American Marine Highway Modeling Toolset

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Overview

• Project Goals
• DES Introduction
• Input Architecture
• Features
• I-64 Express Route
• East Coast Route
• Brown / Blue Water Route
Project Goals

• GMU Project Deliverable
  – A simulation of the economic, environmental, and logistic factors of transferring cargo from trucking routes to American Marine Highways for two scenarios:
    • Short route between Norfolk and Richmond (I-64 Express)
    • Long route between New Bedford, Norfolk, and Cape Canaveral

• GMU Parallel Project Goal
  – Create a reusable modeling tool for evaluating AMH alternatives
    • Excel-driven / runtime model for a marine highway between two ports and three ports

• Current Work
  – Model blue/brown water route on Mississippi and Gulf
Introduction to DES Modeling

• Discrete Event Simulation (DES) is a computer simulation that models the chronological sequence and interaction of events
  – Example: Bank teller operations

• Model is created in ExtendSim 8 DES software
  – Uses Hierarchical Blocks - designed for “toolset” implementation
  – Allows for random interactions and variability
  – Has Monte Carlo capability to optimize process
  – Imports data from Excel – simplifies data input for user
  – Has free runtime version
Scalability Feature

- Fully scalable model for distances and amount of ports/travel segments
- "Lego-block" style architecture allows for interconnection of each block type
- Attributes tracked through each process can be fixed and time based
  - (Mileage based for road travel)
Intelligent Ship Control Feature

- Model tracks amount of cargo available to system. Releases ship only if it’s economically viable.
- Routes cargo if shipping route can’t handle volume
- Optimized release architecture predicts when it is most efficient to sail based on river currents/tides
Seasonal Probability of Cancellation/Costs Feature

- Built in architecture that allows user to specify any possible additional cost or cancellation
- Can be specified to be only activated within certain times
- Examples:
  - Seasonally dependent events such as route cancellation due to heavy fog in autumn or additional stevedoring costs due to rain-pay
  - Maintenance based costs dependent on ship characteristics
Input Architecture

• Inputs for all processes and metrics use the following format:

\[
Cost = a \cdot time + b \cdot distance + c
\]

– Where:
  » \(a\) – time dependant cost, e.g. $/hour
  » \(b\) – distance dependant cost, e.g. $/mile
  » \(c\) – constant or base cost

• Inputs are controlled via MS Excel spreadsheet
Metrics Tracked in Model

- Metrics tracked and summed for every piece of cargo:
  - Operating cost
  - Fuel cost
  - $\text{CO}_2$ emissions

- Metrics available for tracking:
  - Road maintenance cost
  - Congestion added
  - Accident rate
  - $\text{NO}_x$ emissions
  - Particulate emissions
  - Noise pollution
I-64 Express Route Translated to ExtendSim Model
I-64 Express Route Results

- 26% of cargo is rerouted

- Average time between container leaving NIT/APMT/Richmond area and arriving at destination is 1.69 days

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Tug/Barge</th>
<th>Rerouted by Truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Cost</td>
<td>$237.06</td>
<td>$218.36</td>
<td>$317.30</td>
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<tr>
<td>Fuel Cost</td>
<td>$48.59</td>
<td>$44.84</td>
<td>$64.67</td>
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<tr>
<td>Total Cost</td>
<td>$285.65</td>
<td>$263.20</td>
<td>$381.97</td>
</tr>
<tr>
<td>CO₂ Emissions [g]</td>
<td>55,726</td>
<td>49,731</td>
<td>90,029</td>
</tr>
</tbody>
</table>
Exploration Capabilities

• Design of Experiments approach to total cost per container with fluctuating fuel costs
  – Scenario does not have seasonal cancellations
  – Average rerouting rate is 14%
East Coast Long Route Model Translated to ExtendSim Model

GMU Consortium for Marine Highway Freight System
East Coast Long Route Results

- Average for door-to-door delivery
  - Canaveral – Norfolk: 6.84 days
  - Norfolk – New Bedford: 6.47 days
  - Canaveral – New Bedford: 8.19 days

<table>
<thead>
<tr>
<th></th>
<th>70% Full</th>
<th>80% Full</th>
<th>90% Full</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Cost</td>
<td>$1067.69</td>
<td>$1027.16</td>
<td>$982.93</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>$680.75</td>
<td>$611.58</td>
<td>$557.34</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$1748.44</td>
<td>$1638.74</td>
<td>$1540.27</td>
</tr>
</tbody>
</table>

Costs from Canaveral <-> New Bedford
Brown/Blue Water Route Diagram

- Joliet, IL
- Cairo, IL
- Port of NO
- Southern, IL
- Southern, MO
- Western, KY
- NOLA
- Tampa, FL

Key:
- Marine Travel
- Drayage

GMU Consortium for Marine Highway Freight System
Brown/Blue Water Barge Concept

Tow in Deep Draft Blue Water

FIG. 2a

Tow in Shallow Draft

FIG. 2b
Brown/Blue Water Route Preliminary Results

<table>
<thead>
<tr>
<th></th>
<th>Chicago – Tampa</th>
<th>Cairo, IL – Tampa</th>
<th>NOLA - Tampa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Cost</td>
<td>$1237.60</td>
<td>$1079.56</td>
<td>$954.79</td>
</tr>
<tr>
<td>Fuel Cost</td>
<td>$253.65</td>
<td>$215.73</td>
<td>$174.24</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$1489.11</td>
<td>$1295.29</td>
<td>$1128.76</td>
</tr>
<tr>
<td>Total Cost – Drayage &amp; Port costs</td>
<td>$947.15</td>
<td>$756.33</td>
<td>$589.79</td>
</tr>
</tbody>
</table>

- Drayage and port costs have a large affect on door-to-door cost

- Eight (8) locks with 5% failure rate have minimal affect on system
  – Need to include realistic lock schedules and tug/barge queuing
Way Forward

• Support 2-port and 3-port models available to public
  – http://eastfire.gmu.edu/gmu-consortium/marine-highway/

• Add functionality
  – Inflation
  – Business fluctuations
  – Mid simulation fleet additions
  – ROI calculator

• Add model to PHX ModelCenter
  – Variable sensitivity analysis
  – Optimize systems
Questions

• Questions?
Backup
I-64 Express Route Inputs Used

• Environment
  – Simulation time is 365 days
  – Distance between Richmond and NIT is 85 NM
  – Bi-diurnal current on James river fluctuates up to 3 knots
  – 20% route cancellation due to fog in Spring and Fall
  – Marine fuel $3.00/gal Truck fuel $4.00/gal

• Tug/Barge
  – 3 round trips per week
  – 1 barge attached to tug with a capacity of 85 containers
  – 6 knot sailing speed
  – 65 gal/hour fuel burn rate when sailing
  – 10 gal/hour fuel burn rate when idling
  – $7000 operation cost per round trip
I-64 Express Route Inputs Used

- Trucking
  - Distance between Richmond and NIT/APMT is 76 statute miles
  - Drayage distance at Richmond is 10 statue miles
  - Speed
    - 30 MPH minimum
    - 40 MPH most likely
    - 50 MPH maximum
  - Operating cost
    - $83.68/hour
    - $1.73/mile
  - Fuel burn rate is 5 MPG
I-64 Express Route Inputs Used

• Cargo
  – ~16 containers per day are modeled at both APMT and NIT
  – ~32 containers per day are modeled in the Richmond area
  – Cargo is has a deadline to be delivered in 14 days after creation

• Ports
  – $40 per move
  – Ship cancels trip if less than 40 containers are available among all ports
East Coast Long Route Inputs Used

• Environment
  – Simulation time is 180 days
  – MGO fuel $3.00/gal Truck fuel $4.00/gal

• Ship
  – Capacity:
    • 151 53’ trailers
    • 104 53’ containers
  – Design speed 23.7 knots
  – Fuel consumption 106 tons/day at cruising
  – Operating cost $70,000/day*

*Finance costs, ownership costs, owner’s return on equity, insurance, and crew wages
East Coast Long Route Inputs Used

• Trucking
  – Speed
    • 45 MPH minimum
    • 55 MPH most likely
    • 60 MPH maximum
  – Distances
    • Canaveral – Norfolk: 800 miles
    • Norfolk – New Bedford: 600 miles
    • Canaveral – New Bedford: 1300 miles
  – Operating cost
    • $83.68/hour
    • $1.73/mile
  – Fuel burn rate is 5 MPG
East Coast Long Route Inputs Used

• Cargo
  – 30 containers per day are modeled at all ports
  – Cargo is has a deadline to be delivered in 21 days after creation

• Ports
  – $40 per move
  – Each move takes 3 minutes
  – Trip cancels trip if less than 100 containers are available among all ports

• Marine Routes
  – Canaveral – Norfolk: 620 nautical miles
  – Norfolk – New Bedford: 380 nautical miles
Brown/Blue Water Route Inputs

- Tug/barge lease/insurance/labor $14,000
- 65 gal/hour fuel burn rate when sailing
- 10 gal/hour fuel burn rate when idling
- Cargo Capacity
  - Juliet 264 53’ containers
  - Cairo 534 53’ containers
  - NOLA 950 53’ containers
- Tug/barge speed
  - 10 mph brown water South
  - 8 mph brown water North
  - 9 mph blue water (7.8 knots)
Brown/Blue Water Route Inputs

• Environment
  – Simulation time is 365 days
  – MGO fuel $3.00/gal Truck fuel $4.00/gal

• Cargo
  – 20-40 containers per day are modeled at all ports (stochastic)

• Ports
  – $80 per move
  – Each move takes 3 minutes
Brown/Blue Water Route Inputs

- **Locks**
  - Average time 1.5 hours (min 1 hour, max 2 hours, triangular distribution)
  - 8 locks between Juliet and Cairo
  - 5% failure rate

- **Distances**
  - Juliet - Cairo  405nm
  - Cairo - NOLA  640nm
  - NOLA - Tampa  475nm

- Flooding and drought cause cancellation of voyage 10% of trips in summer and winter months
Brown/Blue Water Route Inputs

• Drayage
  – Speed
    • 45 MPH minimum
    • 55 MPH most likely
    • 60 MPH maximum
  – Distances
    • 100 miles from each port
  – Operating cost
    • $83.68/hour
    • $1.73/mile
  – Fuel burn rate is 5 MPG