Modernization of Container Port Operation and Management

Japan Association of Cargo-handling Machinery Systems (JACMS)
Institute of Cargo-handling Technology, Senior Director for Research
Madoka Ikemachi
Japan Association of Cargo-handling Machinery Systems (JACMS)

• JACMS represents the interests of port equipment and technology suppliers in Japan by conducting research for technology development.

• JACMS members includes MITSUI ES, Sumitomo Heavy Industries (SHI), Mitsubishi Logisnext Co., Ltd., JFE engineering and TMEIC.
Japan Association of Cargo-handling Machinery Systems (JACMS)

• Research and Technology Development
  - Safety guideline for remote control operation of RTG published by MLIT (2018)
  - Research for MLIT AI Port Initiative (2018, 2019-)
  - Simulation for the improvement of terminal operation (2018, 2019-)

• Design and Construction management of port equipment

• Dissemination of cargo-handling technology

• Cooperation with international organizations
MLIT AI Port Initiative

■ Productivity Improvement of Container Terminal in Japan
  - AI port initiatives through demonstration project

Demonstration project which utilizes Artificial Intelligence in terminal operation and management will be undertaken to achieve good working environment and world highest terminal productivity.
Increasing Automated Container Terminals

Source: JACMS modified terminals list of Table3.1, pp10 of Koji Takahashi (2018) “Trend analysis of automated container terminals in the world”
APMT Maasvlakte 2 Rotterdam, Netherlands, 2015

Source: https://www.apmterminals.com/en/maasvlakte/about/image-gallery
<table>
<thead>
<tr>
<th>No.</th>
<th>Installation</th>
<th>Country/Region</th>
<th>Port</th>
<th>Terminal</th>
<th>Operator/Owner</th>
<th>Terminal Area (Green/Brown)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2005</td>
<td>Japan</td>
<td>Nagoya</td>
<td>Tobishima</td>
<td>TCB</td>
<td>Green</td>
</tr>
<tr>
<td>2</td>
<td>2016</td>
<td>Indonesia</td>
<td>Semarang</td>
<td>Patikemas</td>
<td>Pelindo III</td>
<td>Brown</td>
</tr>
<tr>
<td>3</td>
<td>2017</td>
<td>Ireland</td>
<td>Dublin</td>
<td>Dublin Ferryport Terminal</td>
<td>Irish Continent</td>
<td>Brown</td>
</tr>
<tr>
<td>4</td>
<td>2018</td>
<td>Hong Kong, China</td>
<td>Hong Kong</td>
<td>CT9N</td>
<td>HPH</td>
<td>Brown</td>
</tr>
<tr>
<td>5</td>
<td>2018</td>
<td>Indonesia</td>
<td>Kuala Tanjung</td>
<td>PT Prime Multi</td>
<td>Pelindo I</td>
<td>Green</td>
</tr>
<tr>
<td>6</td>
<td>2018</td>
<td>Thailand</td>
<td>Laem Chabang</td>
<td>D1</td>
<td>HPH</td>
<td>Green</td>
</tr>
<tr>
<td>7</td>
<td>2019</td>
<td>UK</td>
<td>Felixstowe</td>
<td>Terminal 8/9</td>
<td>HPH</td>
<td>Brown</td>
</tr>
<tr>
<td>8</td>
<td>2019</td>
<td>UK</td>
<td>Belfast</td>
<td>Belfast Container Terminal</td>
<td>Belfast Harbour</td>
<td>Brown</td>
</tr>
<tr>
<td>9</td>
<td>2019</td>
<td>Indonesia</td>
<td>Belawan</td>
<td>Belawan International Container Terminal</td>
<td>Pelindo I</td>
<td>Green</td>
</tr>
<tr>
<td>10</td>
<td>2019</td>
<td>Oman</td>
<td>Sohar</td>
<td>Terminal C</td>
<td>HPH (OICT)</td>
<td>Green/Brown</td>
</tr>
<tr>
<td>11</td>
<td>2023</td>
<td>Japan</td>
<td>Nagoya</td>
<td>Nabeta</td>
<td>NUCT</td>
<td>Brown</td>
</tr>
</tbody>
</table>
TCB NAGOYA, Japan (MHI), 2005
Retrofitting Automation

• The opportunities for retrofitting automation in existing terminals appear to be in the ascendance.
  （Port Technology 2018 spring edition, Neil Davidson, Drewry Maritime Research, UK）

• Converting to semi-automated operation could be a smart option for RTG terminals looking to lower their operating costs.
  （Moffatt & Nichol presentation at TOC, World Cargo News Nov 2016）

• On the other hand, we did not see too many large greenfield automation projects, but instead saw growing interest in brownfield automation, which also points towards further service opportunities. This was a clear trend of the year.
  （Konecranes Annual Report 2017）

• However, at the same time there is deep concern within the industry over the cost, time, complexity and risks of terminal automation, particularly for the next wave of automated terminals, which are forecast to be brownfield terminals retrofitting automation to their existing operation.
  （TOC tackles automation, World Cargo News Jun 2018）
Promoting the introduction of Remote Control Automated RTG in Japan

- Japan’s aging and decreasing population
- Difficulty in recruiting younger for stevedoring work
- Steady increase in marine freight transportation

Improve Terminal Productivity and Safety
Program for promoting the introduction of Remote Control Automated RTG (2019-)

To address the increase of large vessels calls and concerns over aging and decreasing population, MLIT establishes subsidy for the installation of remote control and automated RTG.

Source: MLIT Policy Brochure 2019
Container Terminal System in Japan

Typical Combination of Port Equipment

Example: STS*3 + TTU *12 + RTG * 9 in 7 lanes

* RTG is the most popular yard equipment, particularly in Asia (Wiese et al. 2009)

Overlap yard equipment (RTG) between YT and ET
(Some RTG lanes might be shared between YT and ET.)
Waterside Traffic (Yard Truck) vs Landside Traffic (External Truck)

- **Yard Truck (YT) Discharging/loading Flow**: YT flow takes priority over ET flow.
- **External Truck (ET) Flow**
- **Waiting Lane for ET**: While ET lane overlaps YT lane, ET waits in this lane.
Lane 3 ET must wait until YT discharging finishes all jobs at lane 3. Terminal operators handle the vessel on schedule at lowest possible cost.
Lack of Container Yard Space

- Lack of container storage area
- Lack of waiting area for external truck

Source: PIANC WG 135 Report “DESIGN PRINCIPLES FOR SMALL AND MEDIUM MARINE CONTAINER TERMINALS”
Designing Container Terminal Layout in Japan

• In designing productive container terminal, the analysis of a container movement in both waterside and landside should be carried out.

• Through the analysis, handling efficiency, safety, and handling cost will be evaluated.

• The terminal layout includes yard stacking type, choice of port equipment, and optimum number of port equipment.

• Container terminal simulation could be used for the analysis.

MLIT, 2018 “Container Terminal Designing, TECHNICAL STANDARDS AND COMMENTARIES FOR PORT AND HARBOUR FACILITIES IN JAPAN”
Container Terminal Simulation

- Discrete event simulation models allow realistic investigation of any process in a container terminal, and a full evaluation of the performance of the layout, equipment and deployment strategy.
  
  (Bani Anvari et al(2019) "Comparison of Fleet Size Determination Models for Horizontal Transportation of Shipping Containers using Automated Straddle Carriers")

- Discrete event simulation is an appropriate means to evaluate the efficiency of container terminal processes. Particularly it is suitable for new technologies not applied yet for which no empirical data is available.

  (Nikolaus A. Bornhöft et al(2010) "MODELING OF INNOVATIVE TECHNOLOGIES FOR CONTAINER TERMINAL YARD STACKING SYSTEMS USING AN OBJECT-ORIENTED SIMULATION FRAMEWORK")
Container Terminal Simulation

• Simulation usually provides valuable information for comparing different scenarios to each other, but it may not necessarily be used as a reference for real life operational productivity.

• Simulation is particularly useful when examining the effects of uncertainties in ship arrivals on yard capacity, capability of adding extra services to the terminal, patterns and rules in the movement of trucks at gates and inside the terminal, synchronisation of train schedules with ship schedules, and in general the effects of operational changes in the terminal throughput.

• Simulation and lately emulation have been used in almost all the recent automated container terminal projects, such as CTA and CTB in Hamburg, APM Terminal Virginia, Antwerp Gateway, London Gateway, Khalifa Container Terminal and others.

PEMA information paper 2016 “Container Terminal Automation”
AutoMod: 3D material handling simulator

<Product overview of AutoMod>
- Ultimate facility and system design
- Justification for facility modification
- Continuous operational improvement
- When intuition and experience is not enough
- The sale results
  - World wide: over 4000 license for 180 company

<Feature of AutoMod>
- Building a model of a real system
  - Accurate - imitate real world behavior over time
  - Data driven - Scale layout, process timing, routing, control logic, equipment downtime/repair, etc
  - Incorporates real world variability
- Exercising the model to:
  - Understand the behavior of the actual system
  - Ask “what-if” questions
  - Visualization for illustrating ideas and principles
- Beautiful 3D real scale animation
  - To presenting system to exective
Snapshot of AutoMod Terminal Simulation
AutoMod Modeling

- Import Cargo Movement (Process)
  - Vessel Arrival (Queue)
  - Reserve Terminal Truck (TT)
  - STS pick up load
  - STS trolley traveling
  - TT Arrival under STS trolley
  - STS load on cargo
  - TT transport to RTG yard lane
  - ... 
  - Setdown RTG yard

- RTG Movement (Path mover)
  - Vehicle movement range
  - Job search conditions etc

begin P_container1 arriving // import cargo from ship to yard 
move into Q_ship containers(A_berth_ID) (A_ship_x,A_ship_y,A_ship_z) 
reserve a vehicle for this at pm_TRK:gc__(1,A_GC_ID) 
move into pm_GC:ship_((A_ship_x,A_GC_ID) 
travel to pm_GC:gc__(1,A_GC_ID) 
move into pm_TRK:gc__(1,A_GC_ID) 
inc V_P_1_start_cnt(A_yard_lane) by 1 
travel to pm_TRK:lane__(A_yard_lane) 
reserve a vehicle at pm_RTG:yard__(A_yard_x,A_yard_lane) 
travel to pm_TRK:yard__(A_yard_x,A_yard_lane) //yard_1_3 
move into pm_RTG:yard__(A_yard_x,A_yard_lane) //yard_1_3 
move into Q_RTGcontainers(A_yard_lane)(A_yard_x,A_yard_y,A_yard_z) 
wait to be ordered on OL_wait_RTG(A_yard_lane) 
end

begin pm_RTG task search procedure 
set V_claim_RTG_load to null 
for each V_load(1) in pm_RTG loads waiting do begin 
  if V_claim_RTG_load = null then begin 
    set V_claim_RTG_load to V_load(1) 
  end 
else if V_claim_RTG_load A_RTG > V_load(1) A_RTG then begin 
  set V_claim_RTG_load to V_load(1) 
  ... 
end
AutoMod Modeling
AutoMod Analysis

• Quantitative analysis of bottlenecks
  -> Lack of port equipment number such as STS, TT and RTG?
  -> Problem in Loading/unloading plan?
  -> Lack of gate slots?

• Quantitative analysis of terminal layout (enough Waiting area)
  -> Lack of waiting area for road truck?

• Quantitative analysis of remote operation of RTG
  -> How many remote operator needs for 8 RTG?
Automod Result Sample

**External Truck Turn Over Time**

- Large Vessel
- Middle size Vessel

**MPH**

- 3 YT
- 4 YT
- 5 YT

**RTG#1 Work Time**

- Traveling time: 36%
- Waiting for Truck: 19%
- Pick up load time: 12%
- Trolley traveling time: 12%
- Setting down time: 10%
- Idle time: 11%

**RTG#2 Work Time**

- Traveling time: 35%
- Waiting for TT: 25%
- Pick up load time: 10%
- Trolley traveling time: 9%
- Setting down time: 11%
- Idle time: 10%
End

Madoka Ikemachi
Senior Director for Research
Japan Association of Cargo-handling Machinery Systems
Email: ikemachi@jacms.or.jp Tel: +81-3-5472-4791
Figure 10.1 Distribution of operational costs (Dobner et al., 2001)

Maasklavit II (2015, 167万TEU)