
MOFFATT & NICHOL
PORT OPERATIONS
EMISSIONS MODEL

AAPA
Harbors, Navigation and Environment Seminar
Vancouver, B.C.

Estimating Emissions From Container Cargo Operations Using a Comprehensive Container Terminal Model

June 7, 2006

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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

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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

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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

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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

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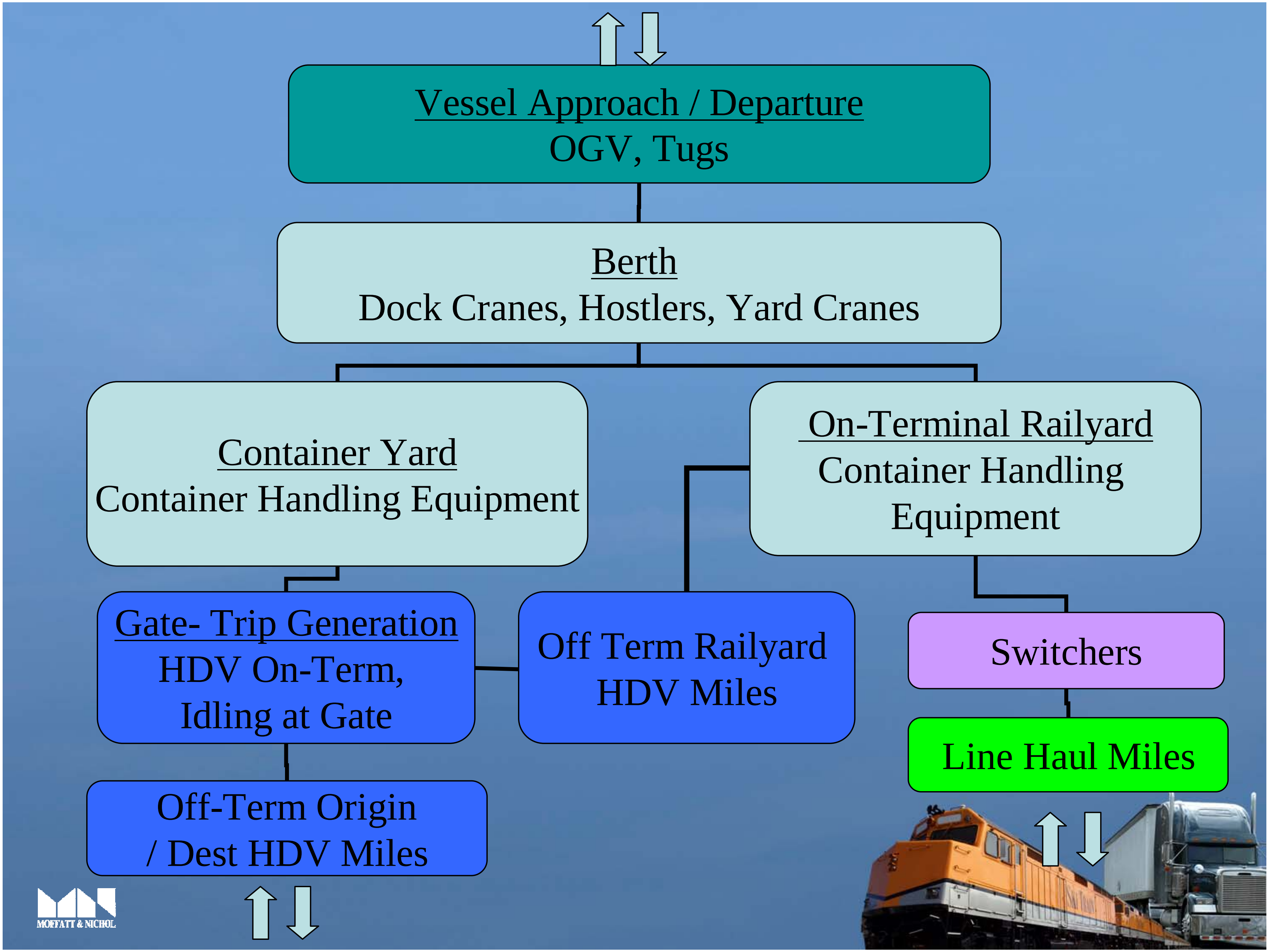
Vessel Approach / Departure
OGV, Tugs
Berth
Dock Cranes, Hostlers, Yard Cranes
Container Yard
Container Handling Equipment
On-Terminal Railyard
Container Handling Equipment
Gate- Trip Generation
HDV On-Term, Idling at Gate
Off Term Railyard
HDV Miles
Switchers
Line Haul Miles
Off-Term Origin / Dest HDV Miles
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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

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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.

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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?

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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)

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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

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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 (NO_X, 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

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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

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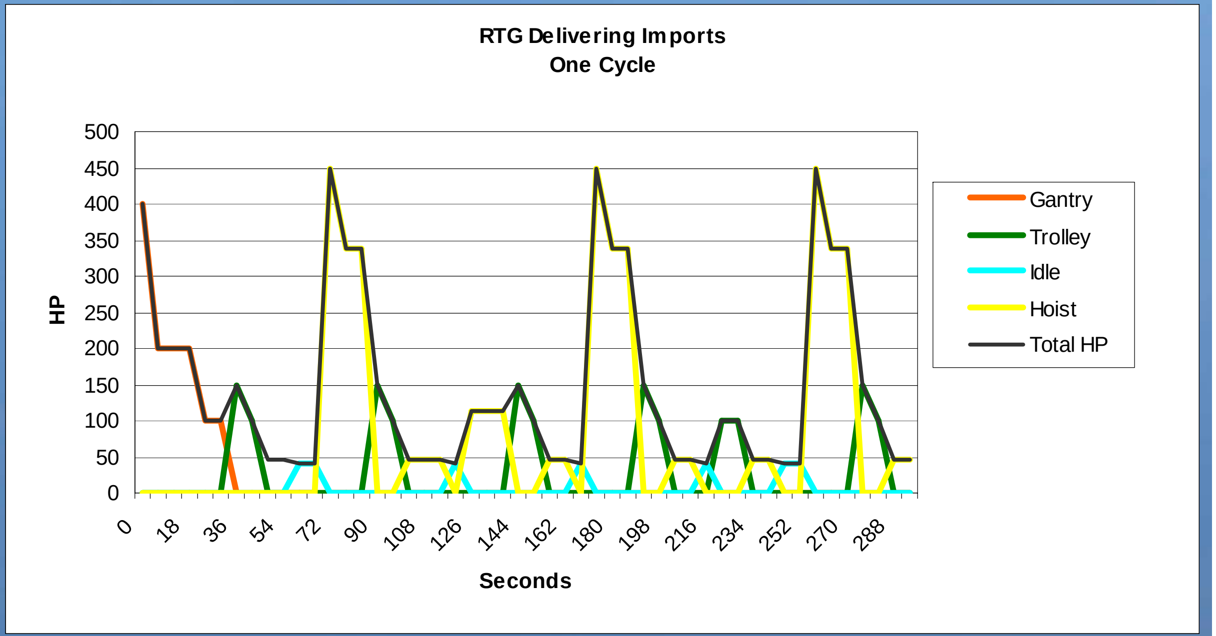
Horsepower Demand per Cycle Example

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



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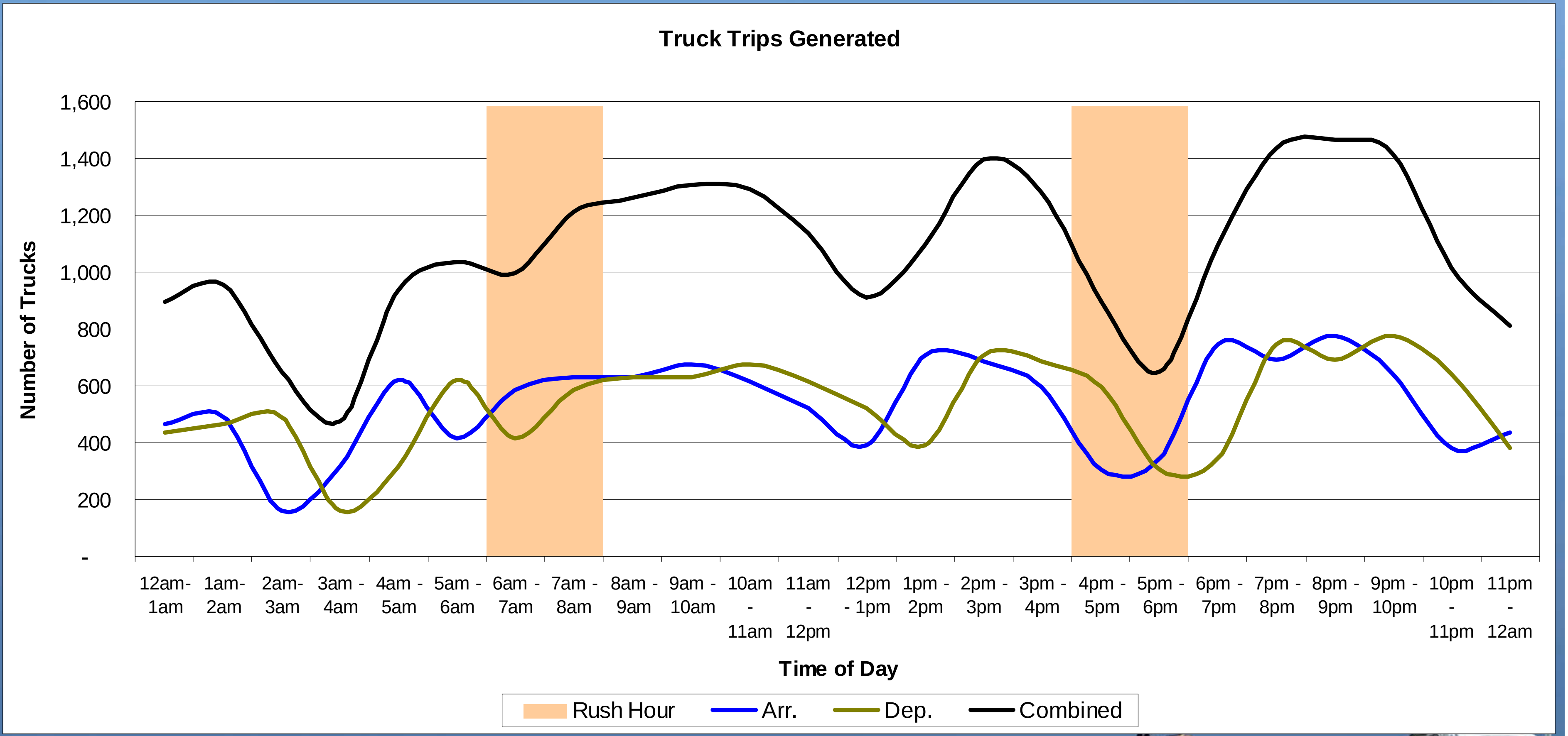
Truck Trips Generated by Hour of Day

- "Quicktrip" traffic generation component



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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

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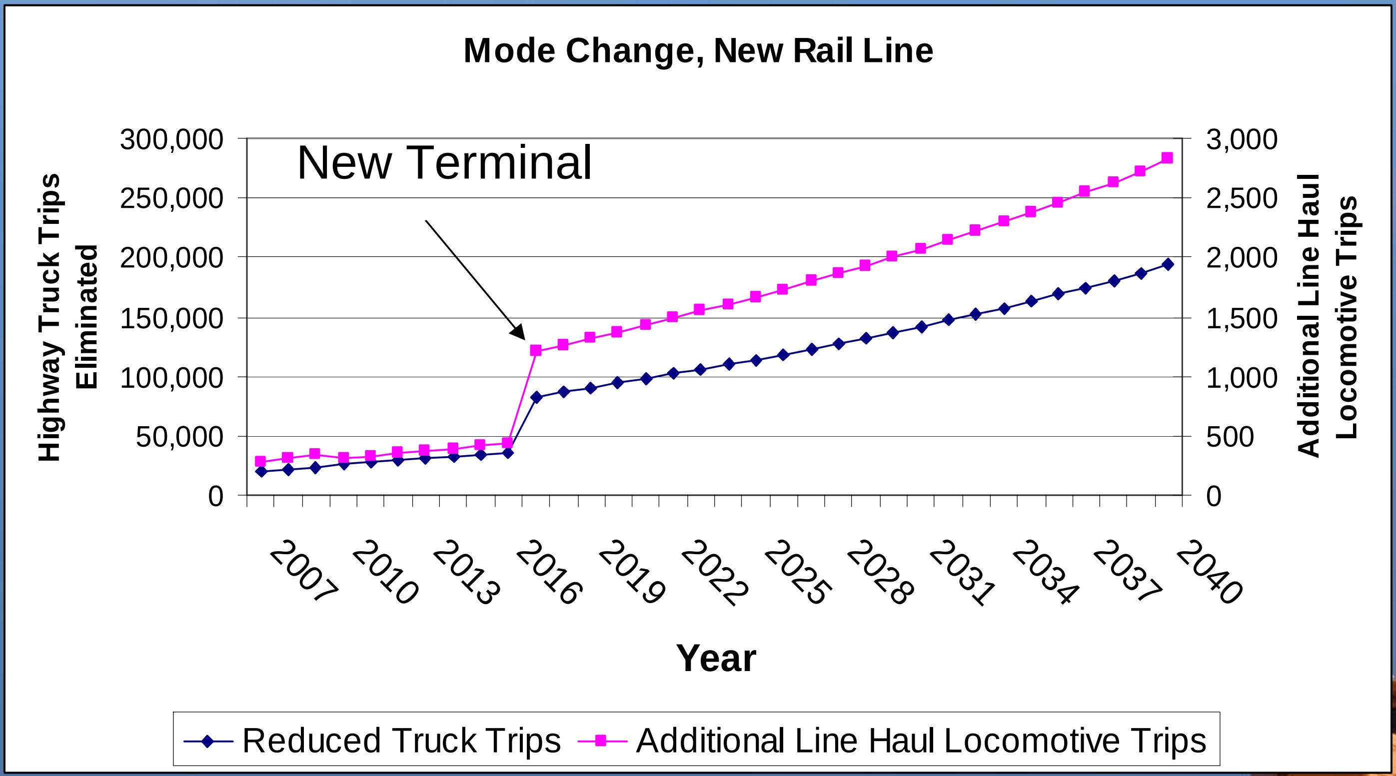
Example 1; Analysis of Benefits of a New Rail Line

- 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



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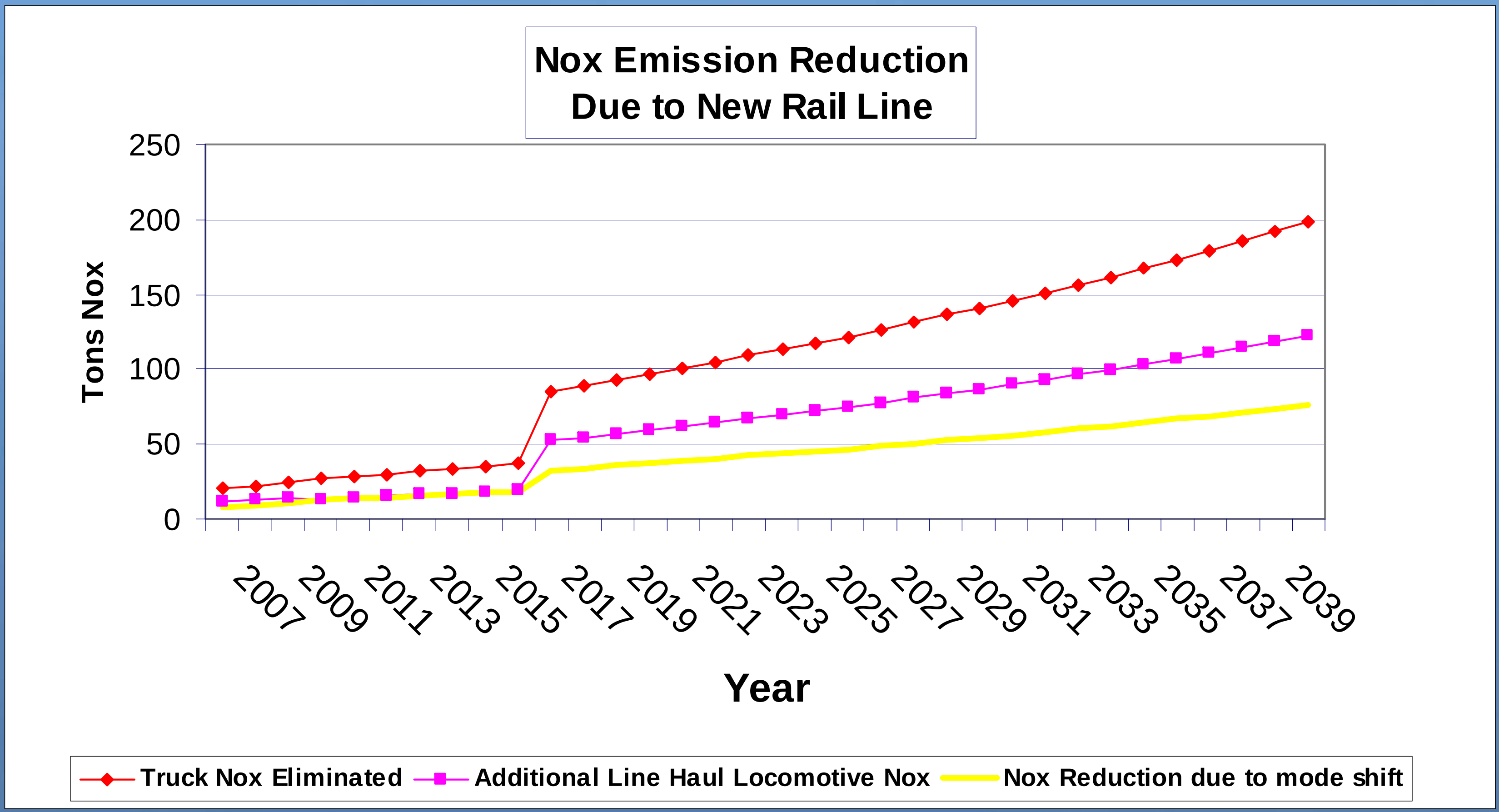
Example 1; Emissions Reduction of New Rail Line



Example 2; NOx Calculation for Straddle Carriers

- Virginia Port Authority

CHE Standard Calculation Example, One Straddle Carrier

Installed HP	354	BHP
Hours	3,000	Reported hrs
Load Factor	71%	Default Nonroad
Nox Emission F	6.02	gr/bhp-hr
Total Nox	5.0	tons

Terminal Model Example, One Straddle Carrier

Installed HP 354 BHP

Hours 3,000 * modeled hours are expected to be lower

	% Time	Hours	Load Factor in Mode	Emission Factor	Nox (tons)
Travel Loaded	29%	870	70%	6.02	1.43
Travel UnLoaded	23%	690	50%	6.02	0.81
Lift Loaded	3%	90	80%	6.02	0.17
Lift/Lower Unloaded	2%	60	50%	6.02	0.07
Idle	43%	1,290	10%	6.02	0.30
Total		3,000	40%	NOx tons	2.78
				Reduction	44%

Even while holding the reported hours the same, by breaking down the cycle of the strad, the emssions 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%

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Advantages of a Terminal Model Driven Estimate of Emissions

<u>Terminal Model Driven Emissions Allow for:</u>

- 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

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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.

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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

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THANK YOU!

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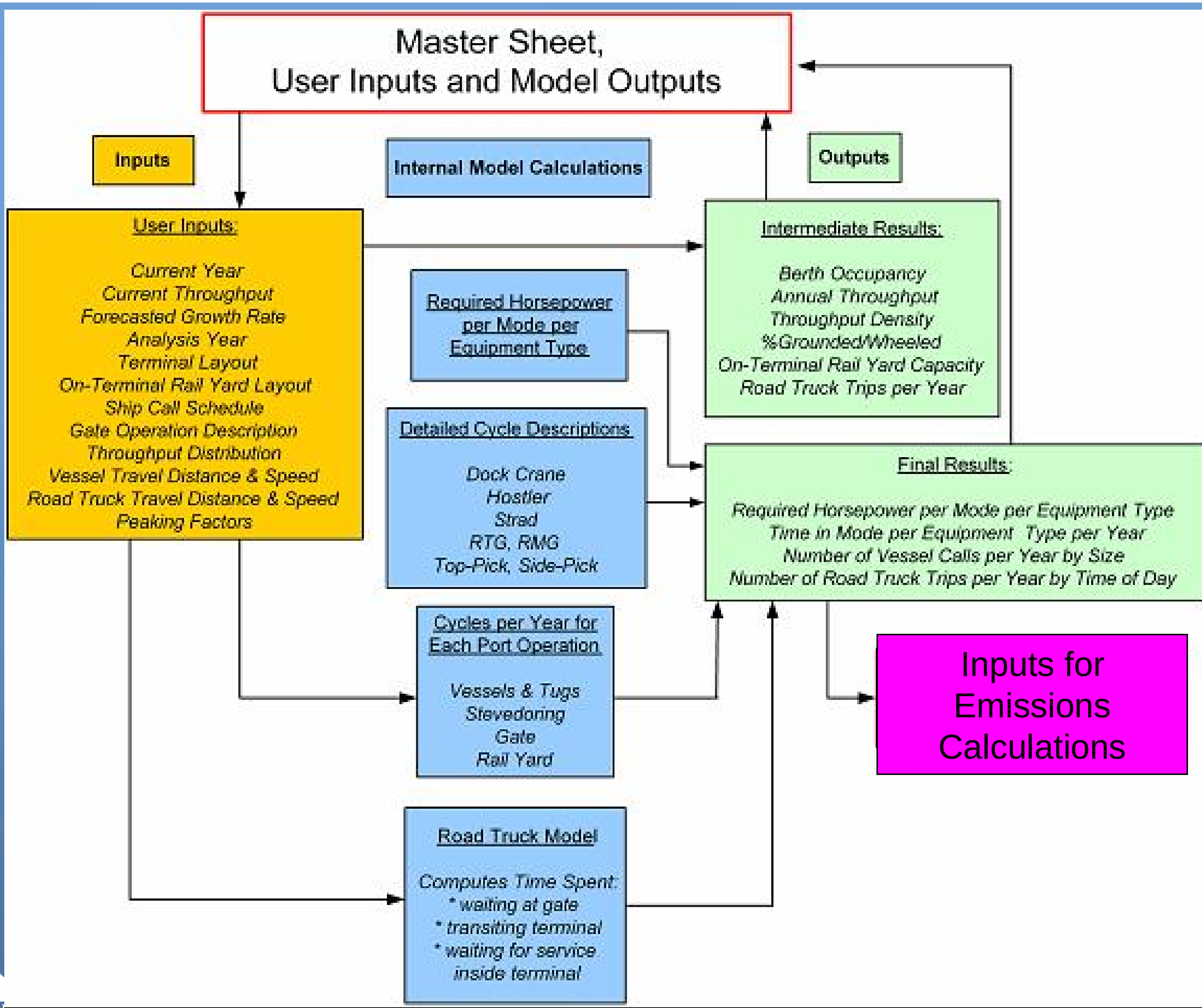
Master Sheet,
User Inputs and Model Outputs
Inputs
Internal Model Calculations
Outputs
User Inputs:
Current Year
Current Throughput
Forecasted Growth Rate
Analysis Year
Terminal Layout
On-Terminal Rail Yard Layout
Ship Call Schedule
Gate Operation Description
Throughput Distribution
Vessel Travel Distance & Speed
Road Truck Travel Distance & Speed
Peaking Factors
Intermediate Results:
Berth Occupancy
Annual Throughput
Throughput Density
%Grounded/Wheeled
On-Terminal Rail Yard Capacity
Road Truck Trips per Year
Required Horsepower per Mode per Equipment Type
Detailed Cycle Descriptions
Dock Crane
Hostler
Strad
RTG, RMG
Top-Pick, Side-Pick
Final Results:
Required Horsepower per Mode per Equipment Type
Time in Mode per Equipment Type per Year
Number of Vessel Calls per Year by Size
Number of Road Truck Trips per Year by Time of Day
Cycles per Year for Each Port Operation
Vessels & Tugs
Stevedoring
Gate
Rail Yard
Inputs for Emissions Calculations
Road Truck Model
Computes Time Spent:
* waiting at gate
* transiting terminal
* waiting for service inside terminal