Designing semi-automated terminals

Using dynamic modelling tools

Dr. ir. Yvo Saanen
1. Automated terminal amid their main competitors

2. Design approach (semi-) automated terminal

3. Emulation as tool to ensure software quality

4. Concluding remarks
Automated terminals amid their main competitors
The most efficient (semi-) automated concept nowadays

4. RMG + AGV

- Density: 1500 TEU / ha
- Terminal capacity: 2000 TEU / m quay
- Operational cost reference number: 1
- Investment cost reference number: 5

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Why automate?

- Labour costs
- Scale of operations
- Performance requirements
- Safety & environment

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Designing a semi-automated container terminal
Simulation approach for robust design of an automated terminal

- **S.M.A.R.T. definition of goals and KPI’s**
  - Realistic operational scenarios
  - Performance targets
  - Operational costs / investment

- **Static terminal design:**
  - Berth capacity
  - Storage capacity

- **Simulation of quay operations**
  - "setting the scenarios"

- **Initial drawings of alternatives**

- **Simulation (alternative) terminal operations**
  - "productivity assessment"
    - Equipment selection
    - Dimensioning of "handling system"
    - Defining the logistical concept
    - Defining business logic

- **Simulation of terminal during 6 weeks**

- **Terminal cost calculation (investment and operational)**

- **Implementation plan**

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Simulation cycle (in each phase)

- Current situation
  - Problem identification and specification
  - Validation
  - Pre-evaluation
  - Search for solutions
  - Post-evaluation

- New situation
  - Choice and implementation
  - Model "as is"
  - Model "to be"

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The key: balanced design of the yard
Right balance / right design

- Target productivity waterside – capable of handling future demands?
  - Peak loads (twin lift, tandem 40, dual cycling, reefer handling, MTs)
  - How many QCs on one vessel?

- Peak at the landside, gate + rail?

- Typical peak scenario: how many out of all QCs are actually in operation?

- How many stacking cranes to meet this demand, in relation to their specifications:
  - Length of stack module
  - Gantry speed & acceleration
  - Hoist speed and acceleration
  - Design of the waterside interchange zone (“buffering”)
  - Rolling percentage (effective rehandling)
  - Landside operation (remote operation)
  - Safety rules (e.g. access to interchange zones)

- Which automated transportation system is the most cost efficient?

- How much waterside equipment to meet demands?
  - Interaction between yard equipment and transportation equipment
  - Sequence during vessel loading
  - Etc.
Right design / which stack handling system?

- **The Twin RMG:**
  - 2 similar RMGs on one track
  - Ability to mutually support

- **The cross-over twin RMG:**
  - One large, one smaller RMG on 2 tracks
  - Ability to pass, and work on either side

- **The cross-over tri RMG:**
  - One large, two smaller RMG on 2 tracks
  - One small RMG for either side
  - Ability to pass, and work on either side
Right design / which transportation system?
Various combinations of yard and transportation equipment (example)

**Iso performance / cost graphs**

quay length = 400m, 4 quay cranes, pooled vehicles

<table>
<thead>
<tr>
<th># Transport vehicles (ShCs)</th>
<th># Stacking cranes</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>16</td>
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<tr>
<td>5</td>
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</tr>
<tr>
<td>14</td>
<td>6</td>
</tr>
</tbody>
</table>

- Berth productivity 100 moves/hour
- Berth productivity 110 moves/hour
- Berth productivity 120 moves/hour
- Berth productivity 130 moves/hour

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Various terminal designs depending on local circumstance

**Terminal 1:**
- 2.0 M TEU
- 5% transhipment
- Dwell time: 9 days
- Peak productivity (WS/LS): 550/400
- Configuration: 30 modules, 60 TEU long, 8 wide

**Terminal 2:**
- 3.5 M TEU
- 50% transhipment
- Dwell time: 5 days
- Peak productivity (WS/LS): 720/400
- Configuration: 52 modules, 45 TEU long, 10 wide

**Terminal 3:**
- 4.5 M TEU
- 45% transhipment
- Dwell time: 4.5 days
- Peak productivity (WS/LS): 840/450
- Configuration: 48 modules, 36 TEU long, 10 wide

**Terminal 4:**
- 1.8 M TEU
- 5% transhipment
- Dwell time: 4 days
- Peak productivity (WS/LS): 375/300
- Configuration: 24 modules, 26/52 TEU long, 11/8 wide

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Effect of the stack length
2-8 Corridor - $V_{\text{gantry}} = 4.0 \text{ m/s}$ - $A_{\text{gantry}} = 0.3 \text{ m/s}^2$ - $V_{\text{trolley}} = 1.0 \text{ m/s}$ - $A_{\text{trolley}} = 0.3 \text{ m/s}^2$ - $V_{\text{hoist}} = 1.0 \text{ m/s}$ - $A_{\text{hoist}} = 0.33 \text{ m/s}^2$ - Scenario 3

<table>
<thead>
<tr>
<th>Stack length [TEU]</th>
<th>Waterside crane</th>
<th>Landside crane</th>
</tr>
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<tbody>
<tr>
<td>30</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>40</td>
<td>19.8</td>
<td>16.2</td>
</tr>
<tr>
<td>50</td>
<td>19.4</td>
<td>14.6</td>
</tr>
<tr>
<td>60</td>
<td>18.6</td>
<td>14.1</td>
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</table>

ACS productivity [mph]

Effect of gantry speed
$A_{\text{gantry}} = 0.3 \text{ m/s}^2$ - $V_{\text{trolley}} = 1.0 \text{ m/s}$ - $A_{\text{trolley}} = 0.3 \text{ m/s}^2$ - $V_{\text{hoist}} = 1.0 \text{ m/s}$ - $A_{\text{hoist}} = 0.33 \text{ m/s}^2$

<table>
<thead>
<tr>
<th>Gantry speed (m/s)</th>
<th>Waterside crane</th>
<th>Landside crane</th>
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<tr>
<td>3.0</td>
<td>21.4</td>
<td>14.8</td>
</tr>
<tr>
<td>3.5</td>
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<td>4.5</td>
<td>22.0</td>
<td>15.8</td>
</tr>
<tr>
<td>5.0</td>
<td>21.9</td>
<td>15.9</td>
</tr>
</tbody>
</table>

ACS productivity [mph]

Spreader position crane 1: 14.5
Gantry speed crane 1: 0
Spreader position crane 2: 14.5
Gantry speed crane 2: 0
Design of the reefer solution

- Dependent on reefer share
- Dependent on # reefer mechanics
- Dependent on reefer solution (location in the stack module, access, ASC restrictions)
Traffic analysis

Traffic density

22 QCs - 88 lift AGVs - correct berthing
Right side of terminal - average number of vehicles per hour

0-15 15-30 30-45 45-60 60-75 75-90 90-105 105-120 120-135 135-150 150-165

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Performance under break-down circumstances (example)
Typical deliverables of a design study

Berth simulation:
- Berth occupancy
- Quay crane utilization
- Vessel service times
- Yard occupation throughout the year
- Handling peaks waterside & landside

Handling system simulation:
- Required numbers of yard cranes & shuttle carriers
- Optimized yard design
- Reefer solution
- Design of interchange zones
- Effect of breakdown and mitigation strategies
- Algorithms for dispatching, scheduling and grounding

Other:
- Solution (conceptually) for scheduling / dispatching ASCs
- Solution (conceptually) for scheduling / dispatching ShCs

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Typical deliverables of a design study
Emulation as a way to ensure software quality and performance
Link software to a virtual terminal (CONTROLS)

Real terminal

Virtual terminal

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Key properties of dynamic models

1. Dynamics
2. Safe and inexpensive trial and error environment
3. Analysis of non-repetitive events
4. See process
5. Quantify and prioritize
3T-Concept: Testing, Tuning and Training

Å Test new software:
- Reducing risk
- More focus on performance
- Knowing problems earlier in process
- Insight for non software experts

Ç Tune your operation:
- Anticipation on problems
- Validation of planning
- Replay of operation
- Running future growth scenarios

É Train “control room” operators:
- Operate a virtual terminal
- No “learning” impact to operation
- Get immediate feedback
- Practice on irregular operations

Key references:
- Pusan Newport (Zodiac)
- MSC Home (SPACE/TRAFIC)
- APMT Virginia (SPARCS)
- Eurokai Hamburg (TOP-X)
- APMT Rotterdam (SPACE/TRAFIC)
- Euromax (SPARCS / TEAMS)
- APMT Aarhus (SPARCS)

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Example: testing the TOS
Concluding remarks
Conclusions

With the right approach, and the proper tools, automated terminals can be designed and implemented:

- Without major risk
- Within time
- Within budget
- Delivering the targeted productivity

The design will vary from site to site, as many conditions determine the “optimal” design.

Automated terminals – more than any other type of terminal – require proper planning, with a long term vision on service levels and handling capabilities.
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