Containing Compounding Container Congestion

Curtis Salinger

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Containing Compounding Container Congestion
Historic Port of Los Angeles Congestion and the Efforts to Alleviate it

submitted to
Professor Mark Huber

by
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Abstract

The Covid-19 pandemic caused major disruptions throughout the container shipping supply chain. Professor Dongping Song of Liverpool University wrote a paper discussing the logistical vulnerabilities in the supply chain, including the issue of congestion in ports. This paper examines the Port of Los Angeles from 2018-2021 as it relates to Song’s paper to see how its operations were impacted during the Covid-19 timeframe. It is found that labor shortages, chassis shortages, and change in trade behavior each contributed to the congestion. Unfortunately, the implemented policies were insufficient to bolster the port against sustained challenges and congestion continues to worsen.
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1 Introduction

One of the most prevalent news topics in the early 2020s has been the supply chain.\textsuperscript{1,2,3} A simple Google search can reveal pages of articles about how issues and bottlenecks in the supply chain are driving inflation and causing global shortages of all types of products, from baby formula\textsuperscript{4} to microchips.\textsuperscript{5} With the Covid-19 pandemic causing mass disruption starting in 2020 and persisting until today, solving supply chain issues has become a paramount interest for governments and companies around the world.

While supply chains of different products may be comprised of various modes of transport, one of the most central components of many supply chains is the shipping container. With 80% of the world's cargo traveling over the ocean, and over 60%\textsuperscript{6} of that cargo traveling in cargo containers, having fluid and efficient logistics for this system is imperative to keep global cargo moving. The world has seen in the past few years the outsized impact that supply chain disruptions cause.

Recognizing that this was such an important problem, Dongping Song Ph.D.-a professor at Liverpool University Management School specializing in operations and supply chain management-published a paper for the Multidisciplinary Digital


Publishing Institute’s (MDPI) 2021 special issue on Optimization and Management in Maritime Transportation. His paper outlines current issues with the supply chain and areas that he sees further research opportunities for. He dissects the entirety of the container shipping supply chain (CSSC) and outlines different logistical difficulties presented at each step of the way. With respect to Port/Terminal logistics, Song emphasizes the need for further improvements in dealing with port congestion after seeing the disruption that congested ports had in 2020 and 2021.

In this paper, I will provide a case study of the Port of Los Angeles (POLA) and its state of affairs from 2018-2022. I will first provide an overview of its typical operations and operational capacity, and then track how the port’s activities changed during the time period. Through this analysis, I find that increases in the duration of time that it takes to process a ship at the port, labor shortages across the entire supply chain, and change in the types of import vs export that the POLA experienced are each causes of the congestion within the port. Then I analyze the efforts that were made to ease the congestion within the port.

2 Dongping Song’s Framework on Logistics

In this section, I provide an overview of Professor Dongpin Song’s paper A Literature Review, Container Shipping Supply Chain: Planning Problems and Research Opportunities published by MDPI in their Logistics journal in a special issue titled Optimization and Management in Maritime Transportation released June 21, 2021. In this article, Dongping Song provides an extensive background of the Container Shipping Supply Chain (CSSC) and argues what he believes to be the two most pressing issues in the CSSC: digitization and decarbonization. In this literature

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review, I focus primarily on the logistical segments from his paper. All information in this section, unless otherwise noted, is cited from Song’s paper.8

Container shipping is a beneficial practice since a single, uniform container can be used from start to finish, regardless of the cargo that is being carried. Once loaded at the point of origin, the cargo is moved as one singular unit until it reaches its destination where it can be unloaded. The uniformity of the containers allows them to be stacked on any of the vehicles used throughout the shipping process (including trains, ships, and trucks), as well as allows them to be handled by all of the auxiliary equipment.

Dongping Song breaks up the CSSC into five business segments:

1. Shipment arrangement
2. Container management
3. Seaborne transport
4. Port and terminal management
5. Inland transport and depot management

and five corresponding logistics management segments:

1. Freight Logistics
2. Container Logistics
3. Vessel Logistics
4. Port and Terminal Logistics
5. Inland Transport Logistics

8Song, “A Literature Review, Container Shipping Supply Chain.”
Noted in the paper is that the logistics optimization is what makes the business segments particularly valuable.

2.1 Freight Logistics

Freight Logistics focuses on the high-level planning of the cargo’s journey. Much of this process happens before any cargo is actually shipped and instead, attempts to optimize the path that will be taken. Freight Logistics is done mainly by companies referred to as freight forwarders. When a company wants to ship their goods, they will contract a freight forwarder who then deals with the shipping logistics. Important duties of the freight forwarder include: determining which mode of transportation to use at which phase of the cargo’s journey, negotiating pricing and delivery terms with contracted ocean shipping partners, customs and import compliance management, consolidation of mutual clients’ goods to optimize container use, and shipping scheduling.

Since shipping containers have the unique advantage of standard sizing, freight forwarders employ intermodal transportation to make the shipping as efficient as possible. Given an ocean vessel, a train, a barge, and a truck each have their own distinct advantages, one of the main focuses of freight logistics is determining what modes of transportation to use for the most efficient transport. Many models have been developed to assist this optimization using different methods including top down and bottom up approaches. The former which optimizes the overall network and pays less attention to the individuals, and the latter which address each company as individual agents which is much more representative of the actual market given companies often operate as independent entities. Song gives examples of these methods which come from many different perspectives such as the freight forwarder’s perspective, the shipper’s perspective, the port’s perspective. Each of these models uses a different
process to try and improve the overall system.

On top of these noted research areas, Song notes the six areas for further exploration he sees in freight logistics:

1. Contracts between shippers and shipping lines where the contract entails solely ocean transport vs ocean and continued inland transport.

2. Terms of sale that dictate at what stage shipping ownership is transferred from shipper to importer.

3. Selection of carriers and services to hedge against industry volatility.

4. Long term contracting risk.

5. Employing synchro-modal transportation (flexibility on the carriers behalf to select whichever mode of transportation is the most efficient during the shipping process).

6. Further development of models to optimize the shipping process.

2.2 Container Logistics

Container Logistics focuses on the actual physical units themselves, and is often managed by the shipping companies. Drewry measured the global container fleet size at over 37 million twenty-foot equivalent units (TEUs) in 2018 with approximately half owned by shipping lines themselves, and half owned by companies who lease them out to shippers. Song indicates that with the exception of the shipping vessel, the containers are the second most important capital investment for a shipping company. Clearly since there is such a large number of containers in circulation, having an efficient and effective method of managing them would improve the industry.
Container logistics deals with how to process containers, which differs depending on if a container is empty, or if there are goods in the container-called a laden container. When a container is laden, the route is dictated by the necessary destination of the container. In these instances, the shipping company decides what types of containers to use, and how to best and most efficiently ship them. For example, when a company opts for a slower shipping speed they may save on fuel cost, but they will need more containers to fulfill all of their duties since many of their containers will be busy in transit.

When a container is empty, the strategy for the shipping company is to relocate the container to the most optimal location for it to be filled and used again, called Empty Carrier Repositioning (ECR). Having a container sit idle is not only an inefficient investment, but it is net negative since the company has to manage storage of the container. During Covid, a surplus of empty containers clogged major shipping ports throughout the world and drove a major backlog in the CSSC (more on this further on in the paper).

Song cites many mathematical models that have been and continue to be developed to optimize ECR vs laden container movement and he notes the following five areas he sees for further research in container logistics:

1. Integrating all of the components of container logistics by establishing stakeholder collaboration

2. Researching ECR’s effect on ports and shipping lines, particularly during high demand volatility, and find optimum strategy for managing empty containers

3. Financial penalty for customers who hold their containers too long while offloading, and likewise, determining when and where to perform container maintenance for containers that are supposed to be in continuous use
4. Internalizing social and environmental impacts of ECR

5. Examine the issues that could be solved by organizational changes, intra-channel and inter channel measures, or technological measures, and explore the relationship between those measures to optimally solve more problems

2.3 Vessel Logistics:

Shipping vessels are the largest and most important capital investment for shipping companies, so using them effectively is paramount to shipping companies success. Vessel logistics seeks to optimize the movement and usage of the over 5,400 container ships in the global fleet.\(^9\) Song breaks down vessel logistics into three categories: strategic, tactical, and operational planning.

Strategic planning includes: trade routes and market coverage (not the specific paths, but where to serve); horizontal partnering; competition assessment; vertical partnering; contract negotiation and strategy; and all things vessel related-design, fuel, and number of ships to have on fleet vs contract. Researchers and companies are trying to improve strategic planning by fostering collaboration between different stages of the CSSC to provide better transparency throughout and thus, improve the ability for all sides to plan.

Tactical planning includes: Shipping network; where and when to deploy which part of the fleet; route planning; scheduling; service and maintenance planning; ship fleet management. Uniquely presented with the CSSC is the regularity of the shipments, which makes alterations to fleet deployment difficult.

Operational planning includes: Pricing; ECR; vessel speed optimization; rescheduling; Disruption management (weather, event); Container storage; vessel

loading and unloading. One issue with the operational planning is that it manifests as short term tactical planning so the distinction between the two is difficult, however, operational planning is highly active and variable. Many of the operational planning duties are reactive instead of proactive. During the incredibly variable supply and demand during the Covid-19 shutdowns, ECR became a primary focus, and it presented incredible challenges for ports and shipping lines who needed to balance ECR when there were so many empty containers occupying much of the CSSC.

Due to the routine nature of vessel shipment, there are overall market expectations that vessels remain on schedule, regardless of their capacity utilization. Since CSSC serves the entire globe, there is incredible pressure on shipping companies to uphold complex relationships with importers and exporters, and it results in outsized impact when disruptions occur.

Song indicates that there is much research occurring on vessel logistics improvement, but notes that the following areas should be further explored:

1. Many optimization models undermine the risk-averse preferences throughout the CSSC, so the deterministic situations and risk-neutral aspects of the models are irreflective of the actual CSSC

2. Shipping lines have pivoted from cost-cutting to profit optimizing strategies which could be studied further

3. Severe disruption, such as Hanjin Shipping going bankrupt in 2016, led to worldwide challenges, so shipping lines should devote more efforts towards ship financing and cashflow optimization to achieve competitive advantage

4. While the CSSC is highly repetitive and dependable, it is also quite fragile to global events such as geopolitical conflict and Covid-19, more can be done to
anticipate, or at least improve the ability to respond to these disruptions

5. Crew management became a high point of focus during Covid-19 and it exposed a lack of attention paid to crew scheduling and management in the shipping industry.

6. The six day Suez Canal blockage during March 2021 resulted in over 350 ships halted waiting for passage with many ships attempting to re-route around the constrained passageway, this exposes the need for better contingency planning particularly where capacity limited infrastructures.

2.4 Port and Terminal Logistics

Ports are the intermediary between shipping vessels and inland cargo transport—generally trucks and trains. Ports have a large suite of machinery to optimize their ability to offload vessels onto the appropriate next mode of transport. Minimal loading and unloading time is optimal as the port can then service more vessels more quickly. Many operations research papers have studied all aspects of port logistics including planning, storage, stacking, and intermediate (quayside, landside) transport.

Port/terminal logistics problems are laid out in the following slightly modified table from Song’s paper (Modified is that the Across Processes section was moved from its own column to the bottom to allow the table to fit better on the page):

<table>
<thead>
<tr>
<th>Type</th>
<th>Quayside</th>
<th>Yardside</th>
<th>Landside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic</td>
<td>Berth layout; Quay crane selection</td>
<td>Yard layout; Yard equipment</td>
<td>Gate layout; Rail terminal layout</td>
</tr>
</tbody>
</table>
Table 1: Port/Terminal Logistical Factors (continued)

<table>
<thead>
<tr>
<th>Type</th>
<th>Quayside</th>
<th>Yardside</th>
<th>Landside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tactical</td>
<td>Berth allocation; Quay crane assignment</td>
<td>Storage planning;</td>
<td>Vehicle booking system; Rail service planning</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Resource assignment</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Quay crane scheduling;</td>
<td>Yard crane scheduling;</td>
<td>External truck handling; Wagon</td>
</tr>
<tr>
<td></td>
<td>Loading/unloading;</td>
<td>Container relocation;</td>
<td>Shunting; Workforce</td>
</tr>
<tr>
<td></td>
<td>Workforce scheduling;</td>
<td>Workforce scheduling;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Internal truck scheduling;</td>
<td>Internal truck scheduling</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Equipment scheduling</td>
</tr>
<tr>
<td>Across</td>
<td>Port competition; Port cooperation</td>
<td>Integration;</td>
<td>Terminal layout; IT systems</td>
</tr>
<tr>
<td>Processes</td>
<td>Multi-modal interfaces</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Song notes that most of the research performed related to ports is that of the quayside operation as it is frequently the bottleneck of the CSSC during the port stage. (Note that a quay is defined as: “A man-made bank or landing stage, typically built of stone, lying alongside or projecting into water for loading and unloading ships.”\(^{10}\))

The studies have focused largely on the proper allocation of quay cranes and berths so ships can be taken care of as efficiently as possible. At the quay, the containers are offloaded from the ship and are then loaded onto another part of the port apparatus. This is port dependent, but examples are onto quayside railways which take the cargo

to an additional staging area where it can then be further sorted, or it can be loaded onto other types of vehicles.

Notably, there is quite a bit of automation during this part of the process. While the quay cranes that unload the cargo from the ships are generally operated manually, (though automated cranes are in trial in Singapore)\textsuperscript{11} these cranes may put a container onto an automated rail or autonomous truck which takes the container to a predetermined location to be stacked by an automated stacking crane.\textsuperscript{12} Song notes that the research in the quayside stage is searching for ways to integrate the strategic, tactical, and operation planning to create an overall more effective system. While logistical processes and planning are being studied, so too is more effective machinery.

Yardside operations is a combination of crane, vehicle, and space management. Crane and vehicle management refers to the stacking and temporary storage of containers during the time between being loaded or offloaded from the vessel, and being collected for the appropriate inland route. Space management handles storing containers in optimal locations to use the ports space most efficiently. Yard logistics must also take into account the empty containers that are being stored in the yard as part of ECR discussed above. In the yard, every shuffling or relocation of containers is costly, so optimizing this is highly important to run an effective yard.

Landside operations has two components: the gate system, which handles the trucks that are picking up or dropping of containers, and the rail terminal, which handles the operation of the freight rails. Most of the research and optimization


being done is for the vehicle interfacing as the rail traffic is generally nominal in ports.

Song indicates the following areas that further research should be done on the port/terminal phase of the CSSC:

1. A further development of disruption planning due to natural or unnatural occurrences

2. Port congestion is incredibly disruptive in the CSSC, particularly during 2020 where many international ports had immanigable congestion, largely of empty containers

3. While many problems have proven to be NP-hard, redesigning research or the target problem would help researchers achieve actionable solutions

4. With the goal to have quayside decisions take less than a second, and yardside decisions take less than a minute, more efficient heuristic algorithms should be designed

5. Logistics should factor in environmental and social impact to reduce emissions and other negative externalities

6. By developing trust and transparency in this stage, more efficient results can be achieved.

2.5 Inland Transport Logistics

This encompasses everything after the vessel has been unloaded and the cargo containers have left the ports. Inland transport logistics manages the operations of the fleets of vehicles needed to transport the cargo-most often trucks, trains, and sometimes barges- and the container auxiliaries such as depots and equipment. The system
consists largely of trains and barges which run on consistent routes and schedules, whereas trucks operate on a more ad hoc basis. These vehicles may transport cargo to depots throughout the country to perform unpacking, servicing, cargo consolidation, and container storage—whether laden or empty.

Much research is being done on inland transportation logistics, given its high impact on the CSSC. Inland transportation enables mass dispersion from the ports into land-locked regions and affords customers a first-and-last mile shipping experience. Researchers are trying to address concerns about road traffic congestion, environmental impact, and safety impact that inland transport has.

The following table from Song’s paper contains the planning problems that inland transport logistics experiences:

Table 2: Inland Transport Logistics Sectors

<table>
<thead>
<tr>
<th>Logistics Sectors</th>
<th>Planning Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck operations</td>
<td>Truck fleet management; Truck pooling and sharing; Container drayage; Vehicle booking system; Empty vehicle repositioning; Empty container repositioning; Truck routing and scheduling; Disruptive event management.</td>
</tr>
<tr>
<td>Rail &amp; barge service</td>
<td>Rail/barge route design; Service timetable design; Wagon shunting; Barge vessel stowage planning; Rail-car fleet management; Empty rail-car repositioning; Container loading and unloading; Transport mode choice; Carrier selection.</td>
</tr>
</tbody>
</table>
Table 2: Inland Transport Logistics Sectors (continued)

<table>
<thead>
<tr>
<th>Logistics Sectors</th>
<th>Planning Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inland depot</td>
<td>Depot/dry port location; Inland container transport network design; Depot layout; Container storage; Container repair and maintenance; Container substitution; Demurrage and detention; Loading and unloading; Consolidation and unpacking.</td>
</tr>
<tr>
<td>Across Processes</td>
<td>Terminal layout; IT systems</td>
</tr>
</tbody>
</table>

One of the heavily researched aspects of inland transport logistics is how to strengthen the connections between ports and the inland network via trains and barges. Given that these two modes of transport operate with high capacity and consistency, the partnership allows for the increase of port capacity by freeing up much of the yard space. There has also been focus on measuring the benefits of intermodal transport vs truck-only transport, as well as how to better preemptively plan out container movement to take advantage of the full capacity of the rail system.

Song points out other areas that he believes should garner more focus:

1. Better dynamic models should be developed to manage the different states of transport-empty/laden, import/export

2. Given the expansive nature of the CSSC, improved transparency from inland shippers would better inform other stakeholders in the chain, particularly ports, as to how planned timetables may be altered

3. Studies should pair the movement of empty vehicles with ECR to help reduce the
number of vehicles that move empty, as well as the number of empty containers that occupy space on shipments

4. There should be an overall analysis of the environmental impact of the inland transport phase of the CSSC

5. An exploration of horizontal integration and collaboration of companies could drastically reduce the number of empty vehicles moving, the key would be how to structure the relationship

6. Given that environmental regulations are likely to be imposed by many governments, preemptive planning is necessary to minimize disruption when the time comes

3 Data Gathering and Cleaning

Data for this thesis came from a variety of different public online sources. On top the many footnoted articles, journal articles, and public statements, this article drew data from the Port of Los Angeles (POLA) website, and the LA


3.1 Container Data

The container statistics for this paper were all publicly available from the Port of Los Angeles website.\textsuperscript{21} They publish yearly container statistics as HTML tables on their website. In order to extract the data from their website, I utilized an online HTML Table to CSV Converter: https://www.convertcsv.com/html-table-to-csv.htm. So, I would go onto the POLA website, use Google Chrome’s inspect element feature, copy the HTML tabel code, and then paste it into the converter. After pasting it into the converter, I would convert the HTML to a csv format, and then download the file. From here, I was able to use R’s \texttt{readr} package to load the data in and manipulate it as needed in R.

Screenshots of the process below:


container_2015 <- read_csv(file =
  "ContainerStats/2015ContainerStats.csv")

container_2016 <- read_csv(file =
  "ContainerStats/2016ContainerStats.csv")

container_2017 <- read_csv(file =
  "ContainerStats/2017ContainerStats.csv")

container_2018 <- read_csv(file =
  "ContainerStats/2018ContainerStats.csv")

container_2019 <- read_csv(file =
  "ContainerStats/2019ContainerStats.csv")

container_2020 <- read_csv(file =
  "ContainerStats/2020ContainerStats.csv")

container_2021 <- read_csv(file =
  "ContainerStats/2021ContainerStats.csv")

After completing this process for years 2015-2021, I added a Year column to each of the data frames so that I could easily access and group the data by the year that it was coming from.

container_2015 <- container_2015 |> mutate("Year" = 2015)

container_2016 <- container_2016 |> mutate("Year" = 2016)

container_2017 <- container_2017 |> mutate("Year" = 2017)

container_2018 <- container_2018 |> mutate("Year" = 2018)

container_2019 <- container_2019 |> mutate("Year" = 2019)

container_2020 <- container_2020 |> mutate("Year" = 2020)

container_2021 <- container_2021 |> mutate("Year" = 2021)

I then combined all of these data frames into one so that I could start to examine
statistics about the data across the years. I also renamed the columns so that they were easier to manage in R.

```r
container_stats <- rbind(container_2015, container_2016,
                         container_2017, container_2018,
                         container_2019, container_2020,
                         container_2021)
names(container_stats) <- c("Month", "LoadedImports",
                         "EmptyImports", "TotalImports",
                         "LoadedExports", "EmptyExports",
                         "TotalExports", "TotalTEUsChar",
                         "PriorYearChange", "Year")
```

After combining all of the data, I noticed that the `TotalTEUs` column had loaded in as a `char` instead of a `dbl`, so I used the `readr::parse_number` function to create a new column that would have `dbl` values for the `TotalTEUs`.

```r
container_stats <- container_stats |> 
                  mutate(TotalTEUs = parse_number(TotalTEUsChar))
```

At this point, I had all of my data cleaned and organized as shown by a few columns below.

```r
container_stats | head() |>
select(1:4) | kable(booktabs = T) |>
kable_styling(latex_options = c("repeat_header", "striped"))
```

From here, I needed to perform some alterations so that I could draw more informative data from this data frame. First, I grouped the data by the Month
<table>
<thead>
<tr>
<th>Month</th>
<th>LoadedImports</th>
<th>EmptyImports</th>
<th>TotalImports</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>259206.5</td>
<td>8737.25</td>
<td>267943.7</td>
</tr>
<tr>
<td>February</td>
<td>254225.3</td>
<td>5730.75</td>
<td>259956.0</td>
</tr>
<tr>
<td>March</td>
<td>430898.0</td>
<td>8311.30</td>
<td>439209.3</td>
</tr>
<tr>
<td>April</td>
<td>328140.2</td>
<td>11453.50</td>
<td>339593.8</td>
</tr>
<tr>
<td>May</td>
<td>348427.0</td>
<td>11258.30</td>
<td>359685.3</td>
</tr>
<tr>
<td>June</td>
<td>368708.5</td>
<td>9072.10</td>
<td>377780.6</td>
</tr>
</tbody>
</table>

and the Year so that when I performed aggregating functions on the data, it would calculate in monthly and yearly bins. Then, I used `dplyr`'s summarize command to generate mean data for all of the columns.

```r
container_means <- container_stats |
  group_by(Month, Year) |
  filter(Month %in% c("January", "February", "March", "April", 
                       "May", "June", "July", "August", "September", 
                       "October", "November", "December")) |
  summarize(meanLoadedImports = mean(LoadedImports),
            meanEmptyImports = mean(EmptyImports),
            meanTotalImports = mean(TotalImports),
            meanLoadedExports = mean(LoadedExports),
            meanEmptyExports = mean(EmptyExports),
            meanTotalExports = mean(TotalExports),
            meanTotalTEUs = mean(TotalTEUs)) |

container_means$Month <-
  factor(container_means$Month, levels =
            c("January", "February", "March", "April", "May",
              "June", "July", "August", "September", "October",
```
<table>
<thead>
<tr>
<th>Month</th>
<th>Year</th>
<th>meanLoadedImports</th>
<th>meanEmptyImports</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>2015</td>
<td>328140.2</td>
<td>11453.50</td>
</tr>
<tr>
<td>April</td>
<td>2016</td>
<td>343574.1</td>
<td>10629.45</td>
</tr>
<tr>
<td>April</td>
<td>2017</td>
<td>372040.9</td>
<td>9475.75</td>
</tr>
<tr>
<td>April</td>
<td>2018</td>
<td>361108.3</td>
<td>11418.00</td>
</tr>
<tr>
<td>April</td>
<td>2019</td>
<td>360744.7</td>
<td>17598.85</td>
</tr>
<tr>
<td>April</td>
<td>2020</td>
<td>370111.0</td>
<td>4075.00</td>
</tr>
</tbody>
</table>

So now, I had all of the data in the proper groupings. However, I realized that if I wanted to plot multiple columns against each other, it would be helpful to gather the data to have one column of Metrics, and then a corresponding column for the Value. This way, I could group by metric type, and plot different metrics against each other, which I will show later.

The following plot shows the resulting means broken down by month and year.
<table>
<thead>
<tr>
<th>Month</th>
<th>Year</th>
<th>Metric</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>2015</td>
<td>meanLoadedImports</td>
<td>328140.2</td>
</tr>
<tr>
<td>April</td>
<td>2016</td>
<td>meanLoadedImports</td>
<td>343574.1</td>
</tr>
<tr>
<td>April</td>
<td>2017</td>
<td>meanLoadedImports</td>
<td>372040.9</td>
</tr>
<tr>
<td>April</td>
<td>2018</td>
<td>meanLoadedImports</td>
<td>361108.3</td>
</tr>
<tr>
<td>April</td>
<td>2019</td>
<td>meanLoadedImports</td>
<td>360744.7</td>
</tr>
<tr>
<td>April</td>
<td>2020</td>
<td>meanLoadedImports</td>
<td>370111.0</td>
</tr>
</tbody>
</table>

\[
\text{container\_means\_plot} \mid\rangle
\]

\[
\text{filter(Year } \%\text{in} \% \text{c("2018", "2019", "2020", "2021")}) \mid\rangle
\]

\[
\text{ggplot()} +
\]

\[
\text{geom\_bar(aes(x = Year, y = Value, fill = Month),}
\]

\[
\text{stat = "Identity", position = "dodge"} +
\]

\[
\text{theme(axis.text.x = element\_text( angle = 45))} +
\]

\[
\text{facet\_wrap(~Metric, scales = "free")} +
\]

\[
\text{labs(title = "Container Means by Month and Year",}
\]

\[
\text{subtitle = "2018-2020")}
\]
3.2 Vessel Data

I went through a very similar process to gather the data for vessels. The vessel data was also all available on the POLA website\textsuperscript{22}, however this was in a different format. Instead of integrated into the website as an HTML table, this was all reported daily in a 10 page PDF. To gather this data, I used an online PDF to Excel Converter: https://www.pdftoexcelconverter.net/. I first downloaded the PDFs from the POLA website, and then uploaded them to the tool. From here, I downloaded the csv files that were generated, cleaned them up in Excel, making sure to remove the duplicate headers that were present from each page, and then loaded them into R.

vessels_2018 <-
read_xlsx("POLAContainer-Vessel-Activity-Summary-2018.xlsx")
vessels_2019 <-
read_xlsx("POLAContainer-Vessel-Activity-Summary-2019.xlsx")
vessels_2020 <-
read_xlsx("POLAContainer-Vessel-Activity-Summary-2020.xlsx")
vessels_2021 <-
read_xlsx("POLAContainer-Vessel-Activity-Summary-2021.xlsx")
vessels_data <-
  rbind(vessels_2018, vessels_2019, vessels_2020, vessels_2021)

Since all of this data was daily, I used the R package lubridate to extract a Month and Year out of the data, and renamed the columns so they were more intuitive. Finally, there were 9 NA values dispersed throughout the data set, and since I had plenty of data, I removed the NA rows from the dataset.

vessels_data <- vessels_data |
  mutate (Date = as.Date(vessels_data$Date,"%m/%d/%Y"))
vessels_data <- vessels_data |
  mutate(Month = month(Date, label = TRUE, abbr = FALSE),
         Year = year(Date))
names(vessels_data) <- c("Date", "POLAVesselsAtAnchor",
                          "POLAVesselsAtBerth", "POLAVesselsDeparted",
                          "AverageDaysAtBerth","AverageDaysAtANCBerth",
                          "Month","Year")
vessels_data <- drop_na(vessels_data)

Now that I had all of the data cleaned and organized, I again pulled all of the
mean values, grouping by Month and Year again. I also gathered the data into a Metrics and Value column again so that I could plot the data.

```r
vessels_means <- vessels_data |
  select(-Date) |
  group_by(Month, Year) |
  summarise(
    meanPOLAVesselsAtAnchor = mean(POLAVesselsAtAnchor),
    meanPOLAVesselsAtBerth = mean(POLAVesselsAtBerth),
    meanPOLAVesselsDeparted = mean(POLAVesselsDeparted),
    meanAverageDaysAtBerth = mean(AverageDaysAtBerth),
    meanAverageDaysAtANCBerth = mean(AverageDaysAtANCBerth)
  )

vessels_means_plot <- vessels_means |
  gather(key = "Metric", value = "Value", 3:7)
```

Again, the data transformations and calculated means are showcased in the plot below, broken up by month and year.

```r
vessels_means_plot |
  ggplot() +
  geom_bar(aes(x = Year, y = Value, fill = Month),
            stat = "Identity", position = "dodge") +
  theme(axis.text.x = element_text( angle = 45)) +
  facet_wrap(~Metric, scales = "free") +
  labs(title = "Vessel Means by Month and Year",
       subtitle = "2018-2020")
```
3.3 California Covid-19 Data

Importing this data was very simple. On the California Health & Human Services Agency website\(^{23}\), they had all of the Covid-19 data available to download in a csv format. So I simply downloaded the data, and loaded it into R. Once I loaded the data into R, I again used the `lubridate` package to extract the Month and Year out of the data. Finally, I grouped by month and year, and plotted the data.

```r
Covid_data <- read_csv(file = "covid19cases_test.csv")
Covid_data <- Covid_data |
  mutate(Month = month(date, label = TRUE,

Covid_data <- Covid_data |\> filter(area == "Los Angeles") |\> drop_na()

Covid_data |\>
\>
\>
\>
\>
group_by(Month, Year) |\>
\>
ggplot() +
\>
geom_bar(aes(x = as.factor(Year), y = cases, fill = Month),
\>
stat = "Identity", position = "dodge") +
\>
labs(title = "LA County Covid-19 Data", subtitle = "2018-2022") +
\>
xlab("Year") + ylab("Cases")

LA County Covid-19 Data
2018–2022
4 Port of Los Angeles Background

The Port of Los Angeles (POLA) was the 17th busiest container port in the World in 2020, shipping over 9 million TEUs, and handled a port record 10.7 million TEUs in 2021. The POLA is the busiest port in the country, followed by the Long Beach Port (LBP) which processed 8.11 million TEUs in 2020. While POLA and LBP share joint operations as the San Pedro Bay Port Complex, they each have their own governing bodies and are operated by their respective cities. To give a sense of the sheer size of the San Pedro Bay Port Complex, one in nine jobs in the the surrounding LA area-San Bernardino, Ventura, Riverside, Orange County, and LA-is connected to the Port complex, and nationally, one in forty eight jobs are connected. The Port complex has a 74% market share of the west coast, and has a 31% market share nationally, market share here meaning percent of cargo serving the area that was moved through the port. POLA alone handled $259 billion in cargo in 2020, containing all sorts of goods including the top five imports: furniture, auto parts, apparel, electronics, and plastics, and the top five exports: animal feed, paper/waste paper, soybeans, scrap metal, and fabrics/raw cotton.

In terms of POLA’s physical presence, the port occupies 7,500 acres split with 4,300 acres of land, and 3,200 acres of water spread across forty three miles of waterfront. A breakdown of the type of port terminals is shown in the table on the following pages. Also see below a map of the port.

---

26 World Shipping Council, “World Shipping Council.”
<table>
<thead>
<tr>
<th>Terminal Type</th>
<th>Number of Berths</th>
<th>Cargo Moved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Container</td>
<td>7</td>
<td>Traditional container shipped cargo that this paper focuses on.</td>
</tr>
<tr>
<td>Liquid Bulk</td>
<td>7</td>
<td>Unpackaged Liquid goods shipped in what are commonly referred to as ‘tankers’. Examples include: Liquified petroleum gas, Liquified natural gas, vegetable oils, juices, etc.</td>
</tr>
<tr>
<td>Break Bulk</td>
<td>4</td>
<td>Break bulk is cargo that is loaded in individually defined loads. Examples include: Bagged cargo (coffee beans, pet food), Barrels (Wine, beer, sauces), Drums (liquids, powders), etc.</td>
</tr>
<tr>
<td>Dry Bulk</td>
<td>3</td>
<td>Large, unpackaged dry goods. Examples include: Coals, ores, grains, sugars, minerals, etc.</td>
</tr>
<tr>
<td>Passenger</td>
<td>2</td>
<td>Passenger terminals serve vessels that are transporting persons including cruise vessels.</td>
</tr>
<tr>
<td>Automobile</td>
<td>1</td>
<td>The automobile port can process fully assembled automobiles. The POLA serves Nissan, Nissan Diesel, Infiniti, and Mazda.</td>
</tr>
<tr>
<td>Multi-Use</td>
<td>1</td>
<td>Has been used in the past for public events including Cirque du Soleil TOTEM, Red Bull Global Rallycross, and other festivals. In addition the SS Lane Victory Merchant Marine museum is docked here.</td>
</tr>
</tbody>
</table>
Table 3: Port of LA Terminal Types (continued)

<table>
<thead>
<tr>
<th>Terminal Type</th>
<th>Number of Berths</th>
<th>Cargo Moved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Support</td>
<td>6</td>
<td>This serves ships that assist with the operations of the port including vessel inspection, vessel repair, towing services, and emergency services.</td>
</tr>
</tbody>
</table>

As this paper focuses on container shipping, below is a breakdown of the container ports of the POLA:

Table 4: Summary of Terminal Infrastructure

<table>
<thead>
<tr>
<th>Company</th>
<th>WBCT - China Shipping</th>
<th>WBCT - Everglades Terminal</th>
<th>TraPac, Inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berth Numbers</td>
<td>Berths 100-102</td>
<td>Berths 121-126</td>
<td>Berths 136-147</td>
</tr>
<tr>
<td>Logistics Method</td>
<td>Containerized cargo; wheeled and grounded operation</td>
<td>Containerized cargo; wheeled and grounded operation</td>
<td>Containerized cargo; wheeled and grounded operation</td>
</tr>
<tr>
<td>Acres</td>
<td>132 acres (53.4 hectares)</td>
<td>186 acres (75 hectares)</td>
<td>220 acres (89 hectares)</td>
</tr>
<tr>
<td>Berth Length</td>
<td>2500’ total berth</td>
<td>2500’ total berth</td>
<td>4,630’ total berth</td>
</tr>
<tr>
<td>Number of Berths</td>
<td>2 berths</td>
<td>2 berths</td>
<td>4 berths (2 automated)</td>
</tr>
</tbody>
</table>
Table 4: Summary of Terminal Infrastructure (continued)

<table>
<thead>
<tr>
<th>Company</th>
<th>WBCT - China Shipping</th>
<th>WBCT - Everglades Terminal</th>
<th>TraPac, Inc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>53’ water depth</td>
<td>45’ water depth</td>
<td>45-53’ water depth</td>
</tr>
<tr>
<td>Cranes</td>
<td>10 post-panamax cranes</td>
<td>5 post-Panamax cranes</td>
<td>10 post-Panamax cranes</td>
</tr>
<tr>
<td>Equipment</td>
<td>Transtainers, sidehandlers, tophandlers, forklifts, UTRs, bombcarts</td>
<td>Transtainers, sidehandlers, tophandlers, forklifts, UTRs, bombcarts</td>
<td>Transtainers, sidehandlers, tophandlers, UTRs, bombcarts</td>
</tr>
<tr>
<td>Transport System</td>
<td>On-dock rail</td>
<td>On-dock rail</td>
<td>On-dock rail</td>
</tr>
<tr>
<td>Availability</td>
<td>Appointment System: Imports, Exports, Empties; Voyager Track</td>
<td>Appointment System: Imports, Exports, Empties; Voyager Track</td>
<td>Appointment System: Imports; eModal Track</td>
</tr>
<tr>
<td>Credentialed</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>N/A</td>
<td>N/A</td>
<td>960 refrigerated container plugs</td>
</tr>
<tr>
<td>Services</td>
<td>N/A</td>
<td>Maintenance and Repair</td>
<td>Maintenance and Repair</td>
</tr>
</tbody>
</table>

35
<table>
<thead>
<tr>
<th>Services</th>
<th>Services</th>
<th>Services</th>
<th>Services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berths 212-225</td>
<td>Berths 226-236</td>
<td>Berths 302-305</td>
<td>Berths 401-406</td>
</tr>
<tr>
<td>Containerized</td>
<td>Containerized</td>
<td>Containerized</td>
<td>Containerized</td>
</tr>
<tr>
<td>Containerized</td>
<td>Containerized</td>
<td>Containerized</td>
<td>Containerized</td>
</tr>
<tr>
<td>cargo; import and export</td>
<td>cargo; wheeled and grounded</td>
<td>cargo; import and export</td>
<td>cargo; import and export</td>
</tr>
<tr>
<td>containers grounded</td>
<td>operation</td>
<td>containers grounded</td>
<td>grounded</td>
</tr>
<tr>
<td>185 acres (75 hectares)</td>
<td>205 acres (82 hectares)</td>
<td>292 acres (118 hectares)</td>
<td>484 acres (196 hectares)</td>
</tr>
<tr>
<td>5800’ total berth length</td>
<td>5800’ total berth length</td>
<td>4000’ total berth length</td>
<td>7300’ total berth length</td>
</tr>
<tr>
<td>3 berths</td>
<td>3 berths</td>
<td>3 berths</td>
<td>6 berths</td>
</tr>
<tr>
<td>47-53’ water depth</td>
<td>45’ water depth</td>
<td>50’ water depth</td>
<td>55’ water depth</td>
</tr>
<tr>
<td>11 post-Panamax cranes,</td>
<td>6 post-Panamax cranes</td>
<td>16 post-Panamax cranes</td>
<td>19 post-Panamax cranes</td>
</tr>
<tr>
<td>including 6 super post-Panamax units</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transtainers,</td>
<td>Transtainers,</td>
<td>Transtainers,</td>
<td>Transtainers,</td>
</tr>
<tr>
<td>tophandlers, UTRs, bombcarts</td>
<td>sidehandlers,</td>
<td>tophandlers, UTRs, bombcarts</td>
<td>sidehandlers,</td>
</tr>
<tr>
<td>On-dock rail</td>
<td>On-dock rail</td>
<td>On-dock rail</td>
<td>On-dock rail</td>
</tr>
</tbody>
</table>
Table 5: Summary of Terminal Infrastructure *(continued)*

<table>
<thead>
<tr>
<th>Yusen Terminals</th>
<th>Everport Terminal Services</th>
<th>Fenix Marine Services</th>
<th>APM Terminals Pacific</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative</td>
<td>Alternative</td>
<td>Alternative</td>
<td>Alternative</td>
</tr>
<tr>
<td>Appointment</td>
<td>Appointment</td>
<td>Appointment</td>
<td>Appointment</td>
</tr>
<tr>
<td>System: Imports, Exports, Empties; Voyage Control</td>
<td>System: Imports; eModal</td>
<td>System: Imports; eModal</td>
<td>Exports; TermPoint</td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>Transportation</td>
<td>Transportation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Worker Identification</td>
<td>Worker Identification</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Credential</td>
<td>Credential</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(TWIC®)</td>
<td>(TWIC®)</td>
</tr>
<tr>
<td>N/A</td>
<td>N/A</td>
<td>706 refrigerated</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>container plugs</td>
<td></td>
</tr>
<tr>
<td>Maintenance and Repair</td>
<td>Maintenance and Repair</td>
<td>Maintenance and Repair</td>
<td>Maintenance and Repair</td>
</tr>
</tbody>
</table>

Details from the table above:

The two distinct logistics methods that the terminals use are wheeled and grounded. These are two different methods to handle the containers that are being processed by the ports. A terminal that uses exclusively a wheeled operation
has a policy that every single container that is in the system is put onto a wheeled chassis throughout the duration of the process. A grounded terminal is one where the containers are stacked in different areas of the port for storage, or while waiting to be loaded or unloaded. Each of these methods has its own advantages, and often ports, such as the POLA, do not operate exclusively with either method. The wheeled method reduces the number of cranes that are needed throughout the port, and increases the maneuverability of each individual container. However, much more yard space is required to store containers when they are wheeled as they are unable to be stacked. Additionally, when containers are waiting to be transported on a train or truck that is delayed, they are occupying a chassis. The grounded technique requires more cranes in different areas of the terminal to load and unload from stacks, but the idle containers occupy far less space since they are able to be stacked.

Panamax, Post-Panamax, and Super-Post-Panamax are terms that are used to describe the size of ships and sizes of cranes in ports. A Panamax class ship means that the ship was able to pass through the original smallest lock of the Panama Canal, so these ships were a maximum of 106 feet wide.\textsuperscript{30} Ships that were not able to fit through these locks were referred to as Post-Panamax. However, an expansion lane of the Panama Canal was opened in 2016, which is able to accommodate ships that are up to 180 feet wide, and this new class of ships is referred to as Neo-Panamax or New-Panamax vessels.\textsuperscript{31} Cranes being referred to by these sizings indicate that the crane is able to load or offload ships of this type. A Super-Post-Panamax crane is on that is able to service vessels larger than a Post-Panamax ship.

The Transportation Worker Identification Credential (TWIC) is a credential provided by the Transportation Security Administration for maritime workers who will be accessing secure areas of vessels and facilities, and is required by the Maritime

\textsuperscript{31}Pratesi, “What Are Panamax and Post-Panamax Cruise Ships?”
Transportation Security Act. Through a process similar, but far less involved, as a security clearance, the TSA will conduct a background check and review worker history to determine whether the worker qualifies for the TWIC.

Ships referred to as reefer ships are those carrying exclusively refrigerated containers on board—often filled with perishable foods. When these vessels arrive at a port, they require prompt service and additional resources to plug in and power the refrigeration systems in the containers on board. To handle this, ports have additional facilities that include energy and other auxiliaries to the refrigeration systems which ensures the cargo maintains its regulated temperature.

5 Song’s Port Congestion Research Applied to the Port of Los Angeles

Now that background about the port has been established, this paper will discuss the point brought up in Dongping Song’s paper: “Port congestion is an industry-wide problem. In the second half of 2020, many European ports (e.g., Felixstowe and Southampton) and North American west-coastal ports (e.g., Los Angeles and Long Beach) reached historically high-level of congestion with no space to put the containers that needed to be discharged from vessels. These ports were congested with empty containers to be positioned back to Asia and with import laden containers to be moved into hinterland customers. The port congestion problem should be tackled not only by improving efficiency and productivity at ports, but also by joint effort from terminal operators, shipping lines, and inland carriers.”

---

34Song, “A Literature Review, Container Shipping Supply Chain.”
port congestion will be addressed within the Port of Los Angeles. Its causes will be analyzed, as well as some attempted solutions to ease the congestion present within the port.

5.1 Congestion Causes

Data for Vessels in this section comes from the Port of LA “Resources for Shippers” page where they have compiled yearly vessel reports.\textsuperscript{35} Data for Containers in this section comes from the Port of LA “Container Statistics” page, where one can view annual container reports.\textsuperscript{36} A note before starting this section: POLA labor data was not directly available. However, labor shortages at POLA are widely reported on and indicated that it has a major impact on port operations.\textsuperscript{37,38,39} This labor shortage will be noted at times throughout the section.

\begin{verbatim}
vessels_data |> group_by(Year) |>
  summarize("Total Ships Processed" = sum(POLAVesselsDeparted),
            "Mean Ships at Anchor" = mean(POLAVesselsAtAnchor),
            "Mean Time at Berth" = mean(AverageDaysAtBerth),
            "Mean Time at Anchor + Berth" =
              mean(AverageDaysAtANCBerth),
            "Adjusted Days Spent" =
              sum(POLAVesselsDeparted) *
              mean(AverageDaysAtANCBerth)) |>  
\end{verbatim}


Table 6: Vessel Means by Year

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Ships Processed</th>
<th>Mean Ships at Anchor</th>
<th>Mean Time at Berth</th>
<th>Mean Time at Anchor + Berth</th>
<th>Adjusted Days Spent</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>707</td>
<td>0.1372549</td>
<td>2.648200</td>
<td>2.634239</td>
<td>1862.407</td>
</tr>
<tr>
<td>2019</td>
<td>655</td>
<td>0.3117409</td>
<td>2.654615</td>
<td>2.702368</td>
<td>1770.051</td>
</tr>
<tr>
<td>2020</td>
<td>626</td>
<td>1.7710843</td>
<td>3.203871</td>
<td>3.448651</td>
<td>2158.855</td>
</tr>
<tr>
<td>2021</td>
<td>839</td>
<td>17.4857143</td>
<td>5.950633</td>
<td>12.623571</td>
<td>10591.176</td>
</tr>
</tbody>
</table>

In 2018, POLA handled 707 container vessels, and in 2019, it handled 655 vessels. The average number of days for a vessel to be at anchor and then be processed at the port berth was 2.634 days in 2018, and 2.702 days in 2019. This was a fairly typical time frame for the port before Covid-19 when there were not exceptional backlog. During 2020, many pointed at ports to be the cause of the onsetting supply chain disruption. The conception was the delays at the ports were causing shortages throughout countries. In 2020, 626 vessels were processed at POLA, which means
that the difference in vessels processed between 2019-2020 was less than the difference between 2018-2019, before Covid.

During 2020, the average days at berth for vessels rose 120.69% to 3.203 days per vessel. Additionally, the average number of vessels at anchor rose from 0.1372 in 2018 and 0.3117 in 2019 to 1.771 in 2020. This number grew even higher in 2021 resulting in an average vessel time at birth of 5.95 days. This is a 185.52% increase from 2020, and a 224.52% increase from 2019. With this increase, the average number of ships at anchor grew sharply to 17.485 in 2021, which is a 987.29% increase over 2020, and a 5,609.065% increase over 2019. The overarching swell in Port traffic is represented in the plots below-first grouped by year, then grouped by month and year.

```r
data <- read.csv('vessels_means_plot.csv')

vessels_means_plot |>
  ggplot() +
  geom_bar(aes(x = Year, y = Value, fill = as.factor(Year)),
            stat = "Identity", position = "dodge") +
  theme(axis.text.x = element_text( angle = 45)) +
  facet_wrap(~Metric, scales = "free") +
  labs(title = "Vessels Metrics per Year",
       subtitle = "2018-2020", fill = "Year") +
  scale_fill_manual(values=c("#591865", "#33829e",
                            "#15bb93", "#feeb43")) +
  xlab("Year")
```
vessels_means_plot |> 

ggplot() + 

geom_bar(aes(x = Year, y = Value, fill = Month), 

    stat = "Identity", position = "dodge") + 

theme(axis.text.x = element_text( angle = 45)) + 

facet_wrap(~Metric, scales = "free") + 

labs(title = "Vessels Metrics per Year", subtitle = "2018-2020") + 

xlab("Year")
With a fixed number of berths, and fixed mechanical infrastructure on the dock, the number of vessels at berth could not increase to account for the slower service time. Since the number of incoming vessels increasing to 839 in 2021, and the mean number of days a vessel spent at berth increasing by almost double, it is seen in the plot above that each of the metrics corresponding to a ship’s waiting time grow largely in the same manner.

vessels_data |> group_by(Year, Month) |> 
summarize(Berth = sum(POLAVesselsAtBerth), 

      Anchor = sum(POLAVesselsAtAnchor), 

      Days = sum(AverageDaysAtANCBerth)) |> 
gather(key = "Metric", value = "Value", 3:5) |> 
ggplot() + 
gem_bar(aes(x = Metric, y = Value,
fill = as.factor(Year)), stat = "Identity") +
theme(axis.text.x = element_text( angle = 45)) +
facet_wrap(~Year, scales = "free") +
scale_fill_manual(values=c("#591865", "#33829e",
"#15bb93", "#feeb43")) +
labs(title = "Vessel Processing Time by Year",
subtitle = "2018-2021", fill = "Year")

In fact, it is seen above that when adding up the cumulative number of ships at
anchor per day over a year and the total number of ships at berth per day over the
year, for 2021, the number ship days at anchor exceeded the number of ship days at
berth.

Again, no major construction projects occurred at the berths within these time-
frames, so other factors must be considered. In a February 21, 2021 interview with
Bloomberg Markets and Finance, the Port of Los Angeles Executive Director Gene Seroka said regarding the high congestion that: “This [congestion] has really been about three years in the making. From the trade tensions with China, to the fiscal policy-including the strength of the US dollar, and then the pandemic buying surge that we’ve witnessed since the beginning of Covid-19. These are levels of shipments that we’ve never seen before in our 113 year history. And at the same time we’re down 24 out of the last 26 months on exports moving from the United States through the port of Los Angeles so it truly is one-way trade.”

In multiple interviews, He alludes to the trade tensions with China as having a high driving impact on the number of imports that we are seeing, and he references the asymmetry between exports and imports particularly to and from China.

```r
container_means |>
  filter(Year %in% c("2018", "2019", "2020", "2021")) |>
  group_by(Year, Month) |>
  summarize( ProportionEmpty =
    sum(meanEmptyImports) / sum(meanTotalImports)) |>
  ggplot() +
  geom_bar(aes(x = Year, y = ProportionEmpty, fill = Month),
            stat = "Identity") +
  labs(title = "Proportion of Empty Imports")
```

40Bloomberg, “Why Are so Many Empty Containers Leaving the Port of Los Angeles?”
42Bloomberg, “Why Are so Many Empty Containers Leaving the Port of Los Angeles?”
Proportion of Empty Imports

container_means_plot |>
filter(Year %in% c("2018", "2019", "2020", "2021")) |>
filter(Metric %in% c("meanEmptyImports",
               "meanLoadedImports",
               "meanTotalImports")) |>
ggplot() +
geom_bar(aes(x = Year, y = Value, fill = Month), stat = "Identity") +
theme(axis.text.x = element_text( angle = 45)) +
facet_wrap(~Metric, scales = "free") +
labs(title = "Imports per Year", subtitle = "2018-2020")
Clearly, in the plots above, the number of loaded containers that the US puts out has sharply decreased, whereas the number of empty containers shipped has increased highly. One result of this is that the majority of containers that are coming in on ships are now loaded, and there is more processing that must be undertaken with a loaded container than an empty one, and at this point, Seroka says that POLA is experiencing an unprecedented number of imports. At the heart of the import surge, according to Seroka is that “In the summer time of 2020, the American consumer buying power took off and we bought more than ever before because our discretionary income left the service sector . . . American consumer buying strength and the retail community has tried for the last 17 months just to keep up with our demand.”

Covid_data_bind <- Covid_data |> group_by(Month, Year) |> filter(Year %in% c("2020", "2021")) |> summarize(CaseCount = sum(reported_cases)) |> gather(key = "Metric", value = "Value", 3)

vessels_means_bind <- vessels_means_plot |> filter(Metric %in% c("meanAverageDaysAtANCBerth")) |> filter(Year %in% c(2020,2021))
bound <- rbind(Covid_data_bind,vessels_means_bind)

bound |> group_by(Month, Year) |> filter(Year %in% c("2020", "2021")) |

ggplot() + geom_bar(aes(x = as.factor(Year), y = Value, fill = Month), stat = "Identity", position = "dodge") + labs(title = "Covid-19 Cases and Mean Vessel Time", subtitle = "2018-2021") + facet_wrap(~Metric, scale = "free") + xlab("Year")
Unfortunately, this substantial growth in imports have occurred at the same time as there have been severe labor shortages on the docks. Seroka said in a January 2021 interview that: “We’ve got more cargo than we do skilled labor. We are told 1,800 workers are not going on the job due to Covid-19 right now [including] those who are isolating through contact tracing or awaiting test results or maybe [those who] fear . . . going on the job when a lot of people are sick.”

This was in the days before the vaccine, however, and the threat of the Covid-19 pandemic has all but gone away. Through ebbs and flows of California’s social distancing and occupancy restrictions, these limitations have not subsided. Gene’s point is illustrated in the below plot which shows how ship time spent at anchor and berth follows the same trends as Covid-19 cases in Los Angeles as shown in the plot above.

One other labor force that has had a large impact on the port congestion is the

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trucking labor force. This force is responsible for mainland transport of many of the containers that come inland from the ports. Gene Seroka said that “The American Trucking Association says that we’re 80,000 drivers short nationwide, and my estimate is that we’re at least three to four thousand short on [the Port of LA] system.”

Truckers have, for a variety of reasons, been leaving their positions or organizing strikes due to working conditions. One such reason is the financial structure that many of them operate under. Since many truckers operate as independent contractors, they are not paid hourly, but rather have flat salaries that are contingent on them delivering their containers. However, due to the labor shortages within the port systems, truckers were having to wait extended periods of time to load their truck and exit the port-some even had to wait eight hours to load their truck. This led to incredible wage loss on behalf of truckers and caused national movements by truckers to adjust their compensation to make their work more feasible. One group settled with XPO Logistics and won $30 Million dollars through a class action lawsuit after their pay was resulting in less than minimum wage due to the waiting periods.

Chassis are another source of congestion for the Port of LA. Similar to the trucking issue, a large problem with chassis movement throughout the CSSC is the dwell time for a container at any given point in the supply chain. Whether within the port itself, waiting to be attached to a vehicle, or waiting at a warehouse, the total time for a chassis to be picked up and returned to the port (the street dwell) was over seven days; often a street dwell of over four days is enough to start causing issues.

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within the supply chain.\textsuperscript{50} The issue that is being seen is that chassis are piling up at warehouses, which causes a surplus of idle chassis and containers in a warehouse while there is a shortage of chassis at the ports.

A second issue that chassis provide are the differently structured agreements for their use. Chassis use is structured on either a single or dual transaction, of which terminals far prefer a dual transaction. Dual transactions are such that a truck drops off a chassis and picks up another from the same terminal, which is much more logistically efficient. As such, terminals allow for far more dual transaction appointments than single transactions.\textsuperscript{51} The drawback is if there is a delay on either side of the dual transaction, it slows up both ends of the transaction. The third largest issue presented with the chassis system, which became an issue in 2021, is that the Port initiated rules that only certain branded chassis can be used at a certain terminal. So if a truck was carrying the incorrectly branded chassis to service its appointment, it would have to return the rented chassis, and rent a different brand that was compatible with the regulation.\textsuperscript{52}

Even when the trucks were able to make it to the warehouses, many warehouses were at capacity. The Inland Empire—a region about 40 miles inland of Los Angeles—which harbors many warehouses and acts as a sort of dry port reported that 98% of warehouses were at full capacity in October 2021. And to deal with this surge of containers, was a depleted workforce with 400,000 warehouse job openings in the US with an estimated eight or nine thousand in Southern California.\textsuperscript{53} So warehouses being entirely overrun with full containers awaiting transit inland, and empty/export containers waiting to be taken to the ports, there is more congestion within the CSSC.

\textsuperscript{51}Critchfield, “West Coast Chassis Pool Challenges at Ports of LA and Long Beach.”
\textsuperscript{52}Critchfield, “West Coast Chassis Pool Challenges at Ports of LA and Long Beach.”
\textsuperscript{53}Washington Post Live, “Gene Seroka on the Origins of the Current Supply Chain Crisis.”
These problems all compound on each other. Seroka says, “A lot of what we’re seeing right now is the dwell time of merchandise both here on the port docks as well as out near the warehouses away from the port area. Those containers are sitting for longer periods of time without being emptied and returned back to the port for normal circulation. We’ve got to push the inventory out of the warehouses into the domestic supply chain onto store shelves and to the fulfillment centers. Once that begins to happen in earnest we’ll start to see things loosen up here at the port and allow the other modes of transportation to begin approaching fluidity once again.”

Again, it is a cyclical problem: dock worker shortages increasing the time necessary to process a vessel, in turn leading to less efficient trafficking of containers within the ports, which causes less efficient container management including chassis shortages and stacking buildups, which creates delays in loading and unloading trucks, which delays shipment to the internal warehouse, which causes build up in the warehouses which are already understaffed, (some warehouse companies saying they are entirely sold out of space), which causes delays getting containers back to port, which have to be processed by an understaffed port, which the containers then need to wait for their respective vessel to dock to be loaded, so they must be stored on a dock, and this cycle has perpetuated for the past 20 months.

5.2 Combatting the Congestion

Since the POLA is such a significant port, efforts have been made to ease the congestion and solve the issue, which Song indicated that there needed to be more focus on. This section will address the actions that have been taken so far.

One of the primary labor solutions that the Port was able to take advantage of

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54 Bloomberg, “Why Are so Many Empty Containers Leaving the Port of Los Angeles?”
was vaccinating all of their workers. After conversing with public health officials, the POLA was able to secure 14,000 vaccinations during phase 1B of California’s vaccine rollout.\textsuperscript{56} The early vaccine access was available along the CSSC with truckers and maritime crew members also being able to receive vaccines in phases 1B or 1C of the CDC’s vaccine rollout.\textsuperscript{57} Receiving this many doses early on reduced worker worry and enabled more workers to return back to work in a safe fashion, but still the number of containers coming in exceeded the ability of the equipment operators to fulfill the demand.\textsuperscript{58}

Another attempt to ease the labor shortage induced congestion was introduced by United States President Joe Biden when he announced that the Port of Long Beach would begin operating twenty four hours a day in mid September 2021, and the Port of LA would open additional off-peak night and weekend operations.\textsuperscript{59} This was designed to have multifaceted benefits. In addition to simply extending the hours of operation, having the operations run at night allowed for trucks to be far less impeded by the busy Southern California rush hours, and thus would optimize container throughput. This was a complex deal that required collaboration from many different organizations including the International Longshore and Warehouse Union, as well as retail and shipping partners such as Walmart, Target, Home Depot, UPS, FedEx, and Samsung.\textsuperscript{60} The labor union agreed to have workers staff the ports during these extra hours, and the retail partners committed to operating 24/7 to clear their containers from the port. Whitehouse.gov indicated that with UPS, FedEx, Samsung, The Home Depot, and Target’s collaboration, they expected an additional 3,500 per

\textsuperscript{56}LA County Public Health, “Los Angeles County Department of Public Health COVID-19 Vaccination Strategy.”
\textsuperscript{59}The White House, “FACT SHEET.”
\textsuperscript{60}The White House, “FACT SHEET.”
The White House, “FACT SHEET.”

Ashe, “US Ports and Rails.”

Ashe, “US Ports and Rails.”

increasing by $100 a day until the container is either moved inland, or taken via vessel. After the initial fee on dwelling laden import containers was implemented, the number of containers in violation of this policy decreased by 60% at POLA, so POLA never ended up actually instituting the fee, the response to the announcement was deemed sufficient. A similar course of action was taken with the empty containers, and the fee was never implemented. However, POLA cited a different reason that there were difficulties with certain empty containers being stacked under others and so freeing them up to be moved would cost extra time and labor that the terminals could not afford to spend.⁶⁶ Port Authorities were pleased that they had incited thought, response, and future planning to prevent container buildup in the future.

Another contributing organization to this fee not being implemented was the Harbor Trucking Association, which weighed in heavily saying that ocean carriers would not bring their empty containers back to port from the warehouses, and thus, the trucks would not be able to deliver a container topped chassis in exchange for another to complete their route.⁶⁷ The CSSC has to decide at this point who needs to bear the burden of the sitting empty containers, and this seems to be an ongoing discussion within all of the different organizations that make up the CSSC.

To ensure that the port keeps operating during this time of unprecedentedly high congestion, heavy triaging has been put in place to ensure that the essential systems throughout the country can be maintained. Seroka said that the POLA“expedite[s] the products that are necessary, whether they be the vegetables and fruits or those parts, components, and peripherals that go into the American manufacturing system. It’s the retail goods that seem to be sitting longer.”⁶⁸ He notes then that they

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⁶⁷Curtis, “Port of LA Defers Plan to Charge Carriers for Empty Containers.”

⁶⁸Bloomberg, “Why Are so Many Empty Containers Leaving the Port of Los Angeles?”
are continuously working with the retail sector to improve the throughput of the containers to free them from whichever phase of the CSSC they are dwelled in.

As is seen in this analysis, Song is correct that further development of algorithms and research in how to manage congestion at the port level of the CSSC could be incredibly valuable. The solutions posed by the POLA have had some impact, and the data shows that in the period of easement during the Covid-19 pandemic, which happened to coincide with a regularly annual slow down of vessels, POLA was able to make progress on its congestion. However as seen in the port data, it has not been enough though as further waves of Covid-19 continue to destabilize the Port. From the analysis above, it is evident that even though Covid-19 continues to hamper the operation of the CSSC, there are areas for logistical improvement that could bolster the port operations and reduce the disruption.

6 Conclusion

Covid-19 had a profound impact on the container shipping supply chain. It had direct impact by infecting workers along the supply chain and forcing personnel limitations, and it had indirect impact like the alteration of consumer habits. Through these combined impacts, the world saw a global shipping industry that worked relatively efficiently pre-Covid-19 become a hampered system that needs a world-wide effort to restore. The Port of Los Angeles, the nation’s busiest port, was heavily impacted by Covid-19 and measures of port efficiency such as the average time taken to service a ship, and the average number of ships at anchor waiting for berth space increased 185.52% and 987.29% respectively since the beginning of 2020.

Since no evidence was found of major infrastructure projects on the port, this paper investigated other factors that drove this decrease in port function. Overall, the paper identified the following as causes of the congestion:
1. Longshore dock workers, truckers, and warehouse laborers out sick, isolating, restricted, or hesitant to work due to Covid-19

2. Chassis shortages within ports with often corresponding chassis congestion at warehouses

3. Asymmetric import and export of empty containers with China

4. Inefficient stacking on docks resulting in buildups of containers

5. Truck drivers dissatisfaction with the congestion within ports resulting in their pay essentially being

6. Consumer behavior changes, in particular an increase in the American retail spending

With these six factors driving congestion, there were corresponding efforts put in place to ease the congestion:

1. Early vaccination of employees and expanded working hours

2. Manufacturing and improving movement of chassis within the port system

3. Proposing fees on idle containers to prevent them from occupying space within the port complex

4. Triaging container types when possible to keep the essential cargo flowing

Unfortunately, even with these policies and practices implemented, the Port of Los Angeles experienced disruption from the waves of Covid-19. This shows that the POLA, and for that matter the global economy, could benefit greatly from improved algorithms and logistics practices throughout the CSSC.
Bibliography


Clark, Don. “The Huge Endeavor to Produce a Tiny Microchip.” The New York


