PORT OPERATIONS EMISSIONS MODEL
Estimating Emissions From Container Cargo Operations Using a Comprehensive Container Terminal Model

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- MN has a deep understanding of marine and intermodal container terminal operations due to:
  - Years of working directly with terminal operators on analysis of day-to-day operations
  - Years of development of models to analyze:
    - Capacity & productivity
    - Berths, gates, container yards, rail yards
    - Equipment fleet sizing
    - Operating cost
    - Comparison of alternatives
Integrated Container Port Model

- Throughput driven
- Activity based
  - Maps and counts individual cargo handling activities
- Calculates emissions from all aspects of port operations
  - Vessels and tugs
  - Dock cranes and stevedoring equipment
  - Yard handling and stacking equipment
  - Rail equipment, switchers, line-haul locomotives & dray vehicles
  - Road trucks
    - arriving/departing through the gate
    - being served within terminal
    - outside port within AQMA
Integrated Throughput Forecasting and Capacity

- Throughput forecasting model imbedded
- Truck and train trip generation model (Quicktrip) imbedded
- Capacity calculations imbedded
  - Berth
  - Yard
  - Gate
  - On-terminal rail yard
    - Pop-ups warn user when a component capacity is exceeded
Smart Model for North American Terminals

• Built-in typical N.A. operating modes
  – Wheeled / grounded
  • Automatically assigns percent grounded
  • Automatically assigns yard to RMG’s when threshold throughput density is reached
  – RTG
  – Top-pick
  – RTG augmented with top-picks
  – Side Handlers
  – Strad
  – RMG

• Allows user to define custom operating modes
Benefits of Spreadsheet Format

• Model is transparent
  – No black box
• Results are defendable
• All assumptions can be easily viewed and modified by the user
• Results are presented in tables and charts, intuitive to understand and use as basis for making decisions
• Model is useful for comparing different emissions reductions strategies because iterations can be accomplished quickly
Model Input Parameters

• Current year throughput
• Projected growth rate and year to be analyzed
• Terminal Layout
  – Gross terminal area
  – Net storage yard area
  – Wharf length
  – Average travel distances within the terminal
    • Gate to centroids of storage yard
    • Wharf to centroids of storage yard
    • Chassis areas, roadability, etc.
Model Input Parameters (continued)

• Throughput Distribution
  – % Local Imports
  – % Local Exports
  – % Intermodal Imports (on- and off-dock rail)
  – % Intermodal Exports (on- and off-dock rail)
  – % Empties

• Vessel call schedules
  – Vessel sizes in TEU
  – Scheduled arrival day and time
  – Discharge and load percentages (or lifts per call)
  – Cold-ironed? Ship in a slip?
Model Input Parameters (continued)

• **Vessels**
  - Distance from breakwater (or sea buoy) to Air Quality District boundary
  - Maneuvering distance from breakwater to terminal
    • Distances, speeds and throttle positions (from pilots)
    • Main engine & auxiliary power (bow thrusters)

• **On-Dock Rail Operating Parameters**

• **Gate Operating Parameters**

• **Road trucks outside the terminal**
  - travel speeds
  - travel distances
  - Congestion level (from regional transportation model)
Intermediate Results

• Model produces useful planning and capacity information based on the user inputs
  – Throughput forecast in analysis year
  – Throughput and berth occupancy for given ship call schedule
  – Throughput density (TEU/gross acre and TEU/net acre)
  – Wheeled to grounded ratio required to accommodate throughput density
  – Number of road truck arrivals and departures per day and per hour
  – Train and switcher movements
  – On-dock rail yard capacity
  – Yard equipment fleet sizing
Final Results

- Total trips per ship service, hours in mode for container handling equipment and switchers, truck trips by type and time of day
- Using selectable emission factors (lastest study factors are the default) Emissions by type ($\text{NO}_x$, $\text{SO}_x$, PM, HC, CO) are calculated for each equipment type
- Results are reported both graphically and in table format
- Results are given for an average week and per year
- Emissions calculations follow EPA best practices guide for Port Emission Inventories
Model Methodology-Container Handling Equipment

- **Step 1**
  Select or input typical cycle of each type of CHE, breaking it up into modes (travel, lift, idle etc.), based on terminal layout.

- **Step 2**
  Select or input the HP demand in each mode.

- **Step 3**
  Calculate a load factor for each mode, based on the relationship between hp required and installed hp of representative pieces of the particular CHE fleet.

- **Step 4**
  Use latest or selectable emission factors, hours in mode from model and calculated load factor to calculate emissions.
Horsepower Demand per Cycle Example

Activities: RTG Delivering an Import (from stack to truck)

- gantry to bay
- trolley to stack
- lower spreader
- position spreader
- latch on to box
- hoist box
- move box over truck lane
- lower box over chassis
- position
- release box
- raise spreader
- wait for next truck
- repeat
Truck Trips Generated by Hour of Day

- “Quicktrip” traffic generation component

Truck Trips Generated

- Number of Trucks
- Time of Day
- Rush Hour
- Arr.
- Dep.
- Combined

Graph showing truck trips generated by hour of day with specific time periods highlighted for rush hour.
Model Applications

• Emissions benefits analysis
  – Cold ironing & enforcement policy decisions
  – Alternative fuels
  – Neutral chassis pools
    • Lower in-terminal turn-time
  – Gate technologies
    • Effect of reduced process time & queuing on idle and creep idle times
  – Truck traffic reduction strategies
    • “Pier pass”
    • Appointments
    • Virtual container yards
    • Shuttle trains
    • Off-dock storage yards
Example 1; Analysis of Benefits of a New Rail Line

- Virginia Port Authority
- Proposed new rail line will reduce local truck trips
- Model used to quickly calculate the net savings between reduced truck trips and additional train trips

![Graph showing mode change with new rail line, comparing highway truck trips eliminated and additional line haul locomotive trips over years from 2007 to 2040.](image-url)
Example 1; Emissions Reduction of New Rail Line

Nox Emission Reduction
Due to New Rail Line

<table>
<thead>
<tr>
<th>Year</th>
<th>Tons Nox</th>
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<tbody>
<tr>
<td>2007</td>
<td>0</td>
</tr>
<tr>
<td>2009</td>
<td>10</td>
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<tr>
<td>2011</td>
<td>20</td>
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<td>2013</td>
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<tr>
<td>2037</td>
<td>150</td>
</tr>
<tr>
<td>2039</td>
<td>160</td>
</tr>
</tbody>
</table>

- Truck Nox Eliminated
- Additional Line Haul Locomotive Nox
- Nox Reduction due to mode shift
Example 2; NOx Calculation for Straddle Carriers

• Virginia Port Authority

<table>
<thead>
<tr>
<th>CHE Standard Calculation Example, One Straddle Carrier</th>
<th>Terminal Model Example, One Straddle Carrier</th>
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</thead>
<tbody>
<tr>
<td>Installed HP 354 BHP</td>
<td>Installed HP 354 BHP</td>
</tr>
<tr>
<td>Hours 3,000 Reported hrs</td>
<td>Hours 3,000</td>
</tr>
<tr>
<td>Load Factor 71% Default Nonroad</td>
<td>* modeled hours are expected to be lower</td>
</tr>
<tr>
<td>Nox Emission F 6.02 gr/bhp-hr</td>
<td></td>
</tr>
<tr>
<td>Total Nox 5.0 tons</td>
<td>Total Nox 5.0 tons</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load</th>
<th>% Time</th>
<th>Hours</th>
<th>Mode</th>
<th>Factor</th>
<th>Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel Loaded</td>
<td>29%</td>
<td>870</td>
<td>70%</td>
<td>6.02</td>
<td>1.43</td>
</tr>
<tr>
<td>Travel UnLoaded</td>
<td>23%</td>
<td>690</td>
<td>50%</td>
<td>6.02</td>
<td>0.81</td>
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<tr>
<td>Lift Loaded</td>
<td>3%</td>
<td>90</td>
<td>80%</td>
<td>6.02</td>
<td>0.17</td>
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<tr>
<td>Lift/Lower Unloaded</td>
<td>2%</td>
<td>60</td>
<td>50%</td>
<td>6.02</td>
<td>0.07</td>
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<tr>
<td>Idle</td>
<td>43%</td>
<td>1,290</td>
<td>10%</td>
<td>6.02</td>
<td>0.30</td>
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<tr>
<td>Total</td>
<td>43%</td>
<td>3,000</td>
<td>40%</td>
<td></td>
<td>2.78</td>
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</tbody>
</table>

Even while holding the reported hours the same, by breaking down the cycle of the strad, the emissions dropped by 60%.
Model Driven Hours are likely to be lower, further driving down emissions.
Default Non-road and Onroad load factors are often over 50%, as high as 71%.
Advantages of a Terminal Model Driven Estimate of Emissions

Terminal Model Driven Emissions Allow for:

• Projection of Emissions as Throughput Increases, accounting for changes in ship size, terminal layout and operating mode

• What-ifs to be run on questions such as the emission impact of:
  – Gate Modifications (hours, number of lanes etc.)
  – Operating Mode Changes (Stads, RMG, RTG)
  – Modal Changes, increasing % rail
Traditional Inventories - listing equipment and surveying hours of operation. The areas for improvement in this approach are:

- Standard Inventories are dependent on the fleet and reported operating hours of terminal equipment operators
  - Fleet size and utilization varies greatly among ports

- Collecting equipment lists and operating hours is labor intensive and does not allow for projection of emissions as throughput grows and operating modes change

- Lengthy data collection results in inventories that are often years old by the time they are completed.
Conclusions

• Terminal Capacity Models have been in existence for many years, used to:
  – Forecast throughput capacity
  – Compare alternatives
  – Identify Bottlenecks
  – Forecast Labor & Equipment Needs
  – Evaluate Operating Cost
  – Evaluate Potential Layout & Operating Changes

• Leveraging these Existing Tools to Address the Issue of Emissions Forecasting is the Natural Development of Terminal Planning in the 21st century
THANK YOU!
Inputs for Emissions Calculations