Project 2244 | March 2023

SJSU SAN JOSÉ STATE UNIVERSITY

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# Evaluating Automated Truck Platoon Deployment for the Los Angeles-Inland Empire Trade Corridor Enhancement

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Report 22-62

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March 2023


A publication of the
Mineta Transportation Institute
Created by Congress in 1991
College of Business
San José State University
San José, CA 95192-0219

# TECHNICAL REPORT DOCUMENTATION PAGE

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 22-62 | | |

| 4. Title and Subtitle | 5. Report Date |
|---|---|
| Evaluating Automated Truck Platoon (ATP) Deployment for the Los Angeles–Inland Empire Trade Corridor Enhancement | March 2023 |
| | **6. Performing Organization Code** |
| **7. Authors**<br>Shailesh Chandra, PhD<br>Aastha Chaudhary<br>Prakhar Srivastava<br>Jose Torres-Aguilera | **8. Performing Organization Report**<br>CA-MTI-2244 |
| **9. Performing Organization Name and Address**<br>Mineta Transportation Institute<br>College of Business<br>San José State University<br>San José, CA 95192-0219 | **10. Work Unit No.**<br><br>**11. Contract or Grant No.**<br>ZSB12017-SJAUX |
| **12. Sponsoring Agency Name and Address**<br>State of California SB1 2017/2018<br>Trustees of the California State University<br>Sponsored Programs Administration 401<br>Golden Shore, 5th Floor,<br>Long Beach, CA 90802 | **13. Type of Report and Period Covered**<br><br>**14. Sponsoring Agency Code** |

**15. Supplemental Notes**

**16. Abstract**

The California Freight Mobility Plan 2020 lists the Los Angeles-Inland Empire trade corridor region as a prominent industrial hub experiencing an increase in freight flows. The California Freight Mobility Plan also regards automated truck platoon (ATP) as an emerging opportunity to minimize congestion on the trade corridor routes. Percentage change in accessibility from 2022 ("without" ATP) to 2040 ("with" ATP) is calculated for the eighteen industry sectors of the Los Angeles-Inland Empire trade corridor. The application of the accessibility formulation was carried out with data on travel time from I-710 and I-10 within Los Angeles County. The findings suggest that all the industry sectors have a very high positive percentage change in accessibility by transforming from "without" to "with" ATP deployment-based accessibility. In the vicinity of the prominent freight corridors of I-710 and I-10 within Los Angeles County, notably, the largest increase in accessibility above 90% will be observed for the industry sectors of Agriculture, Forestry, Fishing and Hunting, Health Care and Social Assistance, Finance and Insurance, Transportation and Warehousing, and Retail Trade of the Los-Angeles-Inland Empire. Thus, these findings suggest the deployment of ATP on specific freight routes to enhance and sustain economic activity across the Los Angeles-Inland Empire trade corridors.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Freight, Accessibility, Retail, Industry, Corridor, Automated truck | No restrictions. This document is available to the public through The National Technical Information Service, Springfield, VA 22161. |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 30 | |

Form DOT F 1700.7 (8-72)

DOI: 10.31979/mti.2023.2244

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# Acknowledgments

The research team would like to thank MTI for the funding received to conduct this research.

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# Executive Summary

The California Freight Mobility Plan 2020 lists the Los Angeles-Inland Empire trade corridor region as one of the prominent industrial hubs that have seen a recent increase in warehouses and distribution centers and, thus, an increase in freight flows in the corridor. The region consists of the Southern California counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The California Freight Mobility Plan also regards the automated truck platoon (ATP) as an emerging opportunity to minimize congestion on the trade corridor routes. In fact, as per Assembly Bill (AB) 669, California permits platooning for testing purposes. However, there is no focused research on evaluating the extent of ATP deployment on congestion relief for the supply chain network of the industries in the Los Angeles-Inland Empire trade corridor region.

The ATP appears to ease some of the current challenges industries face by at least partially addressing the truck driver shortage, meeting California's emissions reductions goals, and improving transportation for businesses impacted by the COVID-19 lockdowns. However, the extent to which ATP could benefit industries dependent on the Los Angeles–Inland Empire region trade corridor is unknown. To address this, this research is a comprehensive study focused on evaluating the impact of ATP on potential improvements in accessibility of industries in the Los Angeles–Inland Empire trade corridor through a new measure developed in this project.

Evidence suggests that congestion leads to a negative and non-linear impact on industrial and economic growth, and minimizing congestion by expanding road capacity increases employment growth for industries. Congestion reduction could be significant for the Los Angeles-Inland Empire region's industries if ATP is deployed to optimize various route capacities of the trade corridor. Analysis of the Longitudinal Employer-Household Dynamics (LEHD) data from the Center for Economic Studies shows thousands of industry units concentrated in and around the Los Angeles-Inland Empire region. Prominent industry sectors in the region include Retail Trade, Manufacturing, Health Care and Social Assistance, and Accommodation and Food Services. These sectors directly (or indirectly) depend on freight movements via the access (or accessibility) provided by the Los Angeles-Inland Empire trade corridor, considered crucial for sustaining California's economic growth and international trade.

Various forms of impedance functions for travel are used to evaluate accessibility, and the magnitude of travel impedance is critical in determining the accessibility achieved. The impedances could be in the form of average travel time, distance, or generalized cost. In this research, the application of the accessibility formulation developed in this project was carried out with data on travel time from the I-710 and I-10 within Los Angeles County. Data on travel times was collected for the weekdays (Monday to Friday) using Google Maps on both interstates from June 20–24, 2022. The average peak hour travel times on the I-710 and I-10 were found to be 32 and 55 minutes, respectively—a total of 87 minutes. The average off-peak hour travel times were 26 and 35 minutes, respectively—a total of 61 minutes. These travel times (as impedance) were used as input to the accessibility formulation shown in Eq. (1). The peak hour travel time was considered as a scenario “without” ATP and the off-peak travel time was considered as the “with” ATP scenario.

Percentage change in accessibility from 2022 (“without” ATP) to 2040 (“with” ATP) is calculated for the eighteen industry sectors of: Accommodation and Food Services; Administrative and Support and Waste Management and Remediation Services; Arts, Entertainment, and Recreation; Agriculture; Forestry; Fishing and Hunting; Construction; Educational Services; Professional, Scientific, and Technical Services; Health Care and Social Assistance; Mining, Quarrying, and Oil and Gas Extraction; Management of Companies and Enterprises; Finance and Insurance; Manufacturing; Real Estate and Rental and Leasing; Wholesale Trade; Information; Utilities; Transportation and Warehousing; and Retail Trade.

The findings suggest that all industry sectors have a steep percentage increase in accessibility from “without” to “with” ATP deployment-based accessibility. In the vicinity of the prominent freight corridors of the I-710 and I-10 within Los Angeles County, notably, the largest increase in accessibility, above 90%, is observed for these industry sectors of the Los Angeles–Inland Empire: Agriculture, Forestry, Fishing and Hunting; Health Care and Social Assistance; Finance and Insurance; Transportation and Warehousing; and Retail Trade. Thus, these findings suggest deployment of ATP on specific freight routes to enhance and sustain economic activity across the Los Angeles–Inland Empire trade corridors.

# Introduction and Background

The Trade Corridor Enhancement Program (TCEP) provides $300 million each year for high-priority freight corridor improvements in California—particularly for those corridors that experience inefficiencies in freight movement (TCEP, 2021). The investment also involves exploring options for deploying an automated truck platoon (ATP) to alleviate increasing congestion due to freight activities in California. Research shows that ATP offers various improvements to freight truck movements central to the congestion problem, with increased road space utilization and optimized traffic flow (Kunze, 2011). Tests carried out with a platoon of autonomous trucks have proven successful for significant savings in fuel and reducing greenhouse gas emissions (Tsugawa, 2011). However, how automated truck platooning can benefit industries economically important for California is not well known.

The California Freight Mobility Plan 2020 lists the Los Angeles-Inland Empire trade corridor region as one of the prominent industrial hubs that have seen a recent increase in warehouses and distribution centers and, thus, an increase in freight flows in the corridor (California Freight Mobility Plan, 2020). The region consists of the Southern California counties of Los Angeles, Orange, Riverside, San Bernardino, and Ventura. The California Freight Mobility Plan also regards ATP as an emerging opportunity to minimize congestion on the trade corridor routes. In fact, as per Assembly Bill (AB) 669, California permits platooning for testing purposes (Caltrans, 2019). Yet, there is no focused research on evaluating the extent of ATP deployment on congestion relief for the supply chain network of the industries in the Los Angeles-Inland Empire trade corridor region.

The 2016–2040 Regional Transportation Plan (RTP) for the Los Angeles-Inland Empire region also anticipates future developments related to freight automation [6]. Studies are underway to deploy ATP on the I-10 and I-710 (FHWA, 2021; GATEWAYCOG.ORG, 2021). Fig. 1 shows the spatial location of these two interstates in thick green color. Research findings by a renowned consulting firm, McKinsey & Company, show that a Level 4 autonomous system (nearly fully autonomous trucks without a driver) is anticipated to be deployed in the country as soon as 2025, making this proposed research time-sensitive (McKinsey & Company, 2021).

The RTP for the counties of the Los Angeles-Inland Empire in Southern California shows several future-year developments to accommodate ATP. Truck "platooning" occurs when automated trucks safely follow or draft each other at very close distances to conserve fuel and maximize road space. The ATP would operate on the trade corridor's critical highways in the Los Angeles-Inland Empire that encompasses Los Angeles, Orange, Riverside, San Bernardino, and Ventura counties. Currently, trade corridor highways experience perpetual congestion and capacity limitations that inhibit efficient truck movement. This adds to the increased burden on the supply chain network of the corridor-dependent industries.

The ATP appears to ease some of the current challenges industries face by at least partially addressing the truck driver shortage, meeting California's emissions reductions goals, and improving transportation for businesses impacted during COVID-19 lockdown. However, the extent to which ATP could benefit industries dependent on the Los Angeles-Inland Empire region trade corridor is unknown. To address this, this research is a comprehensive study focused on evaluating the impact of ATP on potential improvements in accessibility of industries in the Los Angeles-Inland Empire trade corridor through a new measure developed in this project.

Evidence suggests that congestion leads to a negative and non-linear impact on industrial and economic growth (Boarnet, 1997; Sweet, 2011), and minimizing congestion by expanding road capacity increases employment growth for the industries (Hymel, 2009; Jin and Rafferty, 2017). Congestion reduction could be significant for the Los Angeles-Inland Empire region industries if ATP is deployed to optimize various route capacities of the trade corridor. Preliminary analysis of the Longitudinal Employer-Household Dynamics (LEHD) data of the Center for Economic Studies shows thousands of industry units concentrated in and around the Los Angeles-Inland Empire region (see Fig. 1 for a portion of the region's retail trade distribution as an example) (LEHD, 2021). Prominent industry sectors in the region include Retail Trade, Manufacturing, Health Care and Social Assistance, and Accommodation and Food Services (laedc.org, 2021). These sectors directly (or indirectly) depend on the freight movements via the Los Angeles-Inland Empire trade corridor, considered crucial for sustaining California's economic growth and international trade.

Figure 1. Trade Corridor Components of a Portion of the Los Angeles-Inland Empire with Retail Trade as an Example Component

The Los Angeles-Inland Empire's freight truck routes offer accessibility to the region's industry sectors. Goods that arrive at the ports are transported to various industry locations via intermodal terminals. Studies suggest that improving transport connectivity between originating points of goods movement to their final industry destination facilitates overall supply chain access (Vadali and Chandra, 2014). However, the influence of ATP in the network on industry unit accessibility is a matter of research. Only select routes can be eligible for ATP deployment within the region, benefiting specific industry sectors while potentially not causing any accessibility benefits to the other industries. This will invariably result in industry sector "winners" and "losers" impacting the region's economic growth. Therefore, critical routes and accessibility changes need to be determined within the corridor for ATP deployment to succeed, which this research investigates.

# 2. Literature Review

In this section, a review of studies on truck platooning is presented, which includes content from the work by Chandra and Thai (2022).

Truck automation and platooning are essential to achieve energy efficiency and improve transportation capacity. Compared to conventional freight truck movements, truck platooning offers several improvements that can help address the issue of congestion on the roads. These improvements include better utilization of road space and optimized traffic flow, which can lead to more efficient transportation and reduced traffic congestion (Alam et al., 2015).

Field experiments conducted by the California PATH Program in the United States using heavy truck platooning technology demonstrated the potential for fuel savings of up to 10% (Tsugawa et al., 2016). Volvo Trucks North America, FedEx, and the North Carolina Turnpike Authority have recently completed a successful demonstration of truck platooning technology on N.C. 540. (Volvo Trucks USA, 2019). The platoon consisted of three Volvo VNL tractors, each pulling double 28 ft. trailers. Several other private and public entities in the United States have also conducted truck platoon demonstrations and testing. The Federal Highway Administration (FHWA)-Caltrans-PATH-Volvo team, for instance, demonstrated cooperative adaptive cruise control (USDOT, 2018). In all of the truck platooning experiments conducted, the primary focus has been on utilizing some form of cooperative adaptive cruise control (CACC), which involves the use of radar and vehicle-to-vehicle (V2V) communication to coordinate the movements of the trucks in a platoon. This technology utilizes connected vehicle technology (CVT).

As a freight transportation technology, truck platooning is quickly evolving in supply chain and logistics (Bibeka et al., 2021) and has significant potential for demand in cities that are hubs of high freight traffic and congestion (Browne et al., 2017). Tests conducted with a platoon of autonomous trucks have demonstrated significant potential for fuel savings and reductions in greenhouse gas emissions (Bibeka et al., 2021; USDOT, 2016).

The timely arrival of commodities for transfers at intermodal stations and terminals is intrinsically linked to the freight transportation costs for shippers and carriers. From an economic standpoint, delays in the arrival of goods can result in increased costs and reduced efficiency in the supply chain. When a truck arrives late at a transfer station or a point in a network, it can result in delayed pick-ups and deliveries at the final terminal point, ultimately increasing the overall transportation costs of multimodal freight operations. This can make freight transportation unsustainable, as delayed arrivals can disrupt the entire supply chain and cause increased costs for shippers and carriers (Rodrigue et al., 2009; Vis and De Koster, 2003). Thus, the sustainability of goods movement in platooning depends on a truck's timely access to destinations, which needs to be appropriately evaluated.

When congestion is high on a truck platoon's routes, accessibility is expected to be low. Congestion can cause an increase in travel times for freight trucks, which in turn reduces accessibility to destinations. Delays resulting from an increase in travel time can be difficult to model in truck operations (Simoni and Claudel, 2017). The travel time and delay can significantly impact the accessibility of destinations for freight trucks, which can in turn affect the sustained growth of industries and businesses in a region (Fowkes et al., 2004). Maintaining a timely delivery of commodities is crucial for the optimal operations of a multimodal transportation system. In order to optimize the operations of this system, every mode must operate in sync within certain predicted travel time ranges to minimize delays and costs to the overall system. Thus, efficient mobility of freight trucks is crucial for ensuring appropriate accessibility between stations or pairs of points in a multimodal transportation system.

# 3. Methodology

Accessibility has been used as an indicator of the mobility of people and goods. It is a measure which has most widely been used for policy-related decision-making in transportation and has been evaluated using expected travel time to access a region (Khalili et al., 2020).

## 3.1 Freight accessibility as a performance measure

Various forms of impedance functions can be used to accessibility. Travel time as an impedance function is commonly used to evaluate accessibility for freight (Chandra et al., 2017). Accessibility has been modeled using a gravity-based measure as defined below (Khalili et al., 2020; Chandra and Thai, 2022):

$$A_i = \sum_{j \in N} W_j \cdot \zeta\left(T_{ij}\right) \qquad (1)$$

where, $A_i$ is the accessibility of an entity $i \in N$, $W_j$ is the weight indicating the importance of the destination $j \in N$, and $\zeta\left(T_{ij}\right)$ is the impedance function that often takes the form of a power decay function such as travel time, distance, generalized cost, etc., with $\beta$ being the decay parameter that needs to be calibrated with local transportation data.

In practice, transportation performance evaluations that use accessibility (as defined in Eq. 1 above) as a measure are not customized for capturing impacts from freight trucks moving in a platoon. Recent advancements in platooning allow flexibility in path detours and deviations (Hjälmdahl et al., 2017), making the accessibility formulation in Eq. 1 unsuitable for gauging the success of ATP deployment for various industry sectors.

Therefore, we developed a new accessibility measure incorporating the impact of ATP deployment in the trade corridor for the industry sectors of the Los Angeles-Inland Empire region. Comparing the accessibility for both "with" and "without" ATP cases would highlight which industry sectors will be "winners" or "losers" for route-specific ATP deployment in the region. The findings will show the growth potential for the Los Angeles-Inland Empire trade corridor region per industry if an automated freight truck platoon is deployed.

# 4. Application of the Method

The application of the theoretically derived formulation for accessibility in Eq. 1 was carried out with data on travel time from the I-710 and I-10 within Los Angeles County. Data on travel times was collected for the weekdays (Monday to Friday) using Google Maps on the two interstates from June 20–24, 2022. The average peak hour travel times on the I-710 and I-10 were found to be 32 and 55 minutes, respectively—a total of 87 minutes. The average off-peak hour travel times for the I-710 and I-10 were 26 and 35 minutes, respectively—a total of 61 minutes. These travel times (as an impedance) were used as input to the accessibility formulation shown in Eq. (1). The peak hour travel time was considered as a scenario "without" ATP and the off-peak travel time was considered as the "with" ATP scenario.

The industry sector Employment was used as the surrogate of economic activity for the Los Angeles-Inland Empire trade corridor. Thus, employment data was considered an important input for the accessibility calculation. The data was obtained from the Longitudinal Employer-Household Dynamics (LEHD) through OnTheMap—a web-based mapping and reporting application that shows where workers are employed and where they live (LEHD, 2023). Employment data for the three years of 2011, 2015, and 2019 were used to extrapolate data for 2022 and 2040. The year 2022 was considered "without" ATP deployment, and the year 2040 as the "with" ATP deployment scenario. Accessibility values are calculated for the various industry sectors thereof. A total of eighteen industry sectors were considered for the analysis: Accommodation and Food Services; Administrative and Support and Waste Management and Remediation Services; Arts, Entertainment, and Recreation; Agriculture, Forestry, Fishing and Hunting; Construction; Educational Services; Professional, Scientific, and Technical Services; Health Care and Social Assistance; Mining, Quarrying, and Oil and Gas Extraction; Management of Companies and Enterprises; Finance and Insurance; Manufacturing; Real Estate and Rental and Leasing; Wholesale Trade; Information; Utilities; Transportation and Warehousing; and Retail Trade. The percentage change in accessibility from 2022 to 2040 are calculated for each industry, depicting change from the "without" ATP to the "with" ATP deployment scenario.

The maps in Figs. 2–4 show these industry locations within a half-mile distance from the I-710 and I-10 with employment of more than one hundred at the spatial resolution of a block in Los Angeles County. The employment and industry location data for the available latest year, 2019, from the LEHD has been utilized to develop these maps.

Figure 2. Spatial Distribution of the First Set of Key Industry Locations: (1) Accommodation and Food Services, (2) Administrative and Support and Waste Management and Remediation Services, (3) Arts, Entertainment, and Recreation, and (4) Agriculture, Forestry, Fishing and Hunting.

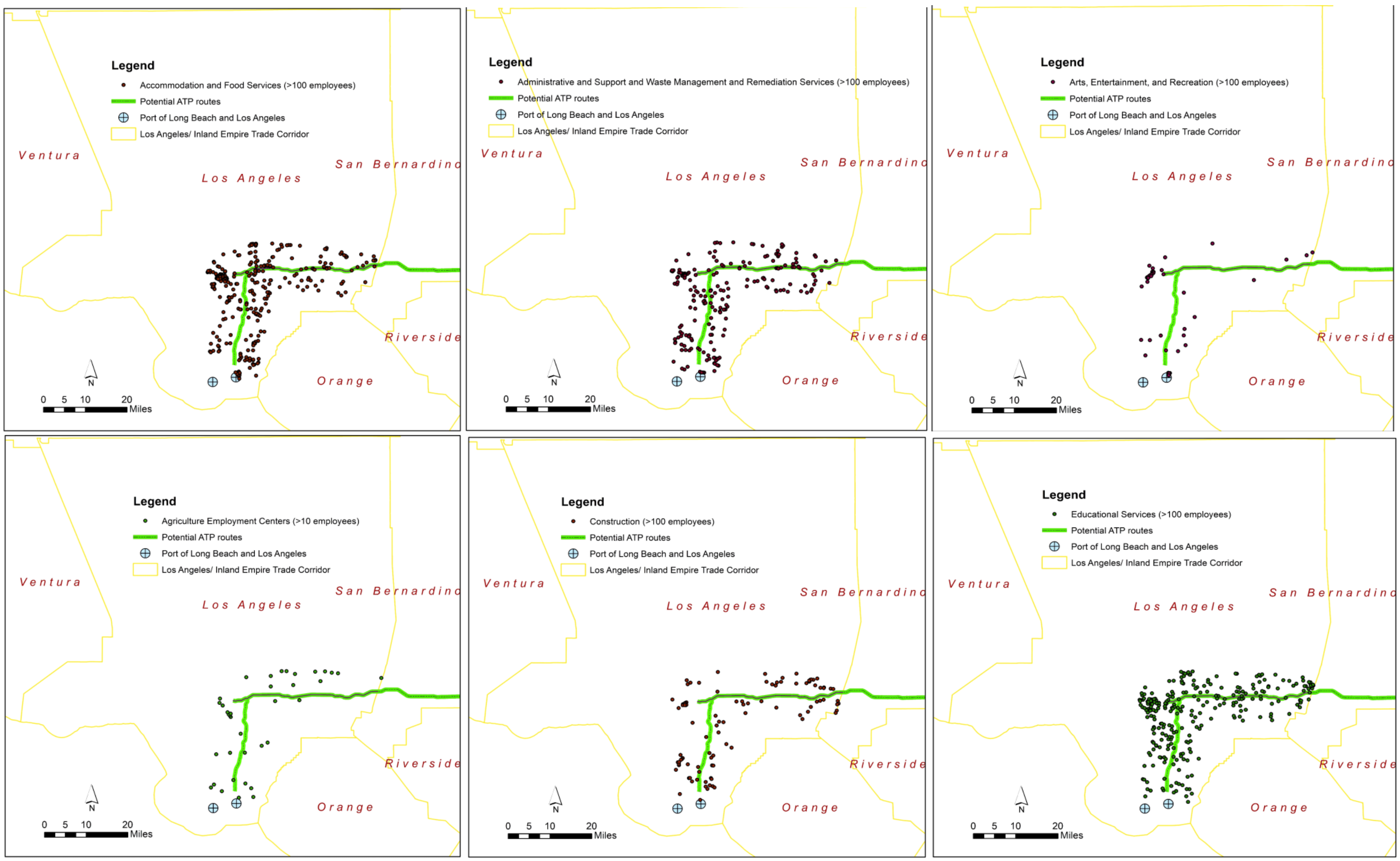


Figure 3. Spatial Distribution of the Second Set of Key Industry Locations: (7) Professional, Scientific, and Technical Services, (8) Health Care and Social Assistance, (9) Mining, Quarrying, and Oil and Gas Extraction, (10) Management of Companies and Enterprises, (11) Finance and Insurance, and (12) Manufacturing.

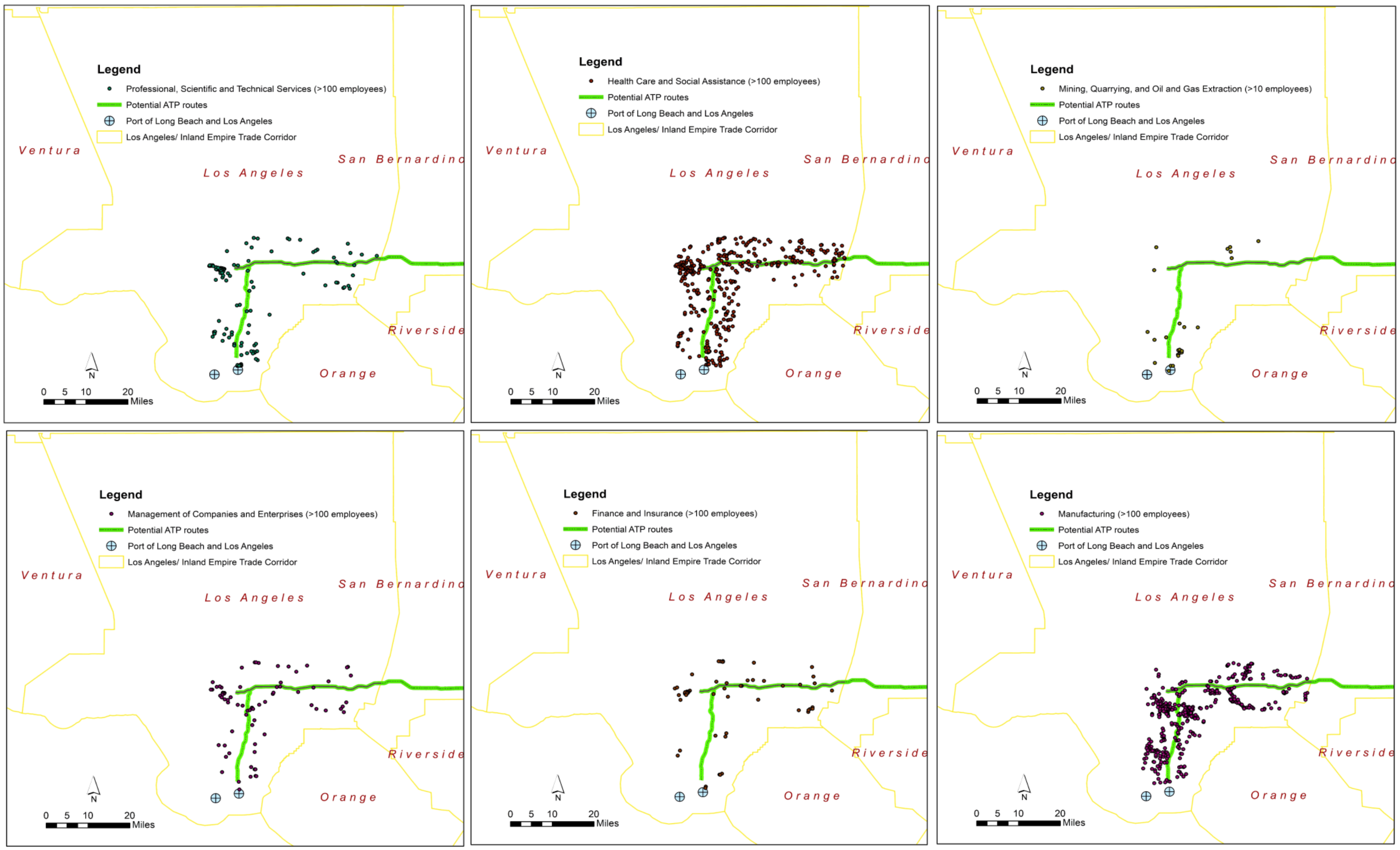
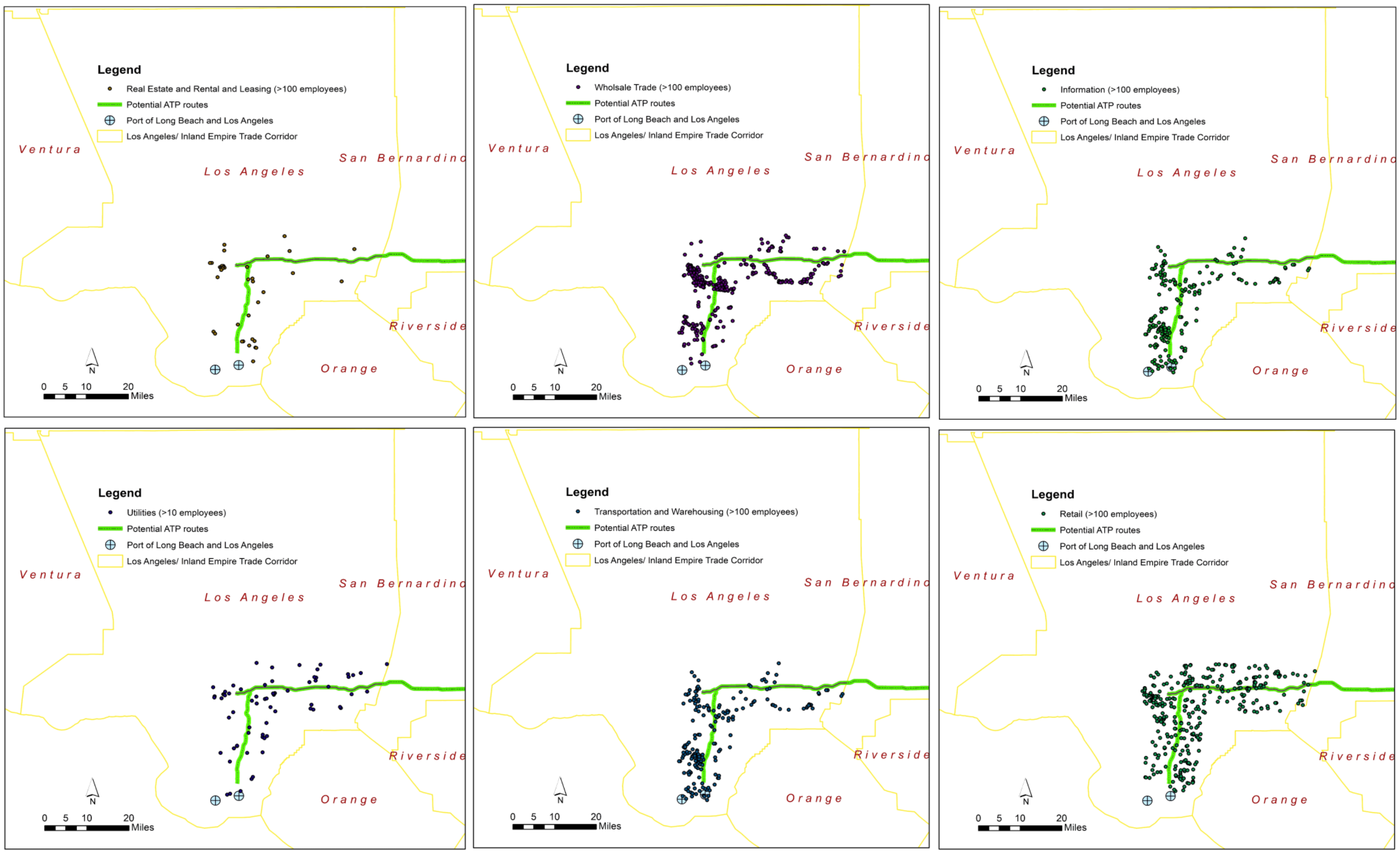


Figure 4. Spatial Distribution of the Third set of Key Industry Locations: (13) Real Estate and Rental and Leasing, (14) Wholesale Trade, (15) Information, (16) Utilities, (17) Transportation and Warehousing, and (18) Retail Trade.



# Results and Discussion

Percentage changes in accessibility from 2022 ("without" ATP) to 2040 ("with" ATP) are calculated for the aforementioned eighteen industry sectors. The findings are presented in Table 1 where all industry sectors have a significant percentage increase in accessibility from "without" to "with" ATP on prominent freight corridors within Los Angeles County. Notably, the largest increases in accessibility, above 90%, is observed for these industry sectors of the Los Angeles-Inland Empire within the Los Angeles County: Agriculture, Forestry, Fishing and Hunting; Health Care and Social Assistance; Finance and Insurance; Transportation and Warehousing; and Retail Trade.

Table 1. List of Industry Sectors and Their Percentage Change from 2022 to 2040

| | Industry Sector | Percentage Change in Accessibility (from 2022 to 2040) |
|---|---|---|
| 1 | Accommodation and Food Services | 84 |
| 2 | Administrative and Support and Waste Management and Remediation Services | 89 |
| 3 | Arts, Entertainment, and Recreation | 79 |
| 4 | Agriculture, Forestry, Fishing, and Hunting | 90 |
| 5 | Construction | 82 |
| 6 | Educational Services | 89 |
| 7 | Professional, Scientific, and Technical Services | 78 |
| 8 | Health Care and Social Assistance | 93 |
| 9 | Mining, Quarrying, and Oil and Gas Extraction | 77 |
| 10 | Management of Companies and Enterprises | 87 |
| 11 | Finance and Insurance | 91 |
| 12 | Manufacturing | 88 |
| 13 | Real Estate and Rental and Leasing | 81 |
| 14 | Wholesale Trade | 84 |
| 15 | Information | 89 |
| 16 | Utilities | 79 |
| 17 | Transportation and Warehousing | 90 |
| 18 | Retail Trade | 92 |

# Summary and Conclusions

In this research, the change in accessibility of eighteen industry sectors was calculated in circumstances “without” ATP in the year 2022 and “with” anticipated ATP deployment in 2040 across the Los Angeles-Inland Empire of the LA county. The analysis was carried out with employment data across the prominent industry sectors and using data on travel time from the I-710 and I-10 within the Los Angeles County. This research suggests that the industry sectors of Agriculture, Forestry, Fishing and Hunting; Health Care and Social Assistance; Finance and Insurance; Transportation and Warehousing; and Retail Trade of the Los-Angeles-Inland Empire within the Los Angeles County will show a very high improvement in accessibility with ATP deployment in 2040. In essence, ATP deployment indicates supporting economic growth of the various industry sectors across the Los Angeles-Inland Empire.

There are two key limitations of this research. First, the analysis has been carried out for industry sectors that strictly lie within a half mile distance around the I-710 and I-10 corridor of the Los Angeles-Inland Empire of the Los Angeles County. Second, only those industry sectors have been included in this research that have employment higher than one hundred employees for most industry locations.

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