PLANNING, DESIGN, and REALIZATION OF AUTOMATED TERMINALS

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Senior Port Engineer / Vice President
Moffatt & Nichol

• Founded in 1945 in Southern California to serve the U.S. Navy & the evolving port & maritime industries

• 600+ employees w/29 offices (North America, Europe, Latin America, Middle East, Pacific Rim)

• A recognized leader in marine terminal planning, analysis, design & goods movement economics
## Services for Development of Automated Terminal Matrix

<table>
<thead>
<tr>
<th>Services</th>
<th>Moffatt &amp; Nichol</th>
<th>Typical Simulation Consultant</th>
<th>Typical Infrastructure Consultant</th>
<th>Typical Equipment Vendor</th>
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<tbody>
<tr>
<td>Master Planning</td>
<td>✓</td>
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<td>Investment Advisory</td>
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<td>Basis of Design</td>
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<td>Simulation</td>
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<td>Interface Plan</td>
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<tr>
<td>Equipment Specifications</td>
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<tr>
<td>IT, Application Specifications</td>
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<td>Procurement Process:</td>
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<tr>
<td>Equipment</td>
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<td>✓</td>
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<tr>
<td>IT, Application</td>
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<tr>
<td>Program Management (infrastructure)</td>
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<td>Contract Management (equipment)</td>
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<tr>
<td>Emulation</td>
<td>✓</td>
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<td>Training</td>
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<td>Go-Live Support</td>
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<tr>
<td>Optimization</td>
<td>✓</td>
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</tbody>
</table>
The Business Case

E³

Economical
(meeting the business case)

Efficient
(delivering capacity, speed and reliability at lowest cost)

Environmentally sustainable
(lowest energy consumption)
Planning and Layout – Tailoring to Fit the BC

• So, the planner is like a tailor
• He must try to fashion the terminal to fit the business case perfectly

**CAPACITY**
• Annual throughput

**PRODUCTIVITY**
• Vessel
• Gate
• Rail

**COST**
• Facilities
• Equipment
• Labor
• Energy

• One size does not fit all!
Conventional “Bottom-Up” Planning

Operations

Logistics

Equipment

Infrastructure

Traditional
New “Top-Down” Planning

New

Operations

Logistics

Equipment

Infrastructure
Project Organization?

Executive / Steering Committee

Project Manager
  Reporting
  Cost Control
  Schedule Control

Core team

Operations
  Terminal Ops
  TOS
  IT
  Equip
  Maint

Program Integration Team
  Coordinate:
    Operations–Infrastructure

Infrastructure
  Wharf
  Buildings
  Backlands Elect/Comm
  Rail
  Gate

Systems & Process Integrator
Development Philosophy

• The infrastructure for an automated terminal is fixed for its economic life
• An automated container terminal will be designed to perform under high utilization
• It is critical to predict performance and operating cost for the life of the infrastructure
• An early preparation of well-integrated, long-term masterplan and development plan is required
Path to Completion is Complex
Wharf

Robotic Operation

Manned Main Trolley
Automated Secondary Trolley
Automated Horizontal Transport AGV’s
Automated Container Stacking, Retrieval, Shuffling ASC’s
Semi-Automated Delivery to Outside Truck

Vessel
Quay Crane
Container Yard
Outside Truck
Wharf Design Issues
Wharf Design Issue

- Quay design load will depend on crane:
  - Gage
  - Back reach
  - Out reach
  - Setback from face of the quay
  - Type of operation (tandem, single, double trolley etc.)
  - Wind and seismic load
  - Crane wharf interaction
Seismic Design Approach

• Performance-based design approach:
  – Operating Level Earthquake (OLE)
  – Contingency Level Earthquake (CLE)
  – Code-Level Design Earthquake (DE)

• Performance goals:
  – OLE performance = No damage
  – CLE performance = Repairable damage
  – DE performance = No collapse
Berthing and Mooring Loads

• Berthing Load
  – Design Vessel 20,000 TEU +
  – Ship Approach Velocity and Angle 0.26 ft/s, 5°
  – Length Overall (LOA) 1,300 feet +
  – Maximum Displacement 254,000 metric tons +
  – Beam 194 feet
  – Maximum Draft 50.8 feet
  – Allowable Hull Pressure 4.13 ksf

• Mooring Load
  – 200 metric ton bollards
Horizontal Transport Area

Robotic Operation

Manned Main Trolley
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Horizontal Transport

• Gathering and distributing tasks to/from storage
  – Move any box, from any location to any location at any time

• Must be rubber-tired
  – AGV/L-AGV (diesel/ battery operated)
  – AShC/ASTraddle (hybrid diesel)
Typical AGV Traffic Layout

- It is important to understand the traffic pattern
- Operationally acceptable grades
- Requirements for systems such as transponders and magnets
- Appropriate position for all above ground structures

6 long travel lanes
Cross-travel and holding lanes
1 long travel lane
6 transfer lanes
LS QC rail
WS Transfer Area

- Understand the operational requirements
- Interface with AGV system
- Interface with ASC control/ safety systems
- Load repetition
- Durability of pavement
- Different solutions for different modes of operation
Pavement Areas
Vehicle / Wheel Load Repetition

Favored Storage Location

Berth 1

Berth 2

Berth 3

Berth 1 Favored Area

Berth 2 Favored Area

Berth 3 Favored Area
Vehicle / Wheel Load Repetition

Container Location Distribution

Equal Storage

Proportional Storage

60% to Favored Storage

- Berth Location 8 - 20
- Berth Location 21 - 31
- Berth Location 32 - >37
Vehicle / Wheel Repetition
Results – Equal Storage Case

- Max Reps at middle of blocks
- 1M reps ~ 55% of terminal throughput
Vehicle / Wheel Repetition

Proportional Storage Case

- Max Reps at middle of blocks
- 1M reps ~ 55% of terminal throughput
Vehicle / Wheel Repetition

Favored Storage Case

- Max Reps flattened and reduced
- 0.65M reps ~ 35% of terminal throughput
## Vehicle / Wheel Repetition

### Summary of Result

<table>
<thead>
<tr>
<th>Allocation Assumptions</th>
<th>Equal Storage</th>
<th>Proportional Storage</th>
<th>Favored Storage</th>
<th>Worst Case</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>40%</td>
<td>50%</td>
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<tr>
<td>Max Vehicle Repetition (Loaded)</td>
<td>998,746</td>
<td>1,005,520</td>
<td>973,410</td>
<td>891,698</td>
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<tr>
<td>Block Location When Max Repetition Takes Place</td>
<td>23</td>
<td>19</td>
<td>19</td>
<td>19</td>
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<tr>
<td>Percentage of Throughput</td>
<td>54%</td>
<td>55%</td>
<td>53%</td>
<td>49%</td>
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</table>
Other Pavement Performance Factors

• **Performance after Earthquake**
  - **PCC**
    - Significant damage expected during DE
    - Catastrophic failure
    - Will take months to repair
    - Significant impact to operation to replace pavement
  - **AC or Paver Block on CTB**
    - Some damage during OLE
    - Can be repaired rapidly
      - Overlay AC on top
      - Adjust paver blocks
Other Pavement Performance Factors

• Transponder Installation for AGV
  – App. 20 mm in diameter, 50 mm long (2 inches) glass body sealed with foam cushioning
  – Insert in holes 25 mm in diameter, 80 mm (3 inches) deep, sealed with glue
  – Leaving 0.5 inch gap between transponder and RCC pave for 3-inch AC

• 3-inch AC if rutted, damage on Transponder?
Other Pavement Performance Factors

• Rescue of Automated Equipment
  – Typical rescue method for AGV
    • Reach stackers
    • Permanent damage to pavement
  – Alternative rescue method
    • By terminal trucks with “gooseneck”
    • Lighter wheel load
Comparative Cost

• Life Cycle Cost Summary

<table>
<thead>
<tr>
<th>Material/Location</th>
<th>SHC</th>
<th>AGV</th>
<th>SHC</th>
<th>AGV</th>
<th>SHC</th>
<th>AGV</th>
<th>SHC &amp; AGV</th>
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<tr>
<td>Asphalt on CTB</td>
<td>78%</td>
<td>70%</td>
<td>76%</td>
<td>76%</td>
<td>100%</td>
<td>100%</td>
<td>97%</td>
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<tr>
<td>Asphalt on RCC</td>
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<tr>
<td>Reinforced PCC</td>
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<tr>
<td>Paver Block</td>
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<tr>
<td>Waterside Traffic Area</td>
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<tr>
<td>Waterside Transfer Area</td>
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</table>

Lowest: $0.00
Automated Stacking Area

Robotic Operation

Manned Main Trolley
Automated Secondary Trolley
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Semi-Automated Delivery to Outside Truck
Container yard

- End-loaded stacking/retrieval cranes
- Side-loaded stacking/retrieval with landside transfer cranes
Why Low Tolerance?
Why Low Tolerance?
Why Low Tolerance?
Well Consolidated Landfill

- Critical to minimize total and differential settlements due to:
  - Dynamic loads created by crane operation
  - Stacked container storage
  - Impact loads from container stacks
Drainage

• Stacking area flat and drainable
• Drainage and storm water treatment
  – Design slope that meets operational requirements
  – Comply with local regulation in treating storm water
Other Utilities

- Fresh water supply
- Sanitary sewer
- Light poles (do we need any?)
- Antenna poles
- Camera poles
- Fencing
- X-ray inspection (VACIS)
- Fire protection
- Security systems
Power System

- Redundancy
- 100% fault tolerance
- Reliable
- Location and size of substations, transformer
- Each crane in same stack energized from two independent sources
Design Issues ASC Blocks

- RMG rails and beams
- Reefers
- Hazardous
- Grading and drainage
Reefer Racks

• Clear understanding of operational requirements
• Consider all safety requirements
• Understand the access control and interfaces with crane system
• Comply with building requirements
ASC Runway
Pre-fabricated Runway Beams
Land Side Transfer Area

Robotic Operation

- **Manned Main Trolley**
- **Automated Secondary Trolley**
- **Automated Horizontal Transport AGV’s**
- **Automated Container Stacking, Retrieval, Shuffling ASC’s**
- **Semi-Automated Delivery to Outside Truck**
Landside Transfer Area

- Understand the operational requirements
- Interface with gate systems
- Interface with ASC control/safety systems
- Load repetition
- Durability of pavement
Landside Transfer Area

• Truck maneuvering to the transfer area
• Use island to locate electrical substations and communication hub building
Intermodal Rail Area

Robotic Operation

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Vessel

Quay Crane

Container Yard

Outside Truck
IY Area

- On dock rail
- Designed for efficient rail loading operations
  - Semi-automated remotely operated rail loading cranes
  - Safety fence and gate locations and access control
  - The right crane rail
Rail Operation
Buildings

• Gates
  – Highly automated
  – RFID for truck identification
  – OCR
  – TWIC reader for security
  – Truck holding areas

• Administration/Operation/IT
  – House IT systems
  – Remote operator’s room(s)
  – Other operation

• Maintenance
  – Provide sufficient storage for spare parts
  – Almost all electrical equipment
  – Almost all maintenance is performed at the equipment site, not in the workshop
  – Connected to IT systems
  – Location depends on
    – Mode of waterside transport
    – Mode of fueling (battery/diesel)

• Battery Exchange Building
Robotic Battery Changing Station
Example of Operations Control Room

• Orientation
• Windows
• Light
• Noise
• Table space
Integration Management

- An automated terminal is a highly integrated system of components that must fit together perfectly.
- The only standard is the container.

**THIS IS WHERE PROJECTS TYPICALLY SUCCEED OR FAIL**
Thank You