for warehousing purposes. "Base" represents the scenario for the current status; that is, the state land has not been used for warehousing purposes yet.

- Scenario 2: added + 5% ZEV vs. base. "5% ZEV" refers to the scenario in which 5% ZEV is assigned to the generated truck traffic resulting from warehousing activities.

- Scenario 3: added + 12.5% ZEV vs. base. "12.5% ZEV" refers to the scenario in which 12.5% ZEV is assigned to the generated truck traffic resulting from warehousing activities.

- Scenario 4: added + 50% ZEV vs. base. "50% ZEV" refers to the scenario in which 50% ZEV is assigned to the generated truck traffic resulting from warehousing activities.

As mentioned above, for housing and associated traffic and air pollution estimation, we used 30 units per acre to develop the C-LINE models.

Emission Analysis Case 2

To match our warehousing supply and demand analysis, we also calculated traffic generated and associated air pollution from increased warehousing activities. We developed C-LINE models for scenarios in which we experience a shortage in warehouse space based on Supply Scenario 1 in 2040; we developed models based on two sub-scenarios to demonstrate how estimated air pollution varies across vastly different scenarios. As shown in Table 10, for warehousing of Scenario 1: Base Case, Los Angeles County experienced a 43,529,293 square foot shortage in warehousing space. For Scenario 4: Moderate Upside with E-Commerce & Improvements, Los Angeles County and Orange County experienced 145,937,593 square feet and 28,589,777 square feet shortages in warehousing space, respectively. Our C-LINE models focused on scenarios in which all the shortages of warehouse space as predicted in 2040 are met, so as to determine the impact of the associated air pollution on local communities.

Table 10. Surplus and Shortage in Warehouse Space – Based on Supply Scenario 1

	2023 Q1	2040 Q4
Scenario 1: Base Case		
Inland Empire	82,849,196	352,709,899
Los Angeles	-25,484,588	-43,529,293
Orange County	-3,800,985	94,846
Ventura	8,458,929	18,678,057
Total	62,022,551	327,953,509
Scenario 4: Moderate Upside with E-Commerce & Improvements		
Inland Empire	75,463,035	137,536,508
Los Angeles	-35,718,521	-145,937,593
Orange County	-7,203,552	-28,589,777
Ventura	7,753,599	2,654,621
Total	40,294,562	-34,336,241

While a space shortage of affordable housing was predicted to appear in the entire SCAG region in 2040, we only developed the C-LINE simulation models for Los Angeles and Orange County.

Emission Analysis Case 3

One of the project goals is to explore whether to use the state land of California to resolve potential warehousing space shortages. We developed C-LINE models based on a combination of state land scenarios (20% and 50%) and ZEV adoption rates (50% and 0%). These scenarios represent the air pollution impacts of the corresponding state land use and ZEV adoption rates for warehousing purposes.

ZEV:

- Regulated categories of heavy-duty fleet (~50%).
- In 2040, 100% fleet into ZEV, results in 100% * 50% = 50% ZEV.

Scenarios based on state land usage and ZEV adoption rate:

- Scenario 1: 20% state land vs. base. "20% state land" refers to the scenario in which we use 20% of the state land for warehousing purposes. "Base" represents the scenario for the current status; that is, the state land has not been used for warehousing purposes yet.
- Scenario 2: 20% SL + 50% ZEV vs. base. "50% ZEV" refers to the scenario in which 50% ZEV is assigned to the generated truck traffic resulting from warehousing activities.

- Scenario 3: 50% SL vs. base.
- Scenario 4: 50% SL + 50% ZEV vs. base.

We showed major places of interest within the SCAG region where most warehouses were located, including South Los Angeles, Central Los Angeles, Orange County, Ventura County, and Inland Empire. For housing and associated traffic and air pollution estimation, we used California's new housing goal of 40% as the rate of target affordable housing mentioned above to develop the C-LINE models.

4. Findings from Warehousing Supply and Demand

4.1 Descriptive Statistics

This study collected quarterly data for 2008–2021 at the county level from multiple sources. Tables 11 and 12 report the descriptive statistics for all counties and the means of the variables in the four regions, respectively. Table 12 shows that LA has the highest warehouse demand with the highest employment, sales, wage, social vulnerability, and air pollution. Inland Empire has the most delivered warehouse space and the best land affordability, that is, the lowest wage and rent. Orange has the highest rent and the lowest unemployment rate. Ventura has the lowest delivered warehouse space, social vulnerability, and air pollution level.

Table 13 reports the correlations among all the variables. It shows that higher warehouse demand is associated with higher employment, higher sales, higher wage, lower vacancy, higher social vulnerability, and more air pollution. It is consistent with the hypothesis that proximity to the market, land availability, land affordability, labor availability, social factors, and environmental factors impact warehouse demand.

Table 11. Descriptive Statistics for All Counties (2008–2021)

Variable	Obs *	Unit	Mean	Std. Dev.	Min	Max
Demand	224	Sq Ft	449,000,000	313,000,000	64,400,000	926,000,000
Employment	224	Persons	1,841,058	1,459,597	273,226	4,604,807
Sales	224	Millions	18,077	12,709	2,281	53,581
Delivered	224	Sq Ft	1,368,267	2,246,484	1**	10,200,000
Unemployment	224	Ratio	0.077	0.030	0.028	0.141
Wage	224	$/Week	944.4	147.9	757.5	1359
Rent	224	$/Sq Ft	9.43	2.59	4.97	15.91
SVI	224	Percentile	0.54	0.22	0.28	0.82
AQI	224	Index	10.11	1.28	6.80	13.20

** Observations*

*** For the quarters with no delivered space, the value for delivered is inputted as "1" because zero cannot be converted by natural log.*

Table 12. Descriptive Statistics (Mean) by County (2008–2021)

Variable	Los Angeles	Inland Empire	Orange	Ventura
Demand	904,000,000	534,000,000	290,000,000	66,700,000
Employment	4,217,729	1,339,368	1,514,522	292,612
Sales	36,908	17,108	15,018	3,273
Delivered	952,619	4,285,568	179,521	55,359
Unemployment Rate	0.086	0.087	0.062	0.071
Wage	1,105	818	967	888
Rent	10.4	6.7	11.1	9.5
SVI	0.787	0.733	0.330	0.313
AQI	10.7	10.3	10.7	8.7

Table 13. Correlation Matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Demand	1.00								
(2) Employment	0.93	1.00							
(3) Sales	0.95	0.96	1.00						
(4) Delivered	0.31	0.02	0.17	1.00					
(5) Unemployment Rate	0.20	0.10	0.04	-0.04	1.00				
(6) Wage	0.47	0.65	0.68	-0.24	-0.23	1.00			
(7) Rent	0.02	0.25	0.29	-0.31	-0.49	0.83	1.00		
(8) SVI	0.90	0.70	0.74	0.51	0.35	0.14	-0.32	1.00	
(9) AQI	0.46	0.44	0.42	0.16	0.29	0.05	-0.03	0.36	1.00

4.2 Regression Results

Table 14 reports the results of the regression model. The corresponding regression equation is shown in Equation 8. The F-test shows a good model fit. The R-squared value is 0.999, implying that this model can explain 99.9% of the variations in warehouse demand.

*Equation 8: ln(Demand) = 8.885 + 0.909*ln(Employment) + 0.096*ln(Sales) + 0.001*ln(Delivered) + 0.101*ln(Unemployment Rate) - 0.332*ln(Wage) + 0.157*ln(Rent)) + 0.21 * ln(SVI) - 0.137*ln(AQI) – 0.566*LA - 0.513*OC – 0.382*VT*

Regarding proximity to the market, if employment increases by one percent, warehouse demand is expected to increase by 0.909%, holding other variables constant. A one-percent increase in retail sales leads to 0.096% higher warehouse demand. Regarding land availability, a one-percent increase in the delivered warehouse space in the previous quarter leads to 0.001% higher warehouse demand. Regarding labor availability, if the unemployment rate increases by one percent, warehouse demand increases by 0.101%. For land affordability, the warehouse demand is affected by wages and rent. A one-percent increase in average weekly wage leads to 0.332% lower warehouse demand. When monthly rent increases by one percent, warehouse demand goes up 0.157%.

Regarding the social factor, the regression result shows that more social vulnerability leads to higher warehouse demand when other variables are controlled. It implies that logistics activities are expanding to the regions where there are more poor people, who have limited access to vehicles. Regarding the environmental factor, Table 14 shows that higher warehouse demand is associated with higher air pollution. In contrast, the regression result shows that more air pollution leads to lower warehouse demand, holding other variables constant.

Table 14. Regression Results

DV: ln(Demand)	Coef.		Std. Err.	t	P>t
ln(Employment)	0.909	***	0.170	5.340	0.000
ln(Sales)	0.096	**	0.040	2.420	0.016
ln(Delivered)	0.001	*	0.001	1.880	0.062
ln(Unemployment)	0.101	***	0.016	6.260	0.000
ln(Wage)	-0.332	***	0.084	-3.970	0.000
ln(Rent)	0.157	***	0.050	3.120	0.002
ln(SVI)	0.211	***	0.030	7.100	0.000
ln(AQI)	-0.137	***	0.035	-3.880	0.000
LA	-0.566	***	0.180	-3.150	0.002
OC	-0.513	***	0.029	-17.640	0.000
VT	-0.382		0.238	-1.610	0.109
Constant	8.885	***	2.563	3.470	0.001
Observations	224				
R-squared	0.999				
F(12, 211)	35,297				
Prob > F	0.0000				

*Robust standard errors in parentheses. ***=p<0.01; **=p<0.05; *=p<0.10*

4.3 Demand Forecast

To forecast the demand from 2022–2040, this study collected forecasts for all independent variables from multiple sources and develops scenarios. The sources and their forecasts are summarized below.

4.3.1 CoStar's Forecast – Employment, Rent, and Delivered Space

CoStar provided forecasts in 2022 for employment, rent, and delivered warehouse space for 2022–2032 based on Oxford Economics Forecasts and seven forecasting scenarios.

- **Scenario 1 CoStar's Base Case** (2022): The economy is forecast to enter a mild recession in the first half of 2023 after seeing 1.7% annual growth in 2022. About 4 million jobs will be added in the first three quarters of 2022, and another 653,000 more will be added in Q4 2022. Employment momentarily peaks in Q1 2023, and payrolls by the end of 2023 are expected to be 0.5% lower than at the end of 2022. A recovery in employment will follow over the next two years and return to its long-term growth rate of 0.6% in 2026.

- **Scenario 2 Oxford Economics' Moderate Upside** (2022): This forecast predicts that the economy will undergo a fast recovery in global supply chains, and that this will alleviate inflationary pressures. As a result, the Federal Reserve will slow the pace of monetary tightening; GDP growth will accelerate to 1.9% in 2022 and 1.5% in 2023; there will be 839,000 jobs added in Q4 2022; and job growth will decrease but remain positive, with 0.6% job growth in 2023 and 0.5 % in 2024.

- **Scenario 3 Oxford Economics' Moderate Downside** (2022): This forecast expects persistently high inflation and faster policy rate hikes, leading to a recession in Q4 2022. It projects that the economy will grow 1.4% in 2022 and contract 1.9% in 2023, job losses will begin in Q4 2022 and continue through late-2024, and the unemployment rate will rise to 7.7%.

- **Scenario 4 Oxford Economics' Severe Downside** (2022): This forecast expects a sharp fall in economic activity in Q4 2022 because of a significant escalation of geopolitical tensions, catastrophic supply chain disruptions, and a full-scale financial crisis. This is represented as causing the economy to enter a prolonged recession through mid- to late-2023, with job losses beginning immediately and continuing through the end of 2023, so that the unemployment rate rises above 11% in 2024.

- **Scenario 5 CoStar's Trend Growth** (2022): This forecast assumes that labor market growth continues at a constant rate equal to its average growth rate over the past three years, and the unemployment rate reverts linearly from its current rate to its average historical rate since 2000.

- **Scenario 6 CoStar's Interest Rate Shock** (2022): This forecast predicts a shock in the BBB corporate bond yield, leading to a sudden increase in the risk originating in financial markets, with the result that high-risk spreads drive cap rates higher, leading to losses in near-term property value.

- **Scenario 7 CoStar's Depression** (2022): This forecast assumes large-scale job losses totaling 50 million, or a third of the pre-COVID workforce, a scale of job losses not experienced since the Great Depression.

Tables 15, 16 and 17 summarize CoStar's forecasts on the growths of total employment, rent, and delivered warehouse space for 2023–2032 by scenario, including the compound annual growth rate (CAGR) from 2024–2032. We adopted the forecasts for total employment and rent from Scenarios 1, 2, and 4 and used them in warehouse demand forecasts. The forecast for delivered space relies solely on the base case because of data availability.

Table 15. CoStar's Forecast on Total Employment Growth for SCAG Region, by Scenario

Total Employment	2020 Q1	2021 Q1	2022 Q1	2023 Q1	2024 Q1	2024-2032 CAGR
1. Base Case	1.75%	-8.48%	7.36%	3.25%	0.68%	0.53%
2. Oxford Moderate Upside				3.62%	0.81%	0.52%
3. Oxford Moderate Downside				0.39%	-0.66%	0.66%
4. Oxford Severe Downside				-3.06%	-1.21%	0.99%
5. Trend Growth				1.74%	0.54%	0.72%
6. Interest Rate Shock				0.39%	-0.66%	0.66%
7. Depression				-5.15%	3.07%	3.99%

Source: CoStar Database

Table 16. CoStar's Forecast on Rent Growth for SCAG Region, by Scenario

Rent	2020 Q1	2021 Q1	2022 Q1	2023 Q1	2024 Q1	2024-2032 CAGR
1. Base Case	5.69%	6.30%	12.80%	11.86%	8.42%	2.33%
2. Oxford Moderate Upside				12.32%	8.95%	2.40%
3. Oxford Moderate Downside				8.45%	3.71%	1.66%
4. Oxford Severe Downside				6.38%	0.08%	1.30%
5. Trend Growth				11.62%	7.77%	2.35%
6. Interest Rate Shock				8.45%	3.71%	1.66%
7. Depression				-3.94%	-12.67%	-1.34%

Source: CoStar Database

Table 17. CoStar's Forecast on Delivered Space by County, Base Case Scenario

Delivered	2020	2021	2022	2023	2024	2032	2024-2032 CAGR
Inland Empire	-11.5%	-9.6%	42.6%	8.1%	-4.9%	-1.0%	-5.6%
Los Angeles	86.8%	-25.3%	29.1%	14.4%	29.8%	-3.3%	-9.7%
Orange County	81.3%	-26.3%	280.5%	5.4%	22.5%	-2.1%	-6.8%
Ventura	57.1%	145.8%	456.2%	-100.0%	0.0%	0.0%	0.0%
SCAG Region	0.5%	-12.0%	54.3%	0.7%	2.1%	-1.5%	-6.4%

Source: CoStar Database

4.3.2 California State's Forecast – Employment, Wage, Taxable Sales, Unemployment, and Inflation

The State of California provides several forecasts to assist decision-making. The forecast data were collected from the California Employment Development Department, the Transportation Economics Branch, and the California Energy Commission.

The California Employment Development Department – Employment and Wages

The California Employment Development Department (EDD) uses Current Employment Statistics and the Quarterly Census of Employment and Wages to conduct employment projections. It estimates changes in the industry and occupational employment over time resulting from industry growth, technological change, and other factors and produces long-term (10-year) employment projections every two years for the State and county. Statewide short-term (-year) projections are revised annually. Table 17 presents the 10-year long-term forecast. The 2018–2028 forecast by county does not include the impact of the COVID-19 pandemic and recession, which may cause structural changes to the economy. The 10-year CAGR for the SCAG region is 0.85%, which is higher than those of the five scenarios in Table 18.

The 2020–2030 and 2021–2023 forecasts for California were published in 2022 and are presumed to have included the impact of the COVID-19 pandemic and recession. Based on the latest 10-year and 2-year forecasts for California's employment in Table 18, the CAGR for 2023–2030 is calculated to be 0.96%, which is also higher than the CAGRs of the five scenarios in Table 18.

In addition, the EDD calculated average annual wages as total wages and salaries divided by the number of wage and salary jobs. This study referred to TDD's forecast on the average annual wages and their growth trend in the transport and warehousing industry. The wage growth was volatile during 2020–2023 and stabilized afterward. Given that the Federal Reserve set the long-term goal of an inflation rate at 2%, we assumed that the wage growth will match inflation in the long term and gradually reduce the forecast wage growth rate to 2%.

Table 18. Forecast on Employment by California Employment Development Department

10-Year	Base Year Employment Estimate 2018	Projected Year Employment Estimate 2028	CAGR
Inland Empire	1,610,500	1,773,100	0.97%
Los Angeles	4,842,300	5,269,800	0.85%
Orange	1,764,000	1,890,300	0.69%
Ventura	356,400	395,100	1.04%
SCAG Region	8,573,200	9,328,300	0.85%
10-Year	**Base Year Employment Estimate 2020**	**Projected Year Employment Estimate 2030**	**CAGR**
California	17,785,900	20,629,600	1.49%
2-Year	**Base Year Employment Estimate 2021**	**Projected Year Employment Estimate 2023**	
California	18,004,000	19,296,200	3.53%

Source: EDD, retrieved from https://www.labormarketinfo.edd.ca.gov/data/employment-projections.html in October 2022

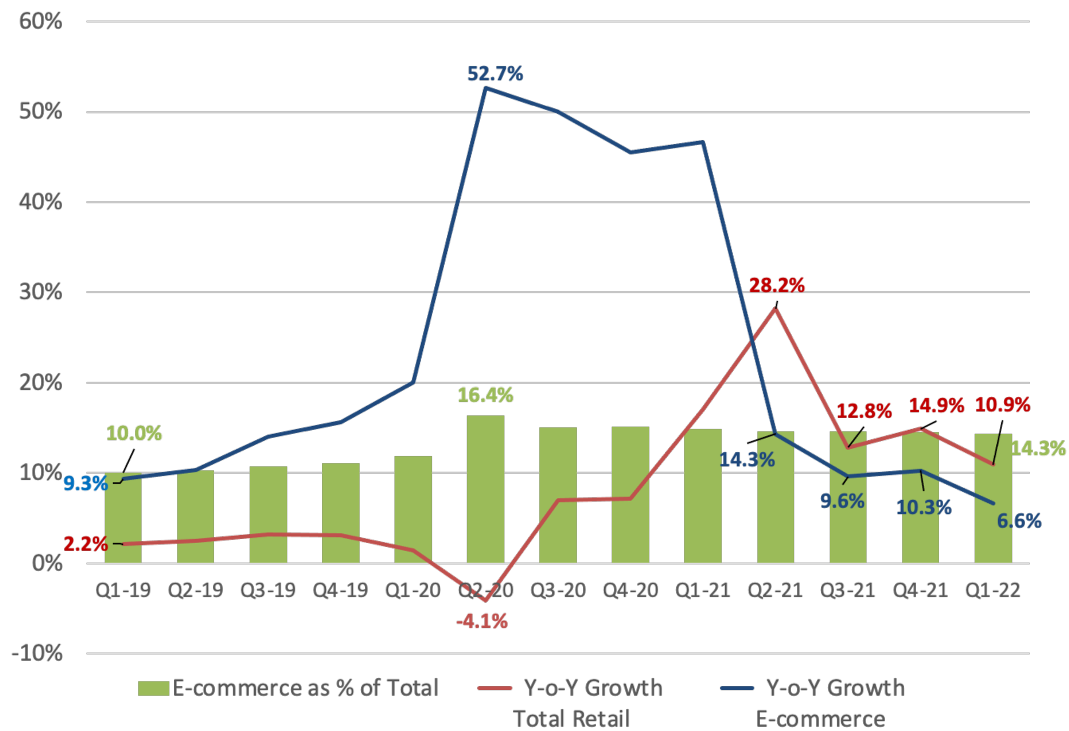
4.3.3 Developing Scenarios for Demand Forecasts

We considered three main factors when developing scenarios for demand forecasts:

1) **Projected Economic Growth**: the economy is determined by the Federal Reserve's monetary policy, geopolitical tensions, supply chain disruptions (e.g., China's lockdowns), and trade policy. In this study, we adopted CoStar's forecast on employment, and factored it into projections of economic growth in the different scenarios.

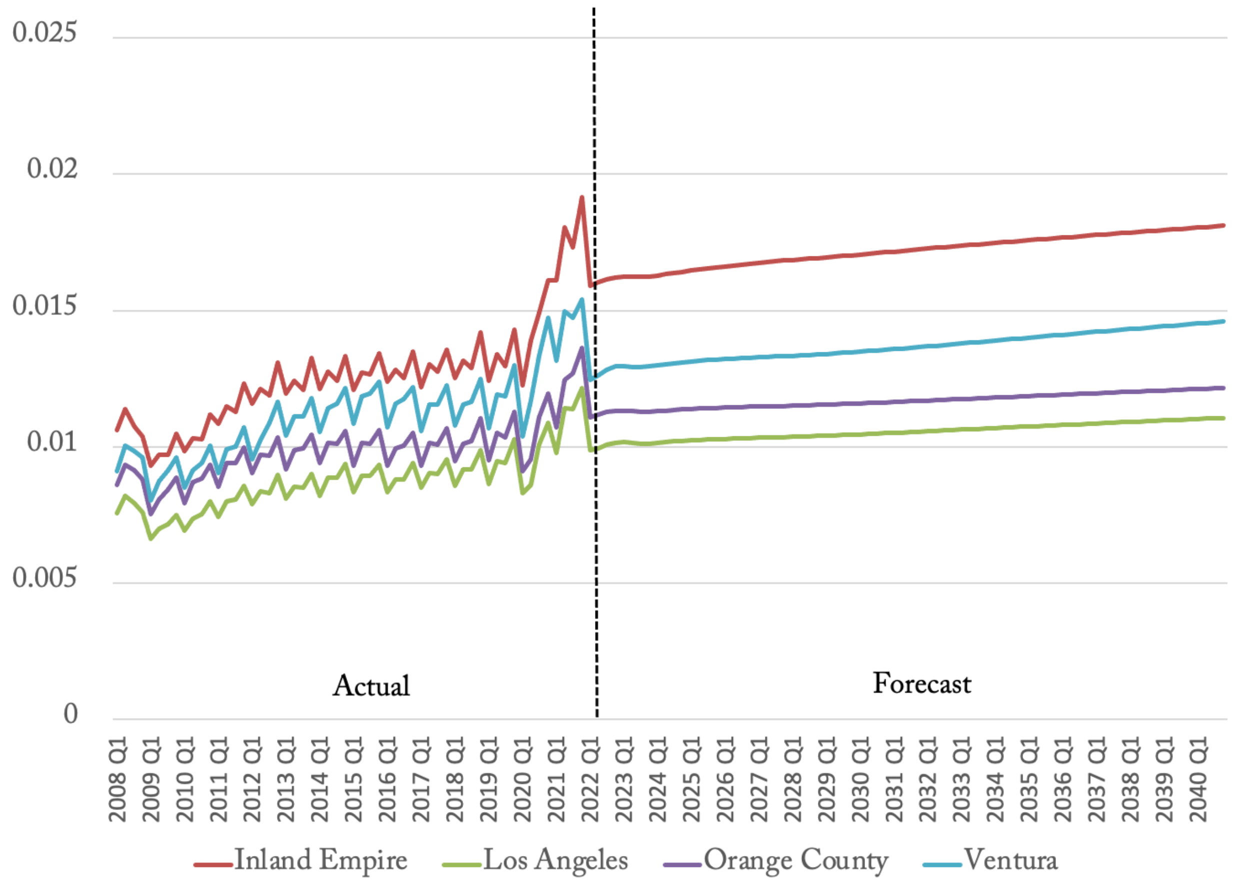
2) **E-Commerce Growth**: The empirical study of e-commerce shows that e-commerce adoption improves business efficiency regarding inventory turnover and supply chain costs (Baršauskas et al., 2008). Such a relationship was evidenced during the pandemic. Figure 20 shows that the e-commerce share of U.S. retail peaked at 16.4% in Q2 2020 and slipped to 14.3% in Q1 2022. Figure 21 shows that the sales-to-employment ratio jumped during the pandemic, suggesting that a higher e-commerce share contributes to a higher sales-to-employment ratio. Inland Empire has the highest sales-to-employment ratio because of its high density of e-commerce distribution centers. Given that Southern California is becoming a hub of e-commerce businesses, we assume that the adoption rate of e-commerce will get higher over time, leading to a higher sales-to-employment ratio over the next three decades, in three scenarios.

Figure 20. Quarterly U.S. Retail Sales: Total and E-Commerce



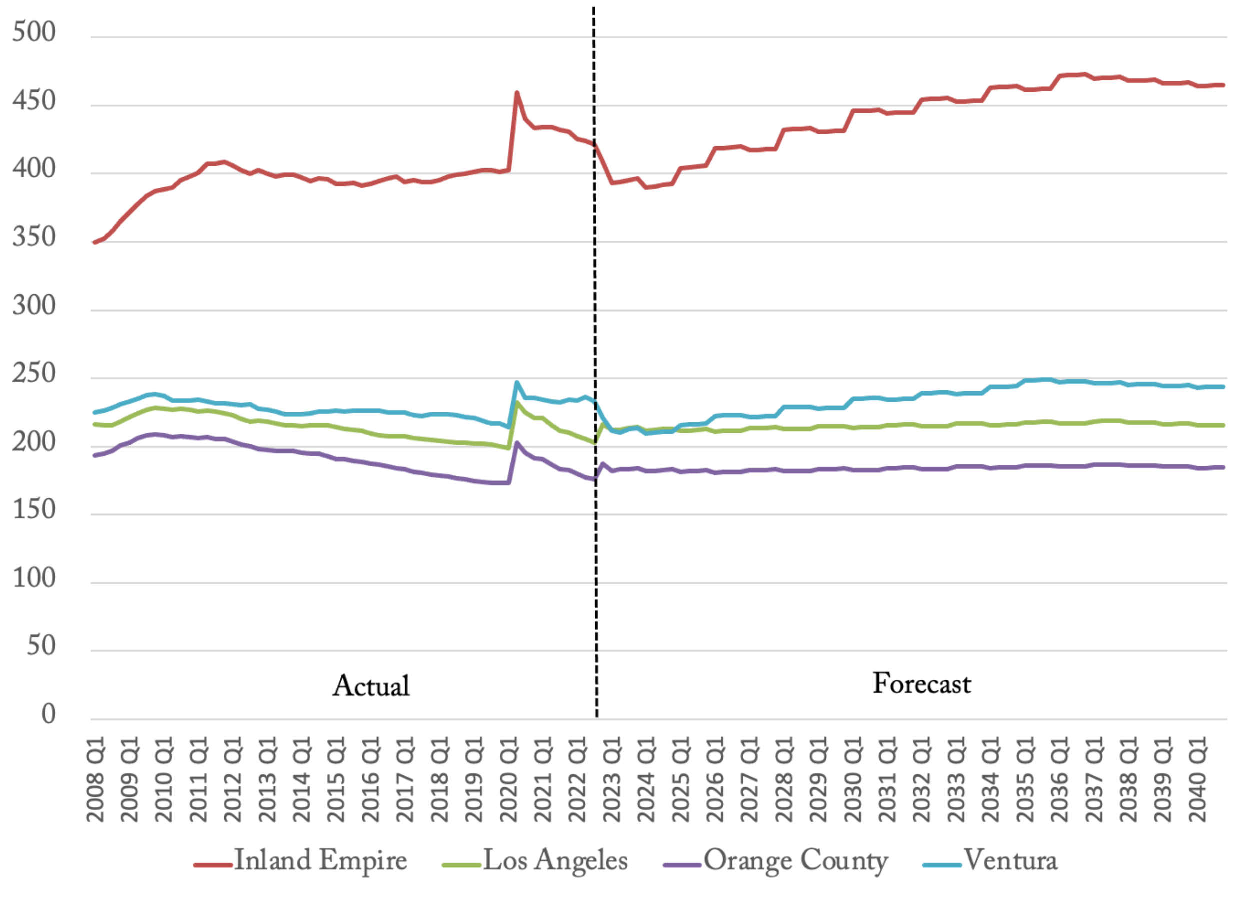
Source: The U.S. Census Bureau

Figure 21. Sales to Employment Ratio: Base Case with E-Commerce Adjustment



3) **Technological and Infrastructure Improvements**: To increase operational efficiencies and reduce operating costs, many companies are incorporating information technology, primarily Industry 4.0 technologies, in their distribution centers. The most popular systems are Warehouse Control Systems, Warehouse Management Systems, Radio Frequency Identification, Voice Activation Systems, and Transportation Management Systems (Cambridge Systematics, 2018). Besides, in areas with high land costs and limited development sites, such as Los Angeles County, infrastructure improvement focuses on improving operational efficiency. Technological and infrastructure improvements allow a company to use fewer employees to manage a larger warehouse space. This implies that the occupied warehouse space per employee increases with technological and infrastructure improvements. Figure 22 shows that Inland Empire has the highest occupied warehouse space to employee ratio; this is because of better land availability. The occupied warehouse space to employee ratio jumped during the pandemic. The layoffs, lockdowns, and social distancing led to lower employment and a higher occupied warehouse space to employee ratio. While the ratio is expected to return to normal by the end of 2022, the technological and infrastructure improvements will increase the ratio in the long run.

Figure 22. Occupied Warehouse Space to Employee Ratio: Base Case with Technological and Infrastructure Improvements



Eight independent variables were included in the demand model. They are employment, taxable sales, delivered warehouse space, unemployment rate, wage, rent per square foot, social vulnerability index, and air quality index. To predict warehouse demand, we developed forecasts for the independent variables and input them into the demand model to get a demand forecast.

Regarding the forecasts for employment, rent, and delivered warehouse space, we used CoStar's versions for the base case, moderate upside, and severe downside scenarios. Since CoStar only provides the 2022–2032 forecasts, we used the exponential smoothing method to extend the forecasts to 2040.

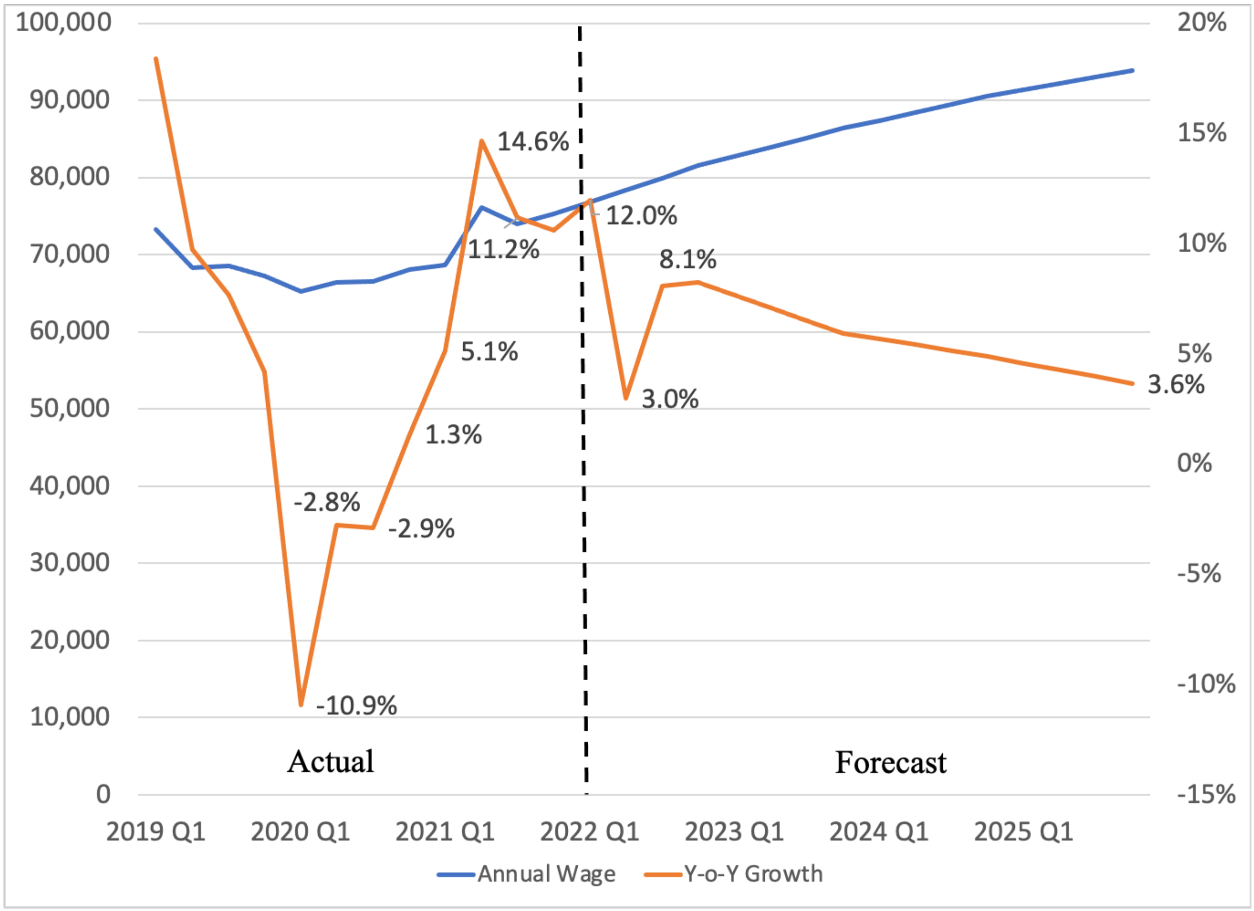
The 2008–2022 data for employment and taxable sales allowed us to use a simple regression model to predict sales based on the employment data in different scenarios. We applied the California Transportation Economics Branch's (TEB) inflation and unemployment forecasts to calculate predicted wages during 2022–2040. The social vulnerability index and air quality index were assumed to remain the same during 2022–2040.

Table 19 presents the growth rates for warehouse supply and demand. Warehouse supply is presented in two scenarios: (1) CoStar Base Case and (2) Inland Empire Warehousing Moratoria, as described in Section 2.2. In Warehouse Supply – Scenario 2, we assumed that certain Inland Empire areas do not allow new development, leading to a 26.6% loss of the increase in the inventory supply from 2023 to 2040. Warehouse demand is presented in six scenarios: (1) Base Case, (2) Base Case with technology improvement and e-commerce adjustment, (3) Moderate Upside, (4) Moderate Upside with technology improvement and e-commerce adjustment, (5) Severe Downside, (6) Severe Downside with technology improvement and e-commerce adjustment.

Table 19. Scenarios for the Growths in Warehouse Supply and Demand

	Actual			Forecast		
Total Employment	2020 Q1	2021 Q1	2022 Q1	2023 Q1	2024 Q1	2024–2040 CAGR
Supply for Warehouse Space						
Warehouse Inventory – Scenario 1	1.50%	0.94%	1.00%	2.07%	1.24%	0.93%
Warehouse Inventory – Scenario 2	1.50%	0.94%	1.00%	1.84%	0.94%	0.73%
Demand for Warehouse Space						
Scenario 1: Base Case	1.19%	1.34%	2.49%	0.61%	-0.56%	0.31%
Scenario 2: Base Case with technology improvement and e-commerce adjustment				1.54%	0.86%	1.12%
Scenario 3: Moderate Upside				1.22%	0.64%	0.27%
Scenario 4: Moderate Upside with technology improvement and e-commerce adjustment				2.16%	2.08%	1.08%
Scenario 5: Severe Downside				0.45%	-3.84%	0.43%
Scenario 6: Severe Downside with technology improvement and e-commerce adjustment				1.38%	-2.46%	0.86%

Figure 23. Forecasts for Annual Wage and Wage Growth



Source: EDD and Department of Finance, retrieved from https://dof.ca.gov/forecasting/Economics/economic-forecasts-u-s-and-california/ in October 2022

Transportation Economics Branch – Employment, Unemployment Rate, Taxable Sales, and Inflation

The TEB, part of the California Department of Transportation, published California County-level forecasts to assist local and regional agencies in their planning and travel forecasting efforts. The project provides long-term socio-economic forecasts, including taxable sales and unemployment rates, for each county. The latest forecast was released in December 2021. Tables 19, 20, 21, and 22 summarize the forecasts on employment growth, unemployment rate, taxable sales growth, and inflation, respectively. We used the inflation rate in Table 14 as a proxy for the wage growth during 2022–2040 while using the demand model to forecast demand.

The TEB provides actual data and forecasts for these variables for 50 years, which we used in regression models to estimate the causal relationship between employment, unemployment rate, and taxable sales. Then we used the estimated employment in each scenario to predict the unemployment rate and taxable sales. Lastly, we input these forecasts into the warehouse demand model to predict the demand in each scenario.

Table 20. Forecast on Employment Growth

	2020	2021	2022	2023	2024	2040	2024–2040 CAGR
Inland Empire	-4.2%	4.2%	3.7%	2.1%	2.0%	0.7%	1.2%
Los Angeles	-9.1%	4.6%	3.3%	1.8%	1.4%	0.5%	0.7%
Orange	-8.9%	4.6%	2.9%	2.6%	1.7%	0.5%	0.9%
Ventura	-6.5%	3.3%	1.8%	1.5%	1.2%	0.4%	0.7%

Source: Transportation Economics Branch, part of the California Department of Transportation

Table 21. Forecast on Unemployment Rate

	2020	2021	2022	2023	2024	2040
Inland Empire	9.7%	7.4%	5.4%	4.5%	4.1%	3.8%
Los Angeles	12.9%	9.4%	7.6%	6.8%	6.5%	6.2%
Orange	8.9%	5.3%	3.5%	3.0%	2.8%	2.7%
Ventura	8.6%	5.9%	4.4%	3.7%	3.4%	3.1%

Source: Transportation Economics Branch, part of the California Department of Transportation

Table 22. Forecast on Taxable Sales Growth

	2020	2021	2022	2023	2024	2040	2024–2040 CAGR
Inland Empire	1.6%	2.3%	2.0%	3.1%	2.9%	2.7%	2.5%
Los Angeles	-10.3%	13.2%	2.7%	2.1%	2.2%	2.6%	2.2%
Orange	-10.4%	11.2%	2.1%	3.2%	2.7%	2.6%	2.3%
Ventura	-4.4%	7.7%	1.6%	2.9%	2.6%	2.6%	2.3%

Source: Transportation Economics Branch, part of the California Department of Transportation

Table 23. Forecast on Inflation

	2020	2021	2022	2023	2024	2040
California	1.6%	4.3%	4.9%	4.1%	3.3%	2.0%

Source: Transportation Economics Branch, part of the California Department of Transportation

4.4 Final Scenarios

Figures 24 and 25 demonstrate the trends and the inventory surplus and shortage of the six demand scenarios from 2008–2040 based on Supply Scenario 1 – CoStar Base Case. Figure 25 shows that inventory shortages are expected to occur in Q1 2031 and Q4 2033 based on Scenarios 4 and 2, respectively. Table 24 analyzes the inventory surplus and shortage by county. Though the inventory shortage will not occur until Q1 2031, Los Angeles County, followed by Orange County, are the ones suffering a shortage in most scenarios throughout 2023–2040. The gap in inventory space will mainly be bridged by the surplus in Inland Empire.

Figure 24. Warehouse Supply and Demand Forecasts – Based on Supply Scenario 1

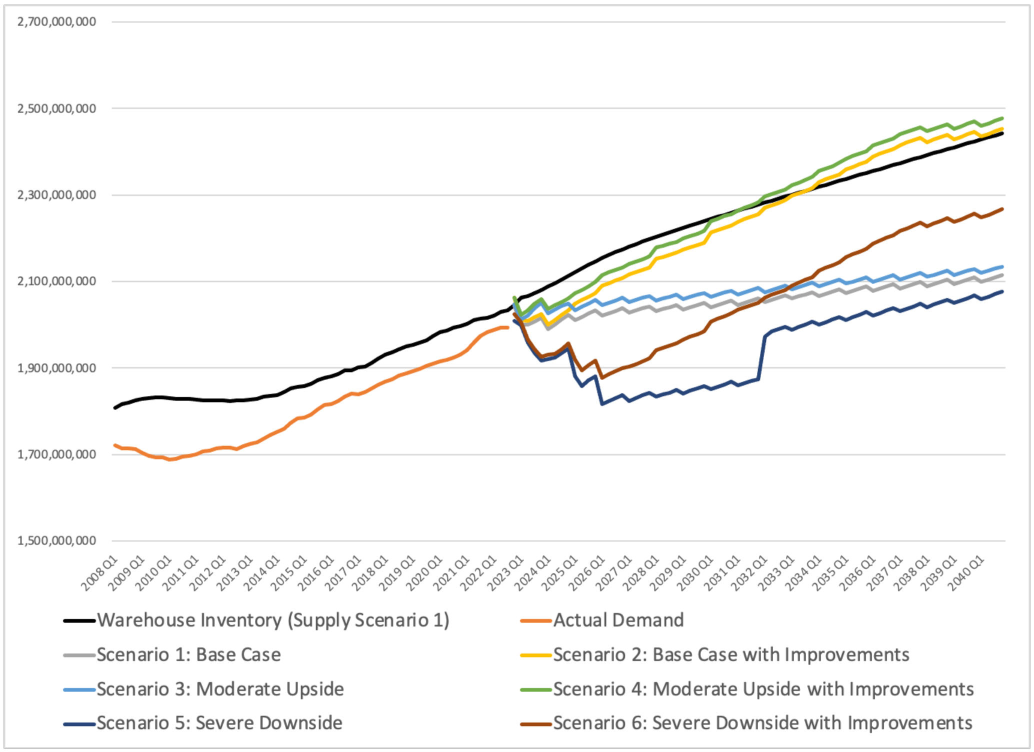


Figure 25. Surplus and Shortage in Warehouse Space – Based on Supply Scenario 1

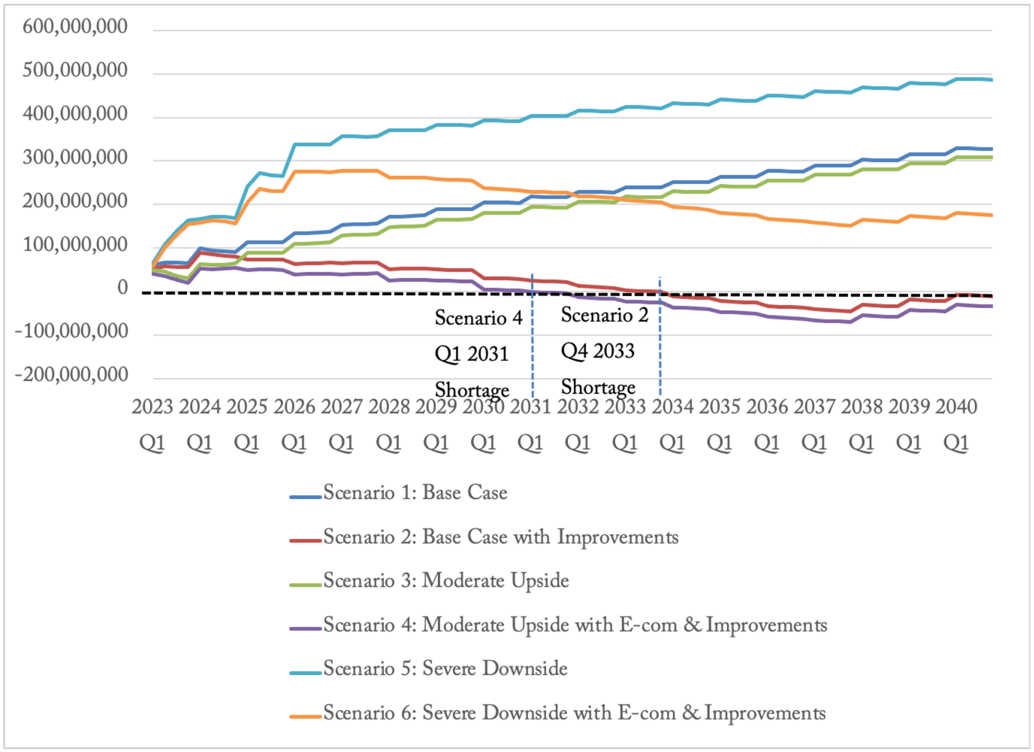


Table 24. Surplus and Shortage in Warehouse Space – Based on Supply Scenario 1

	2023 Q1	2040 Q4
Scenario 1: Base Case		
Inland Empire	82,849,196	352,709,899
Los Angeles	-25,484,588	-43,529,293
Orange County	-3,800,985	94,846
Ventura	8,458,929	18,678,057
Total	62,022,551	327,953,509
Scenario 2: Base Case with E-Commerce & Improvements		
Inland Empire	79,416,616	149,991,375
Los Angeles	-30,063,824	-135,606,585
Orange County	-5,237,192	-27,550,428
Ventura	8,148,711	2,595,254
Total	52,264,311	-10,570,383
Scenario 3: Moderate Upside		
Inland Empire	78,579,209	342,806,537
Los Angeles	-31,112,785	-52,950,361
Orange County	-5,758,130	-857,435
Ventura	8,065,668	18,723,789
Total	49,773,962	307,722,530
Scenario 4: Moderate Upside with E-Commerce & Improvements		
Inland Empire	75,463,035	137,536,508
Los Angeles	-35,718,521	-145,937,593
Orange County	-7,203,552	-28,589,777
Ventura	7,753,599	2,654,621
Total	40,294,562	-34,336,241
Scenario 5: Severe Downside		
Inland Empire	71,865,763	413,948,463
Los Angeles	5,150,844	25,321,562
Orange County	-18,269,926	24,521,587
Ventura	6,409,048	22,850,085
Total	65,155,729	486,641,697
Scenario 6: Severe Downside with E-Commerce & Improvements		
Inland Empire	70,795,604	228,913,515
Los Angeles	715,853	-60,122,509
Orange County	-19,774,259	-921,000

Ventura	6,089,179	7,809,228
Total	57,826,377	175,679,234

Figures 26 and 27 demonstrate the trends and the inventory surplus and shortage of the six demand scenarios from 2008–2040 based on Supply Scenario 2 Inland Empire Warehousing Moratoria. Because the warehouse supply is constrained by the moratoria, the shortage occurs earlier than that in Supply Scenario 1. It shows that inventory shortages are expected to occur in Q1 2028 and Q1 2030 based on Demand Scenarios 4 and 2, respectively. Table 25 analyzes the inventory surplus and shortage by county. Figure 28 reports the changes in the shares of warehouse demand in 2008, 2023, and 2040 based on the base-case demand. The share of Los Angeles is expected to decrease from 53.2% in 2008 to 46.9% in 2040, while the share of Inland Empire increases from 25.9% to 34.8%.

Figure 26. Warehouse Supply Scenario 2 and Demand Forecasts

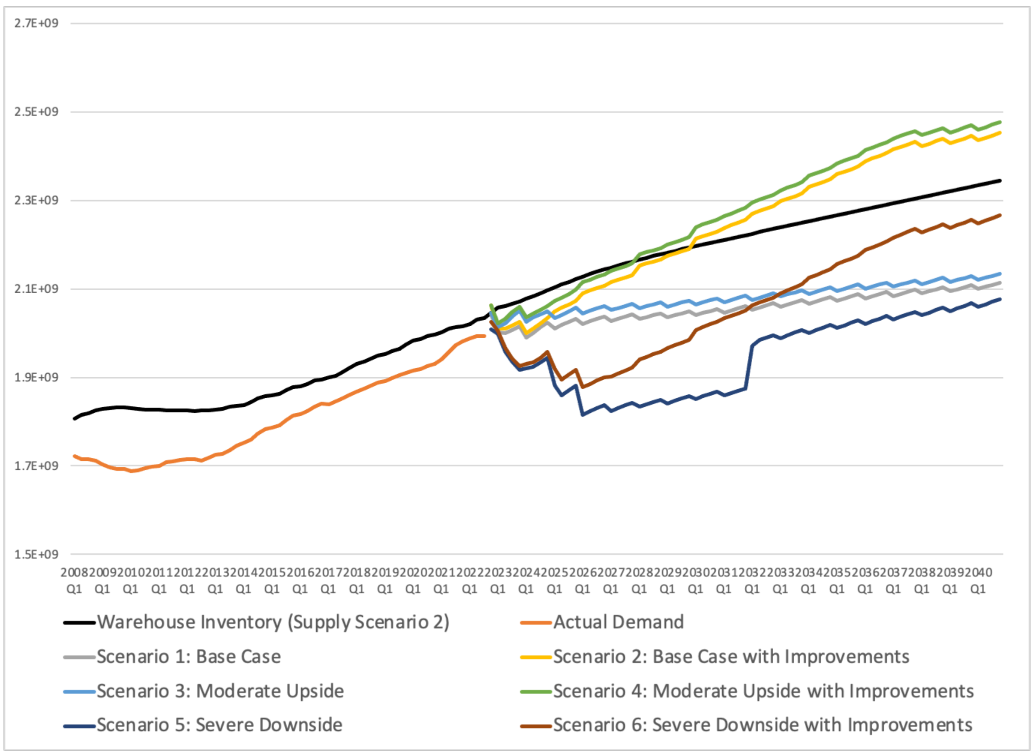


Figure 27. Surplus and Shortage in Warehouse Space – Supply Scenario 2

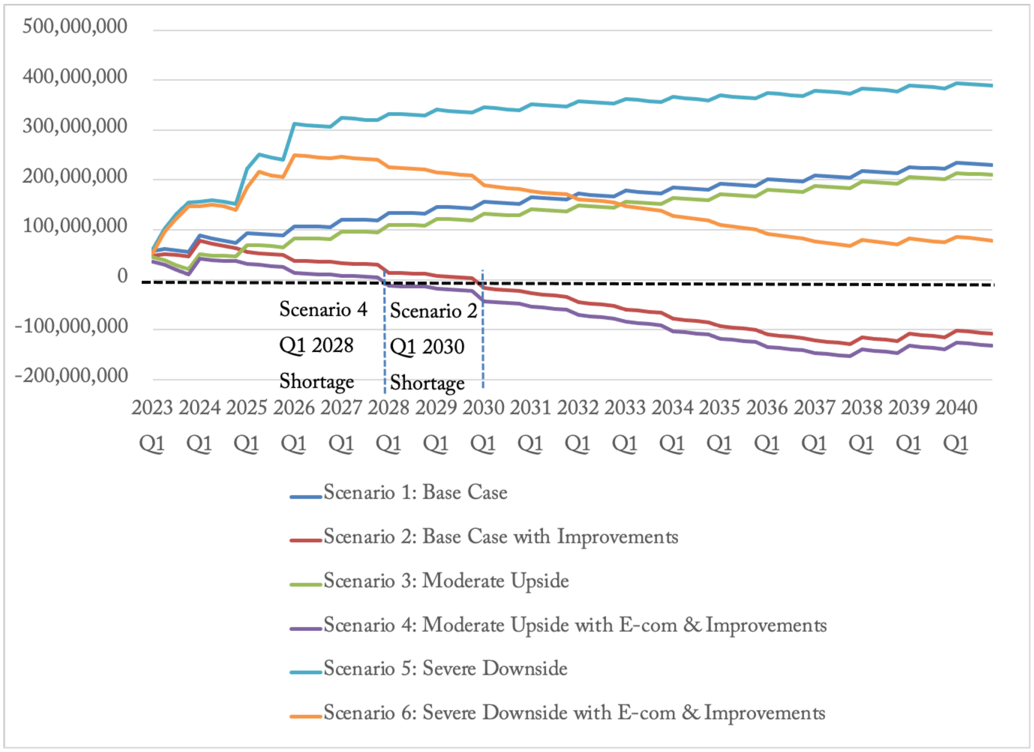
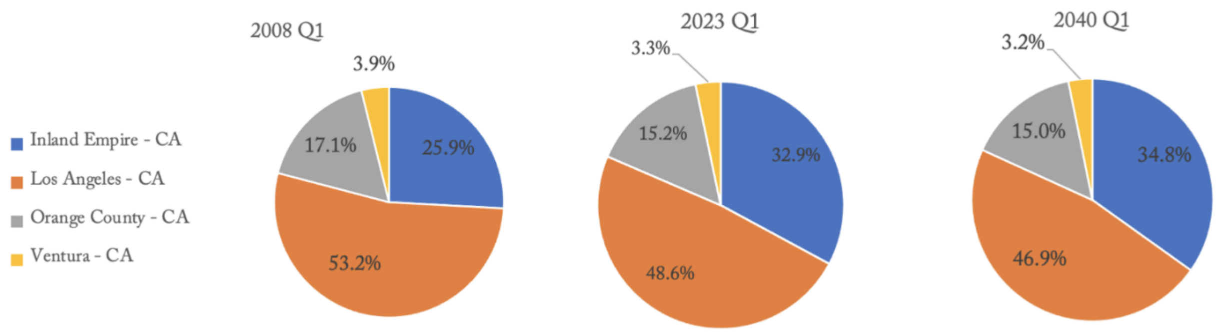


Table 25. Surplus and Shortage in Warehouse Space – Based on Supply Scenario 2

	2023 Q1	2040 Q4
Scenario 1: Base Case		
Inland Empire	78,280,330	254,904,154
Los Angeles	-25,484,588	-43,529,293
Orange County	-3,800,985	94,846
Ventura	8,458,929	18,678,057
Total	57,453,685	230,147,763
Scenario 2: Base Case with E-Commerce & Improvements		
Inland Empire	74,847,749	52,185,630
Los Angeles	-30,063,824	-135,606,585
Orange County	-5,237,192	-27,550,428
Ventura	8,148,711	2,595,254
Total	47,695,445	-108,376,128
Scenario 3: Moderate Upside		
Inland Empire	74,010,343	245,000,792
Los Angeles	-31,112,785	-52,950,361
Orange County	-5,758,130	-857,435
Ventura	8,065,668	18,723,789
Total	45,205,096	209,916,785
Scenario 4: Moderate Upside with E-Commerce & Improvements		
Inland Empire	70,894,169	39,730,763
Los Angeles	-35,718,521	-145,937,593
Orange County	-7,203,552	-28,589,777
Ventura	7,753,599	2,654,621
Total	35,725,695	-132,141,986
Scenario 5: Severe Downside		
Inland Empire	67,296,897	316,142,718
Los Angeles	5,150,844	25,321,562
Orange County	-18,269,926	24,521,587
Ventura	6,409,048	22,850,085
Total	60,586,862	388,835,952
Scenario 6: Severe Downside with E-Commerce & Improvements		
Inland Empire	66,226,737	131,107,770
Los Angeles	715,853	-60,122,509
Orange County	-19,774,259	-921,000

Ventura	6,089,179	7,809,228
Total	53,257,511	77,873,489

Figure 28. Shares of Warehouse Demand in Base Case – 2008, 2023, and 2040



5. Housing Analysis

This section explores demand for housing in California, and the extent to which current and projected deficits could be addressed through policy. After discussing land use and housing in California, we focus on housing and homelessness policy at the state and regional levels, and the important role of city and neighborhood zoning in housing development decisions and the potential for growth. We then focus on estimates of housing deficits to generate projections comparable to those provided in the prior chapter on warehousing. Next, we model a low-income housing provision to better understand associational factors. Finally, we use housing deficit and low-income housing analysis to generate scenarios for environmental impact analysis in the following chapter.

5.1 Land Use and Housing

The Southern California region grew precipitously in the 20th century thanks in part to an abundance of agricultural and undeveloped land. LA County grew from 2.2 million in 1930 to 6.0 million in 1960, and 8.9 million in 1990 (CA DoF, 2023). The rate of growth in LA County slowed in the 2000s, and even began to decline from 2017 onward (USAFacts, 2023). Some of this slowing pace has been offset by significant and sustained growth in neighboring counties, especially the Inland Empire counties of Riverside and San Bernardino. To house this population, large areas of single-family tract housing blocks were developed, especially in the mid-20th century (Caltrans, 2011). For example, during the 1950s, an average of 72,000 new housing units were built annually (U.S. Census, 2023). By 1990, Los Angeles County had reached 3.16 million housing units and the state containing 11.18 million housing units (California Department of Finance, 2023).

Since 1990, the pace of growth has been much lower than the mid-century peak and has remained around 15,000 new units per year in Los Angeles County and around 100,000 at the state level (California Department of Finance, 2023). This is partly due to a lack of less-developed space to grow in to, in addition to zoning constraints discussed further below, and topographical constraints. In response, higher-density living has emerged to accommodate population growth in a slowing housing development market. The rate of persons per household has increased gradually since 1990. Another notable shift during this period is the increase in higher-density developments. In LA County, multiple-unit developments now account for a clear majority of new units, reflecting a wave of infill developments, accessory dwelling units, and higher-density transit-oriented developments that have been allowed through state and city-level exceptions to prior zoning ordinances. This stands in contrast to California as a whole, for which the numbers have been somewhat constant since 2010 (California Department of Finance, 2023).

These constraints on growth and continuing demand have caused prices to increase significantly across the region as supply has failed to keep pace with demand. Higher prices have pushed many to move out of Southern California, and have likely put off others from moving in. During the

COVID-19 pandemic, many more workers were able to work remotely, and used the opportunity to find more value for money in the suburban or rural areas of California, or neighboring states. In this sense, they are benefiting from the strong job market in the Southland, while escaping the high cost of housing.

5.2 Recent Housing Policy

California has a complex history as it relates to land use, as discussed in the literature review above. In 2022, the California legislature presented a housing and homelessness package, which included forty-one bills addressing zoning, density, infill development, bridge housing, creative and adaptive reuse, public-private ownership, etc. This comprehensive package demonstrates the need to understand housing and homelessness from a cross-sector perspective.

Land use and access to public space continue to be points of political debate (Butler, 2009). In fall 2015, Los Angeles Mayor Eric Garcetti and city council members declared a homelessness "state of emergency." Since that call to action, affordable housing developers and policy makers have worked toward closing the gap. With the passing of Measure H (2015; property tax funded) and Prop HHH (2016; sales tax funded) Los Angeles County and City, respectively, have developed a pathway to address the crisis, with around $4 billion in spending on implementation over the decade. The use of public land for the purpose of housing as described in Executive Order N-06-19 is the most recent policy that uses surplus land. Such policies were first introduced with the passing of The Surplus Land Act in 1968. Historically public land has been used to house people of color and has led to the increased density of marginalized communities in neighborhoods that are often more polluted and burdened by industrialization than higher income neighborhoods. With the demand for housing increasing beyond the rate of production, housing policy is critical.

In 2020, the COVID-19 pandemic prompted the government to work together to address homelessness. As a result, Project Roomkey was developed as a collaborative effort by the State, County and the Los Angeles Homeless Services Authority to secure hotel and motel rooms for the most critical populations of people experiencing homelessness. Project Roomkey is an innovative initiative leveraged by local governments to address homelessness, decrease barriers for affordable housing developers, and mitigate impacts on marginalized communities. It is an example of how funding and adaptive reuse can target housing with limited external impacts.

In 2022, the U.S. Department of Housing and Urban Development (HUD) reported 171,521 people experiencing homelessness in California, approximately 30% of the homeless population for the entire United States. California has set a goal of creating 1.2 million affordable homes by 2030. President Biden's Housing Supply Action Plan outlines a commitment to increase funding for current programs to boost the availability of affordable housing. The federal housing choice voucher program and the state low-income housing tax credit (LIHTC) program were highlighted in the Presidential Action Plan as significant programs that would advance the feasibility of the state development of new affordable homes. Current policy offers various opportunities and limitations for addressing housing and warehouse development. The exploration of the use of publicly owned land as a way to navigate this issue provides a new set of criteria that is explored through this study.

5.3 Housing Shortage

California appears to have a housing shortage. Estimates vary, but the most rigorous estimates (based on population, demographics, and other factors) are in the one to two million range for California. The 3.5 million number used by Governor Newsom was based on a 2016 McKinsey report that used housing per capita for New York as the basis (Woetzel et al., 2016). As shown in Table 26, using Texas housing per capita instead suggests a deficit of 1.5 million, while using all states' per capita housing suggests a deficit of 1.4 million (Embarcadero Institute, 2019). Other approaches yield different estimates still: a 1.3 million deficit based on average household size (Embarcadero Institute, 2019), and a surplus of 1.1 million based on the jobs-housing ratio (Building Industry Association, 2017). The California Department of Housing and Community Development has a more rigorous projection approach based on multivariate modeling of factors such as anticipated household growth, household size trends, household income, rate of household formation, vacancy rates, and the relationship between jobs and housing; this approach estimates a deficit of 1.1 million housing units.

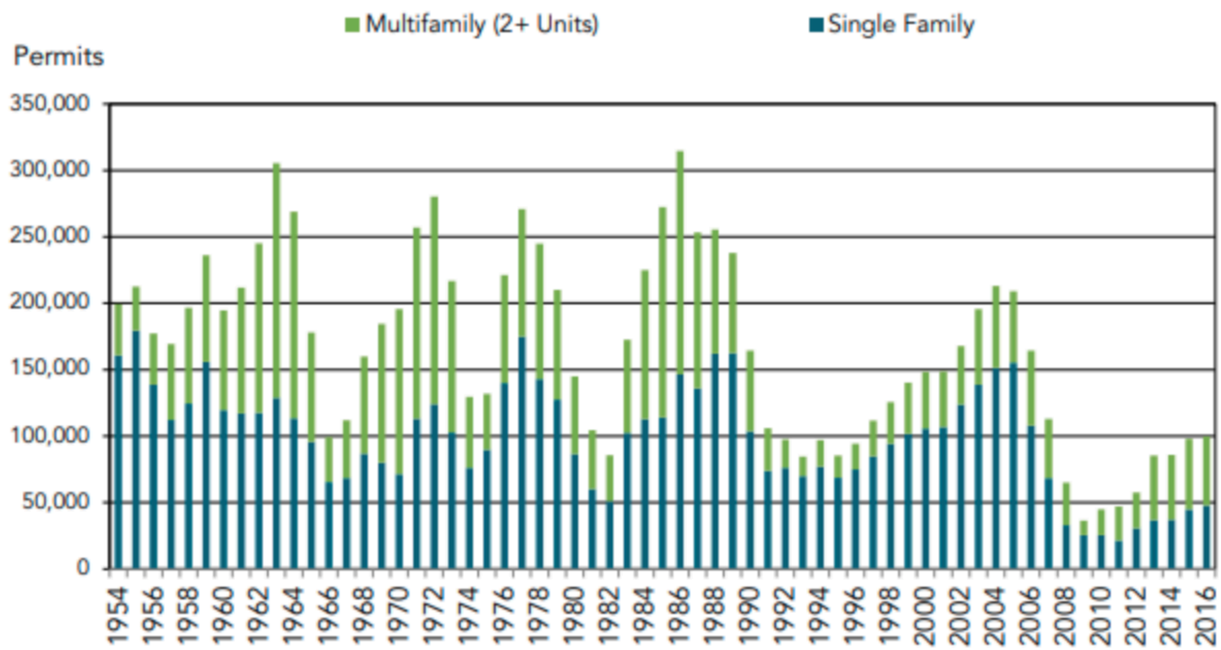
Table 26. Comparison of California Housing Shortage Estimates

Organization	Deficit	Approach
California Department of Housing and Community Development (2018)	1.1 million	Multivariate model: • Anticipated household growth • Household size and trends in household size • Household income • Rate of household formation (age, gender, ethnicity) • Vacancy rates • Relationship between jobs and housing
California Governor (Newsom, 2017)	3.5 million	Based on McKinsey upper estimate
McKinsey (Woetzel et al., 2016)	2 million	Housing per capita (New York and Texas)
	1.5 million	Housing per capita (Texas)
	3.5 million	Housing per capita (New York)
Embarcadero Institute (2019)	1.4 million	Housing per capita (All states)
	1.3 million	Average household size (Population/Avg hh size)*(1+Vacancy rate)
Building Industry Association (2017)	1.1 million	Jobs-Housing ratio (1.5 jobs per house)
USC Price Study (Myers et al., 2018)	1.1 million	Housing-Demographic model

This deficit is pushing prices above what is affordable for many households. The drop off in recent housing unit developments shown in Figure 29 suggests this has been many years in the making, and current trends do not suggest a turnaround, despite a slightly declining population since the COVID-19 pandemic. This situation exacerbates the need for affordable and low-income housing, which is also being built at lower rates than is needed, despite a recent uptick. There remains potential for more house building, especially around transit hubs, which would facilitate worker commutes. For the purposes of this study, we can assume that housing—affordable or otherwise—would be demanded in the locations offered to warehousing.

If there is a need for additional housing (per these analyses), and land zoned for development that is not being used (as highlighted in the McKinley analysis), then why is the market not rebalancing more quickly? In short, developments take time, project investments are risky, and zoning and available land are tighter (more expensive and time-consuming) in high-demand areas.

Figure 29. New Build Permits, 1954–2016



Source: Department of Housing and Community Development

Affordable and low-income units appear to be needed. In 2018, 43% of California households were low-income, but only 23% of housing production was low-income. As shown in Figure 30, affordable housing production has been relatively stable, in contrast to much larger fluctuations in new housing units. This suggests that affordable housing production had not kept pace with regular housing development, though the more recent uptick in 2020 and 2021, shown in Figure 31, suggest efforts have been made to close the gap. Nonetheless, the California Housing Partnership estimates 120,000 affordable units a year are needed to meet demand (Tobias, 2022).

Affordable housing development is limited for a number of reasons. Primarily, it is a complex process, with projects taking four to seven years to complete and requiring close collaboration among multiple public and private stakeholders (LISC, 2019). Projects need organizational commitment from all stakeholders, zoning, environmental, and financial feasibility analysis, financial support, and reliable developers and vendors. Private funds may be sufficient given tax incentives; however, public funds and/or support might also be required for projects to be realized. Public funds are limited, as highlighted in Section 5.4. City-level requirements and approaches are varied (as discussed in the literature review). Some affordable units are financed by high-price housing developments (either within the building or located elsewhere), and compared to private housing developments, projects are more complex and often have longer lead times, constraining returns on investment, and increasing risk for financiers.

Because of each of these factors, and the clear demand for affordable housing in Southern California, later scenarios focus on affordable development housing units only. This has implications for traffic and environmental impact analysis. A recent study found that more urbanized neighborhoods with lower average resident incomes have significantly lower transportation and pollution impact than other neighborhood types after controlling for other key factors (Howells et al., 2018). This suggests that affordable housing is likely to have these characteristics too, especially if developed in urban locations with appropriate transportation links.

Figure 30. Affordable Housing Developments, 2011–21

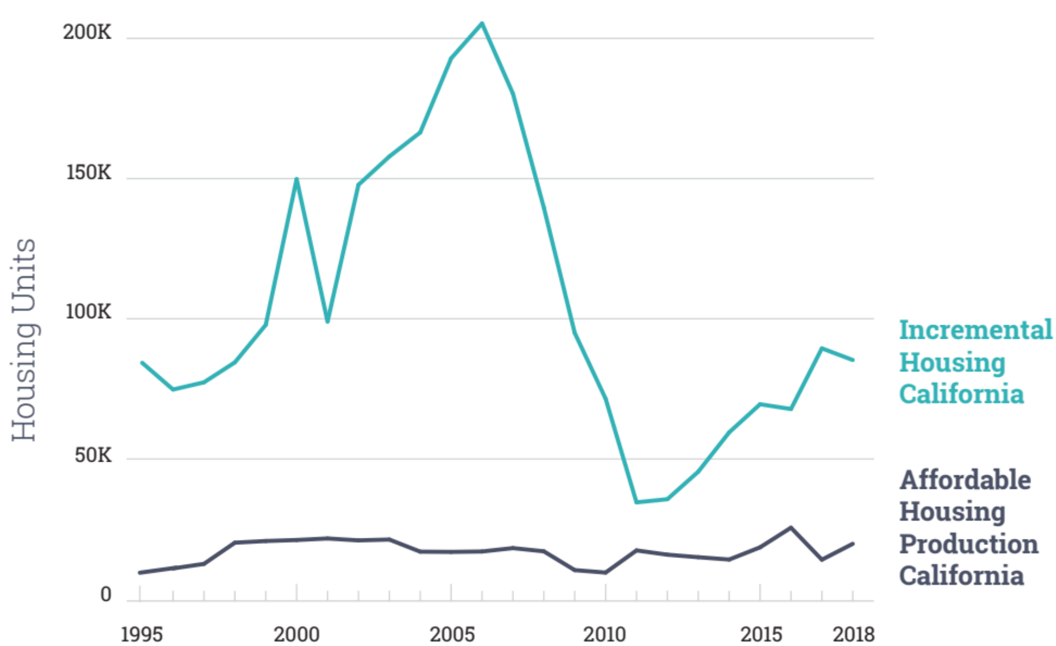
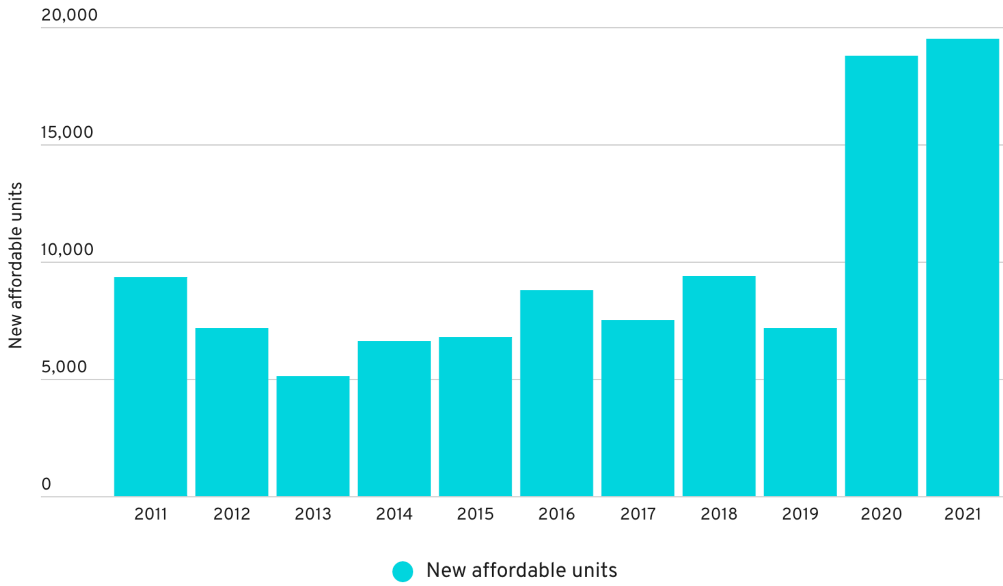


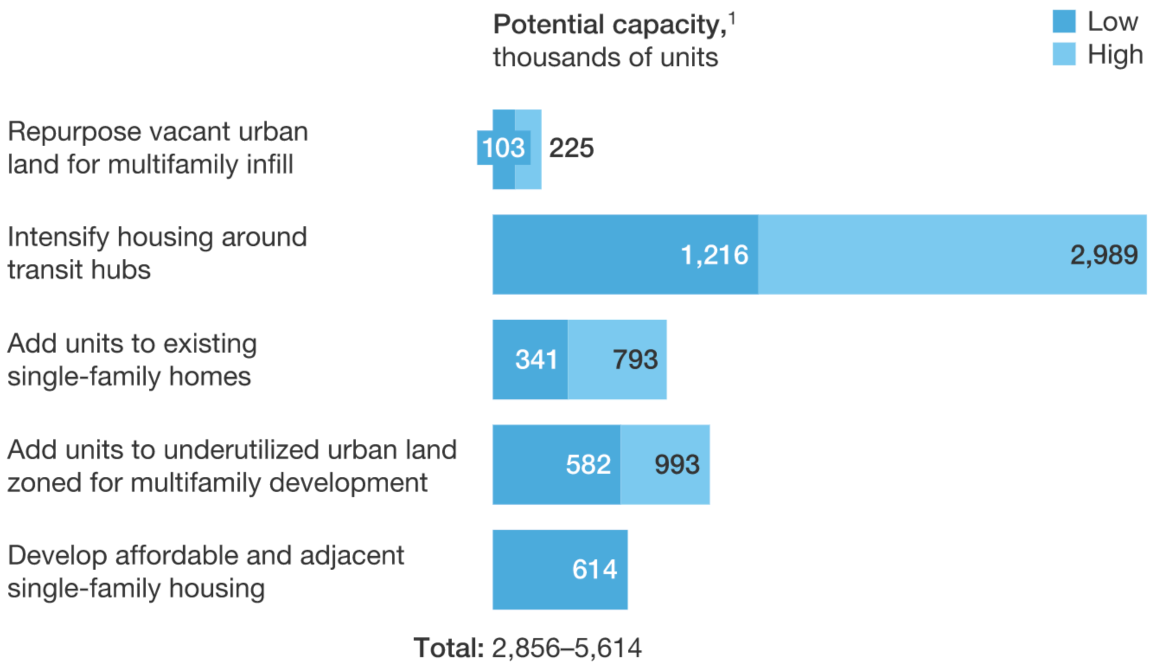
Figure 31. New Affordable Units, 2011–21



Source: California Housing Partnership

It is therefore important to consider whether the locations proposed for warehousing are suitable for housing. Do they have appropriate transportation links? Where are new houses most likely to be built? Intensifying building around transit hubs offers the most potential; however, adding to single family units or underutilized land zoned for multifamily use has significant potential too. Los Angeles County has 5,600 to 8,900 vacant parcels zoned for multifamily use, with zoned capacity for 32,000 to 75,000 units. California has the capacity to create between one million and three million housing units within half a mile of transit hubs.

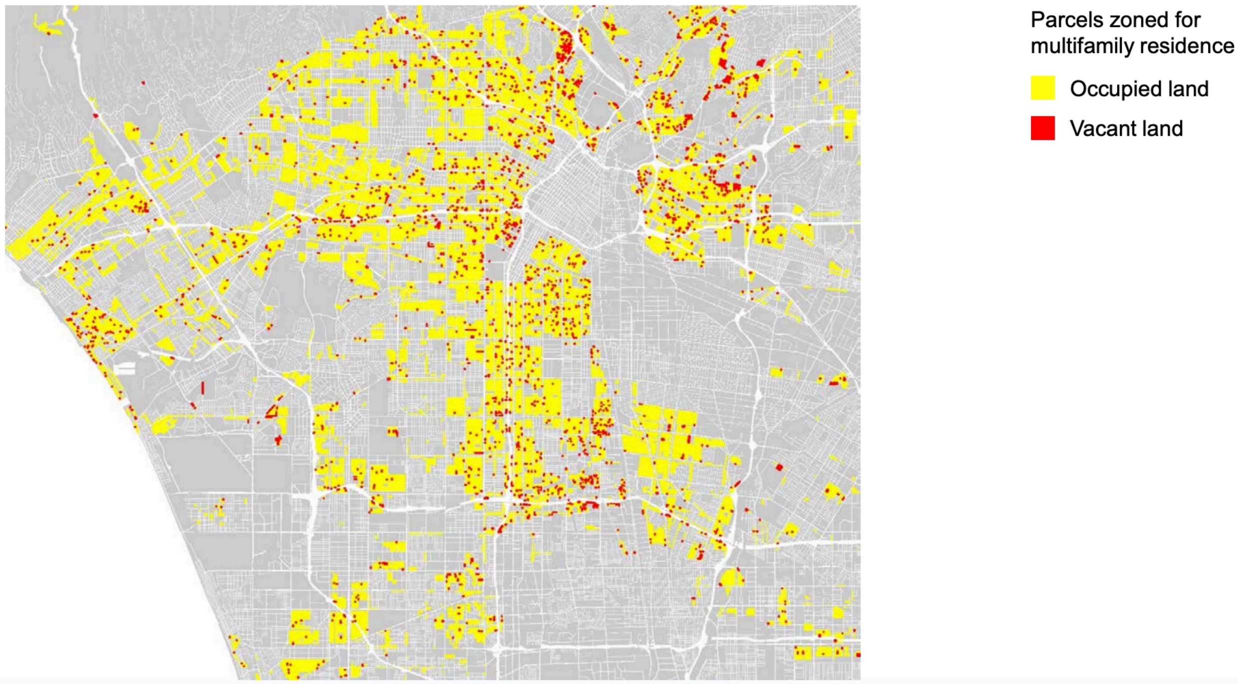
Figure 32. Potential Capacity of Housing by Location Type



[1]Highly conservative estimate, based on only 3 counties: Contra Costa, Sacramento, and San Bernadino.

McKinsey&Company | Source: McKinsey Global Institute analysis

Figure 33. Vacant Land Parcels Zoned for Multifamily Residences in a Section of Los Angeles County



Source: Los Angeles County GIS Data Portal; McKinsey GIS analysis; McKinsey Global Institute analysis

Figure 34. Additional Units at Potential Sites for Transit-Oriented Housing

Urban type	**Existing units** Thousand	**Additional units**[1] Thousand
Regional hub >15 units per net acre	563	379
Urban center 6.5–15 units per net acre	409	3,321–938
Suburban node <6.5 units per net acre	192	516–1,672
Total	1,164	1,216–2,989

Source: Bay Area Metropolitan Transportation Commission; San Diego Regional Data Warehouse; Sacramento County GIS portal; Los Angeles GIS Portal; Fresno Bus Rapid Transit Master Plan; Amtrak; California High-Speed Rail Authority; McKinsey GIS analysis; McKinsey Global Institute analysis

5.4 Low-income housing

Figure 35. Relationship Between Unemployment Rate and Low-Income Units Across California Counties

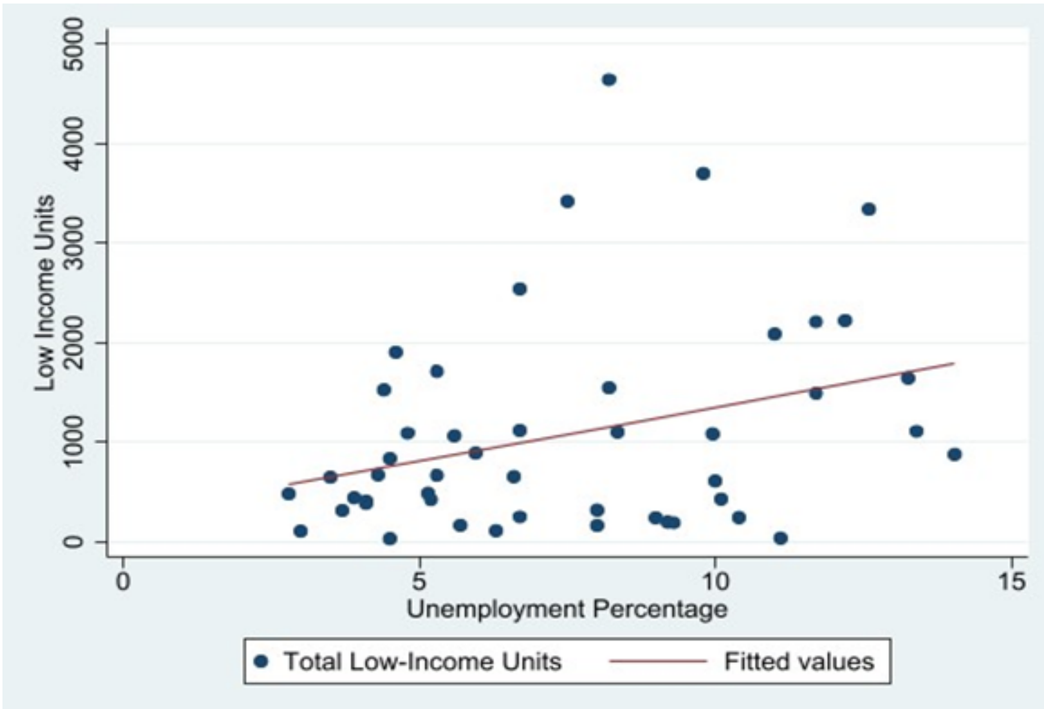


Figure 35 shows that the relationship between low-income units and the unemployment rate is positive.

This section uses the data from HUD's Low-Income Housing Tax Credit Database (LIHTC Database Access, 2023) for the State of California. The LIHTC program is a tax incentive program designed to increase the availability of low-income units for people to rent. It is designed to subsidize either 30% or 70% of the costs of rental units for low-income units. We have selected four main counties, namely, Los Angeles County, Ventura County, Orange County, and Inland Empire County, for our analysis due to their distances from the main export and import ports and data availability from 2008 to 2019. The data are reported annually for each county. Table 27 shows descriptive data for our analysis from 2008 to 2019.

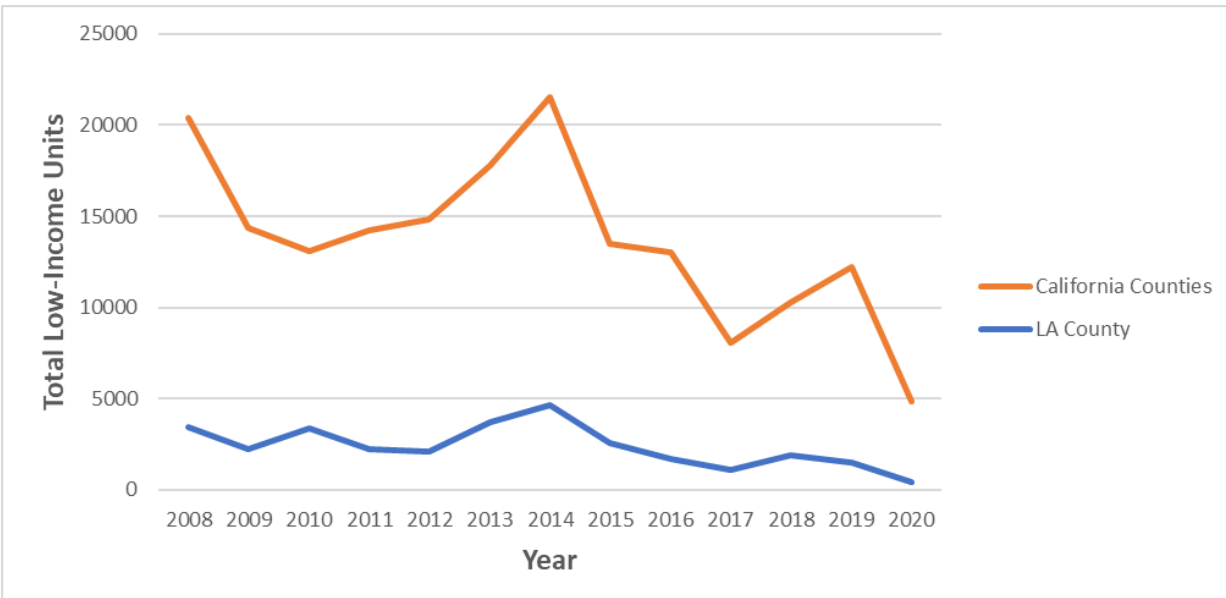
Table 27. Descriptive Data for Total Number of Low-Income Units, 2008–19

County	Observations	Mean	Std. Dev.	Min	Max
Inland Empire	12	998.583	413.596	385	1650
Los Angeles	12	2534.67	1036.96	1092	4643
Orange	12	559.417	329.599	107	1120
Ventura	12	235.333	144.47	30	441

The descriptive analysis shows that Los Angeles County had completed 2535 low-income units annually on average over these years with a maximum of 4643 units and a minimum of 1092 units. Moreover, Los Angeles County alone is responsible for 60% of all low-income units among these four main counties. Ventura County has the lowest number of low-income units built with an average of 235 units.

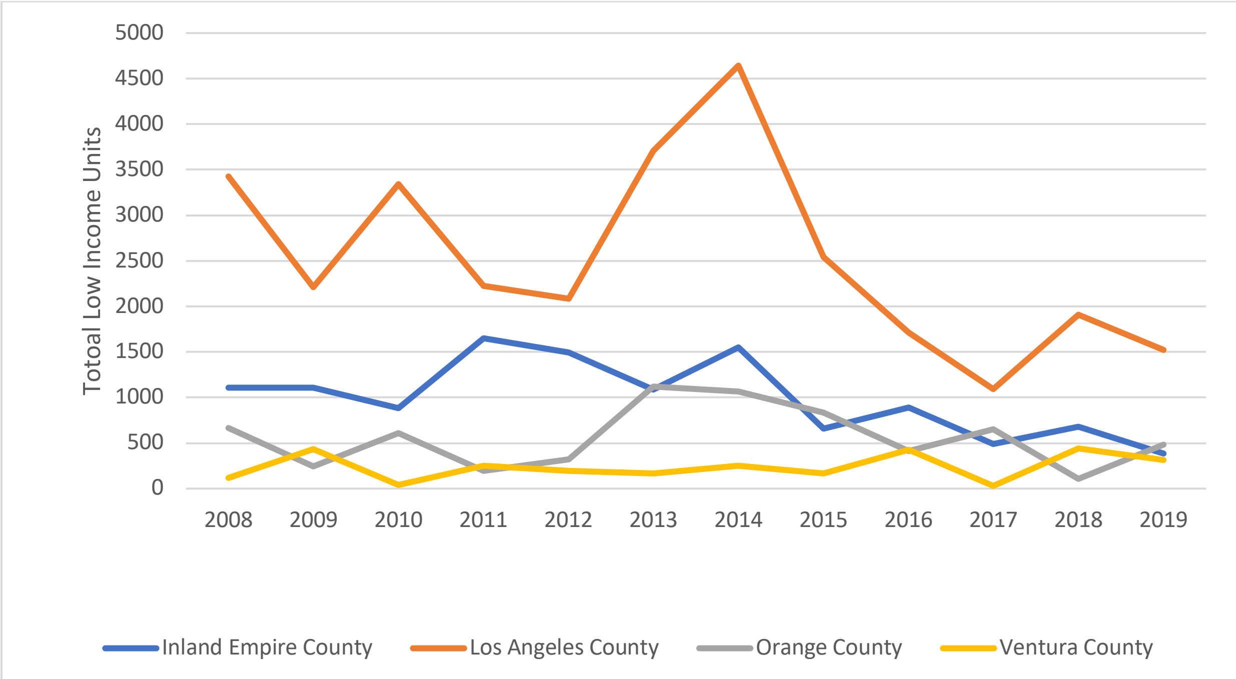
Figure 36 demonstrates the total number of low-income units in Los Angeles County and other counties in California. This figure shows that the trend is similar in Los Angeles County and other California counties regarding the total number of low-income units. In 2014, we had the highest number of low-income units for both California counties and LA county, whereas the lowest number of homeless across California was reported in the same year.

Figure 36. Total Low-Income Units in Los Angeles and Other California Counties



Moreover, Figure 37 displays the total low-income units across Inland Empire County, Los Angeles County, Orange County, and Ventura County from 2008 to 2019. They have almost the same pattern and trend. We expect that increasing the number of low-income units will reduce the number of homeless across these counties.

Figure 37. Total Low-Income Units in Southern California Regions



5.4.1 Methodology and Findings

Table 28 shows the regression results used to estimate low-income units across counties.

Table 28. The Effect of Unemployment Rate on Total Low-Income Units.

Variables	Model (1)	Model (2)	Model (3)	Model (4)
Unemployment Rate	107.34**	453.25***	58.98**	404.20**
	(47.25)	(120.57)	(28.11)	(153.54)
Los Angeles			1566.55***	1744.92***
			(231.14)	(213.70)
Orange			-275.99	679.12
			(243.45)	(468.86)
Ventura			-663.98***	-82.85
			(235.49)	(325.85)
Constant	267.03	-1781.67*	482.52	-2030.38
	(383.66)	(959.78)	(295.17)	(1273.65)
Year-Fixed Effects	No	Yes	No	Yes
County-Fixed Effects	No	No	Yes	Yes
R-Squared	0.1009	0.3683	0.7381	0.8558
Observations	48	48	48	48

*Standard errors in parentheses. ***=p<0.01; **=p<0.05; *=p<0.10*

The results of the regression models indicate that a strongly positive relationship between unemployment rate and total low-income units exists in all models. In Column 1, we show the regression model without county- and time-fixed effects. In column 2, we show the model by adding a time-fixed effect. In column 3, a county-fixed effect is added to the model, and finally we used both time- and county-fixed effects on the model in column 4. The findings show that once the unemployment rate goes up/down, the number of low-income units increases/decreases as well. Our comprehensive model is shown in Equation 9.

Equation 9: Total number of low-income units = -2030.38 + 404.20 (unemployment) + 1744.92 LA + 679.12 OC - 82.85 VT

The results indicate that when an unemployment ratio increases/decreases by one percent (1%) the number of low-income units increases/decreases by 404 units. The findings indicate a strongly positive relationship between the unemployment rate and low-income units across counties.

This study uses a dynamic panel estimation model including one-step GMM and two-step GMM models as well as static models to estimate the number of low-income units (see Table 29). This study uses the following dynamic panel estimation models to obtain low-income units supply at the county level. Equation 10 uses one period lag of low-income units to estimate the current low-income units; meanwhile Equation 11 uses two period lags of low-income units as the main explanatory variables to estimate current low-income units.

$$\text{Equation 10: } Low-Income\ Units_{it} = \beta_0 + \beta_1 (Low-Income\ Units)_{i,t-1} + \beta_2 (Unemployment)_{it} + \varepsilon_{it}$$

$$\text{Equation 11: } Low-Income\ Units_{it} = \beta_0 + \beta_1 (Low-Income\ Units)_{i,t-1} + \beta_2 (Low-Income\ Units)_{i,t-2} + \beta_3 (Unemployment)_{it} + \varepsilon_{it}$$

Table 29. Dynamic Panel Estimation Model Results.

Variables	One-Step Dynamic GMM	Two-Step Dynamic GMM
$(Low-Income\ Units)_{t-1}$	0.227*	0.374**
	(0.147)	(0.161)
$(Low-Income\ Units)_{t-2}$		-0.123
		(0.161)
Unemployment	61.957**	62.45**
	(29.125)	(29.82)
Constant	280.80	345.008
	(251.97)	(291.665)
Wald chi2	10.80***	11.61***
Observations	40	36

*Standard errors in parentheses. ***=p<0.01; **=p<0.05; *=p<0.10*

The results of the GMM models (both one-step and two-step) are similar to our static models. The findings indicate that the unemployment ratio has a strongly positive impact on low-income units. Moreover, one lagged low-income units is statistically significant to explain the low-income units at the county level. The results show the number of low-income units in previous years have a positive impact on the number of current low-income units. Thus, this study indicates that local governments and policy makers might focus on job opportunities in order to reduce the demand for low-income housing. This study shows that the unemployment rate is the main factor determining the number of low-income units in selected counties. In Table 30, we have added other explanatory variables to extend the results.

Table 30. The Effect of Unemployment Rate, Market Effective Rent per Unit, and Market Sale Price per Unit on Total Low-Income Units

Variables	Model (1)	Model (2)
Unemployment Rate	62770.11** (26167.43)	627770.11** (30434.02)
Market Effective Rent	2.275 (3.77)	2.275 (4.456)
Market Sale Price Per Unit	-0.014* (0.007)	-0.014** (0.006)
Los Angeles	2188.695 (2140.68)	2188.69 (2612.75)
Orange	2024.125 (2783.96)	2024.12 (3333.89)
Ventura	558.41 (2126.47)	558.41 (2534.5)
Constant	-5444.88 (3334.06)	-5444.88 (3506.43)
Year-Fixed Effects	Yes	Yes
County-Fixed Effects	Yes	Yes
Robust	No	Yes
R-Squared	0.874	0.874
Observations	48	48

*Standard errors in parentheses. ***=p<0.01; **=p<0.05; *=p<0.10*

The results show that the unemployment rate has a positive effect on the supply of low-income units and the market sale price per unit has a negative impact on the supply of low-income units. This study suggests that increasing the unemployment rate would increase the demand for low-income units across counties. Also, one would expect that increasing the market sale price per unit has a negative impact on low-income units across counties.

5.5 Housing inputs to Environmental Modeling

To create comparable scenarios for the environmental impacts of housing developments, we have calculated estimates of the traffic generated with respect to each warehousing scenario. For Emissions Analysis (C-LINE) Scenario 1, the generated traffic is estimated for the same land area used for the N-19-21 policy. We assume that affordable housing units would be developed in an area of land equivalent in size and in the same jurisdiction. While there is no standard industry average available in terms of housing units per acre, the State Housing Element law requires that urban sites permit at least 30 units per acre to accommodate affordable housing (City of Los Angeles, 2021).

For Emissions Analysis (C-LINE) Scenario 2, we calculated the generated traffic for the 2040 forecast scenario of housing and associated air pollution. We would like to focus on affordable housing; however, there are limited data, so forecasting is not appropriate. Instead, as shown in Table 31, we first estimate the annual housing unit deficit by combining the housing deficit approach identified above with population forecasts from the California Department of Finance and CoStar (the latter of which we extended to 2040, as it only runs to 2033), and current housing unit data from the California Department of Finance Historical Housing Estimates.

For example, the population of California is projected to be 43.4 million by 2040. Pre-pandemic projections had this number much higher; however, recent years have seen a decline in total population due to increases in California residents leaving the state and a significant drop in foreign immigration due to pandemic controls. Using Equation 12, the corresponding state housing units needed for 2040 is 15.8 million, which is 1.2 million higher than current housing stock. Therefore, 65,000 units per year must be built across the state to meet the deficit.

Equation 12: Regional housing units needed = −5717 + 0.465(Population) – 234e−11(Population)2

Table 31 also presents projected housing deficits for the Southern California regions used in this analysis. It is important to note that these individual region deficits do not necessarily sum to the state level. The total annual housing deficit for the four Southern California regions in this analysis is around 120,000 units, which is higher than the state total. It is possible that other counties are projected to have a surplus of housing. Moreover, while the sum of individual counties for the California Department of Finance projections and current housing units should equal state totals, the total units needed are based on the regression analysis model in Equation 12, and therefore may vary across counties.

The annual unit deficit for the Southern California regions is multiplied by the average share of annual new California housing units that is affordable (14.3%; see Table 32). This number has increased in recent years, not least thanks to new state targets requiring that higher proportions of new housing units are affordable. As such, Emissions Analysis (C-LINE) Scenario 2 for housing is effectively a lower bound assumption, as the affordable housing share is likely to be at least at the average levels of the past decade.

Emissions Analysis (C-LINE) Scenario 3 serves as the upper bound estimate. This uses the same projected housing deficit but multiplies it by the state's 40% target. While this target is possible, based on evidence from the past decade it is unlikely to be met. This is in part due to numerous cities across the state—including in Southern California—that are not in compliance with state directives on affordable housing. Some cities actively oppose state directives while others have struggled to implement targets due to local zoning processes and limited development opportunities.

Table 31. Annual Unit Deficit Based on Projected Population and Housing Deficit Estimates

Projection Location and Year	Projected Population (M)	Vacancy Rate[a]	Average HH Size[a]	Current Housing Units (M)	Projections Based on Texas Housing per Capita			National State Housing per Capita Model		
					Total Units Needed (M)	Deficit	Annual Unit Deficit	Total Units Needed (M)	Deficit	Annual Unit Deficit
CA 2025	40.8[b]	7.03%	2.880	14.6	15.1	514,962	171,654	15.1	489,220	163,073
CA 2040	43.4[b]	7.03%	2.880	14.6	16.0	1,456,765	80,931	15.8	1,171,549	65,086
LA County 2040	10.3[b]	5.32%	2.964	3.6	3.8	170,814	9,490	4.5	894,707	49,706
	9.9[c]	5.32%	2.964	3.6	3.7	25,056	1,392	4.4	730,127	40,563
Inland Empire 2040	5.5[b]	12.08%	3.227	1.6	2.0	419,325	23,296	2.5	863,218	47,957
	5.6[c]	12.08%	3.227	1.6	2.0	460,486	25,583	2.5	912,070	50,671
Orange County 2040	3.3[b]	5.33%	3.003	1.1	1.2	84,439	4,691	1.5	367,990	20,444
	3.4[c]	5.33%	3.003	1.1	1.3	111,579	6,199	1.5	400,948	22,275
Ventura County 2040	0.9[b]	5.22%	3.046	0.3	0.3	32,629	1,813	0.4	109,195	6,066
	0.9[c]	5.22%	3.046	0.3	0.3	29,204	1,622	0.4	104,929	5,829

Projections are for 2040, except for the first row. [a] California Department of Finance Historical Housing Estimates; [b] California Department of Finance Population Projections; [c] CoStar/CSUDH Population Projections.

Table 32. New California Housing Development and Affordable Shares, 2011-21

Year	Total Housing Units	New Housing Units	New Affordable Units	Affordable Share of Total New Units	Total Population	New California Population
2010	13,670,304				37,253,956	
2011	13,704,840	34,536	9,318	27.0%	37,561,624	307,668
2012	13,740,400	35,560	7,172	20.2%	37,924,661	363,037
2013	13,785,895	45,495	5,090	11.2%	38,269,864	345,203
2014	13,845,405	59,510	6,636	11.2%	38,556,731	286,867
2015	13,914,933	69,528	6,752	9.7%	38,865,532	308,801
2016	13,982,747	67,814	8,759	12.9%	39,103,587	238,055
2017	14,072,205	89,458	7,474	8.4%	39,352,398	248,811
2018	14,157,502	85,297	9,386	11.0%	39,519,535	167,137
2019	14,235,201	77,699	7,177	9.2%	39,605,361	85,826
2020	14,392,140	156,939	18,798	12.0%	39,538,223	-67,138
2021	14,471,112	78,972	19,520	24.7%	39,303,157	-235,066
		72,801	9,644	14.3%		

Source: California Housing Partnership

6. Environmental Impact Analysis

6.1 Land Use in the SCAG Region

Warehouse clusters and truck routes exhibit a discernible pattern of operation in urban areas that are close to both freeways and residential areas, indicating the concentration of externalities. This pattern holds true for densely populated regions within the SCAG region, including South Los Angeles County, West Inland Empire, and Northern Orange County, as well as Ventura County, where warehouse clustering is less prominent. In assessing the relationship between warehouses and land-use choices, disadvantaged areas, as determined by CalEnviroScreen 4.0, can serve as an indicative factor for identifying locations where clustering tends to occur in each county.

Socioeconomically disadvantaged groups, who face challenges in competing for land that lacks the externalities associated with warehousing such as pollutants, traffic burden, and low aesthetics, bear a disproportionate burden of these impacts in higher concentrations. The preference of warehouse developers to locate near labor is intrinsically linked to their choice of land within disadvantaged areas, which suggests that the labor force predominantly comprises individuals from socioeconomically disadvantaged backgrounds.

There have been claims that the location of warehouses is often concentrated in disadvantaged areas due to their proximity to freeways. As shown in Figures 38-41, areas outside the borders of disadvantaged areas with freeway access were more likely to exhibit minimal to no warehouse presence. This visual pattern is particularly pronounced in all four regions, although there may be a few dense clusters that are located further away from disadvantaged areas in Inland Empire and Orange County.

It Is crucial to recognize that the impacts of warehousing are not limited solely to the geographical areas where warehouses are located, but also extend to the areas through which goods are transported via heavy-duty diesel trucks. The historical planning of freeways and the challenges associated with NIMBY have resulted in the placement of freeways in disadvantaged areas as well. As a result, both mobile and stationary impacts of warehousing tend to concentrate within communities that are already socioeconomically disadvantaged, and this pattern is likely to persist if warehouse expansion continues to be guided by the current planning practices.

Figure 38. Spatial Distribution of Warehouses and Disadvantaged Areas in Los Angeles County

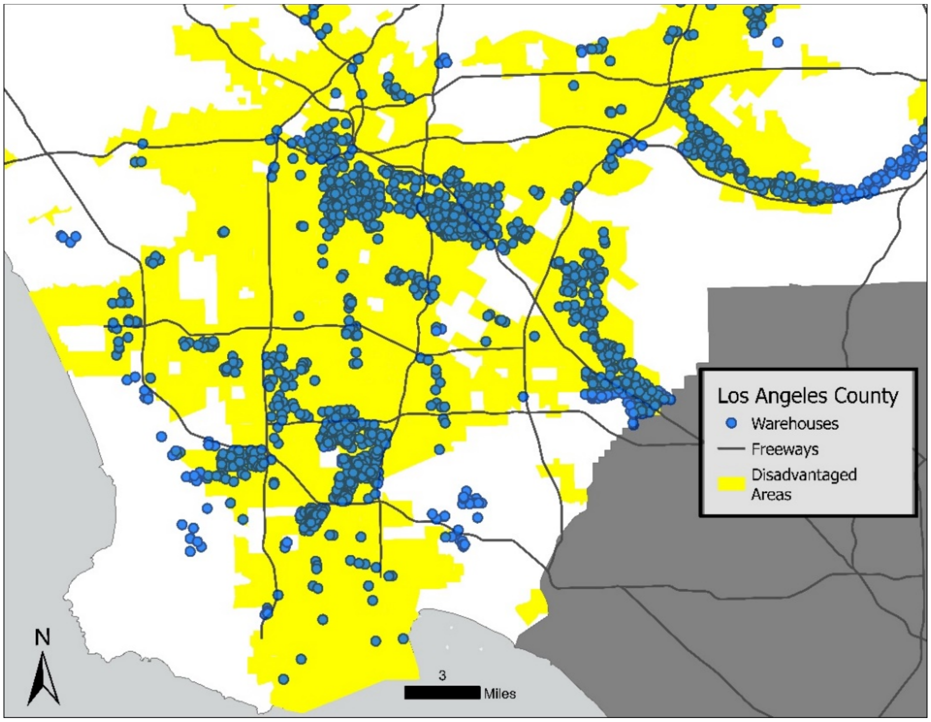


Figure 39. Spatial Distribution of Warehouses and Disadvantaged Areas in Ventura County

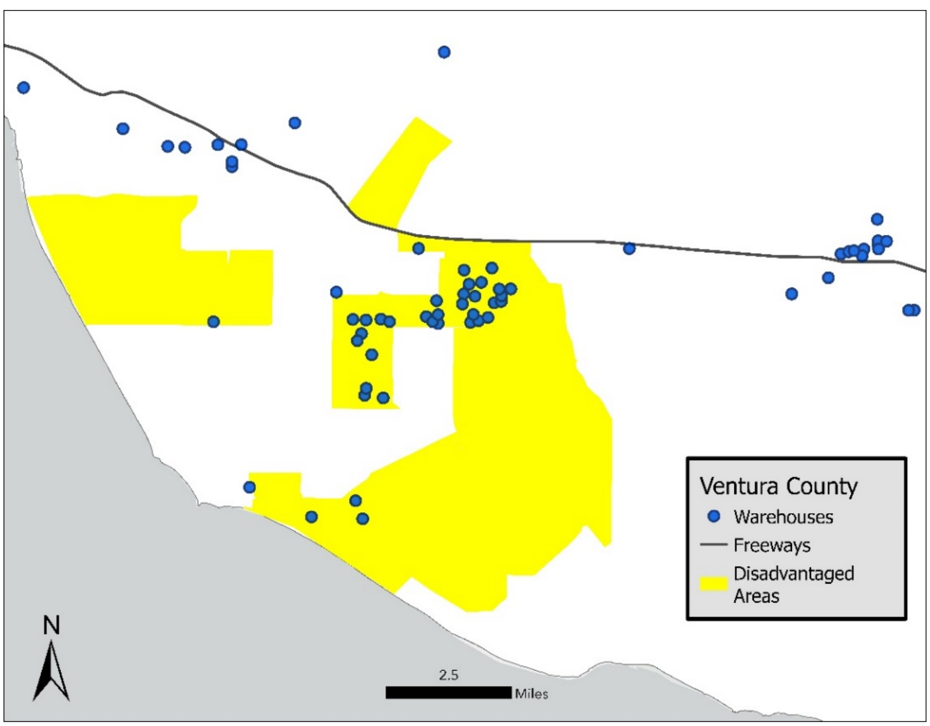


Figure 40. Spatial Distribution of Warehouses and Disadvantaged Areas in Inland Empire

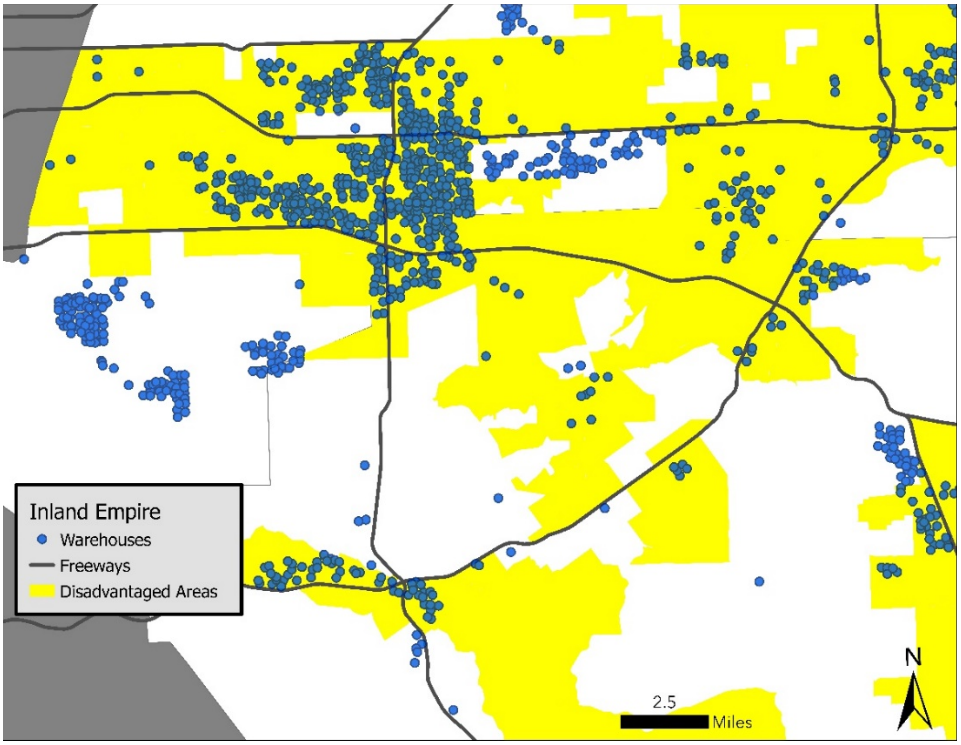
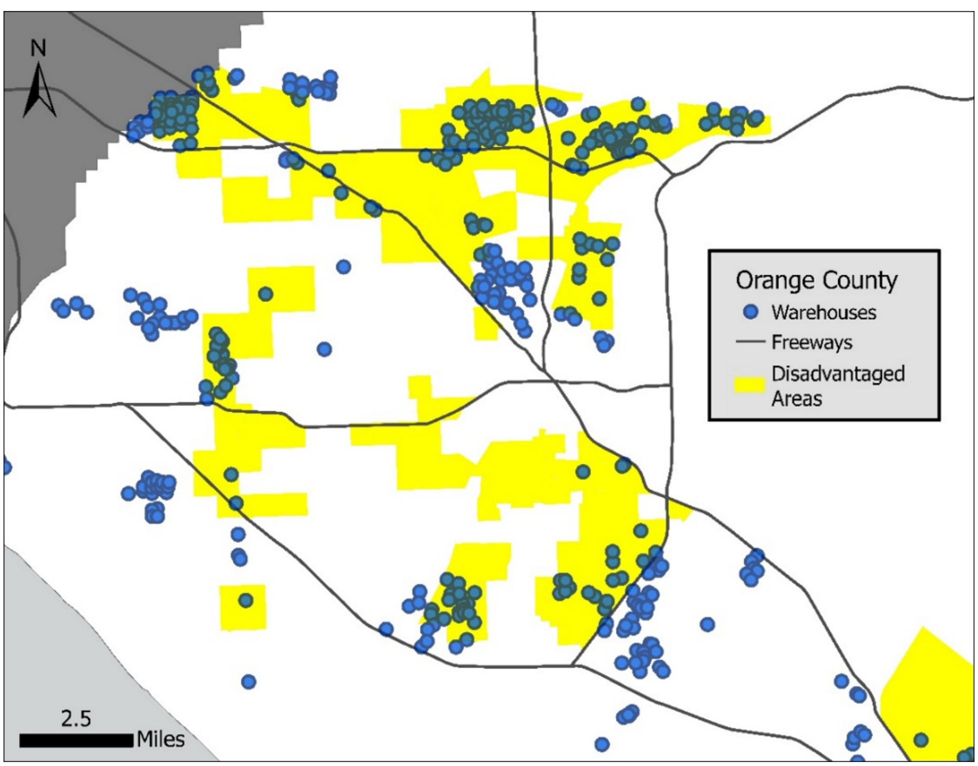


Figure 41. Spatial Distribution of Warehouses and Disadvantaged Areas in Orange County



6.2 Air Pollution in the SCAG Region

$PM_{2.5}$, a pollutant with multiple sources, including emissions from trucks and traffic-related activities, contributes to elevated concentrations across various counties (Figures 42–44). While $PM_{2.5}$ concentrations are notably high in Los Angeles, the areas with the highest concentrations (76th to 100th percentiles) are found near clusters of warehouses. The presence of warehouses in residential areas causes the emission of pollutants related to operational and traffic activities from heavy-duty trucks associated with warehousing.

Although newly established warehouses may initially contribute relatively low amounts of $PM_{2.5}$ emissions to the disadvantaged areas where they are often located, any amount of emissions adds to the existing burden of particulate matter in these vulnerable areas, which already face significantly higher concentrations. Empirical evaluation of the air quality impacts of warehouse clusters provides a crucial tool for accurately assessing the potential impacts when considering the allocation of state lands for warehouse expansion. This information is vital for informed decision-making in the planning and management of warehouse development to mitigate air pollution in disadvantaged areas.

Ventura County is less heavily urbanized, has fewer warehouses, and fewer freeway connections, resulting in a decreased area for truck travel. As a result, $PM_{2.5}$ concentrations in Ventura County are generally lower than in the other counties, reflecting the influence of these factors on air quality in the region; however, this means that if additional warehouses were to be clustered in Ventura County, the air pollution could be impacted (Figure 43).

Warehouse clusters in Inland Empire were concentrated in disadvantaged regions that were also home to other major polluters, such as airports. Most warehouses were located within regions with $PM_{2.5}$ concentrations ranging from the 75th to 100th percentile, forming dense clusters that likely contribute to the elevated levels of $PM_{2.5}$ within the area. This underscores the need to consider the cumulative impacts of multiple pollution sources, including warehouses, in the planning and management of industrial development in these disadvantaged regions to effectively address air quality concerns (Figure 44).

Figure 42. Spatial Distribution of Warehouses and $PM_{2.5}$ in Los Angeles County

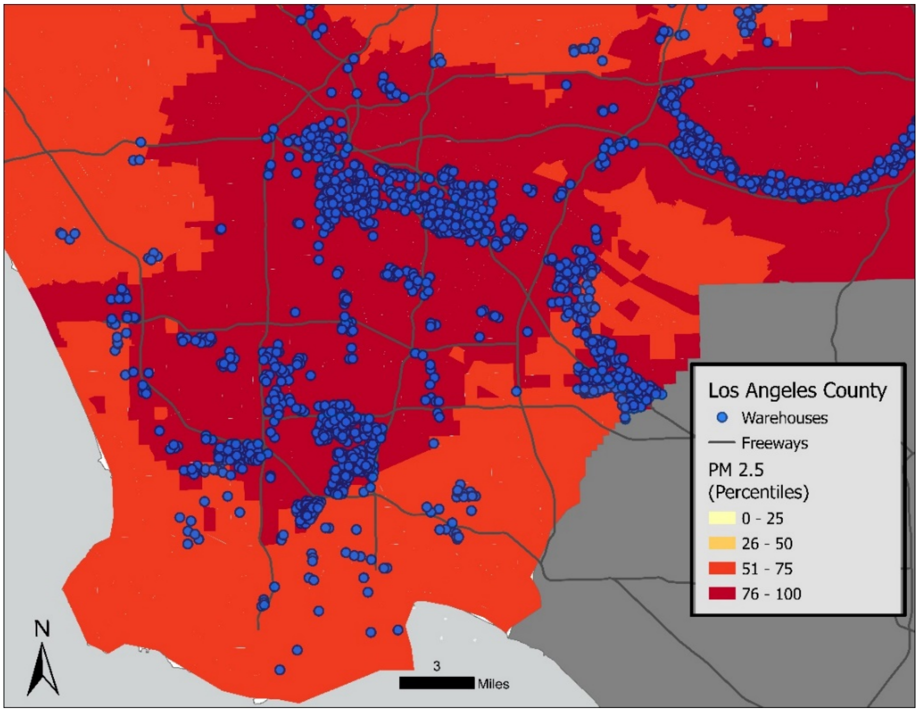


Figure 43. Spatial Distribution of Warehouses and $PM_{2.5}$ in Ventura County

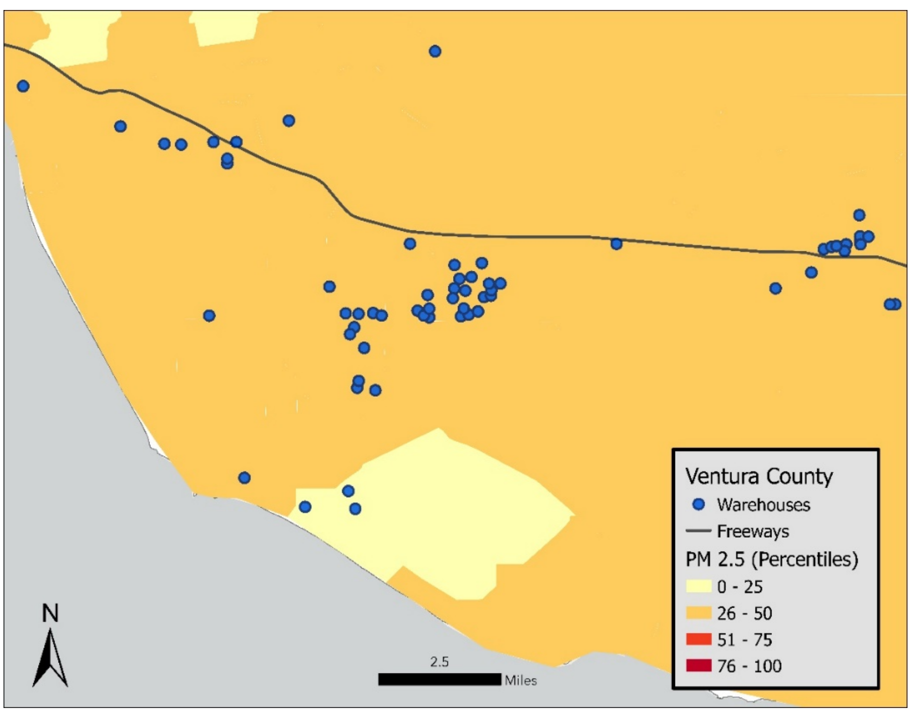
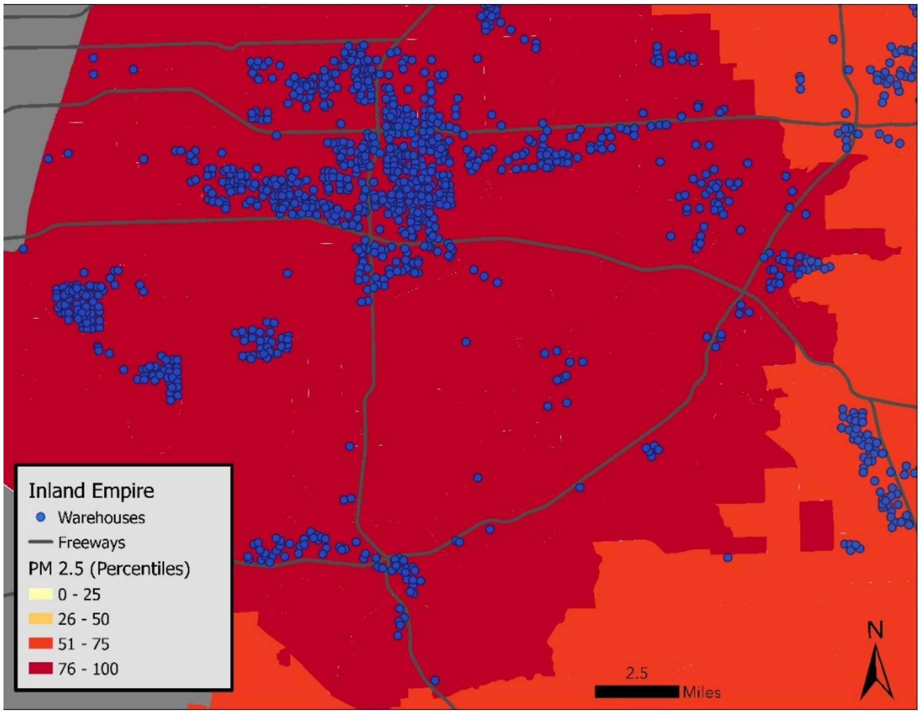


Figure 44. Spatial Distribution of Warehouses and $PM_{2.5}$ in Inland Empire



The spatial patterns of current dense warehouse clusters, as observed in the SCAG region, clearly highlight their impact on disadvantaged areas. If warehouse expansion were to occur, it is expected that we would see a simultaneous intensification of the issues identified in this report, including increased concentrations of air pollution, and the disproportionate impact on vulnerable communities. Such an expansion would further exacerbate the vulnerability of disadvantaged communities, running counter to efforts towards achieving environmental equity and environmental justice.

To address the issue of environmental equity, warehouse expansion should be carefully planned and managed. This could involve exploring options for locating warehouses in less densely populated areas, or in areas of higher affluence that currently have no warehouses and fewer environmental pollutants. By considering environmental equity alongside warehouse expansion, it is possible to balance economic development with social and environmental concerns and move towards a more equitable and just approach to industrial development.

6.3 C-LINE Simulation

Figure 45. C-LINE Simulation of Lancaster and Palmdale for NO_2 (Case 1)

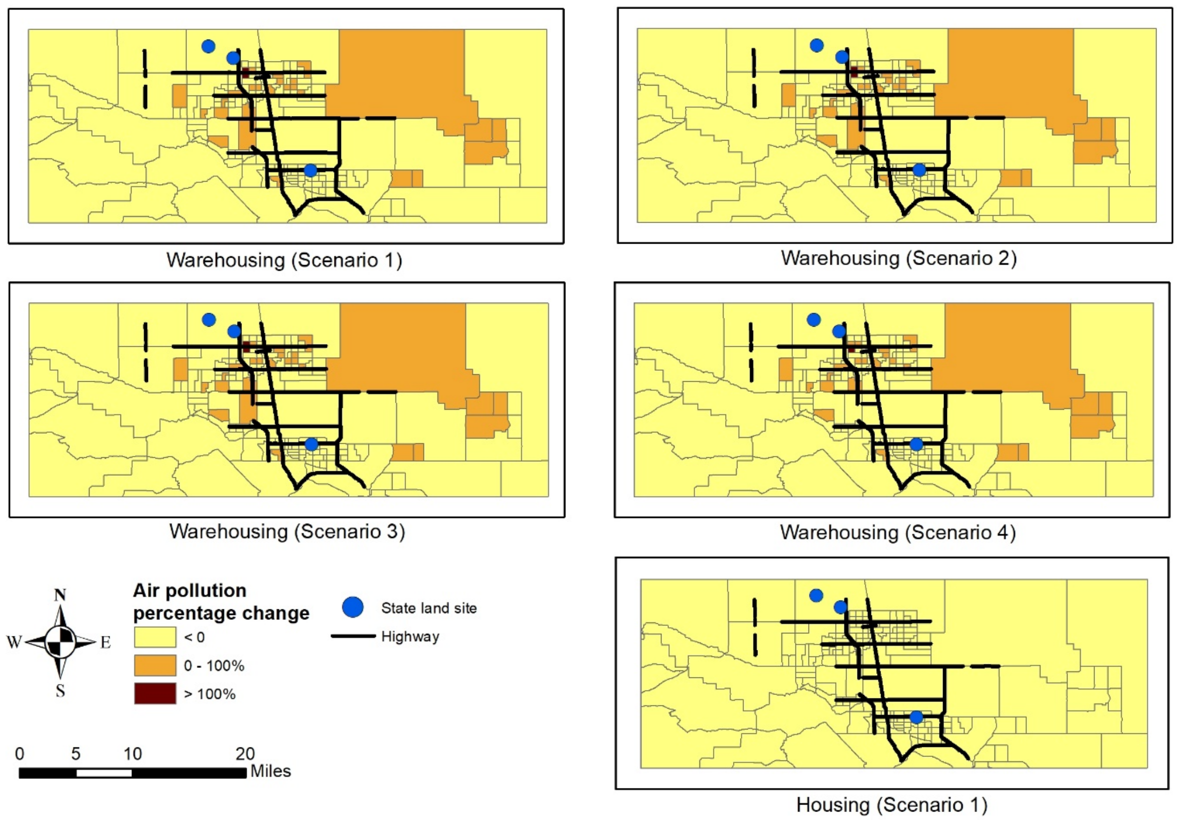
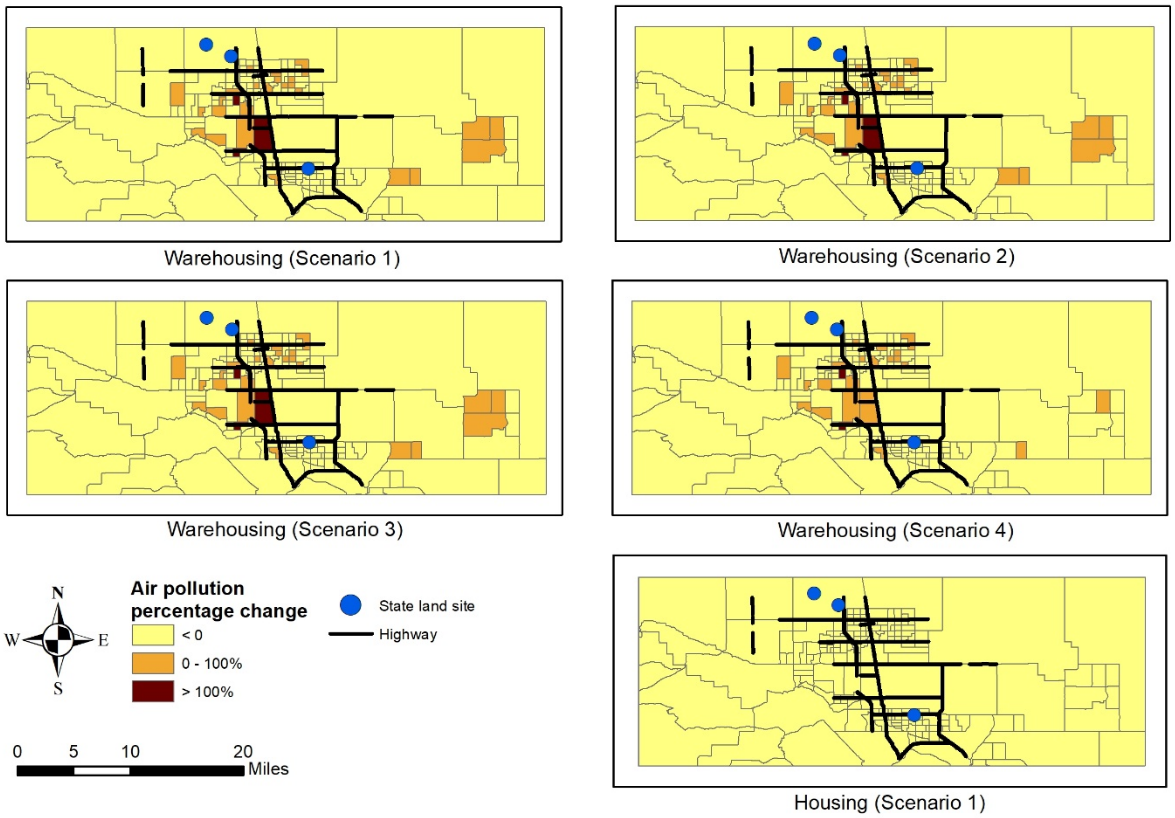


Figure 46. C-LINE Simulation of Lancaster and Palmdale for $PM_{2.5}$ (Case 1)



As shown in Figures 45 and 46, the air pollution impacts of housing were minimal as compared to the impacts of warehousing when using the state land sites in Lancaster and Palmdale. Note that only scenario 1 of housing was shown due to minimal impacts from housing. For warehousing-related air pollution impacts, replacing existing diesel trucks with ZEVs would result in reduced air pollution emissions.

Some block groups around highways showed 0–100% change of air pollution. The air pollution "hotspots" (where the percentage change was over 100% with surrounding highways) suggests that further environmental evaluations are necessary if using the three sites for warehousing purposes; the "hotspots" were more apparent for PM2.5 as compared to NO2.

Figure 47. C-LINE Simulation of South Los Angeles for NO_2 (Case 2)

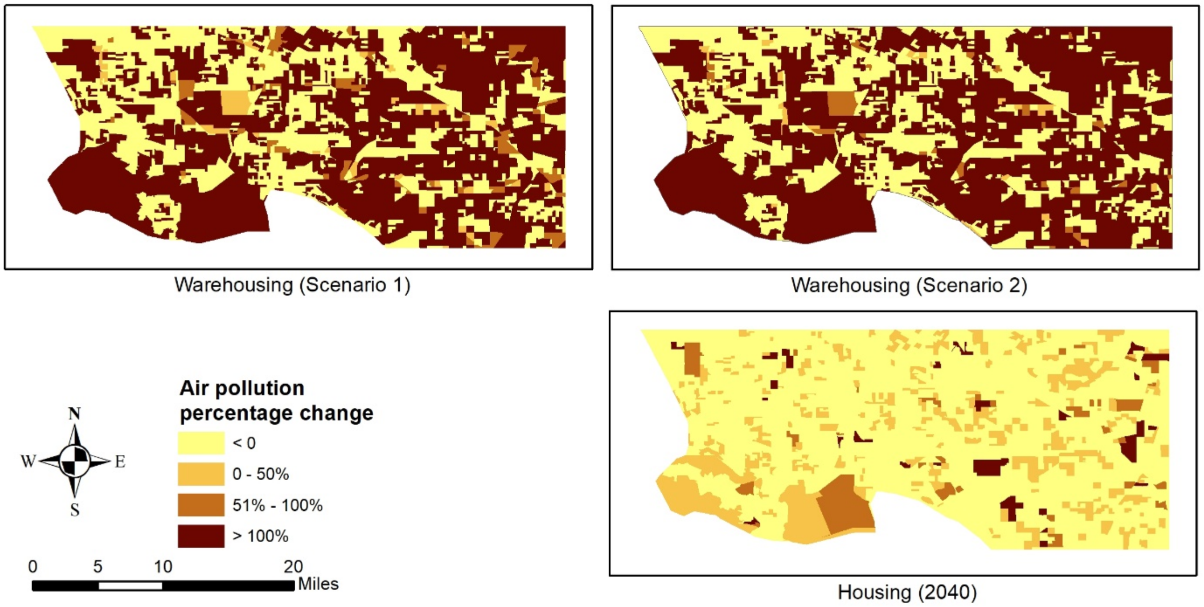


Figure 48. C-LINE Simulation of South Los Angeles for $PM_{2.5}$ (Case 2)

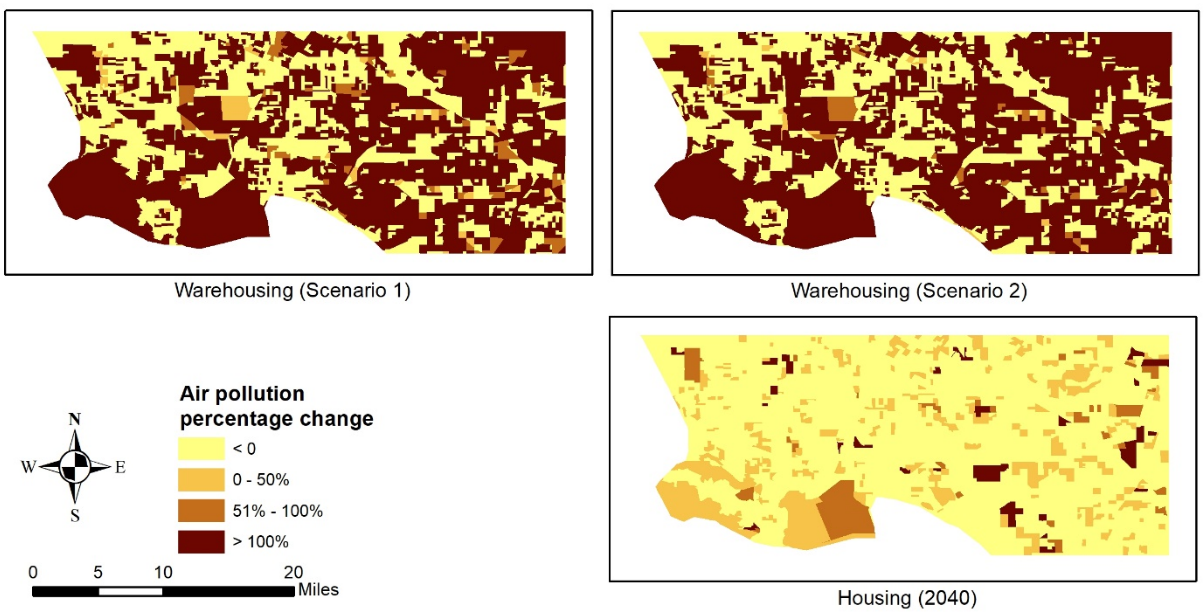


Figure 49. C-LINE Simulation of Central Los Angeles for NO_2 (Case 2)

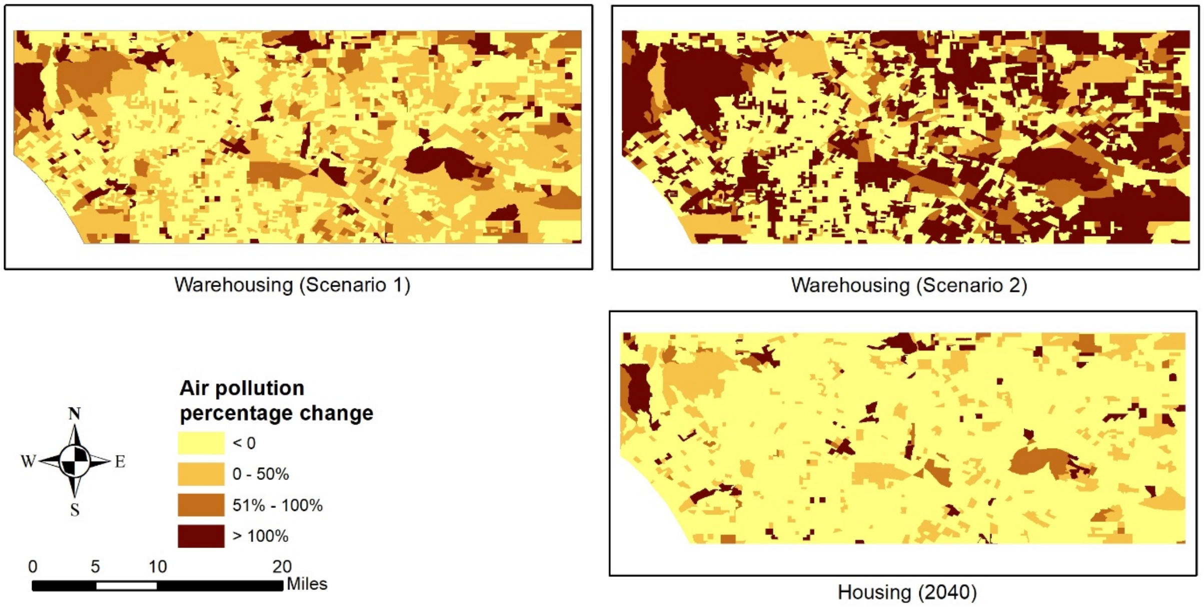


Figure 50. C-LINE Simulation of Central Los Angeles for $PM_{2.5}$ (Case 2)

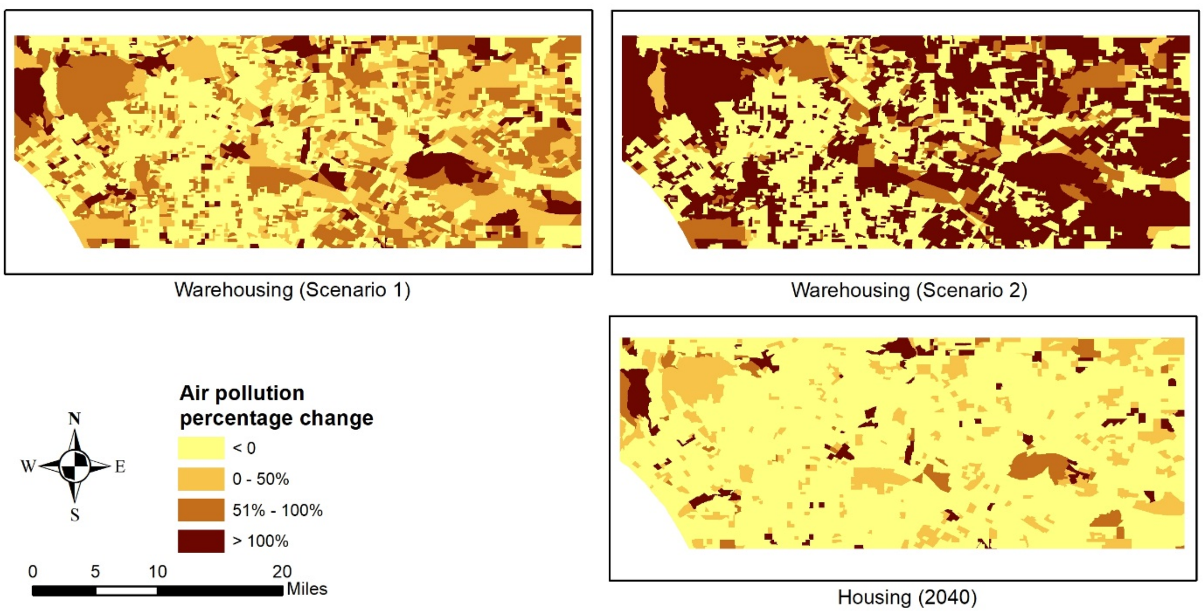


Figure 51. C-LINE Simulation of Orange County for NO_2 (Case 2)

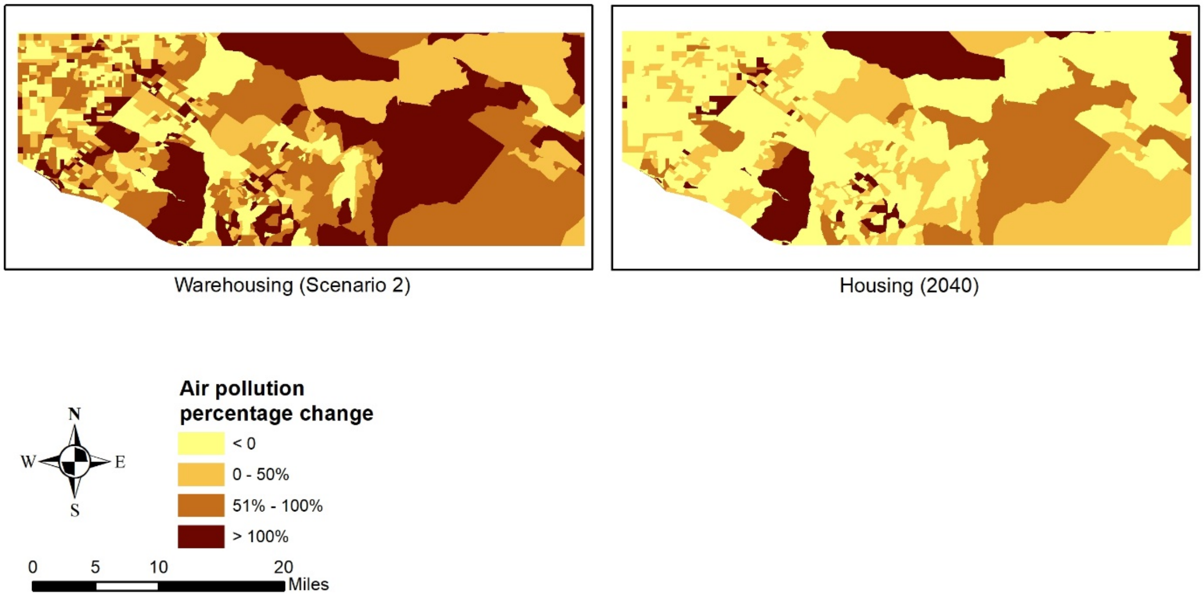
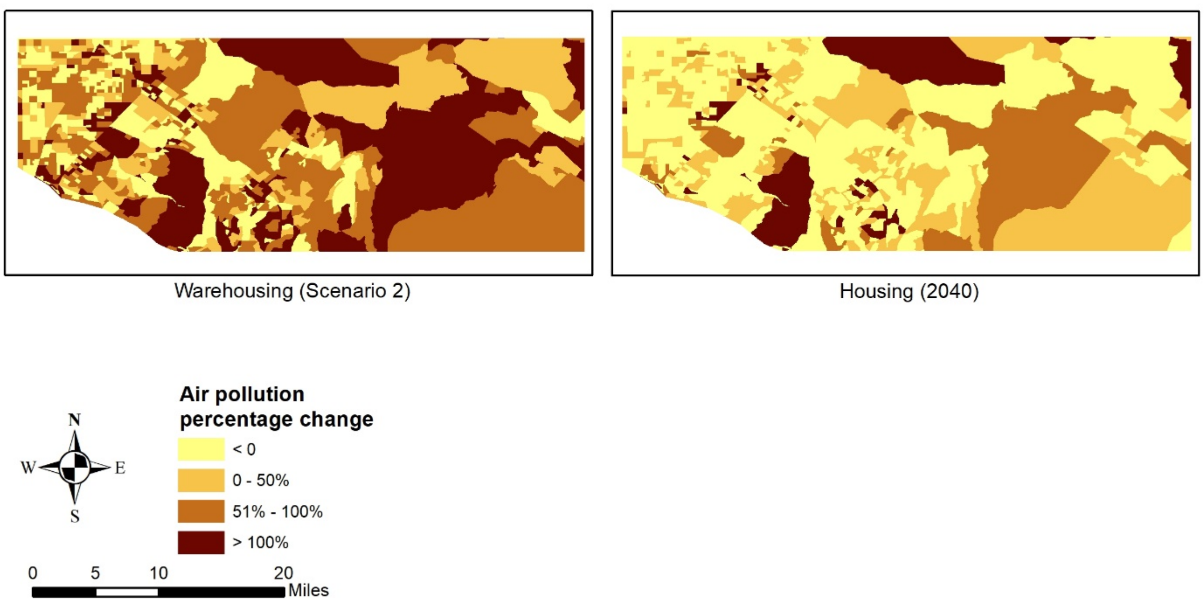


Figure 52. C-LINE Simulation of Orange County for $PM_{2.5}$ (Case 2)



As shown in Figures 47–52, the air pollution impacts of housing were minimal as compared to the impacts of warehousing when using the state land in South Los Angeles and Central Los Angeles to fill the estimated gap in 2040. Only a few block groups showed air pollution “hotspots” when using state land for affordable housing. However, when using the state land in Orange County, more areas showed air pollution “hotspots,” suggesting that further investigation is necessary.

In comparison, for warehousing, for the scenario where we have moderate upside with technology improvement and e-commerce adjustment, more warehousing space shortages appeared in 2040. This shortage increase was partly reflected in the Warehousing (Scenario 2) map in which more block groups are exposed to higher concentrations of air pollution. Only Scenario 2 was shown in Orange County since there was no predicted warehousing space shortage in Scenario 1. In general, filling in the predicted warehousing space shortages in 2040 would result in more air pollution “hotspots.”

Figure 53. C-LINE Simulation of South Los Angeles for NO_2 (Case 3)

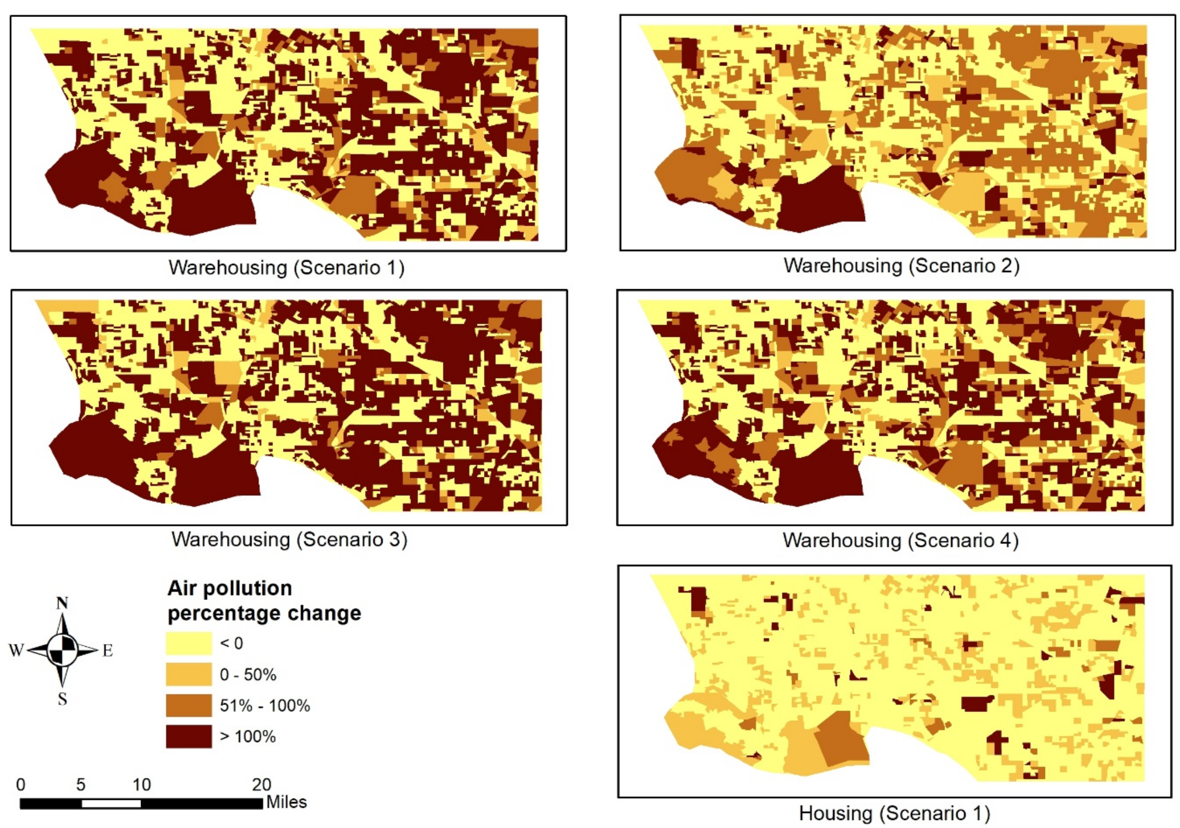
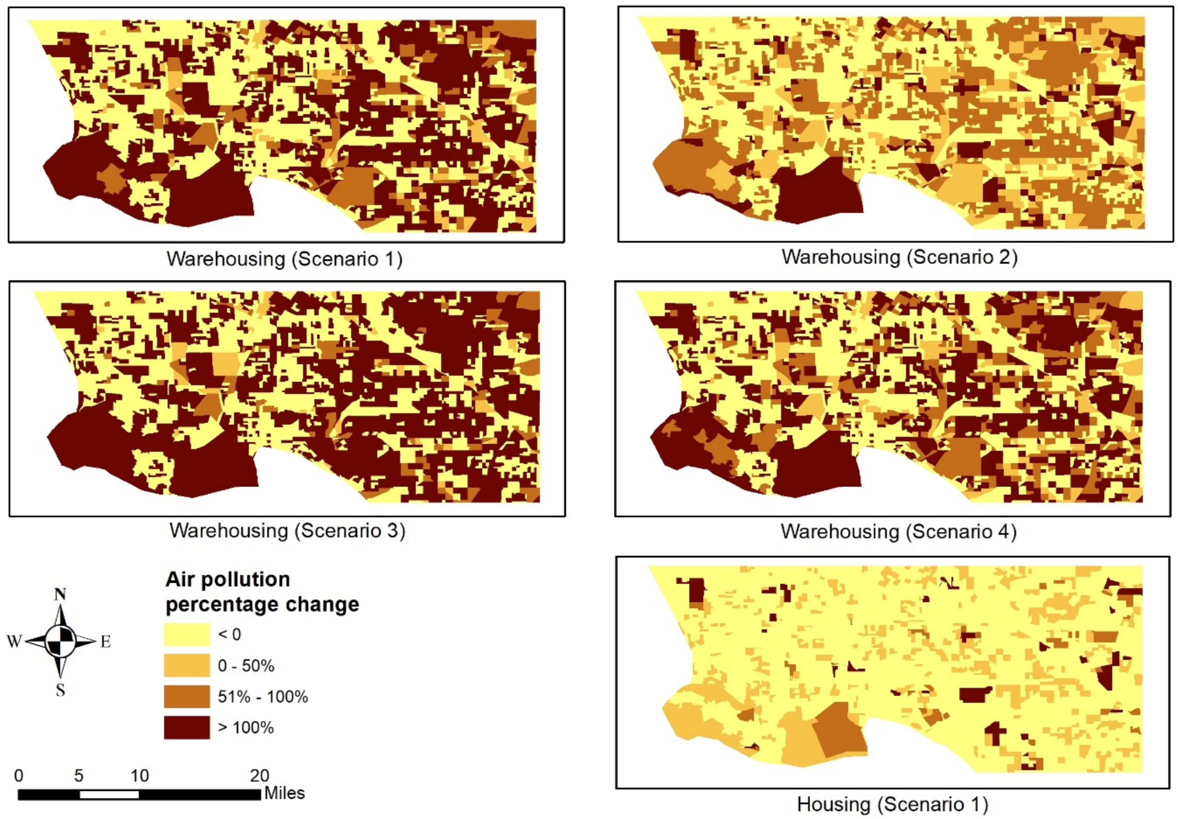


Figure 54. C-LINE Simulation of South Los Angeles for $PM_{2.5}$ (Case 3)



Similarly, as shown in Figures 53 and 54, the air pollution impacts of housing were minimal as compared to the impacts of warehousing when using the state land (20%). For warehousing, replacing 50% of existing diesel trucks with ZEVs would result in reduced air pollution emissions, with a much smaller number of "hotspots" of block groups. Using higher percentages of state land (50% vs. 20%) would make air quality worse.

Figure 55. C-LINE Simulation of Central Los Angeles for NO_2 (Case 3)

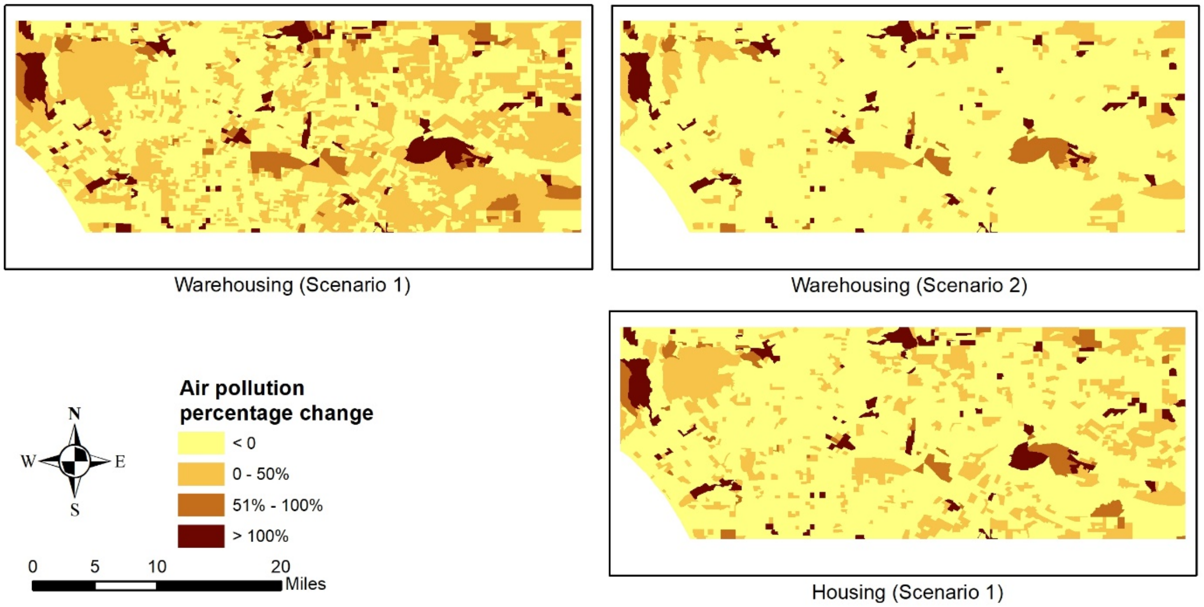


Figure 56. C-LINE Simulation of Central Los Angeles for $PM_{2.5}$ (Case 3)

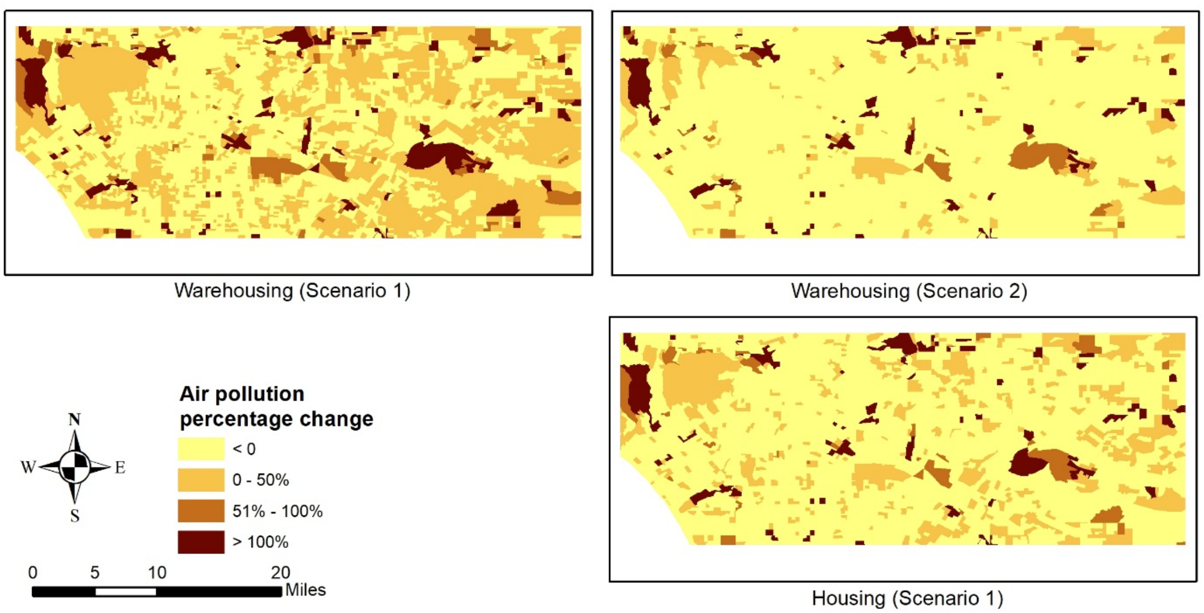


Figure 57. C-LINE Simulation of Orange County for NO_2 (Case 3)

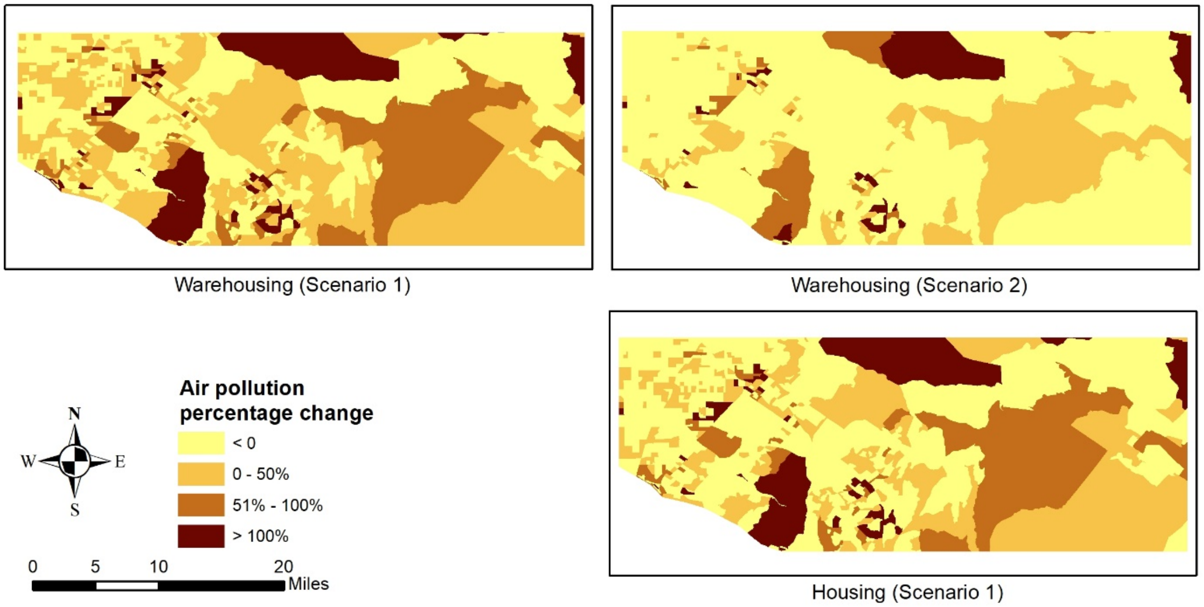


Figure 58. C-LINE Simulation of Orange County for $PM_{2.5}$ (Case 3)

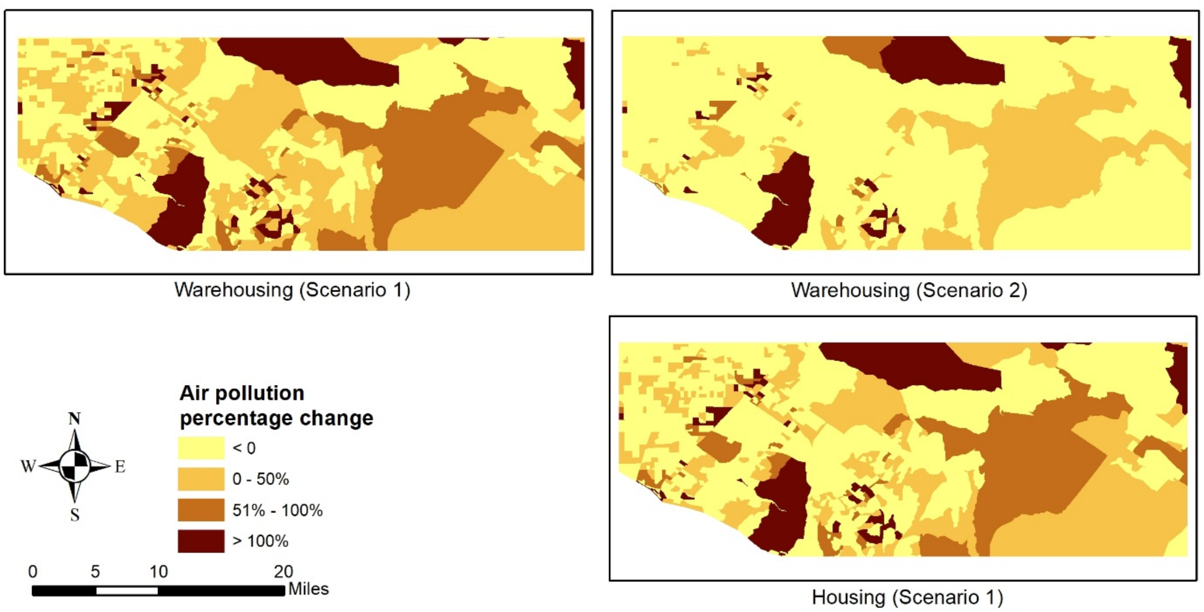


Figure 59. C-LINE Simulation of Ventura County for NO_2 (Case 3)

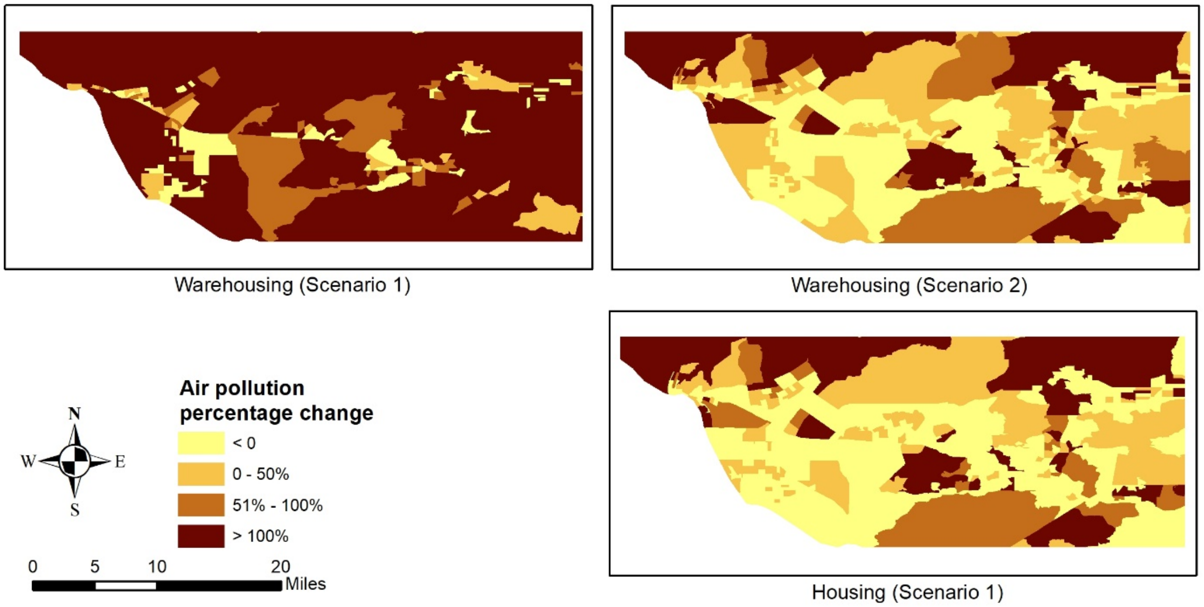


Figure 60. C-LINE Simulation of Ventura County for $PM_{2.5}$ (Case 3)

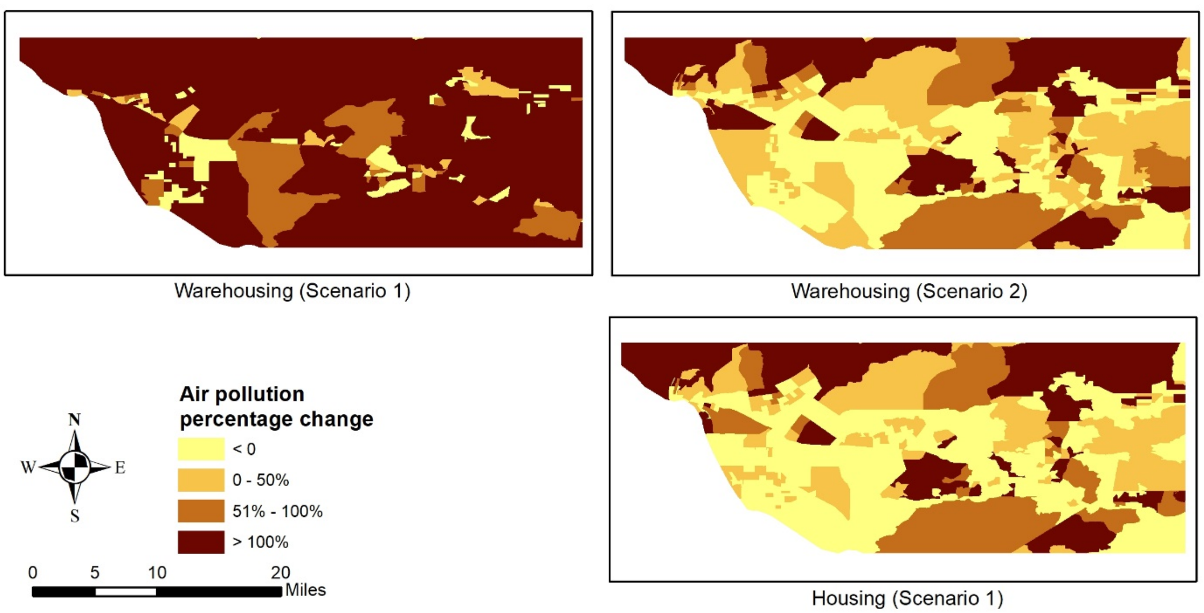


Figure 61. C-LINE Simulation of Inland Empire for NO_2 (Case 3)

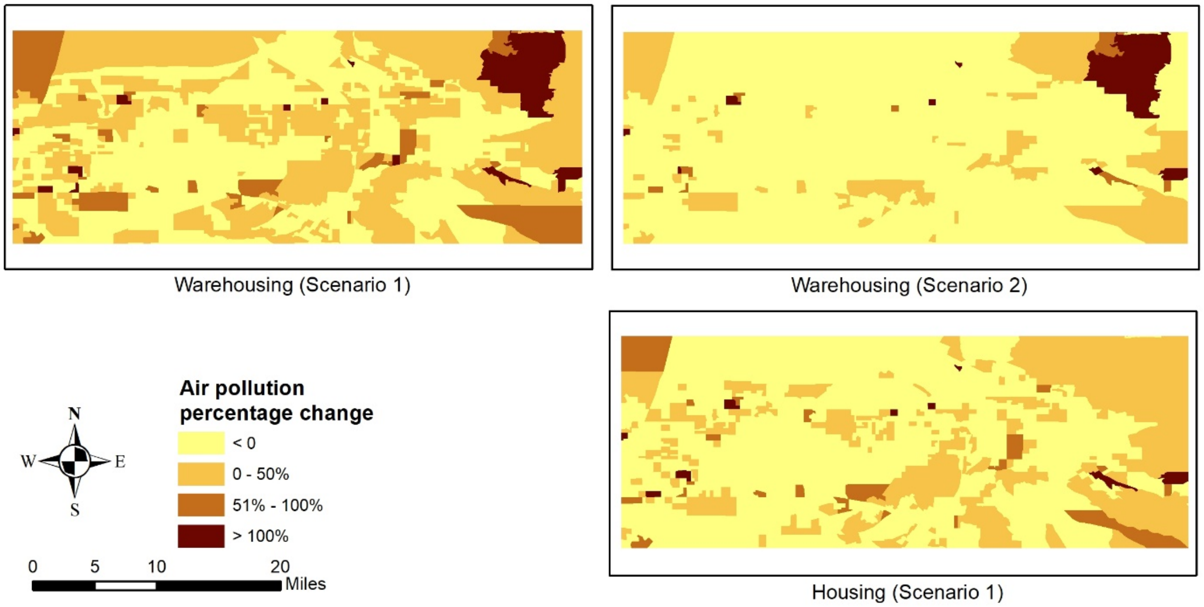
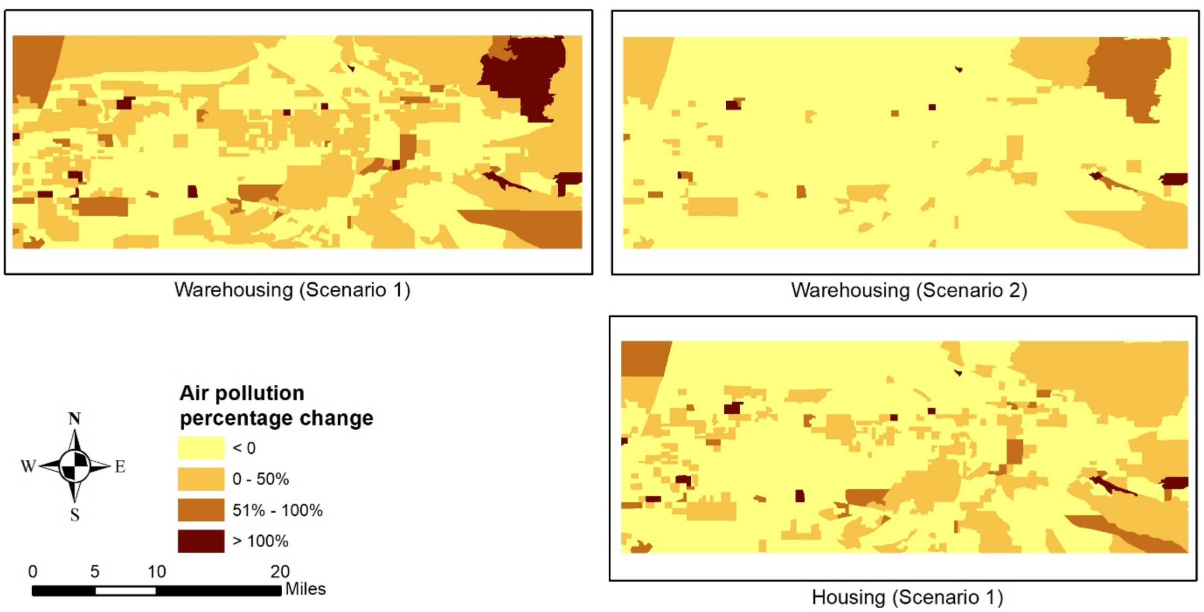


Figure 62. C-LINE Simulation of Inland Empire for $PM_{2.5}$ (Case 3)



As shown in Figures 55–62, while the air pollution impacts of housing were minimal as compared to those of warehousing when using the state land in Central Los Angeles and Inland Empire, housing-related air pollution impacts suggested further investigation in Orange County and Ventura County. Noticeably, these findings matched the existing air pollution analysis in the SCAG region. That is, adding warehousing activities to areas where current air pollution is not that serious may easily disrupt the environment. In general, using state land to meet the warehousing demand would result in more "hotspots" of air pollution. The impacts can be reduced by using a higher proportion of ZEVs.

7. Summary & Conclusions

The COVID-19 pandemic caused severe disruptions to the global supply chain and to Californian warehousing and logistics. This unprecedented cargo surge caused significant supply chain challenges, especially in warehousing. To unblock this bottleneck, it is crucial to bridge the gap between warehousing supply and demand, which can be impacted by location, costs, the economy, technological improvements, supply chain practices, and public policy. Despite the potential challenges that may arise in supply chain management, there have been few studies on the warehousing gap, hindering preparations for future challenges.

The expansion of warehousing activities also has a significant impact on land use, creating a land-use paradox between prioritizing public lands either for warehousing goods or for housing people. The debate continues over whether to prioritize public land for housing people (e.g., reducing homelessness) or warehousing goods. In response to this dilemma, we explored different scenarios for use of state-owned property while considering the impacts on the economy and environment, as well as implications for other societal issues such as housing for the homeless. To achieve this goal, we conducted a thorough literature review on housing demand estimation and the economic and social impacts of warehousing. We also analyzed various warehousing forecast scenarios, particularly those related to economic conditions, and gathered data on the regional housing market.

We found that Los Angeles County and Orange County are facing supply shortfalls in four of the six scenarios we considered. The unmet demand for warehouses in Los Angeles County and Orange County was mostly taken by Inland Empire. Despite warehouse moratoria enacted by some Inland Empire cities, Inland Empire is expected to increase its share of warehouse space by 2% within the region by 2040. Considering the impact of warehouse moratoria, the earliest time for aggregate warehouse demand to exceed supply in the SCAG region could fall in Q1 2028.

A number of metrics suggested that California has a deficit of housing units overall and of affordable or low-income units. Despite recent State population declines, Southern California has an annual projected deficit of 120,000 housing units, based on a national regression of state-level housing per capita using 2040 county population projections. Over the past decade, new state-level housing development has averaged 73,000 overall and 10,000 affordable units.

Low-income housing appeared to be particularly influenced by the unemployment rate across Southern California regions, suggesting that focusing on employment opportunities might be an effective approach to address this concern. We confirmed prior environmental justice concerns that warehousing is often located close to disadvantaged communities, increasing the likelihood of pollution exposure and adverse health impacts for low-income and minority groups. Our analysis also suggested that the pollution impacts of housing are minimal compared to the impacts of warehousing across each of our scenarios.

Our analysis confirmed a trade-off between meeting warehousing demand and decreasing local air pollution in terms of the number of hotspots. Adding warehousing to areas where air pollution levels were relatively low—such as Ventura and Orange County—could significantly increase the number of air pollution hotspots. This raises important questions about where additional warehousing should be located to meet demand while also addressing environmental justice concerns. Electrifying trucking fleets is a significant way to reduce emissions and air pollution hotspots. However, using higher percentages of state land for warehousing would make air quality worse.

The trade-off between meeting the demand for warehousing and decreasing local air pollution in terms of the number of hotspots is an interesting area to explore further. We studied specific factors that contributed to the trade-off and how to balance the need for warehousing with the need to protect the environment. We also considered the potential long-term consequences of locating warehouses in areas that are already vulnerable, and the implications for land-use, environmental conditions, and transportation planning.

The demand for warehousing may have been affected by the cost and infrastructure requirements of transitioning to electric trucking. To address the short-term demand for warehousing while considering environmental factors, alternative solutions should be explored. One approach involves comparing the environmental impacts of using higher percentages of state land for warehousing with other strategies. Air quality and other environmental factors should also be taken into account.

Furthermore, we studied the role of environmental justice in warehousing location decisions. The fair distribution of the benefits and costs of warehousing across different communities was a key consideration. Specifically, it is important to ensure that communities already disproportionately affected by warehousing activities and associated air pollution are not further burdened by the addition of new warehouses.

Bibliography

Acolin, A., & Green, R. K. (2017). Measuring housing affordability in São Paulo metropolitan region: Incorporating location. *Cities*, *62*, 41-49.

Albouy, D., & Ehrlich, G. (2018). Housing productivity and the social cost of land-use restrictions. *Journal of Urban Economics*, *107*, 101-120.

Allison, J. E. (2020). What happens when Amazon comes to town? Environmental impacts, local economies, and resistance in inland Southern California. In E. Reese & J. Alimahomed-Wilson (Eds.), *The cost of free shipping: Amazon in the global economy* (pp. 176-193). Pluto Press.

American Association of Railroads (AAR). (2022, July 15). Railroads welcome appointment of Presidential Emergency Board. Retrieved November 2, 2022 from https://www.aar.org/news/railroads-welcome-appointment-of-presidential-emergency-board/

Anacker, K. B. (2019). Introduction: Housing affordability and affordable housing. *International Journal of Housing Policy*, *19*(1), 1-16.

Appel, P. (2021, November 5). The chassis shortage: The low-hanging fruit of the supply chain crisis. *Alix Partners*. https://blog.alixpartners.com/post/102ha7d/the-chassis-shortage-the-low-hanging-fruit-of-the-supply-chain-crisis?news#utm_source=Mondaq&utm_medium=syndication&utm_campaign=LinkedIn-integration

Axe, J., Childs, E., & Manion, K. (2020). In search of employment: Tackling youth homelessness and unemployment. *Children and Youth Services Review*, 104704.

Baker, L. (2021, January). 'Insatiable demand' drives Southern California warehouse boom. *FreightWaves*. https://www.freightwaves.com/news/insatiable-demand-drives-southern-california-warehouse-boom

Barboza, T., & Schleuss, J. (2017, March 2). L.A. keeps building near freeways, even though

living there makes people sick. *Los Angeles Times*. http://www.latimes.com/projects/la-me-freeway-pollution/

Baršauskas, P., Šarapovas, T., & Cvilikas, A. (2008). The evaluation of e-commerce impact on business efficiency. *Baltic Journal of Management 3*(1), 71-91.

Bertrand, A. (2019). Proxy war: The role of recent CEQA exemptions in fixing California's housing crisis. *Columbia Journal of Law and Social Problems, 53*, 413.

Burnson, P. (2021, May 5). Top 30 U.S. ports: Big ports got bigger in 2020. *Logistics Management*. Retrieved October 23, 2023, from https://www.logisticsmgmt.com/article/top_30_u.s._ports_big_ports_got_bigger_in_2020

Businesswire. (2022, August 9). Pioneer partners' Mojave inland port will alleviate supply chain issues, create new jobs, and boost local and state economies. Retrieved November 2, 2022 from https://www.businesswire.com/news/home/20220809005897/en/Pioneer-Partners%E2%80%99-Mojave-Inland-Port-Will-Alleviate-Supply-Chain-Issues-Create-New-Jobs-and-Boost-Local-and-State-Economies

Cai, Y., Sam, C. Y., & Chang, T. (2018). Nexus between clean energy consumption, economic growth and CO_2 emissions. *Journal of Cleaner Production*, *182*, 1001-1011.

California Air Resources Board (CARB). (2022). Advanced clean fleets regulation—Standardized regulatory impact assessment. CARB. Retrieved August 23, 2022, from https://ww2.arb.ca.gov/rulemaking/2022/acf2022

California Department of Finance (CA DoF). (2022). California budget 2023–24. Retrieved from https://ebudget.ca.gov/

California Department of Finance (CA DoF). (2023). Historical population and housing estimates for cities, counties, and the state. Retrieved from https://dof.ca.gov/forecasting/demographics/estimates/

California Department of Housing and Community Development. (2018). California's housing future: Challenges and opportunities final statewide housing assessment 2025. Retrieved from https://www.hcd.ca.gov/policy-research/plans-reports/docs/sha_final_combined.pdf

California Department of Transportation, Traffic Data Branch. (2006). Annual average daily truck traffic. http://traffic-counts.dot.ca.gov/truck2006final.pdf

California Department of Transportation (Caltrans). (2011). Tract housing in California, 1945–1973: A context for national register evaluation. Retrieved from: https://dot.ca.gov/-/media/dot-media/programs/environmental-analysis/documents/ser/tract-housing-in-ca-1945-1973-a11y.pdf

California Housing Partnership. (2023). Retrieved March 1, 2023, from https://chpc.net/

Cambridge Systematics. (2018). Southern California Association of Governments industrial warehousing study. Southern California Association of Governments (SCAG). Retrieved August 23, 2022, from https://scag.ca.gov/post/industrial-warehousing-study.

CBRE. (2021). Greater Los Angeles industrial marketview Q3 2021. CBRE. Retrieved August 23, 2022, from https://www.cbre.com/insights/figures/greater-los-angeles-industrial-marketview-q3-2021

CBRE. (2022, February 11). 2022 North America industrial big box. CBRE. Retrieved July 16, 2022, from https://www.cbre.com/insights/reports/2022-north-america-industrial-big-box

Chinchilla, M., & Gabrielian, S. (2020). Stemming the rise of Latinx homelessness: Lessons from Los Angeles County. *Journal of Social Distress and Homelessness, 29*(2), 71-75.

Choi, C., & Jung, H. (2017). Does an economically active population matter in housing prices? *Applied Economics Letters, 24*(15), 1061-1064.

City of Los Angeles. (2021, May 21). Report relative to citywide equitable distribution of affordable housing (CF 19-0416). Retrieved Feb. 6, 2022, from https://clkrep.lacity.org/onlinedocs/2019/19-0416_misc_PLUM_06-24-21.pdf

Clifton, K. J., Currans, K. M., Schneider, R., Handy, S., Howell, A., Abou-Zeid, G., ... Gehrke, S. R. (2018). *Affordable Housing Trip Generation Strategies and Rates* (No. CA18-2465). Retrieved October 23, 2023 from https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca18-2465-finalreport-a11y.pdf

Contreras, Z., Ngo, V., Pulido, M., Washburn, F., Meschyan, G., Gluck, F., Kuguru, K., Reporter, R., Curley, C., Civen, R., Terashita, D., Balter, S., & Halai, U. A. (2021). Industry sectors highly affected by worksite outbreaks of coronavirus disease, Los Angeles County, California, USA, March 19–September 30, 2020. *Emerging Infectious Diseases*, *27*(7), 1769.

Corinth, K. (2017). The impact of permanent supportive housing on homeless populations. *Journal of Housing Economics, 35*, 69-84.

Dablanc, L. (2013). Commercial goods transport, Paris, France. Retrieved from https://unhabitat.org/sites/default/files/2013/06/GRHS.2013.Case_.Study_.Paris_.France.pdf

Dablanc, L., Guiliano, G., Holliday, K., & O'Brien, T. (2013). Best practices in urban freight management. *Transportation Research Record: Journal of the Transportation Research Board, 2379*(1), 29-38. https://doi.org/10.3141/2379-04

Dablanc, L., Ogilvie, S., & Goodchild, A. (2014). Logistics sprawl: Differential warehousing development patterns in Los Angeles, California, and Seattle, Washington. *Transportation Research Record*, *2410*(1), 105-112.

Dadhich, P., Genevese, A., Kumar, N., & Acquaye, A. (2015). Developing sustainable supply chains in the UK construction industry: A case study. *International Journal of Production Economics, 164,* 271-284. https://doi.org/10.1016/j.ijpe.2014.12.012

Davis, J. (2021, July 15). The double-edged sword of upzoning. *Brookings, How We Rise Blog*. Retrieved from https://housingtoolkit.nmhc.org/wp-content/uploads/2019/04/F2_NMHC_PDF-Sections_Tools_By-Right-Dev_PG-63-TO-73.pdf

De Lara, J. D. (2013). Warehouse work: Path to the middle class or road to economic insecurity? *University of Southern California*. Retrieved November 13, 2022, from https://www.academia.edu/4607598/Warehouse_Work_Path_to_the_Middle_Class_or_Road_to_Economic_Insecurity

Department of Energy and Climate Change (DECC). (2013). Energy consumption in the UK (2013). UK Government, London.

Department of General Services (DGS). (2022). New leases will make state-owned properties available for storing up to 20,000 shipping containers to help alleviate national supply chain issues. Press Release. Retrieved from https://business.ca.gov/new-leases-will-make-state-owned-properties-available-for-storing-up-to-20000-shipping-containers-to-help-alleviate-national-supply-chain-issues/

Dessouky, M., Giuliano, G., & Moore, J. E. (2008). Selected papers from the National Urban Freight conference. *Transportation Research Part E*, *2*(44), 181-184.

Embarcadero Institute Board. (2019). California's 3.5 million housing shortage. Retrieved from https://embarcaderoinstitute.com/portfolio-items/3-5-million-california-housing-shortage-number-is-wrong-fueling-poor-policy/

Evans, C. (2022). The warehouses are full: Cargo begins clogging Port of Los Angeles amid railroad worker shortage. CBS News. Retrieved August 23, 2022, from https://www.cbsnews.com/news/port-of-los-angeles-clogged-railroad-worker-shortage/.

Fichtinger, J., Ries, J. M., Grosse, E. H., & Baker, P. (2015). Assessing the environmental impact of integrated inventory and warehouse management. *International Journal of Production Economics*, *170*, 717-729, https://doi.org/10.1016/j.ijpe.2015.06.025

Friesen, G. (2021). No end in sight for the COVID-led global supply chain disruption. *Forbes*. Retrieved August 23, 2022, from https://www.forbes.com/sites/garthfriesen/2021/09/03/no-end-in-sight-for-the-covid-led-global-supply-chain-disruption/?sh=e3b0df43491f

Gabbe, C. J. (2018). How do developers respond to land use regulations? An analysis of new housing in Los Angeles. *Housing Policy Debate*, *28*(3), 411-427.

Garland, M. (2021, December 8). 7 charts show Southern California's warehousing crunch. Supply Chain Dive. Retrieved August 23, 2022, from https://www.supplychaindive.com/news/charts-california-inland-empire-warehouse-capacity-real-estate-labor/610321/.

Ghadge, A., Wurtmann, H., & Seuring, S. (2020). Managing climate change risks in global supply chains: A review and research agenda. *International Journal of Production Research*, *58*(1), 44-64.

Giamarino, C., Brozen, M., & Blumenberg, E. (2022). Planning for and against vehicular homelessness: Spatial trends and determinants of vehicular dwelling in Los Angeles. *Journal of the American Planning Association*, 1-13.

Giuliano, G., & O'Brien, T. (2007). Reducing port-related truck emissions: The terminal gate appointment system at the Ports of Los Angeles and Long Beach. *Transportation Research Part D: Transport and Environment*, *12*(7), 460-473.

Gong, Y., & Yao, Y. (2022). Demographic changes and the housing market. *Regional Science and Urban Economics*, *95*, 103734.

Gould, T., & Williams, A. (2010). Family homelessness: An investigation of structural effects. *Journal of Human Behavior in the Social Environment*, 170-192.

Hickey, R., & Sturtevan, L. (2015, February) Public land & affordable housing in the Washington DC region: Best practices and recommendations. *Urban Land Institute*. https://nvaha.org/wp-content/uploads/2015/02/ULI_PublicLandReport_Final020215.pdf

Houston, D., Krudysz, M., & Winer, A.M. (2008). Diesel truck traffic in port-adjacent low-income and minority communities: Environmental justice implications of near-roadway land-use conflicts. *Transportation Research Board Journal 2076*, 38-46.

Howell, A., Currans, K. M., Gehrke, S., Norton, G., & Clifton, K. J. (2018). Transportation impacts of affordable housing. *Journal of Transport and Land Use*, *11*(1), 103-118.

Igielnik, R. (2020, August 27). Majority of Americans who lost a job or wages due to COVID-19 concerned states will reopen too quickly. Pew Research Center. Retrieved July 3, 2022, from https://www.pewresearch.org/fact-tank/2020/05/15/majority-of-americans-who-lost-a-job-or-wages-due-to-covid-19-concerned-states-will-reopen-too-quickly/

Indrawati, S., Miranda, S., & Bryan Pratama, A. (2018). Model of warehouse performance measurement based on sustainable warehouse design. 2018 4th International Conference on Science and Technology (ICST). https://doi.org/10.1109/icstc.2018.8528712

Industrial Economics, Incorporated. (2020). Assessment of warehouse relocations associated with the South Coast Air Quality Management District warehouse indirect source rule. South Coast Air Quality Management District. Retrieved from http://www.aqmd.gov/docs/default-source/planning/fbmsm-docs/iec_pr-2305-warehouse-relocation-report-(12-23-20).pdf?sfvrsn=8

IPCC (Intergovernmental Panel on Climate Change). (2000). Emissions scenarios: A special report of working group II on the intergovernmental panel on climate change. Cambridge University Press.

Isik, C., Ongan, S., & Özdemir, D. (2019). The economic growth/development and environmental degradation: Evidence from the US state-level EKC hypothesis. *Environmental Science and Pollution Research*, *26*(30), 30772-30781.

Jaller, M., & Pineda, L. (2017). Warehousing and distribution center facilities in Southern California: The use of the commodity flow survey data to identify logistics sprawl and freight generation patterns. National Center for Sustainable Transportation. Retrieved July 16, 2022, from https://rosap.ntl.bts.gov/view/dot/36932

Jaller, M., Qian, X., & Zhang, X. (2020). E-Commerce, warehousing and distribution facilities in California: A dynamic landscape and the impacts on disadvantaged communities. *University of California Institute of Transportation Studies*.

Ji, G., Gunasekaran, A., & Yang, G. (2014). Constructing sustainable supply chain under double environmental medium regulations. *International Journal of Production Economics, 147*, 211-219. https://ideas.repec.org/a/eee/proeco/v147y2014ipbp211-219.html

Jin, M., Granda-Marulanda, N. A., & Down, I. (2014). The impact of carbon policies on supply chain design and logistics of a major retailer. *Journal of Cleaner Production*, *85*, 453-461.

Kang, S. (2020). Warehouse location choice: A case study in Los Angeles, CA. *Journal of Transport Geography*, *88*, 102297.

Ke, J. Y., Prager, F., Martinez, J., & Cagle, C. (2021). Achieving excellence for California's freight system: Developing competitiveness and performance metrics incorporating sustainability, resilience, and workforce development (No. 21-28, CA-MTI-2023). *San José State University.* https://transweb.sjsu.edu/sites/default/files/2023-Ke-California-Freight-System.pdf

Kioumourtzoglou, M. A., Schwartz, J., James, P., Dominici, F., & Zanobetti, A. (2016). $PM_{2.5}$ and mortality in 207 US cities: Modification by temperature and city characteristics. *Epidemiology*, *27*(2), 221-227.

Kozawa, K. H., Fruin, S. A., & Winer, A. M. (2009). Near-road air pollution impacts of goods movement in communities adjacent to the ports of Los Angeles and Long Beach. *Atmospheric Environment, 43*(18), 2960-2970. https://doi.org/10.1016/j.atmosenv.2009.02.042

Kumar, A., Luthra, S., Mangla, S. K., & Kazançoğlu, Y. (2020). COVID-19 impact on sustainable production and operations management. *Sustainable Operations and Computers*, *1*, 1-7.

Kuzman Associates, Inc. (2011). Trip generation analysis for high-cube warehouse distribution center land use. http://www.moval.org/misc/pdf/wlc/deir/append/L-21appS.pdf

Littlejohn, D. (2022, August 15). Los Angeles, Long Beach ports hail supply chain progress. *Transport Topics*. Retrieved November 2, 2022, from https://www.ttnews.com/articles/los-angeles-long-beach-ports-hail-supply-chain-progress

LIHTC Database Access. (2023). Retrieved from https://lihtc.huduser.gov/

Local Initiatives Support Corporation. (2019). The affordable housing process. *Alameda County Housing Development Capacity Building Program.* Retrieved from https://www.lisc.org/media/filer_public/c8/67/c8679790-7bda-484b-9810-9e504a1caf95/the_affordable_housing_development_process_english.pdf

Magableh G. M. (2021). Supply chains and the COVID-19 pandemic: A comprehensive framework. *European Management Review*, *18*(3), 363-382. https://doi.org/10.1111/emre.12449

Martinez, J., Prager, F., Brodmann, J., Ke, J., Garza, N., & Salari, M. (2021). *2021-2022 South Bay Economic Forecast & Industry Outlook*, South Bay Economics Institute, California State University Dominguez Hills. Retrieved from https://www.csudh.edu/Assets/csudh-sites/uce/docs/forecast/2021-CSUDH_South-Bay-Economic-Forecast-Report_final.pdf

Mason, S. J., Ribera, P. M., Farris, J. A., & Kirk, R. G. (2003). Integrating the warehousing and transportation functions of the supply chain. *Transportation Research Part E: Logistics and Transportation Review*, *39*(2), 141-159.

McCrea, B. (2020, March 24). *Measuring COVID-19's impact on the world's supply chains*. SourceToday. Retrieved July 4, 2022, from https://www.sourcetoday.com/supply-chain-trends/article/21126824/measuring-covid19s-impact-on-the-worlds-supply-chains

McDonough, M.S., Elliott, M. E., Huang, E., & Lee, R. M. (2021). *SoCal's rule for warehousing operations tests jurisdictional waters*. Pillsbury Law. Retrieved from https://www.pillsburylaw.com/en/news-and-insights/southern-california-rule-warehousing-operations-test-jurisdictional-waters.html

Mongelluzzo, B. (2021a). LA-LB preparing for record 20 million TEU this year. *The Journal of Commerce*. Retrieved August 23, 2022, from https://www.joc.com/port-news/us-ports/la-lb-preparing-record-20-million-teu-year_20210903.html.

Mongelluzzo, B. (2021b). SSA Long Beach says new fee improving container dwells. Retrieved November 2, 2022, from https://www.joc.com/port-news/us-ports/port-long-beach/ssa-long-beach-says-new-fee-improving-container-dwells_20211227.html

Montalvo, J., & Ravallion, M. (2010). The pattern of growth and poverty reduction in China. *Journal of Comparative Economics*, *38*(1), 2-16.

Morello-Frosch, R., Pastor, M., & Sadd, J. (2001). Environmental justice and Southern California's "riskscape": The distribution of air toxics exposures and health risks among diverse communities. *Urban Affairs Review*, *36*(4), 551-578.

Mostafa, N., Hamdy, W., & Alawady, H. (2019). Impacts of internet of things on supply chains: A framework for warehousing. *Social Sciences*, *8*(3), 84.

Murphy, L. (2016). The politics of land supply and affordable housing: Auckland's Housing Accord and Special Housing Areas. *Urban Studies*, *53*(12), 2530-2547.

Myers, D., Park, J., & Li, J. (2018). How much added housing is really needed in California? Housing Research Brief 1. Retrieved from https://cpb-us-e1.wpmucdn.com/sites.usc.edu/dist/6/210/files/2017/02/HRB-1-How-Much-Added-Housing-is-Really-Needed-in-California-1okfauc.pdf

Nardone, A., Chiang, J., & Corburn, J. (2020). Historic redlining and urban health today in US cities. *Environmental Justice*, *13*(4), 109-119.

Natelson Company, Inc. (2001). Employment density study summary report. Prepared for *Southern California Association of Governments*. Retrieved from https://www.mwcog.org/file.aspx?A=QTTlTR24POOOUIw5mPNzK8F4d8djdJe4LF9Exj6lXOU%3D

National Multifamily Housing Coalition (NMHC). (2019). *Tool: By-Right development.* The Housing Affordability Toolkit. Retreived from https://housingtoolkit.nmhc.org/wp-content/uploads/2019/04/F2_NMHC_PDF-Sections_Tools_By-Right-Dev_PG-63-TO-73.pdf

Newsom, G. (2017). The California dream starts at home. *Medium*. Retrieved from https://medium.com/@GavinNewsom/the-california-dream-starts-at-home-9dbb38c51cae

Nieuwenhuis, P., Beresford, A., & Choi, A.-Y. (2012). Shipping or local production? CO_2 impact of a strategic decision: An automotive industry case study. *International Journal of Production Economics*, *140*(1), 231-241. https://doi.org/10.1016/j.ijpe.2012.01.034

Ntziachristos, L., Ning, Z., Geller, M. D., & Sioutas, C. (2007). Particle concentration and characteristics near a major freeway with heavy-duty diesel traffic. *Environmental Science and Technology*, *41*, 2223-2230.

OECD. (2010). Reducing transport greenhouse gas emissions: Trends and data 2010. *Paris: The International Transport Forum.* Retrieved from https://www.itf-oecd.org/sites/default/files/docs/10ghgtrends.pdf

Oglethorpe, D., & Heron, G. (2010). Sensible operational choices for the climate change agenda. *The International Journal of Logistics Management*, *21*(3), 538-557. https://doi.org/10.1108/09574091011089844

Oloruntobi, O., Mokhtar, K., Rozar, N. M., Gohari, A., Asif, S., & Chuah, L. F. (2023). Effective technologies and practices for reducing pollution in warehouses-a review. *Cleaner Engineering and Technology*, *13*, 100622. https://doi.org/10.1016/j.clet.2023.100622

Paksoy, T., & Özceylan, E. (2014). Environmentally conscious optimization of supply chain networks. *Journal of the Operational Research Society*, *65*, 855-872.

Pastor Jr, M., Morello-Frosch, R., & Sadd, J. L. (2005). The air is always cleaner on the other side: Race, space, and ambient air toxics exposures in California. *Journal of Urban Affairs*, *27*(2), 127-148.

Port of Los Angeles. (2021). Port of Los Angeles statement on 24/7 operations announced by President Biden. Retrieved November 2, 2022, from https://www.portoflosangeles.org/references/news_101321_portstatement

Putra, C.D., Ramadhani, A., & Fatimah, E. (2021). Increasing urban heat island area in Jakarta and its relation to land use changes. *IOP Conference Series; Earth and Environmental Science, 737*(1), 012002. https://doi.org/10.1088/1755-1315/737/1/012002

Quincey, P. (2007). A relationship between black smoke index and black carbon concentration. *Atmospheric Environment, 41*(36), 7964-7968. https://doi.org/10.1016/j.atmosenv.2007.09.033

Rai, D., Sodagar, B., Fieldson, R., & Hu, X. (2011). Assessment of CO_2 emissions reduction in a distribution warehouse. *Energy, 36*(4), 2271-2277. https://doi.org/10.1016/j.energy.2010.05.006

Ramanathan, U., Bentley, Y., & Pang, G. (2014). The role of collaboration in the UK green supply chains and exploratory study of the perspectives of suppliers, logistics, and retailers. *Journal of Cleaner Production, 70*(1): 231-241. https://doi.org/10.1016/j.jclepro.2014.02.026

Ries, J. M., Grosse, E. H., & Fichtinger, J. (2017). Environmental impact of warehousing: A scenario analysis for the United States. *International Journal of Production Research*. http://doi.org/10.1080/00207543.2016.1211342

Saha, D., & Paterson, R. G. (2008). Local government efforts to promote the "Three Es" of sustainable development: Survey in medium to large cities in the United States. *Journal of Planning Education and Research, 28*(1), 21-37. http://dx.doi.org/10.1177/0739456X08321803

Salari, M., Javid, R. J., & Noghanibehambari, H. (2021). The nexus between CO_2 emissions, energy consumption, and economic growth in the US. *Economic Analysis and Policy*, *69*, 182-194.

Schremmer, M. (2022). Driver shortage not the problem, Port of L.A. director says. Land Line. Retrieved August 23, 2022, from https://landline.media/driver-shortage-not-the-problem-port-of-l-a-director-says/

Serkin, C., & Wellington, L. (2012). Putting exclusionary zoning in its place: Affordable housing and geographical scale. *Fordham Urban Law Journal*, *40*, 1667.

Shearston, J. A., Johnson, A. M., Domingo-Relloso, A., Kioumourtzoglou, M.-A., Hernandez, D., Ross, J., Chillrud, S. N., & Hipert, M. (2020). Opening a large delivery service warehouse in the South Bronx: Impacts on traffic, air pollution, and noise. *International Journal of Environmental Research and Public Health, 17*(9), 3208. https://doi.org/10.3390/ijerph17093208

Shepardson, D. (2022, August 10). U.S. works with firms in supply chains to ease port congestion. *Reuters.* Retrieved November 2, 2022, from https://www.reuters.com/markets/us/us-works-with-firms-supply-chains-ease-port-congestion-2022-08-10/

Silver, C. (1997). The racial origins of zoning in American cities. In J. M. Thomas & M. Ritzdorf (Eds.), *Urban planning and the African American community: In the shadows* (pp. 23-39). Sage.

South Coast Air Quality Management District. (2014). Warehouse truck trip study data results and usage. Retrieved from https://www.aqmd.gov/docs/default-source/ceqa/handbook/high-cube-warehouse-trip-rate-study-for-air-quality-analysis/finaltrucktripstudymsc072514.pdf

Stanley, H. (2022). What causes shipping delays? How they impact retailers and How to deal with them. Shopify Retail Blog. Retrieved August 23, 2022, from https://www.shopify.com/retail/shipping-delays

The Economist Newspaper. (n.d.). *What Amazon does to wages.* The Economist. Retrieved from https://www.economist.com/united-states/2018/01/20/what-amazon-does-to-wages

The Mercury News. (2023). California plan calls for 2.5 million new homes by 2030, double previous target. Retrieved March 3, 2023, from https://www.mercurynews.com/2022/03/03/state-plan-calls-for-2-5-million-new-homes-by-2030/

The Office of Environmental Health Hazard Assessment (OEHHA). (2021). *CalEnviroScreen 4.0*. Oehha.ca.gov. Retrieved March 28, 2023, from https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

Theodos, B., Meixell, B., & McManus, S. (2023). What we do and don't know about opportunity zones. *Urban Institute, Urban Wire Blog.* Retrieved from https://www.urban.org/urban-wire/what-we-do-and-dont-know-about-opportunity-zones

Tobias, M. (2022). Newsom campaigned on building 3.5 million homes. He hasn't gotten even close. *Cal Matters.* Retrieved from https://calmatters.org/housing/2022/10/newsom-california-housing-crisis/

United Kingdom Warehouse Association (UKWA). (2010). Save energy. Cut costs: Energy efficient warehouse. London.

USAFacts. (2023). California county population and demographics. Retrieved from https://usafacts.org/data/topics/people-society/population-and-demographics/our-changing-population/state/california/county/los-angeles-county/?endDate=2021-01-01&startDate=1980-01-01

U.S. Energy Information Administration (EIA). (2014). *Electricity Data Browser.* https://www.eia.gov/electricity/data/browser

U.S. Environmental Protection Agency (EPA). (2014). National Emissions Inventory (NEI) air pollution emissions trends data. EPA.gov. https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

Uyanik, C., Tuzkaya, G., & Oğuztimur, S. (2018). A literature survey on logistics centers' location selection problem. *Sigma Journal of Engineering and Natural Sciences*, *36*(1), 141-160.

Voogt, J. (2007). How researchers measure urban heat island. *In the United States Environmental Protection Agency (EPA), State and Local Climate and Energy Program, Heat Island Effect, Urban Heat Island Effect, Urban Heat Island Webcasts and Conference Calls.* https://www.epa.gov/sites/default/files/2014-07/documents/epa_how_to_measure_a_uhi.pdf

Walker, A. (2019). This interactive map shows LA's publicly owned properties. *Curbed LA*. 3 July 2019. Retrieved December 1, 2020, from https://la.curbed.com/2019/7/3/20681291/map-public-property-los-angeles

Wang, W., Wu, Y., & Sloan, M. (2018). A framework & dynamic model for reform of residential land supply policy in urban China. *Habitat International*, *82*, 28-37.

Woetzel, J., Mischke, J., Peloquin, S., & Weisfeld, D. (2016). Closing California's housing gap. McKinsey Global Institute. Retrieved from https://www.mckinsey.com/featured-insights/urbanization/closing-californias-housing-gap

World Economic Forum (WEF). (2009). Supply chain decarbonization. *World Economic Forum, Geneva.* Retrieved from https://www3.weforum.org/docs/WEF_LT_SupplyChainDecarbonization_Report_2009.pdf

Wu, J., Houston, D., Lurmann, F., Ong, P., & Winer, A. (2009). Exposure of $PM_{2.5}$ and EC from diesel and gasoline vehicles in communities near the Ports of Los Angeles and Long Beach, California. *Atmospheric Environment, 43*(12), 1962-1971.

Yakowicz, W. (2017). Robots replaced 75 percent of jobs at this warehouse but not one employee was cut. Inc.com. Retrieved from https://www.inc.com/will-yakowicz/boxed-didnt-fire-one-employee-after-robots-replaced-75-percent-warehouse-jobs.html

Yang, C., Chen, M., & Yuan, Q. (2021). The geography of freight-related accidents in the era of e-commerce: Evidence from the Los Angeles Metropolitan Area. *Journal of Transport Geography*, *92*, 102989. https://doi.org/10.1016/j.jtrangeo.2021.102989

Yang, Z., Yi, C., Zhang, W., & Zhang, C. (2014). Affordability of housing and accessibility of public services: Evaluation of housing programs in Beijing. *Journal of Housing and the Built Environment*, *29*(3), 521–540.

Yeung N., & Saraiva, A. (2022). Los Angeles warehousing mecca halts expansion just as needs soar. Bloomberg. Retrieved December 6, 2022, from https://www.bloomberg.com/news/articles/2022-08-15/los-angeles-warehousing-mecca-halts-expansion-just-as-needs-soar.

Yuan, Q. (2018a). Environmental justice in warehousing location: State of the art. *Journal of Planning Literature*, *33*(3), 287-298.

Yuan, Q. (2018b). Mega freight generators in my backyard: A longitudinal study of environmental justice in warehousing location. *Land use policy*, *76*, 130-143.

Yuan, Q. (2019a). Does context matter in environmental justice patterns? Evidence on warehouse location from four metro areas in California. *Land Use Policy, 82*, 328-338. https://doi.org/10.1016/j.landusepol.2018.12.011

Yuan, Q. (2019b). Planning matters: Institutional perspectives on warehousing development and mitigating its negative impacts. *Journal of the American Planning Association, 85*(4), 525-543. https://doi.org/10.1080/01944363.2019.1645614

Yuan, Q. (2021). Location of warehouses and environmental justice. *Journal of Planning Education and Research*, *41*(3), 282-293.

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