Moffatt & Nichol Engineers

“A Firm Focused on the Waterfront”

• Over 60 Years
• Offices in Major North American Port Cities
• Port & Intermodal Planning
• Terminal Planning & Analysis
• Freight Forecasting
• Port Financial Analysis
• Port Infrastructure Design
• Dredging & Reclamation
• Marinas
• Environmental
• Urban Waterfronts
• Bridge & Highway Design
Change

Change is exciting
This is the most exciting time ever for ports

“The problem with our time is that the future is not what it used to be…”
(Unknown author)

“I have no need for ports…I get everything I need from the internet…”
(Unidentified “CAVE” person)
Ocean Shipping 101:

- People need to move stuff
- The people of the world are connected by very deep water
- Water is very strong
- Water is very slippery
• Floatation is, always & forever, the best way to move stuff on this planet

• Ships have never stopped growing & changing

• We will continue to build better ships

• If bigger is better, then ships will grow

• Ports and terminals will adapt to serve them
Compared to ships, trains and trucks are a silly way to move stuff;

One Ship = 8,000+ TEU
$0.10 per ton mile

And the gap is widening!

One Train = 560 TEU
$.50 per ton mile

One Truck = 2 TEU
$1.00-2.00 per ton mile

And the gap is widening!
“It is only recently, ... and cautiously, that we have moved far from the oceans, to places like Siberia or Nebraska, and it is by no means clear that places so far removed from the sea are viable in the long term.”

John Szarkowski; Author, Director Emeritus, Museum of Modern Art, NY
Green Ports

• How do we continue to grow our ports and minimize the impacts on their communities?

• Balance:
  – Growth in trade
  – Wildlife habitat
  – Traffic
  – Emissions / human health
  – Quality of life
Next Generation 1 TEU “Green” Vessel and Agile Port Concept

- No dredging
- No landfill
- No emissions
- Nothing on the shelves at Walmart
- No jobs
- Etc.
Most Economical Vessel Size

• Equals the capture rate on the service frequency

Container Vessel Size Demand

- 8,500 TEU
- 12,000 TEU

Generation Currently on Order

Next Generation?
Impact of Large Vessels – Port Throughput

- 10,000 TEU Vessels in a Weekly Service
- Loading & Discharging 50% of Capacity per Call
- Generate Port Throughput of 500,000 TEU's per year

Annual Throughput, Weekly Service

Load/Discharge % of Capacity

<table>
<thead>
<tr>
<th>TEU's</th>
<th>12,000</th>
<th>10,000</th>
<th>8,000</th>
<th>6,000</th>
<th>4,000</th>
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<tr>
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<td>80%</td>
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<td></td>
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<td></td>
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</tr>
</tbody>
</table>

Annual Throughput, Weekly Service
“Next” Generation Container Ships

Suez Max 12,000-13,000 TEU
Azimuthing Drives
125,000 hp (2x65,000)

Suez Max 12,000-13,000 TEU
Twin Screw, Twin Diesel
125,000 hp (2x65,000)

Samsung 8,800-9,200 TEU
Single Screw Diesel
90,000 hp-100,000

Power Plants
Drives
Engine, Drive Shaft & Rudder
13,000 TEU Vessel Suezmax / “New Panamax”, Azimuthing Drives?

“Suez / New Panamax” 12,000 - 13,000 TEU

- Multiple Diesel-Electric Azimuthing Pod Drives
- 1300 feet long overall
- 185 foot beam (20 - 22 containers)
- 45 - 48 foot draft
- 165 - 185 foot airdraft
- Optimum hull design
- High maneuverability
Sulzer Marine Engine

- 14 Cylinder Inline Diesel 108,000 hp
- 10,000 TEU Vessel at 25 knots
- 5,000,000 pounds
- 90 feet long, 45 feet high
- Largest single-screw possible?
Sulzer Marine Engine

12 Cylinder Version

Piston & Rod
10,000 TEU Vessel Carrying Capacity

1 10,000 TEU Container Ship
18 8,000 Foot Double-Stack Trains (27 Miles) (50 Acres)
5,800 Trucks (60 Miles) (95 Acres)
570 Boeing 747 Cargo Liners

DISCHARGE OR LOAD ONLY!
Impact of Large Vessels - Port Traffic - West Coast

10,000 TEU Vessel
85% Discharge / 85% Load
50% Local / 50% Intermodal

8 - 8,000 Foot Double-Stack Trains

2,500 Truck Loads
(4,000 Local Truck Trips)

Total Traffic Generated:
16, 8,000 Foot Trains
8,000 Local Truck Trips

2,500 Truck Loads
(4,000 Local Truck Trips)

DISCHARGE

LOAD
10,000 TEU Vessel
25% Discharge / 25% Load
50% Local / 50% Intermodal

750 Trucks
(1,100 Trips)

3, 6,000 Foot Double-Stack Trains

Total Traffic Generated;
6, 6,000 Foot Trains
2,200 Local Truck Trips

750 Trucks
(1,100 Trips)

Impact of Large Vessels – Port Traffic - East Coast

DISCHARGE

LOAD
Impact of Large Vessels – Terminal Size - West Coast

- 10,000 TEU Container Ships in a Weekly Rotation
- 85% Average Discharge / Load
- 880,000 TEU’s / Year
- Wheeled: 3,800 TEU’s / Acre / Year = 230 Acres
- Grounded: 7,000 TEU’s / Acre / Year = 125 Acres
The Goal of Terminal Productivity

• Highest Throughput at Lowest Cost

• Port Throughput Capacity is Limited by Storage Capacity (almost always)

• The Container Yard is the Key
Area - Density – Dwell Time

• The Three Elements of C.Y. Capacity
  – Area, Density, Dwell Time

• Static Capacity = Area x Density

• Throughput Capacity = A x D / Dwell Time

• The Modifying Elements
  – Cost
  – Service

Interrelated & Inseparable
High Dwell Time is Devastating to Capacity!
Effective Storage Density

= Gross Density Less Efficiency Factors
- Sorting Factors
- Digging Space
- Vessel Peaking Factors
- Seasonal Peaking Factors
Gross / Net Density of Storage Mode

GROSS vs NET STORAGE DENSITY

TEU's / Acre

0 50 100 150 200 250 300 350 400

Wheeled
Top-Pick, 2 Wide x 2 High
Straddle Carrier
Top-Pick, 6 Wide x 4 High
RTG, 6 Wide x 4 High

Mode

COST / SERVICE

AREAN

DENSITY

Dwell Time
Container Dwell Time

- Typical U.S. container dwell times
  - Imports: 4 - 6 days
  - Exports: 5 - 7 days
  - Empties: 10 - 40 days
    - Enforce allocations
    - Move off terminal
- As awareness increases, dwell time is being reduced
- Longer dwell dictates higher density
Storage Density / Cost

- **Land Cost**
  - Higher Density = Lower Cost (+)

- **Civil Development Cost**
  - Higher Density = Higher Cost (-)

- **Labor Cost**
  - Higher Density = Higher Cost (-)

- **Equipment Cost**
  - Higher Density = Higher Cost (-)
Grounded Costs
(California Costs)

1. Discharge
   $75

2. Receive
   $15

3. Deliver
   $15

4. Load
   $25

5. Shuffle
   $65

Total Intermodal $130

Total Local $180-$250
Wheeled Costs
(California Costs)

1. Discharge
$75

2. Receive
$0

3. Deliver
$10

4. Load
$25

5. Shuffle
$10

Total Intermodal $110
($20 Savings)

Total Local $85-$100
($90-$150 Savings)
Effect of Sorting

Front-End Loader Access

One Sort = 32 Boxes

Gross Capacity
Effect of Digging

6-wide, 1 over 3 RTG
Gross Cross-Section, 18 Boxes
Effective Height, 2.67

6-wide, 1 over 4 RTG
Gross Cross-Section, 24 Boxes
Effective Height, 3.5

6-wide, 1 over 6 RTG
Gross Cross-Section, 36 Boxes
Effective Height, 5
Effect of Vessel (Inventory) Peaking

12 Vessels, Peak/Average Ratio = 1.1
Max. Util. = 91%

3 Vessels, Peak/Average Ratio = 1.25
Max. Util. = 80%
Yard Productivity - Crane (Hook) Density

- The ratio of yard cranes to TEU’s of storage capacity
- Yard cranes must meet total service demand
- Required hook density is a function of:
  - Peak demand
    - Vessel
    - Gate
    - Train
  - Dwell Time (Turnover Rate)
- Solution varies considerably
  - Port to port
  - Day to day
Yard Productivity – Crane (Hook) Density

- TEU’s of Storage per Hook
- Balance Physical & Dynamic Factors

Stack Height
Crane Footprint
Crane Spacing
Stack Width
Yard Productivity - Crane (Hook) Density

- Example HIT, Hong Kong
- Need for high density (125 Yard cranes in 80 Acres)
- Semi-Automated RMG’s
  - 12 wide x 6 high
  - High degree of automation
  - 1,100 TEU’s / crane
  - 300 foot spacing
  - 80 feet bumper-bumper
- Insufficient hooks to meet peak demand
- Vessel priority/poor gate service
  - Even with 24 hr gate & appointments
Density / Service

- Higher Density = Lower Service
- More Digging
- Higher Hook Density
- Extended Hours of Operation
- Appointments
Service Definition

- Vessel Productivity
- Gate Turn Times
Changing Definition of Service

- Ports, Terminal Operators, and Shipping Companies are not driving the train anymore
  - Large Retailers
  - Manufacturers
  - Shippers
  - Logistics Providers Say:

  “What”       “When”      “How”

- The ports neighbors say:

  “Minimize the Impacts”
  or
  “Get Out of Town”
LA/LB Growth

Southern California Capacity vs Forecast

Annual TEU's

- Forecast @ 4% Growth
- Forecast @ 6% Growth
- Forecast @ 8% Growth
- Capacity at Current Average Productivity
- Capacity at Current Maximum Productivity

Southern California Container Terminal Productivity

- Current Average Productivity: 5,000
- Historical Maximum Productivity: 7,000
- Required Productivity: 10,000
West Coast Terminal Productivity

- Priority Imports Wheeled
- Imports RTG’s
- Exports Top-Picks
- Empties Side Picks

- So. Calif. average = 4,800 TEU/ac/yr
- Recent maximum = 7,000 TEU/ac/yr
- Reasonably achievable = 6,500 TEU/ac/yr

West Coast Throughput Density

- TEU’s/terminal acre/year:
  - 4,589
  - 4,831
  - 5,100
  - 5,401
  - 5,739
  - 6,122
  - 6,560
  - 7,066
  - 7,656
  - 8,353
  - 9,191
  - 11,715

- Percent Grounded:
  - 0%
  - 10%
  - 20%
  - 30%
  - 40%
  - 50%
  - 60%
  - 70%
  - 80%
  - 90%
  - 100%
  - RMG
Port Land Productivity & Capacity

- West Coast Container Terminal Area = 4,860 Acres
- 2004 Throughput = 19,860,000 TEU’s
- 2004 WC Average Terminal Productivity = 4,088 T/Acre
- Capacity of Exist. Terminals @ 6,500 T/Acre = 31,577,000 TEU’s
- Latent Capacity @ 6,500 T/Acre = 11,715,800 TEU’s
- Latent Capacity of MP Land = 24,286,800 TEU’s
- Assumes even distribution to WC ports

<table>
<thead>
<tr>
<th>Port</th>
<th>Current Area</th>
<th>Master Plan Area</th>
<th>2004 Throughput</th>
<th>2004 Productivity (TEU's / Acre)</th>
<th>Capacity at 2004 Productivity</th>
<th>Capacity at 6,500 TEU/Ac</th>
<th>Latent Capacity at 6,500 TEU/Ac</th>
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<tr>
<td></td>
<td>Current Land</td>
<td>Masterplan Land</td>
<td>Current</td>
<td>Masterplan Land</td>
<td>Current Land</td>
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<td>710</td>
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<td>1,539,058</td>
<td>3,362,250</td>
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<td>464</td>
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<td>3,827</td>
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<td>Tacoma</td>
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<td>9,621,473</td>
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<tr>
<td>Total</td>
<td>4,858</td>
<td>6,792</td>
<td>19,861,200</td>
<td>4,088</td>
<td>19,861,200</td>
<td>27,768,067</td>
<td>31,577,000</td>
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</table>
Capacity Enhancement Strategy Comparison

### Effect of Stacking Height Alone + 40%

<table>
<thead>
<tr>
<th>Container Stack Height</th>
<th>TEUs per Acre per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 High</td>
<td>6,540.4</td>
</tr>
<tr>
<td>4 High</td>
<td>7,625.9</td>
</tr>
<tr>
<td>5 High</td>
<td>8,395.6</td>
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<tr>
<td>6 High</td>
<td>9,106.9</td>
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### Effect of Chassis + 50%

<table>
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<th>Current Chassis Use</th>
<th>TEUs per Acre per Year</th>
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<tbody>
<tr>
<td></td>
<td>7,313</td>
</tr>
<tr>
<td>No Chassis</td>
<td>11,657</td>
</tr>
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</table>

### Effect of Dwell Time Alone + 50-90%

<table>
<thead>
<tr>
<th>Container Stack Height</th>
<th>TEUs per Acre per Year</th>
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</thead>
<tbody>
<tr>
<td>Current Dwell</td>
<td>7,625.9</td>
</tr>
<tr>
<td>One Day Less</td>
<td>10,396.2</td>
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<tr>
<td>One Day Less</td>
<td>11,505.1</td>
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<tr>
<td>One Day Less</td>
<td>14,601.9</td>
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### Effect of All + 275%

<table>
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<tr>
<th>Current Dwell, 3.5 High</th>
<th>TEUs per Acre per Year</th>
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<tbody>
<tr>
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<td>7,313</td>
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<tr>
<td>One Day Less, 4.5 High</td>
<td>9,213</td>
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<tr>
<td>Two Days Less, 5.5 High</td>
<td>13,049</td>
</tr>
<tr>
<td>One Day Less, 5.5 High, No Chassis</td>
<td>20,224</td>
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Growth Issues

- Growth & Capacity
  - Port
    - Landside Infrastructure
- Labor & Technology
- Impacts
  - Traffic
  - Emissions
- Security
Integrated Strategy for Growth

- Expand terminals
- Increase container storage density
- Reduce dwell time in port
- Extend gate & yard R/D hours
- Truck RFI tagging & OCR systems
- Mandatory appointment systems
- Cold Ironing of vessels
- Integrated smart truck dispatch system
- Rail-mounted (electric) yard cranes
- Virtual container yard equipment sharing
- Gray chassis pools managed by truckers
- Shuttle trains to distribution centers
- Driver I.D. and credentialing system
- Radiation & other WMD screening
- Vaccis (gamma ray) screening
- Surveillance systems
Traffic Generation Modeling

Truck Trips Generated by Hour of Day

- Arrivals
- Departures
Conclusions

• The “Area / Density / Dwell / Service / Cost” Equation Varies from Port to Port

• The “Best Solution” Varies with Location & **Time**
  – Hence Maximum Operational Flexibility is Always Highly Desirable
  – Higher Density Reduces Flexibility
Conclusions

• The Problems Will Not Be Solved by Technology Alone

• An Integrated Approach is Needed
  – Automation Generally Addresses (Labor) Cost Only
  – C.Y. Automation Usually Precludes Operational Flexibility
  – Automation Does Not Currently Co-Exist with Density & Service
  – But Higher Levels of Automation are Required in U.S. Terminals
The U. S. Terminal of the (Near) Future

• Virtually all grounded up to 6 high
• Rail-mounted yard cranes (semi-automated)
• Significantly automated gates
  – RF Tagging of tractors & chassis
  – OCR
  – Paperless
• 24 hour “steady-state” terminal operations
  – 50% Day – 35% Night – 15% Hoot
  – R&D, pre-mounting
  – Stack grooming
• Appointment systems
• Integrated truck dispatch system
• Chassis stored outside terminals
• Empty yards / depots off terminal
• All local drivers registered & documented
• Maximum use of on-dock / near-dock intermodal
• Shared local shuttle trains serving distribution centers
Next Generation U.S. Semi-Automated Terminal

- Electric Rail Mounted Gantries perpendicular to berth
  - Internal stack moves fully automated
  - Remote crane operators for vessel / gate service
- Dock crane service by bomb carts or strads (shuttle carriers)

2-3 Cranes per Stack
Next Generation U.S. Semi-Automated Terminal

100' Gauge Gantry Crane

100' High Mast Light Standard

120' Laydown Area

Stevedoring Lanes

Hatch Cover

RMG Section

A

B

Typical RMG Storage (Typical)
Modeling of Automated Terminals

### Crane Configuration per Stack
- **Model Run**
- **Stack Width (Containers)**
- **Cranes per Stack**
- **Number of stacks/cranes possible across yard**
- **Ratio, yard vessel server cranes to dock cranes**
- **Estimated Average Yard Crane Productivity**
- **Vessel Moves Possible per Hour per Dock Crane**
- **Stack Width (Containers)**
- **Cranes per Stack**
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### Table:

<table>
<thead>
<tr>
<th>Stack Width (Containers)</th>
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</thead>
<tbody>
<tr>
<td>12</td>
<td>3</td>
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<td>10</td>
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</tr>
<tr>
<td>8</td>
<td>3</td>
<td></td>
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<tr>
<td>17.48</td>
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<td>17.64</td>
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<td>24.67</td>
<td>29.56</td>
<td>35.28</td>
<td>23.65</td>
<td>27.85</td>
<td>33.16</td>
</tr>
</tbody>
</table>

### Statistics:
- **Total yard cranes:** 45, 51, 57, 51, 60, 72, 54, 48
- **Hook Density (Static TEU's / Hook):** 881, 778, 696, 778, 661, 551, 1,167, 992, 826
- **Interior Aisle Width:** 98, 93, 125, 138, 115, 96
- **Stack Length (TEU's):** 52, 41, 41
- **Stack Length (ft):** 939, 994, 1,112
- **Feet of Crane Rail Required:** 68,324, 81,194, 99,705, 34,957, 41,789, 46,920
- **Total Yard Crane Cost (Mil $):** $108.00, $119.85, $131.10, $122.40, $141.00
- **Estimated Cost of Crane Rails (Mil $):** $68.32, $81.19, $99.71
- **Total Cost of Yard Cranes & Crane Rails (Mil $):** $176.32, $201.04, $230.81
- **Cost per Possible Vessel Move per Hour (Mil $):** $8.07, $8.15, $8.52
- **Net Stack Area (acres):** 79.63, 83.18, 90.76
- **Net CY Density (TEU/Ac):** 498.2, 476.9, 437.1
Conclusions

- Smarter People: Ports & Terminal Operators
- Understanding: We Must Understand the Problems to Craft the Solutions
- Smarter Ports & Terminal Facilities
- Prudent, Incremental Application of Technologies
- Reasonable Cooperation of Labor
- Environmentally Responsible

“Good judgment comes from experience and a lot of that comes from bad judgment.”

Will Rogers
thank you!
10,000 TEU Vessels

- Since only one crane per hatch can be deployed, Minimum port time is increased, no matter how many cranes are deployed

“SUEZ CLASS”
20 WIDE
10,000 – 12,000 TEU
293 CONTAINERS
22 HOURS @ 27 LPH

“SUPER POST-PANAMAX”
16 WIDE
17 WIDE
5,500 TEU
213 CONTAINERS
16 HOURS @ 27 LPH

“POST-PANAMAX”
13 WIDE
17 WIDE
4,000 TEU
130 CONTAINERS
10 HOURS @ 27 LPH

“PANAMAX”
13 WIDE
5,500 TEU
65 CONTAINERS

10,000 TEU Vessels

West Coast
10,000 TEU Vessel
Discharge/Load 85% of Cap.
9,700 Moves per Call
22-24 Hatch Positions

Conventional Berth
4 - 5 Cranes
@ 27 Moves / Hour
80 Productive Hours, Min. Req.
4 - 5 Days in Port
1,000 Container Initial Discharge
Yard Crane Density 1:850 TEU

Indented Berth
8 - 10 Cranes
@ 27 Moves / Hour
40 Productive Hours, Min. Req.
2 - 2.5 Days in Port
2,000 Container Initial Discharge
Yard Crane Density 1:650 TEU

West Coast
10,000 TEU Vessel
Discharge/Load 85% of Cap.
9,700 Moves per Call
22-24 Hatch Positions

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8 - 10 Cranes
@ 27 Moves / Hour
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10,000 TEU Vessels

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Discharge/Load 85% of Cap.
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22-24 Hatch Positions

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4 - 5 Cranes
@ 27 Moves / Hour
80 Productive Hours, Min. Req.
4 - 5 Days in Port
1,000 Container Initial Discharge
Yard Crane Density 1:850 TEU