

### 3. (Logjam at the Port of LA)

*In mid-October, when the White House announced it was wading into the logistics logjam at the ports of Long Beach and Los Angeles in a bid to unclog the supply chain before Christmas, 58 container ships were waiting offshore.*

*Nearly a month later, San Pedro Bay's unwilling flotilla has grown to 78 vessels, and more are on the way to meet holiday shopping demand. But on the docks themselves, the situation seems to be improving — slightly.*

*One key problem facing the port complex has been the towering piles of containers left at the import terminals for days on end, taking up space that should go to new containers unloaded from the ships offshore.*

*In response, officials at the ports voted in late October to impose a new fee on containers that sit around for more than six days if intended for rail transport or nine days if intended for trucks. Starting Nov. 15, the ocean carrier companies that brought those idling containers in will be charged \$100 on the first day past deadline, \$200 on the next, and so on — an escalating fine that could quickly grow into the tens of millions of dollars a day for the thousands of containers on the docks.*

— LA Times, November 10th, 2021.

*“What’s moving a lot faster is the cargo that’s showing up here now, it’s just flaming out of here. The stuff that’s been dwelling is moving a little slower, but it is moving*

— Matt Schrap, Chief Executive, Harbor Trucking Association

Assume that a container ship carries approximately 2,000 containers. Every shipping container has its own unique 20-digit identification number, known as a *box number*. Containers' volume is measured in twenty-foot-equivalent units (TEU); one 20ft container equals 1 TEU. Standard containers are made of steel or aluminum, while specialized containers (e.g., that carry bulk liquid, fresh and frozen fruit, produce with controls for atmosphere and temperature) are called reefers.

A brief summary of the cargo operations in a port for a container ship is shown below. The process is overly simplified for the purposes of this question.

1. As ships approach the port, they are met by *tugs* that rotate them to point downwards and nudge them sideways to berth at quay.
2. Containers are lifted off the ship two at a time by *quay cranes*, 450ft high behemoths with booms long enough to reach across the width of the ship.
3. Once placed on the quay, the containers are picked up by a fleet of giraffe-like vehicles known as *shuttle carriers*. A shuttle carrier can pick up 2 containers (i.e., 2 TEUs) at once.

4. After the shuttle carriers have moved the containers, *stacking cranes* – robotic systems – pick up the containers and stack them. A central database stores the location of every container in the port (using the 20 digit identifier) and ensures they are stacked for maximal efficiency.
5. A container is loaded on to a *truck or a railcar* for their next destination. The driver parks in a specified bay, then steps away for safety reasons. The stacking crane does the rest, automatically locating the correct container in the stack, picking it up, and bringing it over. The stacking lines the container and lowers it in place. All the driver needs to do is to secure the load, before heading off.

Assume that if ships are not berthed upon arrival, they wait outside the port, in an area colloquially referred to as the flotilla.

Let us abstract the exact capacities of the various resources in tasks 1–5, and assume that under normal circumstances (i.e., a port that operates 8 hours a day, 5 days a week), the capacity of the port is 320 containers per hour. That is, on average, 320 containers are unloaded from cargo ships and eventually moved to trucks, railcars each hour.

Prior to August 1st, the port of LA experienced a weekly traffic of 6 container ships on average. However, pandemic-induced buying has led to an increase in demand for various goods in mainland US. In fact, studies by the Capital Economics group shows that many Americans, devoid of going on holidays or out to dinner, have increased spending on consumer goods. This increased spending of consumer goods has led to an increase in imports, primarily from China. Since the start of August 1st, the port of LA has seen a weekly traffic of 17.4 ships, on average. Such an unprecedented demand spike has led to wait times for ships at the port of LA to sky rocket, resulting in severe delays to buying firms and consumers.

On October 13th 2021, 10 weeks after August 1st, President Biden announced that the port of LA will expand operations to 24/7 (i.e., 24 hours, 7 days a week).

- (a) (3 points) Make the following assumptions about the arrival process prior to August 1st. Assume the following:
- Each week consists of 40 hours. Ships plan their arrival to a port, and do not arrive on weekends.
  - The inter-arrival time between two ships has an average of  $\frac{40}{6} = 6.67$  hours, with a standard deviation of 3.33 hours.
  - There is no variability in the processing time, given that much of a port's operations are highly mechanized and there is very little human involvement.
  - While a ship is berthed, other ships have to wait in the flotilla outside the harbor.
  - Container ships are processed in a first-come-first-served manner.

On average, how many ships wait in the flotilla (prior to August 1st).

(b) (4 points) Consider the process after August 1st. Assume the following:

- Each month contains 4 weeks.
- At the start of week 11, the port expands its operations to 24/7. The hourly capacity of the port remains unaffected (i.e., 320 containers/hour).
- Assume that the demand rate remains unchanged.

Using Figure 2, draw the inventory buildup diagram for the container ships. Based on your calculations, how long will it take for the buildup of container ships in the flotilla to completely deplete?

Inventory Buildup of Container Ships

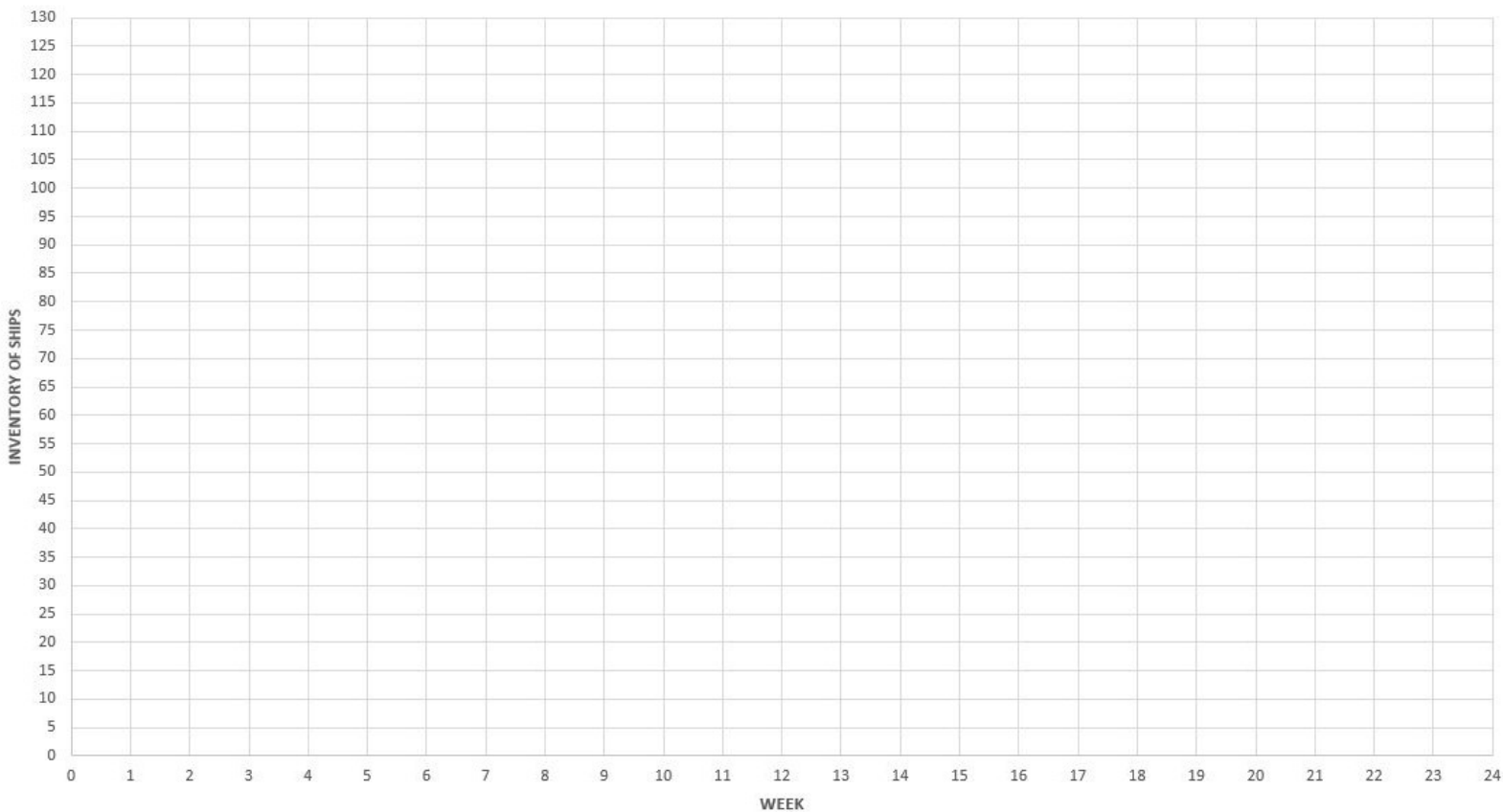


Figure 2: Inventory Buildup at the Port of LA

(c) (3 points) Assume that each week of delay for a ship costs an average of \$10,000 in operational and delay costs. Operational costs correspond to the fuel, wages for ship personnel, maintenance, etc. Delay costs corresponds to the cost to the buying firms and consumers due to delays, possible spoilage of material, etc.

Calculate the total operational and delay costs due to the pandemic-buying-frenzy-induced-delays.