INTRODUCTION TO THE CONTAINER SHIPPING INDUSTRY

University of Wisconsin – Milwaukee
Paper No. 11-1

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January 6, 2011
Introduction to the Container Shipping Industry

INTRODUCTION

This document contains images of all slides in a course module about the container shipping industry and container port operations. Sources and additional content are found on the “note pages” of the original slide presentation. The full presentation contains videos. This presentation is available upon request to Alan Horowitz, horowitz@uwm.edu.
Introduction to the Container Shipping Industry

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Outline

1. Introduction to maritime shipping
2. Introduction to container shipping
3. Container vessels and shipping lines
4. Seaports
5. Railway container transportation / facilities
6. Conclusion
Introduction to Maritime Shipping

- Ships carry 99% of overseas trade in volume terms and 62% in value terms, the remainder being conveyed by air.
- 90% of all international trade moves by sea
- Globally, the ton-miles of freight moved by water are more than twice the total ton-miles moved by road, railway, and air put together.
- Water transportation is less costly and more energy efficient than other modes of transport:

<table>
<thead>
<tr>
<th>Indexed Comparisons:</th>
<th>SHIP</th>
<th>RAIL</th>
<th>TRUCK</th>
</tr>
</thead>
<tbody>
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<td>Fuel Consumption</td>
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<tr>
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<td>Accidents</td>
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<tr>
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<tr>
<td>Noise Levels</td>
<td>1</td>
<td>1.4</td>
<td>1.3</td>
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</tbody>
</table>

Maritime Shipping: Cargo Types

- **Dry Bulk**
  (salt, grain, minerals, cement/gypsum, coal byproducts)
- **Liquid Bulk**
  (crude oil, gasoline, chemicals, liquefied natural gas)
- **Break Bulk**
  (steel, lumber, heavy machinery)
- **Automobile**
- **Containerized**
  (finished consumer goods)

Maritime Shipping: Major Players

- **Shippers (importers/exporters)**
  (Nike, Wal-Mart, ExxonMobil, Toyota)
- **Shipping lines (ocean carriers, vessel operators)**
  (Maersk Sealand, MSC, CMA CGM, Evergreen, Hapag Lloyd)
- **Seaport terminal operators**
  Morton Salt (dry bulk)
  Shell Oil (liquid bulk)
  Toyota (automobile)
  **Containerized cargo:**
    - PSA Corporation (Singapore)
    - Hutchison Port Holdings (Hong Kong)
    - Dubai Ports World (United Arab Emirates)
    - APM Terminals (Netherlands, Denmark)
- **Railway operators**
  (Union Pacific, BNSF, CSX, Norfolk Southern, CN, CP)
- **Trucking companies (motor vehicle carriers)**
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Container Shipping

World fleet, Feb 2004: 3167 vessels, capacity = 6.5 million 20-ft conts. (TEU)
World fleet, Dec 2008: 4661 vessels, capacity = 12.1 million 20-ft conts. (TEU)
Containers

Contents
- furniture, toys, footwear, clothing, auto parts, electronics, computers, bananas, pineapples, foodstuffs, meat, fish

Sizes
- 20' x 8' x 8.5' high (TEU)
- 40' x 8' x 8.5' high (FEU)
- 45' x 8' x 8.5' high

Capacity
- 30 tons

Where are they manufactured?
- China

Types
- standard dry, high cube (9.5' high) (90%)
- refrigerated ("reefer") (5%)
- other: ventilated, open top, adjustable height (5%)

Quantity
- Global stock = 35 million (10 mill leased); 3.5 million produced in 2008

Cost
- New: $2000 - $20,000; lease rate $1 - $6 per day (5 year term)

Hoisted, lowered, and secured at the corners
Containers

- Hoisted, lowered, and secured at the corners
- Secured aboard vessels, trains, truck chassis using
  1. twist locks
     for securing adjacent containers in the same stack
  2. lashing rods (vessels only)
     for securing containers in high tiers directly to the deck
Containers

- Hoisted, lowered, and secured at the corners
- Secured aboard vessels, trains, truck chassis using
  1. twist locks for securing adjacent containers in the same stack
  2. lashing rods (vessels only) for securing containers in high tiers directly to the deck
Import cargo generally starts at an overseas manufacturer, supplier or consolidation facility. The US buyer may contact an industry professional known as a “Freight forwarder” or logistics company.

1- Product Ordered: A typical import transaction starts when a U.S. wholesaler, retailer or other buyer orders products from an overseas manufacturer.

2- To port: Once the product has been ordered and packaged, the buyer or freight forwarder will arrange for a local trucking company to move the container to seaport, and then for a ship to transport the container overseas.

3- Off-dock railyards: Some export cargo containers are delivered by train to off-dock railyards, where they are placed onto trucks for final delivery to marine terminals.

4- On-dock railyards: Cargo bound for export can be delivered by train directly to on-dock railyards, where it is loaded onto an ocean vessel. On-dock delivery requires no local truck trips.

5- Near-dock railyards: Export deliveries are also made to near-dock railyards, where the cargo is picked up by truck for a short trip to the marine terminal.

6- Vessel loading: Outbound cargo is loaded onto an ocean vessel headed for an overseas port.

7- Unloading the ship: As the ship is arriving, the terminal operator will contact the local union hall and arrange for unionized longshore workers to unload the container (using a giant, electric gantry crane) and place it onto a truck, a rail car or temporary storage area on the terminal property. Unloading an 8,000 TEU ship takes about three days.

8- Security checks: U.S. Customs officials conduct further analysis and determine which containers warrant further inspection.

9- Radiation detection: As a final security safeguard, containers pass through large portals that detect radiation.

10- Coast Guard review: The U.S. Coast Guard reviews crew and cargo manifest information, which must be delivered at least three days before any ship arrives at U.S. shores.

11- Near-dock railyards: Export deliveries are also made to near-dock railyards, where the cargo is picked up by truck for a short trip to the marine terminal.

12- Rail-carrying bed (as opposed to roadbed) moves the cargo from the marine terminal to the local union hall and arrange for unionized longshore workers to unload the container.

13- Port of Long Beach Website

14- Container portal X-ray detects any suspicious containers.

15- Port security personnel review both the images and the manifest and then decide which containers require further inspection.

16- A U.S. Customs official reviews the container, the manifest, and other information, which must be delivered at least three days before any ship arrives at U.S. shores.

17- A U.S. Customs official reviews the container, the manifest, and other information, which must be delivered at least three days before any ship arrives at U.S. shores.
From the port of Long Beach, containers are either transported by train or by truck to their final destination, or to one of several intermediate destinations such as a railyard, warehouse, distribution center, or "transload" facility (a sorting, routing and short-term storage building). A container's final destination determines exactly what path it will take once it leaves the dock.

2. Freight forwarder: A container's movements are determined by the cargo's owner, or an industry professional known as a freight forwarder or "logistics provider".

3. On-dock railyard: Cargo can be placed directly onto trains at the marine terminals' "on-dock" railyards.

4. Near-dock railyards: Cargo is often transported by truck to larger "near-dock" railyards close to the Port.

5. Off-dock railyards: Off-dock railyards are used to coordinate rail deliveries to non-local destinations. Containers are delivered here by truck, then sorted and grouped by final destination. These railyards handle Port cargo as well as domestic cargo from other sources.

6. Transload or storage yard: Shipping containers are often moved initially to a "transload" facility where workers unload the cargo from the marine container, sort it and repackage it into larger-sized truck trailers. The larger trailers are used to transport the cargo from the transload facility to regional distribution centers, local stores or off-dock railyards.

7. Direct delivery: In the simplest transportation plan, a single container imported by a company for its own use would be delivered by truck directly from the marine terminal to a local store or factory.

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Vessels

Capacity
from 100 to 14,000 TEU

Divided into 45’ sections called bays
ship length can be from 3 to 25 bays

Newbuild cost
$1 million per 100 TEU capacity

Speed
20 - 25 knots

Fuel
Marine diesel oil; efficiency ~ 500 ton-miles/gal

20 crew members
captain/master, 3 deck officers, chief engineer w/ 3 assistants,
radio operator, cooks, qualified members of the engine department
(QMEDs), etc.

Fully cellular or geared
Geared vessels can unload and load themselves

Itineraries are cyclical
Every 4 weeks:
Naples-Genoa-Barcelona-New York-Norfolk-Charleston-Naples

Where are they built?
Korea: Hyundai, Samsung, Daewoo, Hanjin
China: Jiangsu, Shanghai, Xiamen, Dalian

The Shipping Line Business

<table>
<thead>
<tr>
<th>Ocean Carrier</th>
<th>Country</th>
<th>TEU deployed in 2006</th>
<th>2007 Revenue (billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. A.P. Moller-Maersk</td>
<td>Denmark</td>
<td>1,600,012</td>
<td>11.8</td>
</tr>
<tr>
<td>2. Mediterranean Shipping Co</td>
<td>Switzerland</td>
<td>937,145</td>
<td>8.8</td>
</tr>
<tr>
<td>3. CMA CGM</td>
<td>France</td>
<td>597,677</td>
<td>5.3</td>
</tr>
<tr>
<td>4. Evergreen</td>
<td>Taiwan</td>
<td>539,801</td>
<td>6.5</td>
</tr>
<tr>
<td>5. Hapag-Lloyd</td>
<td>Germany</td>
<td>448,840</td>
<td>8.8</td>
</tr>
<tr>
<td>6. Cosco</td>
<td>China</td>
<td>385,368</td>
<td>6.5</td>
</tr>
<tr>
<td>7. China Shipping Cont. Lines</td>
<td>China</td>
<td>339,545</td>
<td>7.4</td>
</tr>
<tr>
<td>8. Hanjin</td>
<td>South Korea</td>
<td>328,327</td>
<td>8.2</td>
</tr>
<tr>
<td>9. American President Lines</td>
<td>Singapore</td>
<td>323,319</td>
<td>25.8</td>
</tr>
<tr>
<td>10. NYK</td>
<td>Japan</td>
<td>313,049</td>
<td>19.4</td>
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<tr>
<td>11. Mitsui OSK Lines</td>
<td>Japan</td>
<td>284,848</td>
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<tr>
<td>12. OOCL</td>
<td>China (HK)</td>
<td>268,502</td>
<td>4.1</td>
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<tr>
<td>13. CSAV</td>
<td>Chile</td>
<td>249,885</td>
<td>13.3</td>
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<tr>
<td>14. K Line</td>
<td>Japan</td>
<td>241,772</td>
<td>4.1</td>
</tr>
<tr>
<td>15. Yang Ming</td>
<td>Taiwan</td>
<td>223,192</td>
<td>4.1</td>
</tr>
</tbody>
</table>
The Shipping Line Business

Mediterranean Shipping Co. Website

Port to Port Freight Rates ($ per TEU, Sept 2008):

- Asia → N. America: $1800
- Europe → Asia: $1100
- Asia ← N. America: $1000
- Europe ← Asia: $1900

N. America → Europe: $1300
N. America ← Europe: $1700
The Shipping Line Business: Planning Decisions

Decision
1. When to purchase/charter additional vessels?
2. What kind of vessels to purchase/charter?
3. When to sell/scrap old vessels?
4. Which vessels to sell/scrap?
5. Which ports should be served?
6. Which routes should be served?
7. Which vessels should be assigned to which routes? (“fleet deployment”)
8. Scheduling the vessels assigned to each route. At what times will they arrive/depart from each port in the route sequence?
9. Determine performance requirements for each vessel at each port. How fast must each vessel be served at each port it visits?
10. Negotiating vessel service agreements with seaport facilities (container terminals).
11. Hiring crew members

The Shipping Line Business: Operational Decisions

Decision
1. What should the freight rates be?
2. When to cancel a vessel call at a port?
3. Which containers should be loaded onto which vessel? (applies to large shipping lines or lines belonging to an alliance)
4. How many empty containers should be loaded onto each vessel at each port? (“empty container repositioning”)
5. Where should individual containers be placed on the vessel? (“vessel stowage”)
6. Assigning crew members to vessels.
Because the United States imports more goods than it exports, many empty containers are sent overseas to be refilled with goods. Typically, about a third of the containers loaded onto a ship at the Port of Long Beach will be filled with cargo, while about two-thirds will be empty.

1. **Delivery to local exporter**: A local exporter who needs to fill empty containers may arrange to receive them by truck directly from a marine terminal, from an empty container storage yard or from a local importer. Direct delivery between importers and exporters is encouraged because it eliminates an additional truck trip to a storage yard or marine terminal.

2. **Empty container storage yard**: Empty containers are often transported by truck from a transload facility or local importer to an empty container storage yard. From the storage yard, the empty containers can be transported to a marine terminal for export, or to a local exporter to be filled with cargo. Empty containers are also transported from marine terminals to storage yards, usually when the terminal needs more space for full, incoming containers.

3. **Direct Delivery**: The simplest route for an empty cargo container would be a return trip to the Port from a transload facility or local importer after its imported goods had been unloaded.

4. **Ocean Vessel**: Empty containers are loaded onto an ocean vessel, along with containers filled with export goods, bound for an overseas port.
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Introduction to Container Terminals

- Unloading and loading of containerships
- Temporary storage of containers

Port of Hong Kong
Port of Singapore
Globally, 474 million TEU worth of (empty and loaded) containers were transferred between ships and shore in 2007.

### World’s Busiest Container Ports

<table>
<thead>
<tr>
<th>Million TEU handled in 2007</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Singapore</td>
<td>Singapore</td>
</tr>
<tr>
<td>2. Shanghai</td>
<td>China</td>
</tr>
<tr>
<td>3. Hong Kong</td>
<td>China (HK)</td>
</tr>
<tr>
<td>4. Shenzhen</td>
<td>China</td>
</tr>
<tr>
<td>5. Busan</td>
<td>South Korea</td>
</tr>
<tr>
<td>6. Rotterdam</td>
<td>Netherlands</td>
</tr>
<tr>
<td>7. Dubai</td>
<td>UAE</td>
</tr>
<tr>
<td>8. Kaohsiung</td>
<td>Taiwan</td>
</tr>
<tr>
<td>9. Hamburg</td>
<td>Germany</td>
</tr>
<tr>
<td>10. Qingdao</td>
<td>China</td>
</tr>
<tr>
<td>11. Ningbo-Zhoushan</td>
<td>China</td>
</tr>
<tr>
<td>12. Guangzhou</td>
<td>China</td>
</tr>
<tr>
<td>13. Los Angeles</td>
<td>USA</td>
</tr>
<tr>
<td>14. Antwerp</td>
<td>Belgium</td>
</tr>
<tr>
<td>15. Long Beach</td>
<td>USA</td>
</tr>
</tbody>
</table>

### Terminal Operators

<table>
<thead>
<tr>
<th>Terminal Operator</th>
<th>Country</th>
<th>Million TEU handled in 2007</th>
<th>2007 Revenue (billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hutchison Port Holdings</td>
<td>China (Hong Kong)</td>
<td>66.3</td>
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<tr>
<td>2. PSA Corp.</td>
<td>Singapore</td>
<td>58.9</td>
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<td>3. DP World</td>
<td>UAE</td>
<td>43.3</td>
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<tr>
<td>4. Cosco Pacific</td>
<td>China</td>
<td>39.8</td>
<td>0.1</td>
</tr>
<tr>
<td>5. APM Terminals</td>
<td>Netherlands</td>
<td>31.4</td>
<td>2.5</td>
</tr>
<tr>
<td>6. HHLA</td>
<td>Germany</td>
<td>7.2</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Globally, 474 million TEU worth of (empty and loaded) containers were transferred between ships and shore in 2007.

The DP World controversy began in February 2006 and rose to prominence as a national security debate in the United States. The issue was the sale of port management businesses in six major U.S. seaports to DP World, and whether such a sale would compromise port security.
Container Terminals

Terminal-owned equipment performs 3 kinds of tasks:

1. Unloading and loading of vessels
2. Horizontal transport of cargo
3. Container lifting & stacking

On-dock rail yard

Quay cranes (QCs)
Rubber-tired gantry cranes (RTGCs)
Rail-mounted gantry cranes (RMGCs)

Vessels
quay to yard
yard to quay
Storage yard
On-dock rail yard

Externally-owned trucks (XTs)

Foreign land-locked ports

Land-Scarce Container Terminals

Yard trucks (YTs)

Port of Singapore

External trucks (XTs)
Land-Scarce Container Terminals

Port of Singapore

Cargo stacked up to 7 tiers high in large "blocks"

0-3 truck traffic lanes between blocks

Storage density: 1000-1200 TEU per hectare

Manually operated trucks and cranes

No on-dock rail yard

Cargo throughput: 2000-2500 TEU per meter of wharf line per year

Rubber-tired gantry cranes (RTGCs)

Quay cranes (QCs)

Port of Hong Kong

Land-Scarce Container Terminals

Port of Singapore

Rubber-tired gantry cranes (RTGCs)

Quay cranes (QCs)
Straddle Carrier-Based Container Terminals

- Common on the U.S. East Coast and in Europe
- Cargo stacked 3 tiers high in “lanes” that are 1 container wide
- Spaces between lanes very narrow
- Storage density: 750 TEU per hectare
- Manually operated straddle carriers perform operations 2 and 3
- On-dock rail yard a possibility: RMGCs may be needed
- Cargo throughput: 1500 TEU per meter of wharf line per year
Straddle Carrier-Based Container Terminals

Port of Bremerhaven (Germany)

Aerial view of Northport's container terminal

Simulation of a terminal in which
- SCs used in quay and storage yard areas
- RMGCs used at on-dock rail yard to load trains

Source: HHLA website (http://hhla.de)
YC/SC-Free, Ground-Based Terminals

- Common on U.S. West Coast
- Large forklifts called “top-handlers” and “reach-stackers” stack containers up to 4 tiers high in “blocks”
- Large spaces needed between blocks
- Storage density: 500 TEU per hectare
- Manually operated reach-stackers, top-handlers, side-picks, and tractor-trailers
- On-dock rail yard a possibility
- Cargo throughput: 1000 TEU per meter of wharf line per year

Wheel-Based Container Terminals

- Common on U.S. West Coast
- Loaded containers sitting on trailers (chassies) parked in storage yard (stacking height = 1 tier)
- Empty containers stacked up to 4 tiers high by “side-picks”
- Storage density: 250 TEU per hectare
- Manually operated equipment
- On-dock rail yard a possibility
- Cargo throughput: 500 TEU per meter of wharf line per year
**Automated Container Terminals I**

- Ports of Rotterdam and Hamburg
- Cargo stacked up to 5 tiers high in large “blocks”
- Spaces between blocks very narrow
- Automated guided vehicles (AGVs) perform operation 2
- Automated stacking cranes (ASCs) perform operation 3 in yard
- On-dock rail yard a possibility: RMGCs may be needed

![Image of automated container terminal with AGVs and ASCs](www.hhla.de)

**Automated Container Terminals II**

- Patrick Terminal at Port of Brisbane
- Only automated SC-based terminal in the world
- Cargo stacked 2 tiers high in “lanes”
- Automated straddle carriers perform operations 2 and 3

![Image of Patrick Terminal with QC and automated straddle carriers](www.hhla.de)
Other Possibilities

- Straddle carriers and ASCs used in storage yard
- RMGCs used in on-dock rail yard

Source: HHLA website (http://hhla.de)

Container Terminal Characteristics

Most terminals never close
- Workload processed continuously: 24 hours per day, 365 days per year
- Uneven distribution of workload over time (late vessel arrivals, cust. requests)

Highly uncertain equipment processing times
- Truck travel times affected by road traffic conditions inside terminal
- Crane handling times are variable

10,000+ decisions made per day
- Equipment dispatching, container storage location assignment, etc.
- Decision opportunities come with no prior warning
- Decisions made immediately, usually one at a time
- Inter-decision time highly stochastic, avg. as low as 1 sec.

Quay, yard, and gate operations highly interconnected
- Bottlenecks in yard → Late vessel departures
- Few or no inter-equipment buffers
Measures of Terminal Performance

**Gross crane rate (GCR)**
- Also known as the quay crane work rate
- Avg. # QC lifts made per QC hour beside a vessel that is being worked

**Average vessel turnaround time**
- Avg. time it takes to fully process a vessel
- From time of berthing to time of un-berthing

**Average external truck (XT) turnaround time**
- Avg. time it takes for external truck to be serviced at the terminal
- Drop-off or pick-up
- From time of gate entry to time of gate departure

**Ability to keep vessels and trains on schedule**
- Consistency in performance more important than maximizing avg. performance
- Another goal: keep operations on-time at minimum cost

**Cost per TEU moved between ship and shore**
- USD $150 at U.S. ports

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Container Terminal Planning and Design

**Decision**
1. Where should the terminal be located?
2. What kind of cargo will be handled (import, export, transshipment)?
3. What is the planned throughput capacity?
4. How much cargo storage capacity is needed in the yard?
5. Will there be an on-dock rail yard? A large empty container yard?
6. How much land area will the terminal occupy? What is its shape?
7. What type of container handling equipment will be used? Specs?
8. How many work shifts will there be per day?
9. Should the yard layout be parallel or perpendicular?
10. How many storage blocks should there be? What are their dimensions?
11. How many vehicle lanes should there be between the blocks?
12. How much equipment should be deployed on an average day?
## Design Issue #7: Equipment Selection and Specification

### Yard Equipment Type

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Horizontal Transport</th>
<th>Lifting</th>
<th>Stacking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tractor-trailers (YTs)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Automated guided vehicles (AGVs)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Rubber-tired gantry cranes (RTGCs)</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>4. Rail-mounted gantry cranes (RMGCs)</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>5. Automated stacking cranes (ASCs)</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Bridge cranes</td>
<td>X</td>
<td></td>
<td></td>
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<tr>
<td>7. Top-handlers</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Reach-stackers</td>
<td>X</td>
<td>X</td>
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<tr>
<td>9. Side-picks</td>
<td>X</td>
<td>X</td>
<td></td>
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<tr>
<td>10. Straddle carriers (SCs)</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>11. Shuttle carriers</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>12. Automated lifting vehicles (ALVs)</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

### Specification issues for Quay Cranes

- **Single trolley quay crane** handles one cont. at a time
- Port of Long Beach
- Container-terminal of Bremerhaven

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49. 50.
QC Issue A: The Double Trolley Quay Crane

The Double Trolley Quay Crane

Double Trolley QCs and Straddle Carriers at Port of Hamburg
QC Issue B: Twin-lift (two 20’ conts) and tandem (two 40’ conts) spreaders

Design Issue #10.1: Block Width

What is the optimal width for the storage blocks? (storage capacity is unchanged)
Block Width: Tradeoffs

3 rows per block (10 zones)

5 rows per block (6 zones)

6 rows per block (5 zones)

10 rows per block (3 zones)

---

Block Width: Results

Design Issue #10.2: Block Length

What is the optimal length for the storage blocks? (storage capacity is unchanged)

Block Length: Tradeoffs

- Longer blocks
- Fewer vertical traffic lanes
- Less land area
- More congestion

- Shorter blocks
- More vertical traffic lanes
- More land area
- Less congestion
Design Issue #11: Vehicle Lanes

Container Terminal Operations Management

<table>
<thead>
<tr>
<th>Decision</th>
<th>Frequency (decs/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Allocation of berths to arriving vessels</td>
<td>000010</td>
</tr>
<tr>
<td>2. Allocation of QCs to docked vessels</td>
<td>000010</td>
</tr>
<tr>
<td>3. QC scheduling and job sequencing</td>
<td>10 (off-line) or 10,000 (real-time)</td>
</tr>
<tr>
<td>4. Container storage location assignment</td>
<td>010,000</td>
</tr>
<tr>
<td>5. Container retrieval location assignment</td>
<td>010,000</td>
</tr>
<tr>
<td>6. YC job assignment</td>
<td>010,000</td>
</tr>
<tr>
<td>7. Inter-zone YC deployment</td>
<td>010,000</td>
</tr>
<tr>
<td>8. YT job assignment</td>
<td>010,000</td>
</tr>
<tr>
<td>9. YT routing</td>
<td>100,000</td>
</tr>
<tr>
<td>10. Selecting appointment times for external trucks</td>
<td>010,000</td>
</tr>
</tbody>
</table>
Terminal Manager’s Goal:

Find solutions for operations management (OM) issues that

(1) are viable in a real-time setting
(2) maximize performance (e.g. gross crane rate)

\[ \text{GCR} = \frac{\text{total # QC lifts made}}{\text{total hours of QC time beside a busy berth}} \]

Terminal Operating System (TOS)

- TOS deciding next activity for a particular QC/YC/YT/container
- TOS receiving input:
  - QC/YC/YT task completed
  - Vessel arrives (new jobs added to system)
  - XT arrives (new job added to system)
- TOS manipulating data internally
- TOS is idle

To be viable, a TOS must:
- Use less than 1 second of CPU time per decision on 100% of occasions
- Avoid deadlocks on 100% of occasions
**OM Issues #1 and #2: Terminal, Berth, and Quay Crane Allocation to Arriving Vessels**

*Where* should an arriving vessel be berthed? (Which terminal, which berth?)

*Which* quay cranes should work on the vessel?

---

**Terminal, Berth, and Quay Crane Allocation: A Multi-objective Problem**

**Objectives:**
1. Minimize vessel turnaround times
2. Maximize berth utilization and terminal throughput
3. Maximize satisfaction of customer shipping lines
4. Minimize cost (labor and equipment used) when processing vessels
5. Maximize efficiency of vessel-to-vessel transshipment operations

**Constraints:**
- Water depth
- Berth and vessel lengths
- Quay crane availability and specs
- Vessel schedules
- Transshipment requests
Once a vessel is secured alongside the terminal,

(A) Which containers are moved by which QC?

(B) What is the sequence of moves for each QC?

Objectives:
- Minimize vessel turnaround time
- Unload “hot” containers quickly
- Minimize cost of unloading and loading vessel

Constraints:
1. Ship balance must be maintained
2. Stress on vessel may not exceed certain limits
3. Precedence constraints due to container stacks
4. QCs must remain a minimum distance apart to avoid collisions
5. Visibility: crane operators must be able to easily see containers
6. Stability of above-deck stacks: no “chimneys” (stacks jutting out vertically by more than 2 tiers)
Further complexity:
1. Some cargo booked for a vessel arrives after loading has begun
2. Cranes may work at different speeds
3. Not all container moves are loads or unloads—there are also repositioning moves!

QC Scheduling: Current Practice

Perform a **Crane Split:**
(a set partitioning problem)
- Vessel bays are partitioned into contiguous areas
- Each area is served by one crane
- Partitioning done so that the time when last QC finishes is minimized
- Each QC works the bays in its area from L to R
QC Scheduling: The Crane Split (Equal Crane Speeds)

<table>
<thead>
<tr>
<th>Containers to move</th>
<th>Time required (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay #</td>
<td>Unloading</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>66</td>
</tr>
<tr>
<td>7</td>
<td>35</td>
</tr>
<tr>
<td>10</td>
<td>26</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td>14</td>
<td>72</td>
</tr>
<tr>
<td>18</td>
<td>55</td>
</tr>
<tr>
<td>Total</td>
<td>318</td>
</tr>
</tbody>
</table>

QC Scheduling: The Crane Split (Unequal Crane Speeds)
QC Scheduling: The Crane Split (Unequal Crane Speeds)

Optimal solution: 574 minutes is the minimum vessel turnaround time

<table>
<thead>
<tr>
<th>Bay #</th>
<th>Unloading</th>
<th>Loading</th>
<th>Total</th>
<th>QC1</th>
<th>QC2</th>
<th>QC3</th>
<th>QC4</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>15</td>
<td>19</td>
<td>34</td>
<td>82</td>
<td>102</td>
<td>102</td>
<td>136</td>
</tr>
<tr>
<td>3</td>
<td>9</td>
<td>8</td>
<td>17</td>
<td>41</td>
<td>51</td>
<td>51</td>
<td>68</td>
</tr>
<tr>
<td>4</td>
<td>66</td>
<td>52</td>
<td>118</td>
<td>283</td>
<td>354</td>
<td>354</td>
<td>472</td>
</tr>
<tr>
<td>7</td>
<td>35</td>
<td>35</td>
<td>70</td>
<td>168</td>
<td>210</td>
<td>210</td>
<td>280</td>
</tr>
<tr>
<td>10</td>
<td>26</td>
<td>24</td>
<td>50</td>
<td>120</td>
<td>150</td>
<td>150</td>
<td>200</td>
</tr>
<tr>
<td>11</td>
<td>40</td>
<td>43</td>
<td>83</td>
<td>199</td>
<td>249</td>
<td>249</td>
<td>332</td>
</tr>
<tr>
<td>14</td>
<td>72</td>
<td>76</td>
<td>148</td>
<td>355</td>
<td>444</td>
<td>444</td>
<td>592</td>
</tr>
<tr>
<td>18</td>
<td>55</td>
<td>45</td>
<td>100</td>
<td>240</td>
<td>300</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>Total</td>
<td>318</td>
<td>302</td>
<td>620</td>
<td>574</td>
<td>399</td>
<td>444</td>
<td>400</td>
</tr>
</tbody>
</table>

Optimal solution: 574 minutes is the minimum vessel turnaround time

Yard Control Issues
OM Issue #4: Selection of Cargo Storage Locations

Where should containers be placed in the yard upon their arrival? (e.g. after being unloaded from a vessel)

Container Storage Strategies

I. Re-marshalling strategy
   - Containers have multiple places of rest

II. “Sort and store” strategy
   - Containers have a single place of rest
   - Containers stored based on attributes (e.g. length, height, weight class, loading vessel, destination port)
   - Containers with similar attributes stored in same stack
   - Two versions:
     1) Storage locations determined off-line in advance
     2) Storage locations determined in real-time immediately after container is discharged
**Possible objectives to pursue**

1. Minimize container travel distance
2. Minimize congestion in vicinity of storage locations
3. Minimize number of times each container is touched

Not all objectives can be pursued simultaneously.

Thus, managers need to determine which objectives are most important!! This is not easy!

---

### OM Issue #5: Container Retrieval Location Assignment

Which stack in the yard, among those which are eligible, should provide the container(s) loaded by a QC?
OM Issue #6: Yard Crane Job Assignment

1. When a YC becomes free, which YT does it serve next?

2. How to avoid deadlocks when YCs are working in close proximity and containers halfway between them need to be moved?

OM Issue #8: YT Job Assignment

1. When a YT becomes free, what should it do next?
2. When to carry two 20' containers?
3. Should YT's be pooled at the QC, vessel, or terminal level?
OM Issue #10: Appointment System for External Trucks

What kind of truck appointment system best serves the interests of the terminal, trucking industry, neighboring community, and environment?

What should the appointment date and time be for a specific truck?

Appointment system should:

- automatically generate appointment times for customers who call the terminal or log onto the internet
- determine the number of appointments to be made for a given region of the container yard for a given time period
- minimize average truck service time at the terminal
- minimize truck congestion overflow into local highway system
- maximize gate throughput
- enhance yard and vessel operations in the container terminal
Other Container Terminal Issues

<table>
<thead>
<tr>
<th>Issue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Labor (union or non-union)</td>
</tr>
<tr>
<td>2. Container identification and tracking (OCR, RFID)</td>
</tr>
<tr>
<td>3. Equipment identification and tracking (GPS, local radar, RFID)</td>
</tr>
<tr>
<td>4. Customs</td>
</tr>
<tr>
<td>5. Security (scanning equipment, manual inspections)</td>
</tr>
<tr>
<td>6. Negotiating service agreements with shipping lines</td>
</tr>
<tr>
<td>7. Negotiating lease rates with public municipalities</td>
</tr>
<tr>
<td>8. Purchasing/developing a terminal operating system (TOS)</td>
</tr>
<tr>
<td>9. Tactical issues: when to purchase more equipment (QCs, YCs, YTIs)</td>
</tr>
</tbody>
</table>

Outline

1. Introduction to maritime shipping
2. Introduction to container shipping
3. Container vessels and shipping lines
4. Seaports
5. Railway container transportation / facilities
6. Conclusion
### Railway Container Transportation

--- | --- | --- | ---
1. BNSF | USA | 5,065,005 | 
2. Union Pacific | USA | 3,453,000 | 
3. Norfolk Southern | USA | 3,120,000 | 
4. CSX Corp. | USA | 2,111,000 | 
5. Canadian National | Canada | 1,324,000 | 
6. Canadian Pacific | Canada | 1,238,100 | 
7. Kansas City Southern | USA | 526,370 | 

#### Most Common Intermodal Container Rail Cars

- Well/Double Stack Car
- Conventional Intermodal Car (TDFC or COFC)
Inland (Rail) Container Terminals

- Transferring containers between trains and trucks
- Unloading and loading of intermodal trains
- Temporary storage of containers
Outline

1. Introduction to maritime shipping
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Containerization Impact on Cities

- Container shipping supplies cities and their inhabitants with finished consumer goods
- Chicago: inland container shipping hub of the USA
- Milwaukee: CP “Canadian Pacific” rail facility at the Port of Milwaukee
- Congestion
- Pollution
- Maritime shipping constitutes 4.5% of global CO2 emissions
Inspired architectural innovation

Literature on Container Terminal Ops.

Acknowledgment

Grateful acknowledgment is herewith made for the cooperation and permission to use the materials and photos from the following personnel/websites/institutes:

- Alex Klein / www.renaissanceronin.wordpress.com
- American President Lines Ltd / www.apl.com
- Burlington Northern Santa Fe Railway / www.bnsf.com
- Center for Disease Control and Prevention / www.cdc.gov
- containershipping.nl / www.containershipping.nl
- Danny Cornelissen-Maritime Photographer / www.portpictures.nl
- FRANCETRUCK / www.francetruck.com
- Great Lakes St. Lawrence Seaway System / www.cgmsc.com
- Hapag-Lloyd / www.hapag-lloyd.com
- Hamburger Hafen und Logistik AG / www.hhla.de
- KOCKS / www.kockskrane.de
- Mediterranean Shipping Company MSC / www.mscgva.ch
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- Swedish Timars group / www.timars.se
- VDL Containersystemen / www.infouw.com
- Webmaster / www.infovisual.info
- Wikipedia
- Union Pacific / www.up.com

The End!