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Chapter 8

Understanding and Modeling the Impacts of CoVID-19 on Freight Trucking Activity

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Abstract

Restrictions on travel and in-person commercial activities in many countries (e.g. the U.S., China, European Countries, etc.) due to the global outbreak and rapid spread of the coronavirus disease 2019 (COVID-19) have severely impacted the global supply chain and subsequently affected freight transportation and logistics. This chapter summarizes the findings from the analysis of truck axle and weight data from existing highway detector infrastructure to investigate the impacts of COVID-19 on the freight truck activity. Three aspects of COVID-19 truck impacts were explored: drayage, long and short-haul movements, and payload characteristics. This analysis revealed disparate impacts of this pandemic on freight truck activity because of local and foreign policies, supply chain bottlenecks, and the dynamic changes in consumer behavior. Due to the ongoing effects of COVID-19, it is not yet possible to distinguish between transient and long-term impacts on freight trucking activity. Nonetheless, a future expansion of the study area and the incorporation of other complementary data sources may provide further insights of the pandemic's impacts on freight movement.

8.1 Introduction

Restrictions on travel and in-person commercial activities in many countries (e.g. the U.S., China, European Countries, etc.) due to the global outbreak and rapid spread of the coronavirus disease 2019 (COVID-19) have severely impacted the global supply chain (Molloy et al. 2021) and subsequently affected freight transportation and logistics. In early 2020, Ernst & Young LLP (EY US) conducted a survey of 200 senior-level supply chain executives across various sectors, such as consumer products, industrial products, retail companies, etc. in the United States (Harapko 2021). According to the survey results, 72 percent of the companies experienced negative effects from the COVID-19 pandemic (Harapko 2021). One particularly impacted industry was the automotive sector; all the automotive companies that participated in the survey reported a negative effect. This was caused by three main factors: the disruption of Chinese exports of auto parts, the interruption of automobile manufacturers in Europe, and the closure of assembly plants in the U.S. (Vitale 2020). Similarly, nearly 97 percent of industrial product companies also experienced negative effects from the pandemic. On the other hand, 11 percent of companies reported positive impacts from the COVID-19 pandemic, such as industries which produce essential customer products. The demand was partly driven by the panic-buying of emergency-related products such as toilet paper, canned foods, etc. (Bhattacharjeee al. 2020; Regan and Saphores 2020). In freight transportation and logistics, the ocean shipping and railroad volumes declined by 25 and 20 percent in the U.S., respectively, reflecting the impacts on international and long-distance domestic freight transportation. In contrast, the last-mile truck delivery spiked significantly to more than ten times year-on-year. In addition to the high demand for essential goods, the surge of e-commerce due to the social distancing restrictions (see chapter 7), limited personal travel, and the increased time spent at home also increased the demand for consumer products that fueled the growth of last-mile truck movements.

The San Pedro Bay Port Complex comprising the ports of Los Angeles and Long Beach has been ranked as the busiest in North America for over two decades. It serves as the main U.S. gateway for international trade and was severely affected by the global supply chain disruptions caused by the COVID-19 pandemic. This chapter is focused on investigating the effect of the pandemic on some specific truck activities in the State of California. First, we utilized container statistics published on the webpage of the Port of Los Angeles (Port of Los Angeles 2021) and the Port of Long Beach (Port of Long Beach 2021) to analyze the year-over-year changes on the container counts between 2019 and 2020, and to assess the impact of the global supply chain disruptions effects on the export and import container counts at the Port of Los Angeles. Subsequently, we observed the volume changes of trucks by their operation characteristics near the Port of Los Angeles using the Weigh-In-Motion (WIM) data. This chapter summarizes the findings from the analysis of truck axle and weight data from existing highway detector infrastructure to investigate the impacts of COVID-19 on the freight trucking industry. Three aspects of COVID-19 truck impacts were explored: drayage, long and short-haul movements, as well as payload characteristics.

8.2 Data and Site Description

8.2.1. Type of Sensor Infrastructure

The data for this study was obtained from Weigh-in-Motion (WIM) traffic detector sites located along major freeway and highway corridors in Southern California. WIM sites are equipped with sensors that measure axle spacings and weights of trucks as they traverse the mainline at highway speeds. These direct measurements can be used to distinguish trucks by axle-based classification categories such as the Federal Highway Administration (FHWA) scheme (Table 8.1) and truck weights, respectively (Federal Highway Administration, 2013).

Table 8.1: FHWA Vehicle Classification

Class	Vehicle type	Description
1	Motorcycles	Two axles, two or three tires
2	Passenger cars	Two axles can have one or two-axle trailers
3	Pickups, Panels, Vans	Two axles, 4 tire single units, can have 1 or 2 axle trailers
4	Buses	Two or three axles, full length
5	Single unit two-axle trucks	Two axles, six tires (dual rear tires), single unit
6	Single unit three-axle trucks	Three axles, single unit
7	Single unit with four or more axles	Four or more axles, single unit
8	Single trailer three or four axle trucks	Three or four axles, single trailer
9	Single trailer five-axle trucks	Five axles, single trailer
10	Single trailer six or more axle trucks	Six or more axles, single trailer
11	Multi-trailer five or fewer axle trucks	Five or fewer axles, multiple trailers
12	Multi-trailer six-axle trucks	Six axles, multiple trailers
13	Multi-trailer seven or more axle trucks	Seven or more axles, multiple trailers

Data Source: FHWA Traffic Monitoring Guide (2013; updated October 2016)

This study focused on FHWA Class 9 trucks, which are defined as five-axle tractors pulling a semi-trailer and are the predominant axle configuration associated with trucks that haul domestic and international freight in the United States. Further insights into truck characteristics can be obtained through a more in-depth analysis of WIM data, such as trailer configuration and payload by Hyun et al. (2015). This study applied and extended the work by Hyun et al., which investigated the association of truck axle spacings with certain trailer configurations that are of particular interest in freight activity analysis. For example, tractors hauling 40-foot intermodal containers associated with the port drayage movements have axle spacings that are quite distinct from their line-haul counterparts. These inferences were used in this study to analyze the disparate impacts of COVID on drayage movements, long and short-haul movements, and payload characteristics.

8.2.2. Data Description

We obtained data from six WIM sites along four major freight corridors across Ventura, Los Angeles, and Riverside counties in Southern California. The geographical distribution of the WIM sites with their corresponding facilities' functional classes is presented in Figure 8.1

The selected detection sites capture significant movements of drayage trucks (e.g., WIM sites along I-710 near Los Angeles port) and long- and short-haul trailers and domestic containers (e.g., WIM sites along US-101). Each WIM record includes axle spacings and weight data of each vehicle that traversed the detection site. In this study, the axle spacings data was used to infer the volumes of drayage trucks versus trailers and domestic containers and short- versus long-haul trailer and domestic container movements, while the weight data was used in the payload analysis. We would like to acknowledge that the aforementioned predicted truck body configurations through WIM records only provides rough estimates for our COVID-19 freight impact analysis.

Figure 8.1: The Geographic Distribution of the Study Sites

Data Sources: Open Street Map, California Department of Transportation (Caltrans) WIM Locations

8.2.3. COVID-19 Timeline in California

With the outbreak of COVID-19, California's governor declared a state of emergency on March 4th, 2020, and implemented a state-wide stay-at-home order on March 19, 2020. However, plans for reopening were released on April 28th. Subsequently, the state entered an "early-stage two" reopening. This phase allowed the re-opening of some low-risk businesses. On May 28th, 2020 most of the counties in California started to enter stage 3 of re-opening, and places such as salons, museums, and zoos began to reopen. After five months, the U.S. surpassed 11 million confirmed COVID-19 cases, and the Governor announced a limited stay-at-home order to arrest the rapid spread of the virus. This lockdown order was similar to the first lockdown order with small modifications, applying only to purple-tier counties (those with the highest concentrations of the disease) between 10 pm and 5 am daily. Thus, in order to investigate the pandemic's impacts on freight movements alongside the policy changes, this analysis segmented the calendar year into four phases aligned with the essential lockdown events (Table 8.2). The monthly average truck volumes obtained from 2016, 2017, and 2019 were used as the baseline to compare with the corresponding truck volumes in the year 2020 (the year of the COVID-19 outbreak).

Table 8.2: COVID-19 Timeline in California

	Description	Time
Phase 1	Pre-COVID	Before March 1st, 2020
Phase 2	First Lockdown	From March 1st, 2020 to May 31st, 2020
Phase 3	Re-open	From June 1st, 2020 to October 31st, 2020
Phase 4	Second Lockdown	From November 1st, 2020 to December 31st, 2020

Data Source: Phase definitions based on Wikipedia "COVID-19 pandemic in California"

8.2.4. Data Preprocessing

Prior to the truck activity analysis, we preprocessed and aggregated raw WIM data according to the following steps: First, we validated the raw WIM data by comparing the front axle weight and inter-axle spacing with the reference values from the literature (Hernandez and Baker, 2019) to ensure adequate data quality. Second, we identified time periods containing data gaps at each location, based on the significance of the headway between consecutive vehicles, and subsequently excluded them from the dataset. Finally, we estimated and aggregated into monthly intervals daily truck volumes for each detection site. In this chapter, we took the average of the years 2016, 2017, and 2019 monthly truck volumes available to us to establish the baseline seasonality effect and used the average of the three pre-pandemic monthly volumes as the baseline to analyze the pandemic's impacts on truck movements in 2020. The average weekday volumes of each phase were used in the analysis.

8.3. Truck Characterization for Highway Freight Activities Impacts by COVID-19

In order to investigate the pandemic's impacts on various truck activities, we categorized trucks by their physical and operational characteristics into three schemes: 1) drayage versus trailers and domestic containers, 2) long- versus short-haul trailers and domestic containers and 3) empty versus full-load trailers and domestic containers. We define full-load trailers and domestic containers tractor-trailers those having gross vehicle weights approaching the legal weight limit. The characterized trucks used in this chapter were primarily inferred from the axle configurations and gross vehicle weight (GVW) information obtained from WIM data according to their distinct statistical distribution. It should be noted that several other tractor-trailer configurations such as platforms may share similar axle spacing configurations with trailers and domestic containers tractor-trailers. This should not detract from the analysis, as the targeted truck configurations in this study – 40' intermodal containers and trailers and domestic containers – are dominant in their axle configuration. Hence, the WIM volume estimates of trucks by these configurations remain a useful metric for analysis.

8.3.1 Drayage Truck Activity

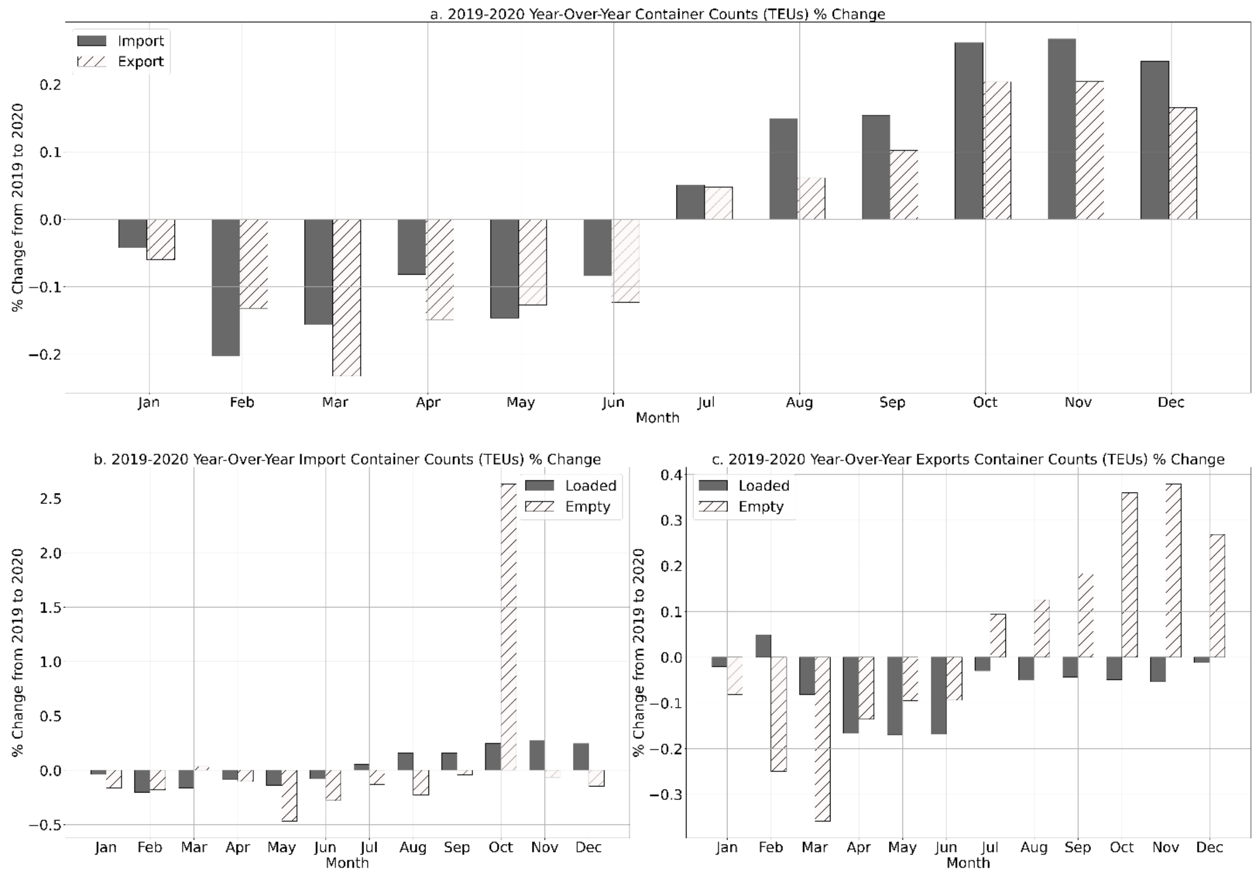
Drayage trucks represent heavy trucks that transport intermodal containers between the seaports or intermodal railyards and many other freight facilities. The standard sizes of the containers used for transport freight are 20 feet, 40 feet, and 45 feet in length (ABCO Transportation, 2018), where 40ft containers are most commonly used and observed along highway freight corridors due to their cost-effectiveness (Approved, n.d.). Hence, we inferred 40ft intermodal container truck volumes from among five-axle tractor-trailers and focused on observing volume changes of 40ft containers at three typical drayage truck corridors near the San Pedro Bay Port Complex to study the impacts of pandemic travel restrictions on drayage truck movements.

<u>Container Counts at the San Pedro Bay Ports</u>

Drayage trucks transport a significant share of intermodal containers to and from the San Pedro Bay Port Complex. Thus, understanding the changes of container counts is one of the essential steps prior to the drayage truck activity analysis. In this section, we reviewed container count data reported by the Port of Los Angeles (Port of Los Angeles, 2021) and the Port of Long Beach (Port of Long Beach, 2021) to assess the impact on supply chain disruption by the pandemic. Figure 8.2a presents the year-over-year percentage changes of the total import and export container counts from 2019 to 2020. Both import and export container numbers decreased at the beginning of 2020 compared to the previous year, with a decline in the magnitude of reduction towards the middle of the year. The intermodal container counts showed a subsequent year-over-year increase starting from August 2020. This trend could be potentially caused by the supply chain disruption at the beginning of the year, with subsequent signs of recovery of some of the essential nodes in the supply chain from some Asian countries. However, drayage operations were significantly affected by operational bottlenecks such as limited container yard storage and driver shortages. Next, we break down the overall import and export container counts into loaded imports, empty imports, loaded exports, and empty exports to understand the demand and supply changes of the international trade (Figure 8.2b and 8.2c).

Figure 8.2 presents the year-over-year percentage changes of import and export container counts respectively, and highlights the increase in freight demand in the U.S., which has significant downstream impacts on portside truck traffic. We explored how the increased portside demand impacted truck activities by their operational characteristics near the port area. Interestingly, the year-over-year percentage changes of import empty container counts spike in October. According to the October data in 2019, there was a significant reduction in the counts of import empty containers at the Port of Long Beach. Therefore, the spike of import empty container counts are unlikely caused by the pandemic and are out of the scope of our study.

Figure 8.2: Container Statistics from 2019 to 2020



Data Sources: Montly container counts data were obtained from the Port of Long Beach (Port of Long Beach, 2021) and Los Angeles (Port of Los Angeles, 2021).

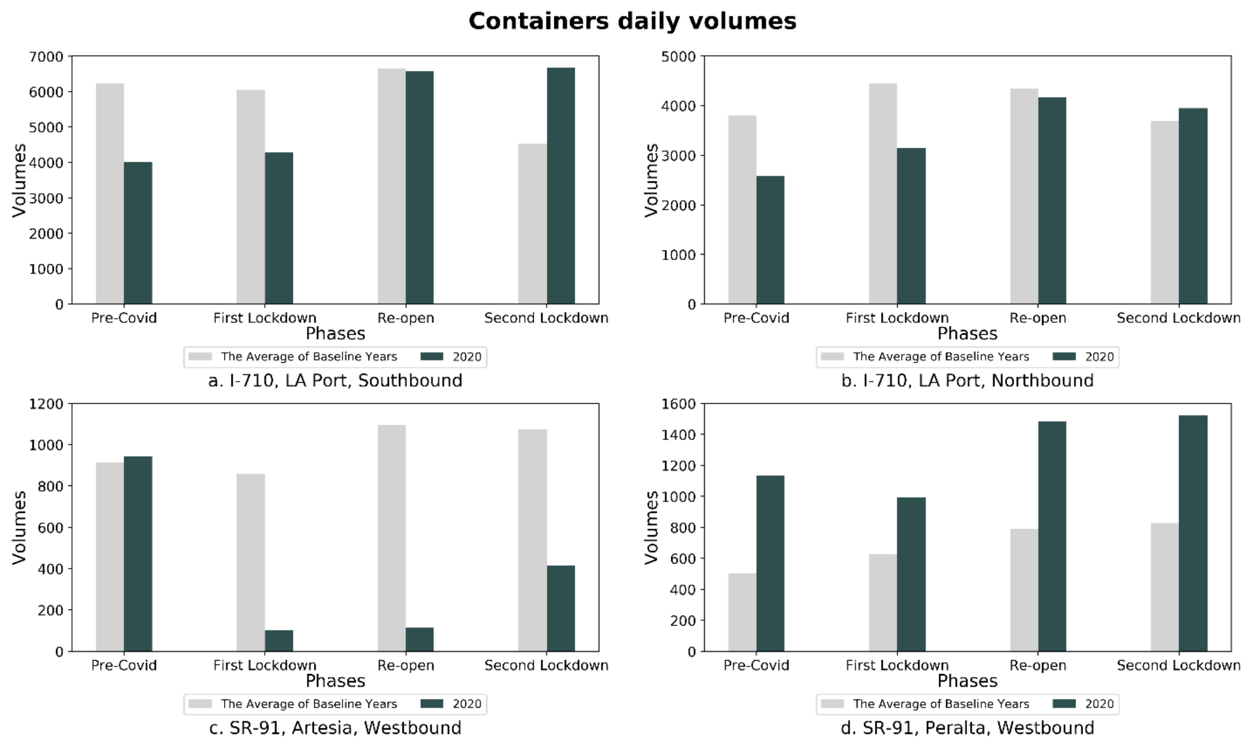
<u>Drayage Truck Identification</u>

In a previous study, Hyun et al. (2015) found that 40ft intermodal container trucks present distinct physical characteristics in terms of vehicle length, axle spacing, and overhang distributions compared to other trailer body configurations within Class 9 trucks. This analysis adopted the approach by Hyun et al. and recalibrated the decision boundary of their model with the newly collected WIM measurements to identify 40ft container trucks from Class 9 vehicles. The identified 40ft intermodal container trucks were used for the analysis of COVID-19 impacts on drayage movements.

Pandemic Impacts on Drayage Movements

We investigated three WIM sites – I-710 at LA port, SR-91 at Artesia, and SR-91 at Peralta – where higher 40ft intermodal container truck volumes were observed, as an example for our drayage movement analysis. Figure 8.3 presents the volume changes of 40ft intermodal container trucks across these three WIM sites between the average of baseline years and the year 2020.

Figure 8.3: Volume Changes on Drayage Movements



Data Source: WIM data records were obtained from California Department of Transportation (Caltrans)

The WIM site is located along the I-710 freeway, north of the I-405 freeway interchange, and captures a significant proportion of the outbound and inbound container truck volumes from and to the port of Los Angeles and Long Beach. As Figure 8.3 shows, 40ft container volumes saw a 30 percent reduction at the beginning of 2020, compared with the average of baseline years for both export and import containers. The volume reduction occurred prior to the implementation of the Stay-at-Home order in California and was likely caused by the supply chain disruption of the US's major trading partner countries such as China, which went into a lockdown three months ahead of California (Bryson, 2021). Drayage truck volumes gradually recovered after California's re-opening. Interestingly, drayage truck volumes surpassed the average of baseline years, especially in terms of export (Southbound) volumes during California's second lockdown, when China was reopening its economy. According to the goods export data from the U.S. Census Bureau, the monthly export values in the U.S. increased by approximately 10 percent from the re-opening to the second lockdown phase (U.S. Census Bureau, 2021).

As Figure 8.1 shows, both Artesia and Peralta are located along the State Route 91 freeway. The Arteria site is located between the I-710 and I-605 freeways, while the Peralta site is situated further east near the border between Orange and Riverside counties. Hence, despite their locations along the same freeway, data from these sites show dissimilar volume changes before and after the onset of the pandemic Figure 8.3). The Artesia WIM site is located near several third-party logistics companies, which serve small businesses, while the Peralta site serves as one of the gateways from the San Pedro Bay Port Complex to major warehouses in the California Inland Empire. This may reinforce the disparate effects observed during the COVID-19 pandemic, with significant negative impacts on small businesses and benefits for large e-commerce firms.

8.4 Long- and Short-haul Trailers and Domestic Containers

Trailers and domestic containers refer to the enclosed box-shaped semi-trailers which are designed to carry palletized, boxed, or loose freight. This section describes the investigation of COVID-19 impacts on long and short-haul trailers and domestic container activities and reports on how the pandemic affects their movements. In this section, we first identify trailers and domestic container trucks from other five-axle tractor-trailers through the recalibration of the model by Huyn et al (2015) using the WIM dataset obtained in this study. Second, we develop a long- and short-haul truck identification algorithm to distinguish long- and short-haul trailers and domestic containers based on their distinct axle spacing between the steering and leading drive axles, as tractors equipped with sleeper units have a longer axle spacing. Finally, we report our observations in volume changes of long- and short-haul trucks between the baseline years and the year 2020.

8.4.1 Long-haul Trailers and Domestic Containers Identification

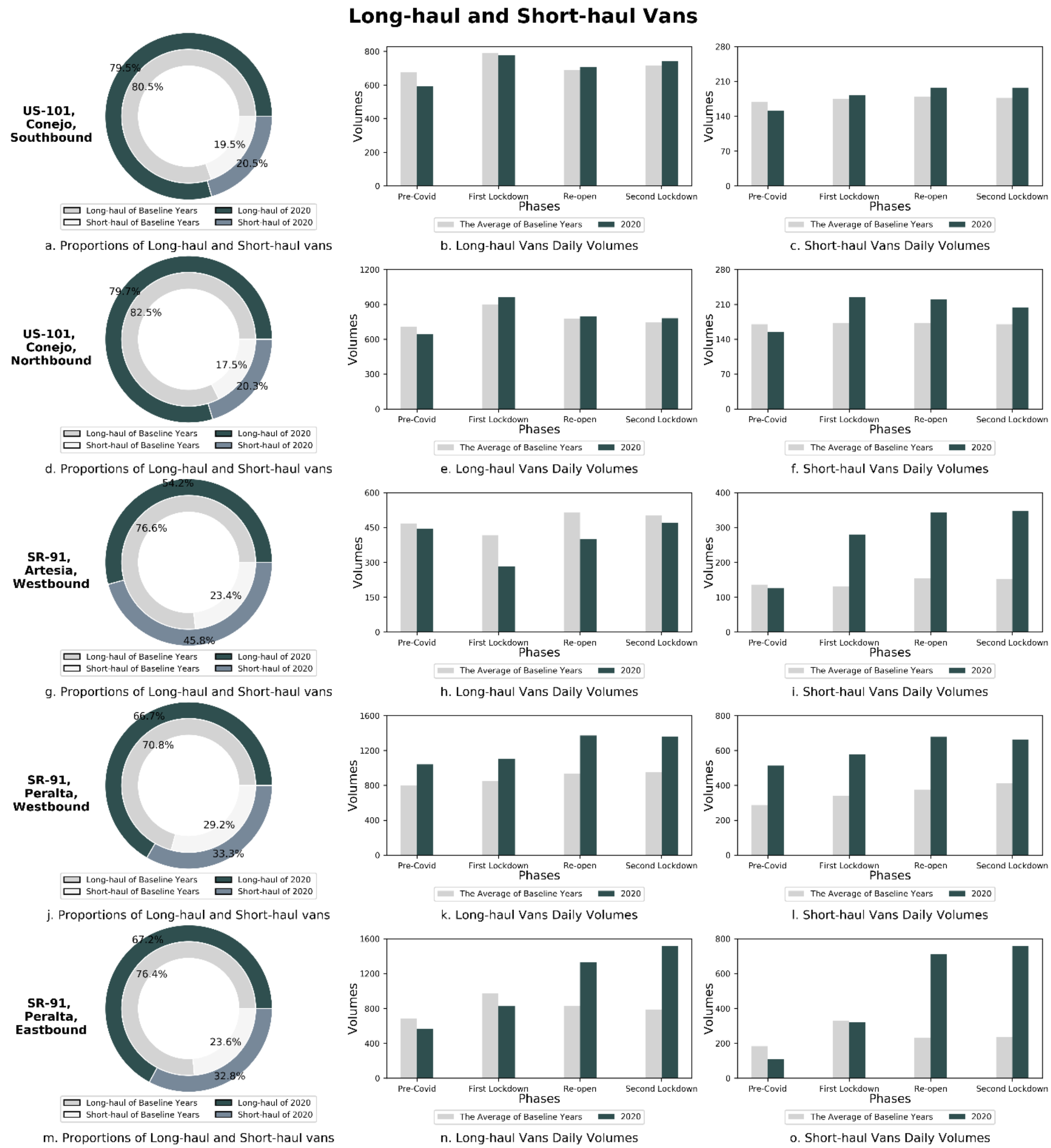
Long-haul trucks are primarily responsible for inter-regional highway freight movements. They serve as critical connectors between locations over 250 miles apart, including population centers, ports, border crossing, and many transportation hubs (Bureau of Transportation Statistics, 2013). The California Vehicle Inventory and Use Pilot Survey conducted in 2014 revealed that tractors with sleeper cabs are predominantly associated with long-haul trips to facilitate overnight rest stops commonly associated with long-haul movements. The sleeper unit attached to the rear of a tractor cab results in an extended axle spacing between the first and second axle (AS1). In this section, we utilize this physical attribute typically associated with long-haul trucks to estimate long-haul truck volumes from the collected WIM data. First, we investigate the AS1 distribution of trailers and domestic containers. Then, we group the Class 9 trailers and domestic containers into long- and short-haul trucks according to their AS1 distribution using the Gaussian Mixture

Model (GMM). Finally, we aggregate the identified long- and short-haul trailers and domestic containers at the monthly level for further analysis.

8.4.2. COVID-19 Impacts on Long- and Short-haul Trailers and Domestic Containers Movements

In this section, we focus our analysis on three urban principal interstate corridors as shown in Figure 8.4. Overall, short-haul truck volumes in 2020 increased over the baseline years and showed an increasing trend across all four phases. Short-haul trailers and domestic container trucks are commonly used to transport freight between warehouses and local retail centers.

Figure 8.4: Long- and Short-haul Truck Volume Changes



Data Source: WIM data records were obtained from California Department of Transportation (Caltrans)

At the beginning of the pandemic, the panic shopping behavior led to high demand for groceries and daily consumables. This may have influenced the increased activity of short-haul trailers and domestic containers in their attempt to re-stock emergency supplies at retail centers from regional warehouses. On the other hand, an expected corresponding significant increase in long-haul trailers and domestic containers was not observed. In hindsight, these observed disparities may have revealed the impending depletion of inventory at major distribution centers, as the demand for consumer products overwhelmed existing inventory that could not be readily replenished, as evidenced by the reduction in long-haul trucking activity. Such phenomenon has also been corroborated in survey results summarized by the American Transportation Research Institute (ATRI) and Owner-Operator Independent Drivers Assn (American Transportation Research Institute, 2020). ATRI reported that the truck trip lengths decreased during the pandemic, according to their survey results. In particular, the longest two trip categories in their survey decreased by 13.4 percent (American Transportation Research Institute, 2020).

8.5 Payload Analysis

Truck payloads refer to the maximum cargo weight that a truck can carry. It is an essential truck attribute that is considered in commodity-based freight forecasting models for freight planning applications. In this section, we extract the payload characteristics from trailers and domestic containers to understand how the proportions of full and empty load trucks changed throughout the pandemic.

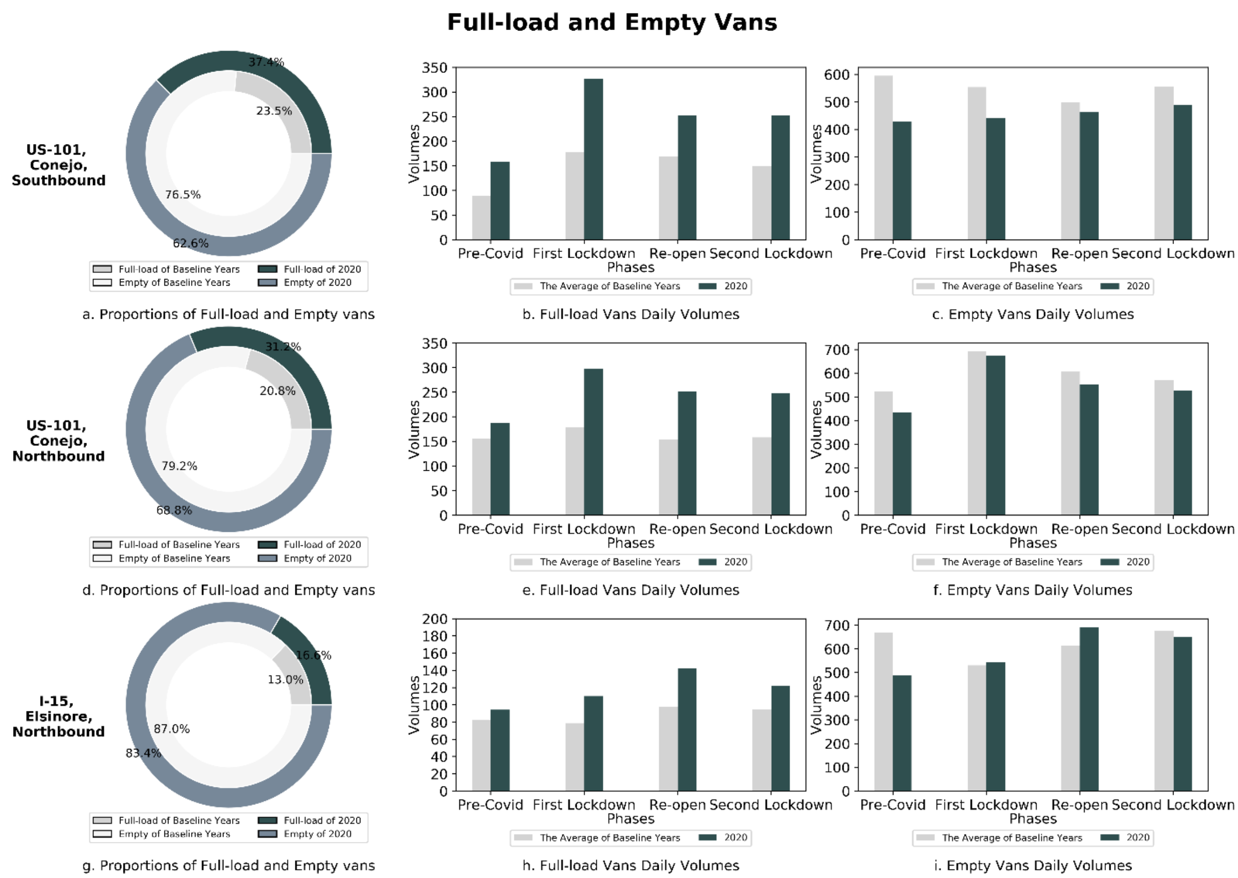
8.5.1 Payload Characterization

We developed a payload characterization model to identify empty and full-load trailers and domestic containers using WIM data. We utilized the gross vehicle weight (GVW) obtained from the WIM system and adopted GMM to estimate the decision boundary of determining empty and full-load trailers and domestic containers through the GVW distribution. The estimated empty and full-load trailers and domestic containers were aggregated at a monthly level. The average weekday volumes of each phase were used to analyze the pandemic's impacts. We excluded from our analysis partially loaded truck volumes since they are mixed with the proportion of empty trucks and the trucks which are loaded approaching the weight limit.

8.5.2 *Trailers and Domestic Containers Payload COVID-19 Impacts Analysis*

We used data from two WIM sites – US-101 at Conejo and I-15 at Elsinore –in this analysis. The US-101 WIM site captures truck activity between the Los Angeles metropolitan area (LA Metro) and the California Central Coast, while the I-15 location monitors truck movements between the San Diego and Imperial County Regions and the LA Metro. As Figure 8.5 shows, the volumes of empty trailers and domestic containers in 2020 were slightly lower than the baseline years, whereas the full-load truck volumes significantly increased. The pie chart presented on the left of Figure 8.5 shows the change of the proportion of full-load and empty trucks between the baseline year and 2020, where the inner ring represents the baseline years, and the outer ring represent 2020. While empty-load volumes remained comparable to previous years, an increase in full-load volumes was observed at both locations after the onset of the pandemic. In fact, the proportion of full-load trucks increased by around 12 percent in both directions at Conejo and 3 percent northbound at Elsinore. This increase in full-load volumes may be indicative of a change in the types of commodities hauled along these corridors, where trucks may have hauled more commodities associated with heavier payloads through these corridors, especially at Conejo. Coincidentally, the Federal Highway Administration had extended the maximum gross vehicle weight (GVW) of each truck to 88,000 lbs. for transporting emergency supplies during the COVID-19 pandemic in certain states to address driver shortages (AASHTO n.d.). However, the sustainability of this payload shift needs further investigation.

Figure 8.5: Payload Characteristics



Data Source: WIM data records were obtained from California Department of Transportation (Caltrans)

8.6. Discussions and Takeaways

In 2020, many countries implemented Stay-at-Home restrictions to curb the rapid spread of coronavirus. Pandemic related absences from work severely affected the global supply chain and created significant bottlenecks in the logistics network. At the initial phase of the pandemic, China shut down many factories in response to the crisis. However, as a critical node of the global supply chain and essential trade partner, China's lockdown had a consequential effect on the U.S. economy and impacted its highway freight movements. The reduction of freight supply and demand from China at the beginning of 2020 and the immense freight demand surge in the

U.S. resulted in year-on-year container counts decrease and subsequent increases, which significantly affected the portside truck traffic. In addition, the COVID-19-related travel restriction changed personal travel behavior and the demand for essential goods due to panic purchasing, and subsequently reshaped the truck travel distance and the weight distribution. This chapter focused on investigating the truck volume changes at specific locations along major freight corridors near the Port of Los Angeles to observe truck count changes between the baseline years and the year 2020. We mainly focused on truck activity changes in three different aspects: drayage, long- and short-haul movement, and payload characteristics.

8.6.1. Drayage Movements

According to the volume changes along I-710, the drayage truck volume reduction started before the observed outbreak of COVID-19 in California and aligned with the timeline of global supply chain disruption. Not surprisingly, the drayage movement appeared closely linked to the global supply chain at the port area. Drayage truck data collected from urban principal arterials shows that the drayage volume changes are dissimilar for different truck routes. The drayage movements on the truck routes connected to third-party warehouses serving small businesses were reduced, while the drayage movements serving large e-commerce warehouses showed significant increases. The drayage truck movements were reshaped during the year 2020 for major drayage corridors.

8.6.2. Long- and Short-haul Movements

The WIM data collected from urban principal arterials showed a slight reduction of long-haul truck volumes. On the contrary, the short-haul movements increased significantly over baseline years. Similar results have also been found in the survey data reported by ATRI (American Transportation Research Institute, 2020). The observation of increased short-haul movements could be explained in part by the transportation of consumer goods from local warehouses to retail centers to meet increased consumer demands, while the reduction in long-haul truck movements could reflect the industries' inability to replenish inventory at the major distribution centers.

8.6.3. Payload Characteristics

The WIM data collected from the urban inter-state truck corridor presents the change in payload characteristics from the baseline year to the year 2020. The volume of empty trucks saw a slight reduction, while full-load trucks saw a significant volume increase. The increase of trucks with full payloads may be indicative of a change in the types of commodities hauled due to the pandemic's impact. A more in-depth analysis of changes in commodities would involve more complex tools such as the commodity-based California Statewide Freight Forecasting Model.

The analysis performed in this chapter is meant to provide an overview of the multifaceted impacts of CoVID-19 on the freight trucking industry. While fairly abbreviated, this analysis clearly demonstrates the disparate impacts this pandemic has had on trucking activity as a consequence of local and foreign policies, supply chain bottlenecks, and the dynamic changes in consumer behavior. Due to the ongoing effects of the pandemic, it is not yet possible to distinguish between transient and long-term impacts on freight trucking activity. Nonetheless, a future expansion of the study area and the incorporation of other complementary data sources may provide further insights into the COVID-19 impacts on freight movement.

8.7. References

AASHTO (n.d.) Maximum Gross Vehicle Weights During the COVID-19 Pandemic. https://systemoperations.transportation.org/maximum-gross-vehicle-weights-during-the-covid-19-pandemic/#:~:text=Close-,Maximum%20Gross%20Vehicle%20Weights%20during%20the%20COVID%2D19%20Pandemic,during%20the%20COVID%2D19%20pandemic.

ABCO Transportation (2018) What is Drayage Service and How It Works for You. https://www.shipabco.com/what-is-drayage-service-and-how-it-works-for-you/. Accessed 29 Jul 2021

American Transportation Research Institute and The OOIDA Foundation (2020, April) COVID-19 Impacts on the Trucking Industry. https://truckingresearch.org/wp-content/uploads/2020/05/ATRI-OOIDA-COVID-19-Impacts-on-the-Trucking-Impacts-05-2020.pdf. Accessed 29 September 2021.

Approved: A Dewit Company website "Think You Need a 20′ Shipping Container? 3 Reasons to Reconsider." n.d. https://www.approvedforwarders.com/20-vs-40-ft-shipping-containers/. Accessed 29 July 2021

Bhattacharjee D, Gould R, Greenberg E, and Kandel M (2020) US Freight after COVID-19: What’s next. https://www.mckinsey.com/industries/travel-logistics-and-infrastructure/our-insights/us-freight-after-covid-19-whats-next. Accessed 21 Jul 2021

Bryson D (2021, March 17). A Timeline of the Coronavirus Pandemic.*New York Times*. https://www.nytimes.com/article/coronavirus-timeline.html. Accessed 4 Aug 2021

Bureau of Transportation Statistics (2013) Freight Facts and Figures, Washington, DC: Federal Highway Administration

Federal Highway Administration (2013; updated October 2016) Traffic Monitoring Guide. Washington, DC: FHWA, https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_fhwa_pl_17_003.pdf

Harapko S (2021) How COVID-19 Impacted Supply Chains and What Comes Next.

https://www.ey.com/en_us/supply-chain/how-covid-19-impacted-supply-chains-and-what-comes-next. Accessed 5 Jul 2021

Hernandez S and Baker J (2019) Final Report: Evaluation of WIM Auto-Calibration Practices and Parameters. TRC 1801. https://cpb-us-e1.wpmucdn.com/wordpressua.uark.edu/dist/d/793/files/2020/01/TRC1801-Final-Report-10042019.pdf. Accessed 29 September 2021.

Hyun K, Hernandez S, Tok A, and Ritchie SG (2015) Truck body configuration volume and weight distribution estimation by using weigh-in-motion data. *Transportation Research Record* 2478:103–112. https://doi.org/10.3141/2478-12

Molloy J, Schatzmann T, Schoeman B, et al (2021) Observed impacts of the Covid-19 first wave on travel behavior in Switzerland based on a large GPS panel. *Transport Policy* 104: 43–51. https://doi.org/10.1016/j.tranpol.2021.01.009

Port of Long Beach (2021) Port Statistics. https://polb.com/business/port-statistics/#teus-archive-1995-to-present. Accessed 23 Sep 2021

Port of Los Angeles (2021) Container Statistics. https://www.portoflosangeles.org/business/statistics/container-statistics. Accessed 4 Aug 2021

Regan A and Saphores J (2020) Will COVID-19 Worsen California's Truck Driver Shortage ? *UC Office of the President: University of California Institute of Transportation Studies*. http://dx.doi.org/10.7922/G2X63K72 Retrieved from https://escholarship.org/uc/item/0js6k8tc

U.S. Census Bureau (2021) Monthly U S International Trade in Goods and Services, March

Vitale J (2020) Understanding COVID-19's Impact on the Automotive Sector. https://www2.deloitte.com/global/en/pages/about-deloitte/articles/covid-19/understanding-covid-19-s-impact-on-the-automotive-sector.html. Accessed 5 Jul 2021

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