Analysis Methods for Inland Waterways

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Overview
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- Approx. 25,000 miles of navigable U.S. waterways
- Approx. 13% of intercity ton miles
- Approx. 4000 towboats
- Approx. 19,000 barges
Traffic:

- Commercial tows
- Recreational boats
- Other

Commercial tows consist of towboats (=powerboats) and unpowered barges (modular, with standardized 195 x 35 ft. dimensions and approx. 1,500 ton capacity), moving at approx. 10 mph.
Lock Operations
DOMESTIC AND FOREIGN WATERBORNE TONNAGE

System Capacity and Service Levels Limited by:

- Lock chamber dimensions
- Parallel chambers per lock
- Lockage times
- Channel characteristics
- Seasonal icing or low water
- Scheduled lock closures
- Unscheduled lock closures
Critical Issues

- Aging infrastructure with very high replacement costs
- Vulnerability to service interruptions due to lock closures, icing, low water, etc.
- Seasonality of demand and supply
- Environmental impacts
- Taxes and subsidies
- Intermodal competition
Comparisons with U.S. Aviation System

1. Federal Agency (U.S. Army Corps of Engineers rather than FAA) builds and operates the infrastructure, except for the terminal facilities.

2. Competing commercial fleet operators and owners of small private vehicles must be served efficiently and fairly.

3. Insufficient capacity results in congestion and queuing delays.

4. The hard infrastructure (locks, airfields) may be difficult to maintain, repair or expand without interrupting service.

5. Severe funding problems.
Comparisons with U.S. Aviation System (2)

6. Political influences on resource allocation
7. More decentralized planning and operation for waterways
8. “Real-time” is slower on waterways
9. Waterway network is more interruptible by single failures
10. Possible control policies for runways and lock chambers have interesting similarities (grouping, sequencing, chamber assignment, direction changes, reserved slots)
11. Similar interference effects among parallel runways and lock chambers
Relevant Methods of Analysis

- Demand forecasting
- Analysis of operations
- **Network simulation**
- Control of lock operations
- Condition assessment
- Reliability analysis
- Investment planning and scheduling
- Maintenance planning and scheduling
Network Simulation

- WAM 1973
- Wang & Schonfeld 2002, 2005
- Navsym
- ORNIM
- Simopt
- Locksim
- UMR
- NaSS
Expectations in New Waterway Simulation Models

1. Validity
2. Generality
3. Automatic extraction and preprocessing of input data
4. User interfaces with visualization and animation
5. Multi-modal equilibrium demand
6. Hierarchical analysis
7. Detailed analysis of lock operations
8. Component-level reliability
9. Complex operating policies
10. Interactions among locks
11. Applications
12. Performance measures
13. Computation efficiency suitable for optimization
Relevant Methods of Analysis

- Demand forecasting
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- Maintenance planning and scheduling
Control of Lock Operations (1)

1. Assignment of tows to multiple chambers
2. Alternating platoons of variable size (M-up and N-down)
3. Priorities and mixing rules for commercial and recreational traffic
4. Fairness objectives and constraints
5. Tow cutting and reassembly considerations
6. Chamber packing
7. Chamber packing with tow cutting
Control of Lock Operations (2)

8. Integrated control of adjacent locks
9. Appointment and reservation systems
10. Priorities based on relative service times, time values for tows and their contents, and relative lateness
11. Auxiliary ("helper") towboats at congested locks
12. Combined control policies
13. Dynamic control policies
Relevant Methods of Analysis

- Demand forecasting
- Analysis of operations
- Network simulation
- Control of lock operations
- Condition assessment
- Reliability analysis
- Investment planning and scheduling
- Maintenance planning and scheduling
Investment Planning and Scheduling for Interdependent Projects

- Project design
- Evaluation
- Selection
- Sequencing
- Scheduling
If budget constraints over time are binding, project sequencing determines project implementation times. Still, identifying the best sequence of projects can be a large combinatorial problem with numerous local optima. Methods used for project evaluation are largely separable from those used for project selection & scheduling. Microscopic simulation is a very expensive way to repeatedly evaluate the objective function during an optimization process, but is becoming practical for waterway networks.
Previous Work (1)

- For evaluation of interdependent projects we tried:
  - Queuing metamodels (Dai & Schonfeld, 1998)
  - Artificial Neural Networks (Wei & Schonfeld, 1993, 1994)
  - ANN-based queuing networks (Zhu et al, 1999)
Previous Work (2)

For optimizing project selection and scheduling we experimented with:

- Swapping algorithms (Martinelli & Schonfeld, 1993)
- Branch and Bound (Wei & Schonfeld, 1993)
- SPSA (Ting & Schonfeld, 1998)
- Simulated annealing
- Island models (Tao & Schonfeld, 2004)
Conclusions

- The U.S. inland waterway system seems less complex in most respects than the air transportation system. Thus, it seems easier to analyze and optimize at a larger scale and, simultaneously, at a finer level of detail.

- Because “real-time” is slower in inland waterways, more complex control policies, based on deeper search and longer anticipation, are feasible.
In most areas of interest the analytic state-of-the-art seems more advanced in aviation than in inland waterways. However, some methods developed for waterways seem promising for aviation applications, including:

- Selection and scheduling of capital improvements
- Maintenance planning and scheduling
- Introduction of new technologies and operating policies
- Scheduling of runway operations
- Optimization based on simulation
- Optimization based on ANN approximations of queuing networks
References


THANK YOU!