Inland Navigation Modeling and Analysis

- Mark R. Hammond
- Economist
- Great Lakes and Ohio River Division Planning Center of Expertise for Inland Navigation (PCXIN)
- 304-399-6928
- 27 January 2010
Inland Navigation Models and Analysis

1. Description of Inland Navigation System

2. Economic Data and Models

3. Evaluation - Application
Inland Navigation System

Inland navigation system is a system of *lock and dam* projects that convert natural rivers with variable water levels into a waterway system with a constant depth sufficient for the movement of commercial vessels.

- Dams convert the river into a series of lakes (pools).
- Locks allow vessels to pass from one pool to the other.
Lock and Dam Project
Greenup Lock and Dam
Typical Ohio River Tow

Towboat and 15 Barges fully loaded is 24,000 tons

Overhead View

Side View
Nearly 12,000 Miles 9 ft & Over
198 Lock Sites / 242 Chambers
Moving Over 600 Million Tons
About 2/3rds Cost of Rail and 1/10 Cost of Truck
Do we have a national freight policy to accommodate expected future traffic growth?
Inland Navigation Models and Analysis

1. Description of Inland Navigation System

2. Economic Data and Models

3. Evaluation - Application
Data Issues

- Traffic Forecasts (Uncertainty)
- Transportation Rates (Elasticity)
- Lock Capacity (Tonnage Transit)
- Structural Reliability (Risk)
- Other Transportation Impacts – congestion, emissions, accidents

![Greenup Main Chamber Closures](chart.png)
Economic Data and Models

Data Sources

- WCSC
  - Forecasts
  - Rates
- LPMS
  - Capacity
- Equipment Costs (IWR)
  - Delays
- Engineering Hz. Values
  - Component Reliability
Economic Data and Models

Models

- Partial Equilibrium
- Input-Output
- Simulation
- Linear Programming
- Econometrics
- Barge Costing
- Rail Costing

![Diagram showing economic data and models with various benefits and costs related to river traffic and capacity expansion.](image-url)
Modeling Lock - Capacity

- Discrete-event simulation
- WAM requires detailed data input
- Shipment is randomly generated using LPMS distributions
- Based on the tow characteristics & project state, shipment is processed
- Statistics are accumulated and an average delay for the year is calculated
Economic Data and Models

Transportation Rates

- Water Routing
- Land Routing
- Metropolitan Statistical Area
Forecasts and Uncertainty

- WCSC gives:
  - History
  - Shippers and Carriers Identified
- What are the drivers?
- Why are they here?
- What will they do?
- What are the possible futures?
- How are they affected by congestion?
- Are there alternative sources?

Economic Data and Models

Forecasts Based on Alternative Futures

- Utility Based High (Coal Model)
- Utility Based (Coal Model)
- Modifies Clear Skies
- NAAQS Growth
- Clear Skies
Economic Data and Models

ORS Rate-Savings Ranked Movements

System Demand
Economic Data and Models

Risk - Engineering Reliability Analysis

- Monte Carlo Simulation
  - Component hazard functions & even trees - probabilities of unsatisfactory performance
  - Consequences of unsatisfactory performance (repair costs & closure duration)
  - Probabilities of failure integrated with economics over 50 year project-life
  - Alternative investments evaluated

![Miter Gate Hazard Functions for Varying Traffic Projections](image)

- ANNUAL HAZARD RATE (%)
- REPAIR LEVEL
  - NEW GATE 5%
  - MAJOR REPAIR 35%
  - TEMP. REPAIR 60% W/ NEW GATE
- CLOSURE TIME/REPAIR COST
  - 180 DAYS/ $6,000,000
  - 30 DAYS/ $2,000,000
  - 60 DAYS/ $5,000,000
- UPDATED RELIABILITY
  - MOVE BACK 5 YEARS ON HAZ. RATE
- NEW GATE RELIABILITY
- SCHEDULED REPLACEMENT
  - 45 DAYS AND $3,500,000

- LOOP TO NEXT YEAR VALUES
- NO FAIL (1 - AHR)
- ANNUAL HAZARD RATE (AHR)
Economic Data and Models

Navigation Investment Model (NIM)

NIM – spatially detailed relational database developed by PCXIN – partial equilibrium

- simulates economic consequences of component reliability
- 3 essential components: supply, demand, benefit calculation
- erodes transportation savings through congestion
Economic Data and Models

Lock Operations
Cargo Forecasts
Reliability Estimates
Long Run Elasticity
Repair Plans and Costs
Budget

Waterway Supply and Demand Module
Lock Risk Module
Optimal Investment Module
Random Closures
Construction Plans

Towboat/Barge Operations
River Network

Short Run Elasticity
NIM – Suite of Modules
Optimal Investment in Projects and Maintenance

Economic Data and Models
Inland Navigation Models and Analysis

1. Description of Inland Navigation System

2. Economic Data and Models

3. Evaluation - Application
Evaluation Procedure

Corps Planning Process

1. Identify Problems & Opportunities
2. Inventory & Forecast Conditions
3. Formulate Alternative Plans
4. Evaluate Alternative Plans
5. Compare Alternative Plans
6. Select Recommended Plan
Small and Old Locks Result in Delays
Key Study Areas

1. Lock Capacity – Supply
2. Component Reliability - Supply
3. Future Traffic Levels - Demand
4. Transportation Rates - Demand
Reliability

1. Major structural problems as well as typical equipment problems.
2. Decide what components to analyze
3. Develop hazard functions and event trees
NIM Lock Risk Module
Simulation of the Engineering Reliability Data

A **hazard function** identifies the probability of failure of a component in a specified time period, given that it has survived up to the selected time period.

An **event tree** describes the levels of failure and the associated consequences and repairs.

...estimates the probability of each potential closure in each year of a component’s life given equilibrium traffic levels, hazard functions and event trees.
NIM Waterway Supply & Demand Module
(WSDM) Determination of Equilibrium Traffic Levels and Transportation Costs

...determines equilibrium waterway traffic levels under a given system configuration and forecast scenario for each year in the analysis period, taking into account scheduled lock closures.

**Step 1 – Determine Shipping Plans**
WSDM calculates the towing costs and determines the cost-effective tow configurations to move the port-to-port tonnage on the waterway network honoring tow and operating characteristics.

**Step 2 – Equilibrate Traffic Levels**
Ranks mvts by base rate savings...adds mvts and iterates until savings are stable with no negatives.
NIM Optimization Module

Quantify & Compare Investment Options

...systematically compares investments and selects the optimal investment strategy and summarizes the results.

INVESTMENT ANALYSIS – Example
Av.Ann. Assuming Investment in Specified Year

1) the recapitalization cost (if there is one);
2) the expected unsch repair costs;
3) the sch repair costs;
4) maintenance costs; and
5) expected transportation impact costs.
### Near - Term (2010-2015)

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emsworth New 600' Lock *</td>
<td>2010</td>
</tr>
<tr>
<td>Dashiells New 600' Lock *</td>
<td>2010</td>
</tr>
<tr>
<td>Montgomery New 600' Lock *</td>
<td>2010</td>
</tr>
<tr>
<td>Markland Main Chamber Rehab</td>
<td>2010</td>
</tr>
<tr>
<td>Meldahl Main Chamber Rehab</td>
<td>2010-2013</td>
</tr>
<tr>
<td>Hannibal Main Chamber Rehab</td>
<td>2011-2012</td>
</tr>
<tr>
<td>Myers Main Chamber Rehab</td>
<td>2011-2014</td>
</tr>
<tr>
<td>Pike Island Main Chamber Rehab</td>
<td>2015-2016</td>
</tr>
</tbody>
</table>

### Medium - Term (2016-2025)

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newburgh Main Chamber Rehab</td>
<td>2016-2025</td>
</tr>
<tr>
<td>Cannelton Main Chamber Rehab</td>
<td>2016-2017</td>
</tr>
<tr>
<td>Belleville Main Chamber Rehab</td>
<td>2017-2028</td>
</tr>
<tr>
<td>Racine Main Chamber Rehab</td>
<td>2019-2020</td>
</tr>
</tbody>
</table>

### Long - Term (2026-2052)

<table>
<thead>
<tr>
<th>Project</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Willow Island Main Chamber Rehab</td>
<td>2027-2028</td>
</tr>
<tr>
<td>Byrd Main Chamber Rehab</td>
<td>2030-2045</td>
</tr>
<tr>
<td>Markland Main Chamber Rehab</td>
<td>2052</td>
</tr>
</tbody>
</table>

* Only 600’ replacements were considered.
NIM Applied - ORNIM
Upper Ohio River Navigation Feasibility Study

- Formulation and evaluation
  - Reactive Maintenance
  - Replacements (components – rehabs)
  - New locks at all three sites

- Inputs
  - Updated forecasts
  - Updated transportation rates & vessel costs
  - Latest shipper response data
  - Closure impact on highway congestion
  - Updated engineering reliability

- Model
  - Modifications
  - Certification
Contact Information

Planning Center of Expertise for Inland Navigation
Huntington – (304) 399-6955

Mark Hammond, Economist
mark.r.hammond@usace.army.mil