Bulk Terminal Planning Trends – Using Simulation

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Outline

- Bulk Terminal Systems, Constraints, Operations
- Why Simulation
- Case Study – Bulk Terminal Rail Loader System
- Case Study Conclusion
Dry Bulk Terminals

- Physical system constraints
  - External rail system
  - Internal rail system
  - Dumping systems
    - Bottom Dumper
    - Rotary Dumper
  - Product storage
    - Product segregation
  - Ship loading system
  - Berths
  - Downtime delays
Dry Bulk Terminals

- Operating procedure constraints
  - External rail
    - Schedule and reliability
    - System Delays
  - Internal rail
    - Switching and car movement
  - Car inspection/repair
  - Days and hours of operation
  - Labor rules
    - Adjacent Track Rule
  - Safety rules
Why Simulation

- Analytic capabilities of other tools (spreadsheets) are limited and can't model complex systems with many interdependencies.
- Provides Visualization and Animation for better communication and presentations.
Why Simulation

- Study system behavior without building the real system

Stockpile A

Stockpile B

Car Dumper

Ship Loader
Why Simulation

- Assess proposed impacts and changes before they are implemented
- Identify system modifications that provide the greatest benefit
- Cheaper and easier than before
Simulation Tool

- **FlexTerm (previously FlexSim CT)**
  - General purpose discrete event simulation software

- Extended from container terminal simulation to bulk terminal simulation

- Embedded objects such as train or barge unloaders, ship loaders, conveyors, stockpiles, etc. for fast model building

- C++ or FlexScript for customization
Simulation Tool

- Drag-and-Drop objects into model space
- Make connections between objects to define material flow according to Process Flow Diagram (PFM)
- Define mixing rules including direct-loading and stockpile logic
- Define events such as break-downs and other delays
- Typically run 10 years with 1 minute time interval
Typical Simulation Outputs

- Typical outputs include:
  - Throughput finished
  - Identification of System Delays
  - Equipment utilization
  - Unloading and loading rate
  - Berth time, port time and waiting time
  - Stockpile contents – average/maximum
Case Study – Objective

- Assess track improvements proposed by the Port and investigate operational changes they would allow

- Build simulation model that replicated the rail delivery system for an existing bulk loading operation

- Determine capacity
  - Existing System
  - System with improvements

- Identify any bottlenecks

- Assess opportunities and their relative benefits
Black product operations
White operations
Shared rail storage yard
Rail System Schematic
Constraints and Assumptions

- Black product is received by train and transferred to storage and vessels for export

- White product has no on-terminal storage
  - Must be transferred directly to vessels upon dumping

- Physical plant is very constrained
  - Limited train length for both commodities prevented simultaneous black and white receiving
Constraints and Assumptions

- There is no Storage tracks for bulk product near the Port

- Staging track for inbound trains is 12 hours away
  - Train cannot be released from staging track until order has been sent to remove train from the port facility
  - Minimum gap between train finish and start is 12 hours

- During white product loading, receipt of black product trains must be suspended
Constraints and Assumptions

- Terminals switch engines are not allowed to touch the mainline tracks
  - Limiting train Length
  - Required one of the terminals two switch engines be buried on a storage track in order to dump maximum length train

- After Dumping Cars must be inspected and bad order cars cut out before train can be removed
Basic Assumptions – Black Product Dumper

- **Existing Single rotary dumper**
  - Typical cycle time 2 to 6 minutes
  - 3.5 minutes per car on average

- **Evaluate**
  - Faster rotary dumper
  - Replacement with bottom dumper
Cut 30 cars (Set 1) of half train on one track
Pull Set 1 to Track 6 using Engine A
Park Engine A at south end of Track 6
Using Engine B, pull Set 1 from north, then push through dumper and unload all cars
After finishing Set 1, use Engine B to pull remaining cars (Set 2) of half train from south
Use tracks on white operation side to maneuver Engine B to north of Set 2
Pull and then push Set 2 through dumper and unload all cars
Engine B pulls empty cars of Set2, then connects Set 2 with Set 1
Engine A pushes empty half train to an empty track
Repeat the process for the second half train
Model output verified with known data
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Acronym</th>
<th>Description</th>
<th>Avg dumper</th>
<th>Train arrival gap (hr)</th>
<th>Empty train dwell (hr)</th>
<th>White Shifts</th>
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<tbody>
<tr>
<td>1</td>
<td>BS</td>
<td>Base scenario</td>
<td>3.5</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
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<td>DDS</td>
<td>Base scenario + double dumper speed</td>
<td>1.75</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
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<td>Base scenario + shorter train arrival gap</td>
<td>3.5</td>
<td>2 to 4 hours</td>
<td>16 to 24 hours</td>
<td>3</td>
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<td>4</td>
<td>SED</td>
<td>Base scenario + shorter empty train dwell</td>
<td>3.5</td>
<td>8 to 12 hours</td>
<td>4 to 8 hours</td>
<td>3</td>
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<tr>
<td>5</td>
<td>NM</td>
<td>Base scenario + no &quot;macarena&quot; operation</td>
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<td>16 to 24 hours</td>
<td>3</td>
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<tr>
<td>6</td>
<td>DAN</td>
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<td>2 to 4 hours</td>
<td>4 to 8 hours</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>SS</td>
<td>Base scenario + shorter arrival gap + shorter empty dwell</td>
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<td>4 to 8 hours</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>DW</td>
<td>Base scenario + doubled white shifts</td>
<td>3.5</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>ZW</td>
<td>Base scenario + 0 white shifts</td>
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<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>SSZ</td>
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<td>2 to 4 hours</td>
<td>4 to 8 hours</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>DN</td>
<td>Base scenario + double dumper speed + no &quot;macarena&quot;</td>
<td>1.75</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
<td>3</td>
</tr>
</tbody>
</table>
Results – Comparison to Base Scenario

Throughput Ratio to Scenario 1

<table>
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<th>Ratio</th>
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<tbody>
<tr>
<td>1-BS</td>
<td>1.00</td>
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<tr>
<td>2-DDS</td>
<td>1.11</td>
</tr>
<tr>
<td>3-SAG</td>
<td>1.13</td>
</tr>
<tr>
<td>4-SED</td>
<td>1.23</td>
</tr>
<tr>
<td>5-NM</td>
<td>1.02</td>
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<tr>
<td>6-DAN</td>
<td>1.31</td>
</tr>
<tr>
<td>7-SS</td>
<td>1.40</td>
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<td>8-DW</td>
<td>0.79</td>
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<tr>
<td>9-ZW</td>
<td>1.24</td>
</tr>
<tr>
<td>10-SSZ</td>
<td>1.75</td>
</tr>
<tr>
<td>11-DN</td>
<td>1.15</td>
</tr>
</tbody>
</table>
Base Scenario dumper utilization less than 60%, not at capacity. For Scenario 10, dumper becomes a constraint with utilization >85%.
Average of Tracks 1, 2, 3, and 4; 80% track utilization considered at capacity
Simulation Conclusions

- Black product capacity is about 283 trains per year, assuming on average 3 white product shifts per week

- Dumper was not a capacity bottleneck for black product operation, as indicated by its relatively low utilization

- Storage yard track is a capacity bottleneck as indicated by its high utilization
1. 2 New tracks at black empty yard (each 14 coal cars capacity)
2. Reactivated WS3 and connectors (additional 23 coal cars capacity)
3. New bypass track 2 (20 white cars capacity)
4. New connector between tracks G6 and G5
5. New crossover between tracks G5 and G4
6. New Pier G lead track
7. New connections at north end
   1. Between G1 and G2
   2. Between G2 and G3
   3. Between G3 and G4
Add a connector between tracks G3 and G4 before white dumper

Eliminate the conflict point between white and black unloading

- Originally G4 and double crossover are needed to access white dumper

Simultaneous unloading operation

- Unload white trains on tracks G1 and G2
- Unload black trains on tracks G3 and G4
Simulation Objectives

- What are potential operational benefits
- Opportunity for simultaneous black and white Operations
- Impact on capacity
- Are there potential bottlenecks
Black Product – Train Unloading

Steps

1. Engine pulls Set 1 (~25 cars on G4) south
2. Engine maneuvers to north of Set 1, pushes and then pulls onto G5
3. Pushes to unload Set 1
4. Engine pulls Set 2 (remaining cars on G4) onto G5, then maneuvers to north
5. Pushes to unload Set 2
6. Engine maneuvers to north lead track, pulls and then pushes Set 3 (~23 cars on G3) onto G5
7. Pushes to unload Set 3
8. Engine pulls and pushes Set 4 (remaining cars on G3) onto G5
9. Pushes to unload Set 4
10. Pulls first half of empty train onto G3
11. Pulls second half of empty train onto G4
White Product – Train Unloading

Steps

1. Cars on each track divided into four sets, each about 10 to 11 cars
   1. Set 1, Set 2, Set 3 and Set 4 on G1
   2. Set 5, Set 6, Set 7 and Set 8 on G2
2. Engine pulls Set 1 and hooks to indexer
3. Unloads Set 1
4. Engine pulls Set 2 and hooks to indexer
5. Engine pushes Set 1 to WS1
6. Engine pulls Set 3 and hooks to indexer
7. Engine pushes and pulls Set 2 empty cars onto BP1
8. Engine pushes Set 4 and hooks to indexer
9. Engine pushes and then pulls Set 3 empty cars onto BP1, and pushes Set 2 empty car back to G1
10. Repeats steps 6 to 9 for remaining sets of cars
11. Pulls and then pushes Set 1 onto G2
Simulation Settings

- **Include**
  - Dumper activity (cycle time per car)
  - Equipment breakdown
  - Labor meal and break times
  - Connecting/disconnecting cars/engines
  - Train arrival and departure delays
  - Train inter-arrival gap
  - On Terminal empty car dwell time
Base Case Scenario

- Modeled both white and black operations
- White trains based on demand
  - 60 trains per year on average
- Continue sending black product trains based on space available to evaluate the capacity
- White trains arrive randomly on either tracks G1&G2 or G3&G4
- Existing black product train unloading sequence used by default
- When simultaneous unloading is possible, switch to revised sequence
Proposed System

Visualization of proposed operations
### Scenarios

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<th>Empty train dwell (hr)</th>
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<tr>
<td>1</td>
<td>BO</td>
<td>Black Only</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
</tr>
<tr>
<td>2</td>
<td>NS</td>
<td>No Simultaneous Unloading of Black and White</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
</tr>
<tr>
<td>3</td>
<td>BC</td>
<td>Base Case</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
</tr>
<tr>
<td>4</td>
<td>BC + RS</td>
<td>Base Case + Revised Sequence</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
</tr>
<tr>
<td>5</td>
<td>BC + WR</td>
<td>Base Case + White Restriction (Track 1 &amp; 2 Only)</td>
<td>8 to 12 hours</td>
<td>16 to 24 hours</td>
</tr>
<tr>
<td>6</td>
<td>BC + RS + WR</td>
<td>Base Case + Revised Sequence + White Restriction (Track 1 &amp; 2 Only)</td>
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<td>10</td>
<td>BC + WR + SS</td>
<td>Base Case + White Restriction (Track 1 &amp; 2 Only) + Shorter arrival gap + Shorter empty dwell</td>
<td>2 to 4 hours</td>
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- **Revised Sequence (RS)**: Black trains will be unloaded by using the sequence that allows simultaneous unloading of white and black trains
- **White Restriction (WR)**: White train will always arrive and depart on Track G1 and G2
- **Shorter arrival gap + Shorter empty dwell (SS)**: The rail side operations are improved for arriving and departing trains
Model Results

- Simultaneous unloading does not significantly help on increasing throughput (Scenario 3 vs. Scenario 2)
Model Results

- Time when both dumpers (white and black) are simultaneously unloading
- Base case indicates there is very little time when both dumpers are working
Model Results

Ratio to Base Case Scenario

- 1-BO: 1.22
- 2-NS: 1.03
- 3-BC: 1.00
- 4-BC + RS: 0.97
- 5-BC + WR: 0.98
- 6-BC + RS + WR: 0.97
- 7-BC + SS: 1.61
- 8-BC + SA: 1.18
- 9-BC + SE: 1.48
- 10-BC + WR + SS: 1.67
Model Results

Black Product Dumper Utilization

Utilization (%)

Scenarios

Include Hoot Shift | Exclude Hoot Shift

1-BO | 55.2 | 41.4
2-NS | 45.2 | 33.9
3-BC | 45.2 | 33.9
4-BC + RS | 46.7 | 35.0
5-BC + WR | 46.7 | 35.0
6-BC + RS + WR | 47.2 | 35.4
7-BC + SS | 86.5 | 64.9
8-BC + SA | 58.4 | 43.8
9-BC + SE | 72.8 | 54.6
10-BC + WR + SS | 66.6 | 88.8
Model Results

Average Track Utilization (Track G1, G2, G3, and G4)

Utilization (%)

<table>
<thead>
<tr>
<th>Track</th>
<th>1-BO</th>
<th>2-NS</th>
<th>3-BC</th>
<th>4-BC + RS</th>
<th>5-BC + WR</th>
<th>6-BC + RS + WR</th>
<th>7-BC + SS</th>
<th>8-BC + SA</th>
<th>9-BC + SE</th>
<th>10-BC + WR + SS</th>
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Conclusions

- **Proposed improvements:**
  - Longer trains for arrival and departure
    - 84 cars/white train, 5% increase
    - 96 cars/black train), 4% increase
  - More capacity for holding empty cars, both white and black
  - Operational flexibility without impacting mainline traffic
    - Using any of G1, G2, G3, and G4 as bypass to access their north ends
    - Better use of track G5 and G6
    - One more by-pass track for white
  - Allows simultaneous black and white operation
  - Black and white simultaneous unloading gives operational flexibility, but not a significant increase in
Conclusions (Continued)

- Proposed system has potential to increase throughput capability by a significant percentage.
- Improving rail side operation or getting near-terminal or more on-terminal rail storage should be the highest priority in terms of a strategy to increase black product handling capacity.
Modelled existing complex operations and proposed improvements providing a visual and analytical tool to study the terminal

- Identified
  - Impacts on operations
  - Potential bottlenecks

- Assessed opportunities and their relative benefits to facilitate decision making process
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