Navigable Inland Waterway Traffic Model for Evaluation of Tow Operation Procedures in the Context of Extreme Weather Events

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The Problem

- Navigable inland waterways are an important component of the U.S. freight transportation network.
- Waterways are susceptible to damage and service disruptions due to extreme weather events.
- Extreme weather events are likely to increase in severity and/or frequency.
Modeling Approach

- Little available data about tow movements during extreme weather events.
- Waterway Action Plans (WAP) provide guidance to decision-makers that influences tow behavior during extreme weather.
- Simulate WAP procedures and add to a behavioral tow traffic model.
Model Implementation & Simplifications

- General waterway segment with 2-way traffic.
- 2 to 3 navigation locks with a single operable lock chamber can be modeled.
- All queueing follows a First-In-First-Out procedure.
- Assumes that tows will carry as many barges as allowed.
- Tows and barges are randomly generated.
- Single origin-destination pair created at segment ends.
- 1 river mile increments.
Navigation locks and bridges that pose navigation obstructions can be placed at river miles of the user's choice.

A single one-way traffic zone can be implemented.

Model updates are linked to a Date-Time clock and occur at 30 minute intervals.

Parameterized tow and lock controls can be manipulated by the user.
Proof of Concept

- Cumberland River test area with segment starting point in Barkley Lake and ending point in Old Hickory Lake (300 miles).
- Simulation results for speed, transit times, locking times and delivered cargo for every tow for every 30 minute interval.
- Ran 42 different simulation scenarios.
- Simulations test parameter effects individually and in combination.

Example Output: Speed by River Mile

![Graph showing speed by river mile with and without passing allowed.](chart.png)
Simulated Traffic Patterns

Example Output: Speed by Time of Day

- Tow traffic patterns meet expectations for basic traffic rules and WAP procedures
  - Restricting passing leads to more pronounced deceleration
  - Tows slow as they approach locks and reduce speed to zero for locking
  - If tows are not allowed to pass bridges at night, average speeds decrease during the night and tows slow as they approach bridges at night
- Overall average speeds fall within bounds of speeds calculated from historic lockage data
Metrics of “Operational Efficiency”

- Metrics give indication of theoretical “best-expected” performance given a set of waterway procedures.
- Nighttime travel restrictions and horsepower to barge ratio restrictions most significantly impact transit times and barge delivery rates.
Application to Ohio River Segment

- Segment starts in Cannelton pool and ends in the Markland pool (210 miles).
- River miles measured as miles from intersection with the Mississippi River.
- Ran simulations for “Normal” and “High Water” operating conditions.
Comparison of OH and CU High Water Traffic Patterns

- For Cumberland and Ohio, average speed decreases ~40% from normal to high water conditions.
- For CU nighttime travel speeds decreased 66% from normal to high water, for OH decrease of 55%.
Take Aways & Next Steps

- Developed a waterway navigation simulation tool
  - Comports with reality
  - Provides resource for evaluating WAP procedural responses to extreme weather

- Extended testing and validation
  - Compare speed profiles to those from AIS data

- Future enhancements
  - Dynamic hydrologic system updates
  - Complete addition of harbor and mid-segment fleeting areas
  - Multiple stakeholder-specific interfaces for participatory simulations
Acknowledgements

- This work was supported in part by the U.S. Army Corps of Engineers and an Oak Ridge Associated Universities (ORAU) graduate student fellowship.
- Thanks to TRB-CMTS for supporting my attendance at this conference.