Technical Review of Draft Report
Navigation System Simulation (NaSS) Design Document

U.S. ArmyCorps of Engineers
Institute for Water Resources

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Independent Technical Review of
Draft Report

Navigation System Simulation (NaSS) Design Document

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Preface

Under Contract Number W912HQ-04-D-0007, Delivery Order #24, CDM is contracted to select independent reviewers to evaluate written products for the U.S. Army Corps of Engineers Institute for Water Resources (IWR). This report provides an independent technical review of a study sponsored by IWR titled, *Navigation System Simulation (NaSS) Design Document*. The objective of the independent technical review is to validate analytical procedures, verify conclusions and enhance the quality of the said study. Three independent reviewers were selected by name by IWR to evaluate the NaSS Design Document and agreed to participate:

Dr. Michael Bronzini, George Mason University
Ms. Arlene Dietz, A & C Dietz Associates, LLC
Dr. Donald Sweeney, University of Missouri-St. Louis

The review document follows a four-section editorial structure that was established in consultation with IWR: 1) written statement by IWR on its original purpose and objectives for the study being reviewed, 2) summary paraphrasal of study conclusions, 3) summary review statement on validity and quality of findings, and 4) individual comments and issues for resolution.

Following this introduction and in adherence to IWR's guidelines, Section I describes the purpose and objectives of the work being reviewed. Section II provides the summary of conclusions as paraphrased by each reviewer, while Section III provides summary review statements by each reviewer on the validity and quality of findings. Finally, individual comments and issues for resolution are provided in Section IV.

Contents

Section 1
Purpose and Objectives

The Navigation Economics Technologies (NETS) research program is an initiative of the US Army Corps of Engineers, Institute for Water Resources (IWR). The purpose of NETS is to build upon the latest navigation research findings and analytical techniques in order to advance the state of navigation economic analysis.

A portion of the NETS effort is devoted to advancements in inland navigation analysis models. The subject of this Design Document, the Navigation System Simulation model (NaSS), is an attempt by the Corps to improve its capabilities to model and analyze, at a microscopic level, the economic aspects of inland navigation systems. The NaSS model is intended to build upon the capabilities of past models and add features which address modeling shortcomings identified during previous reviews.

The purpose of this design document is to define the overall framework for NaSS, describe the individual models/tools that are components of the NaSS suite, and discuss key technical issues that are important to the understanding of the proposed NaSS models. It is important to note that many design features are only concepts at this point in the design process. Therefore, the details of these features are not presented in detail. The prototype phase recommended in the Design Document will serve as a research and discovery phase for these conceptual features.

The IWR requested that the NaSS Design Document be reviewed with the objective of determining how well the proposed NaSS model addresses the features and capabilities they would expect in a next generation microscopic inland navigation operations model. The reviewers were expected to compare their understanding of previous Corps navigation models, previous review comments by entities such as the National Research Council, and their professional expectations, with the features and concepts identified in the NaSS Design Document. The following sections provide the reviewers' evaluation of how well the proposed NaSS model addresses their professional expectations for a model of this type.

Section 2
Summary of Study Conclusions

Reviewer 1

The design document describes the framework for a discrete-event simulation model, entitled "Navigation System Simulation" (NaSS), of the operation of segments of the inland waterway system. The self-stated purpose of the document is "to define the overall framework for NaSS, describe the individual models/tools that are the components of the NaSS suite and discuss key technical issues that are important to the understanding of the proposed NaSS models" [Section 1, page 1]. The model is to be developed by a Project Delivery Team under the management of the U.S. Army Corps of Engineers Institute for Water Resources Navigation Economics Technologies (NETS) program. The objective of the NETS program is to "improve navigation economic analysis techniques" [Section 1, Page 1].

The aspects of the user defined segment of the system to be simulated in the System Network Model include the generation of tows and other vessel trips to be completed on the system segment, the configuration of tows in the system segment, the movements of vessels through reaches in the system segment, the processing of vessels at segment locks, the re-fleeting of tows in the segment, and the reliability of the performance of the locks in the segment. An as yet to be fully defined shipper-response to lock delays and outages will be included in the model as well as the ability to operate the simulated locks under variable queue dispatch disciplines. The model will be a life cycle model and simulate future conditions anticipated on the waterway system.

Additionally, the document proposes development of an Investment Optimization Model to be used in conjunction with the simulation model. The stated purpose of the Investment Optimization Model is to "develop optimal investment plans at waterway and lock level given budget constraints, using a GA (*genetic algorithm*) optimization in conjunction with the System Network simulation as the evaluation model" [Section 2.3, Page 5].

Finally, the document calls for the development of some auxiliary tools to analyze, summarize and present input and output data along with a tool to preprocess input data for use directly in the System Network Model. Together these models and tools form what is termed the NaSS model suite.

The data sources identified to provide the inputs for this effort are the Corps of Engineers' Lock Performance Monitoring System, Waterborne Commerce Statistical Center, and OMNI databases. To the extent possible, these data will be used to construct the probability distributions that the model will draw from in simulating the events modeled in the System Network Model. Additionally the work begun by Wilson and Train (2004) in modeling individual shipper mode, destination, and quantity decisions is identified as a promising basis for incorporating shipper responses to outages and delays in the Network System Model.

For the Investment Optimization Model the document proposes the development of a genetic algorithm (GA) to identify a near optimal set of system investments. This GA algorithm identifies and tests promising combinations of investments which are then passed to the Network System

Model for detailed evaluation. The results of the detailed evaluation are then passed back to the Investment Optimization model in an iterative fashion until no better set of investments (or only those with sufficiently small improvements) can be identified. The document concludes that the SIMOPT model developed by researchers at the University of Maryland has demonstrated that this approach is feasible.

It is further suggested that model development take place under the C++ or C# programming languages using Microsoft Access for data storage. The models will run under the Windows operating system, presumably on a standard desktop PC. For each model in the NaSS suite, a modern Graphical User Interface (GUI) will be developed.

The stated intent of the proposed NaSS model suite is to build and improve upon previously developed Corps of Engineers' navigation system models. It is intended to become the Corps' standard for waterway simulation and investment evaluation.

Finally, the proposed NaSS model suite is itself intended to be part of a larger, tiered system of economic models. Tier 1 models will forecast regional and global product flows and Tier 2 models will route the forecasted flows over stylized regional transportation networks. The NaSS model suite is a microscopic Tier 3 model and will be used to provide detailed evaluations of waterway specific investments. Feedback loops are foreseen between the three tiers of models. The larger system of models is being developed concurrently under the management of the Navigation Economic Technologies (NETS) research program.

Reviewer 2

This document defines the NaSS (Navigation System Simulation) framework. NaSS is a major element in the NETS (Navigation Economic Technologies Program) and is nested into its framework as a tier 3 microscopic systems model. NaSS is to be a unified model that transforms the best of predecessor waterway models into a coordinated suite of models dealing primarily with inland navigation. Using common terms, definitions and same generation software the component models in the suite can be developed, tested, and used independently at the appropriate scale of problem. The focus of the overall effort is the design of a discrete-event multi-lock simulation model based on GUI (Graphical User Interface) control center, Wintel platform, a Microsoft NET framework, Microsoft Access for data and C++ and C# programming languages. All models within the suite will follow a "spiral development approach"—proof of concept, prototype, beta testing and fielded (version1.0) model(s) with training.

The primary NaSS simulation tool is the System Network Model (SNM). Its optimization model, Investment Optimization, is planned to develop optimal investment plans at waterway and lock level using GA (Genetic Algorithms) optimization in conjunction with the System Network simulation. The designers of NaSS clearly state that the Investment Optimization Model cannot be properly designed until the full characteristics of the Systems Network Model are clear and its prototype is complete. Following that, the essential translator component from Simulation to Optimization can be designed.

The Systems Network Model, which is an evolutionary step from previously designed inland waterway lock and network models, involves a complex framework requiring knowledge of the system from lock level involving its physical attributes, operational characteristics, performance including reliability and vessel service; to the interacting lock and channel reaches on the system (with their depth, width and curvatures);to the vessel operating characteristics to include configuration of tows, speed, re-fleeting, equipment utilization [includes interline practices] and recreational vessels; to shipper decisions including reliability [and congestion] responses; and commodity origins and destinations [past and future]. The flotilla's interaction with a lock covers the lockage process, from pre-approach for some, to approach, entry, chambering and exit with the complexities of the conditions under which a vessel enters (described as fly, exchange and turnback), all impact time and the next vessel. Lesser known, and important to the model, are policies regarding fully loaded and empty barge assumptions, re-fleeting, generation of shipments, barges and tows, multi-barge pick-ups and drop-offs in different reaches, and seasonality and its peaking influence. Reliability modeling is planned at the lock and lock component levels with events defining state transitions. These transitions are not needed in the scheduled outage situation. Shipper's responses to lock unavailability will involve decisions such as wait, shift or divert. This work is in the proof-of-concept stage. Finally, the model will consider alternative routings and looping networks.

Investment Optimization Model is designed to help select from among many components and from site level national waterway investment options to obtain "near-optimal" solutions in selecting and scheduling improvements, rehabilitation and even investments in maintenance. Using a genetic algorithm which links via a translator to the network simulation model follows an iterative process to reach the "good" solution for investment scheduling and funding. Considerable process time is required for combining a simulation with a GA optimization; therefore a prescreening process of infeasible solutions is necessary. The design of this model's proof of concept will follow the completion of the design and testing of the System Network.

Reviewer 3

The NaSS Design Document lays out a brief rationale and background for constructing a new combined simulation and optimization model of (primarily inland waterway) navigation systems, and sets forth in some detail the proposed conceptual framework and overall design of such a modeling system. The principal analytical components of the proposed design are the System Network Model and the Investment Optimization Model. These are supported by a database containing the data sources currently used for inland navigation studies, and the model inputs and outputs, and a graphical user interface (GUI) to facilitate data analysis, model runs, and display and interpretation of results. The entire NaSS is intended to reside within the overall Navigation Economics Technologies (NETS) suite of models and data.

Most of the design document is devoted to a detailed explication of the System Network Model. The Investment Optimization Model and the envisioned interaction between the two models are also discussed, but in less detail. The principal conclusion is that development of proof of concept models should proceed, as a means of identifying and resolving the most important outstanding model design questions. Also proposed is parallel research into topics such as tow configuration and dispatching procedures, generation of empty barge and light boat movements and the related concept of conservation of equipment, and shipper response to system component failures. These ancillary research projects are not described in detail, as it is expected that specific research questions will emerge as part of the model development process.

Section 3
Summary Review Statement on Validity and Quality of Findings

Reviewer 1

In general, the intent of the proposed effort is commendable. Certainly existing Corps of Engineers inland navigation planning models can and should be improved. Further, it is especially important that a standard be established in modeling the National Economic Development (NED) impacts of potential inland waterway transportation investments that recognizes the crucial role of empirical evidence regarding the willingness of water transportation consumers to pay for changes created in system operating characteristics when evaluating potential investments. Consequently, it is not only important to understand the changes in system operating characteristics associated with potential investments, which existing planning models do relatively reasonably well, but it is even more important to model how these changes in operating characteristics affect shippers' transportation choices and economic welfare, which existing planning models don't do nearly well enough.

As a matter of practice, any objective assessment of the willingness of consumers to pay for water transportation investments must include an understanding of the full range of choices available to potential water transportation consumers which include: using alternative transportation modes; shipping to or from alternative destinations; and altering the quantities shipped on the waterway in response to changed operating conditions. Of course, the alternatives available to individual shippers vary depending upon the geographic location of the shipper, the commodities being shipped, the location of alternative markets and the availability and characteristics of alternative modes of transportation. This makes it essential that all models developed for use in inland navigation planning be consistent with a spatial equilibrium analytical framework that explicitly recognizes the geographic separation of production and consumption markets and the full range of alternatives available to shippers.

Given this fact, the NaSS suite of models has some promise in that it attempts to improve the modeling of the physical operation of the waterway system and also attempts to capture the fact that potential water shippers respond to changes in water transportation operating conditions. This is an important step forward. That being said, there are several critical, but hopefully constructive, observations that need to be made concerning the design document. These general comments follow:

- Despite its title the "Navigation System Simulation (NaSS) Design Document" is not yet a complete design document in the sense that it can actually be employed to build a suite of models. The document fairly characterizes itself [Section 5, page 69] as; "a rough sketch of the proposed models." Most detailed discussions of model concepts and design issues in the document conclude with statements to the effect that further study and development is required. I concur with those observations. This is especially true for the narratives of how shippers' responses to varied operating conditions will be incorporated into the model suite.

- The document contains numerous typographical, grammatical, and syntax errors which make the document difficult to review. The document could and should be improved with a thorough proof-reading. Further, the document seems inconsistent at times with its stated assumption of an intended audience with previous experience modeling inland waterway system and lock operations. Some of the discussions are clearly intended for only those readers with extensive experience in waterway modeling as presumed by the document, while other discussions (such as those presented in Sections 3.7 and 3.8) are devoted to the most elementary descriptions of the operations of inland navigation locks that should already be well known to experienced waterway modelers. With model transparency in mind I would suggest that the document be recast and not assume that the reader possesses a detailed knowledge of the operation of a waterway system.

- The flow and organization of the document could be improved by supplying a fundamental motivation for the new models' development. Explain why it is advantageous to develop a new discrete-event simulation to "improve navigation economic analysis techniques" [Section1, page 1] as opposed to other types of deterministic or simulation models. Describe the improved capabilities that this type of model will possess and what questions it can answer that cannot be satisfactorily addressed with existing models. For example, while there are analytical techniques available to estimate the impacts of implementing a queue dispatch discipline at a single lock given certain well behaved operational and traffic arrival characteristics, only with a network simulation can the system impacts of individual and jointly implemented queuing disciplines be identified. This is particularly true in systems with non-stationary and inter-dependant arrival processes. Also, the impact of a finite set of available floating equipment at any point in time (tows and barges) on the potential levels of realized congestion in the waterway system is an area which is best analyzed using a system simulation.

- Although the proposed NaSS suite of models is labeled "ambitious", the document does not provide time or cost estimates for development of this model suite. At a minimum, some effort should be made to provide estimates of the resources and time required to complete the tasks identified in Section 2.8 "Recommended Next Steps".

- Most of the document discusses techniques and issues familiar to those who have worked on or developed inland navigation economic or operational models. There are, however, a couple of new ideas that are intriguing. The probabilistic based Wilson and Train (2004) shipper choice model described in the design document would seem to dovetail nicely into a simulation framework allowing for the simulation model to stochastically generate a set of potential waterway movements based upon the operating state of the system. As the document points out, integrating the Wilson and Train (2004) choice model needs further refinement, but this work represents a significant improvement over present Corps methods for generating system movements (i.e. generating a fixed shipment list). The other new intriguing concept is including an Investment Optimization Model that employs a genetic type algorithm (GA) for "near optimization" of waterway investments. While, I believe that this is theoretically feasible, it may be more computationally difficult than the PDT team realizes given the proposed breadth of the Network System Model. See Fu, Glover and April (2005) for a recent discussion of the techniques available for and likely computational problems associated with optimizing in a simulation environment. In any event, since the GA is not integral to the waterway simulation itself, I would suggest that development of the GA be postponed at least until the computational requirements for the Navigation System Model itself are more fully understood.

- There is another strong reason for postponing the development of the Optimization Model. The document states that "Analysis of congestion and other issues on the waterway *given* the knowledge of traffic is then the domain of the tier 3 microscopic models" [Section 2.6, page 10], but then later states "The System Network Model is not a spatial equilibrium model. Rather, the proposed usage is interactive with the regional routing models, which are spatial equilibrium models that incorporate shipper response to congestion" [Section 2.6, page 11]. Since waterway traffic demand levels are determined in response to congestion levels in the regional routing Tier 2 model, it seems a more natural place to me to have the Investment Optimization Model interact with the regional routing Tier 2 model. This reassignment of the Investment Optimization Model will prevent a possible non-convergent loop of: fixing a traffic level in the Tier 2 model; simulating that traffic level in the Tier 3 model; optimizing investments for that traffic level in the Tier 3 model; then re-determining a new traffic level in the Tier 2 model because of the newly estimated congestion associated with the traffic level in the Tier 3 model; then re-simulating traffic in the Tier 3 model; then re-optimizing in the Tier 3 model; then re-determining traffic in the Tier 2 model; etc…

- Model verification and validation are critical in the development of a credible simulation model. Unfortunately, there is no set of specific tests that can easily be applied to determine the "correctness" of any simulation model much less a simulation model with an iterative association with a GA based Investment Optimization Model. Therefore, the design document should discuss how the validity of the simulation model will be established as it is developed in the so called "spiral" process. What explicit metrics will be used to validate and verify the model? Sargent (2005) presents a good summary of verification and validation and some techniques available to establish the credibility of a simulation model.

- The System Simulation Model and the Investment Optimization Model will be used to identify a set of near optimal investments at the lock and system level. The document should describe exactly what variables will be used in the optimization and even more importantly exactly what function will be optimized. If a form of a shipper response function is included in the Tier 3 simulation model as currently envisioned by the PDT and if the optimization is designed to identify the National Economic Development (NED) effects of alternative investments, then the Investment Optimization model must receive NED benefit and cost estimates associated with the various alternatives. The estimates of NED benefits depend on the willingness of system users to pay for water transportation. The willingness to pay for transportation depends on the alternatives available to individual shippers which depend on variables not directly available to the proposed simulation model such as: alternative destinations; alternative mode transportation costs; alternative mode transportation times; alternative mode transportation reliability; and other important individual shipper characteristics. How will NED benefits and costs be estimated and measured in the simulation model and passed to the optimization model? Or more broadly, how will all three Tiers of NETS models be integrated?

- The envisioned Navigation System Model will require more input data and analysis than is identified in the design document. For example, since the simulation model will simulate future system performance over the life-cycle of possible investments, data and probability distributions will need to be forecast for very long (over 50 years) periods of time that are significantly longer than the period of recorded observations used to generate existing probability distributions. How are these forecasts of future probability distributions accomplished? This can be problematic when modeling rare events such as lock component failures or periods of unsatisfactory lock performance when there is little or no historic record. Further, where do the data and probability distributions regarding detailed tow operations at locations away from the observable locks such as re-fleeting and port dwell times come from? This data is certainly not available in or derivable from LPMS, OMNI or WCSC databases.

- The performance aspects of the non-lock components of the navigation system are barely described at all in the design document, yet much of the performance characteristics and reliability of the operation of the waterway system are the result of phenomena that occur at locations remote from system locks. For example, ice, fog, night, day, hurricanes, floods, labor strikes, terrorism, and many other exogenous variables not directly connected with lock performance can directly affect the use of the system by tows. In fact most of the time-weighted operational activities of inland waterway vessels occur at locations away from the system locks. A detailed discussion of the performance characteristics of non-lock system components and their role in the simulation model would provide a useful context for the reader to judge the potential of the simulation model to accurately capture the reliability of system operations.

Reviewer 2

I strongly embrace the concept of NaSS as a suite of models, not a single simulation model. Data driven by consistently defined, extracted and/or derived inputs strengthen all models and the ability to draw outputs from each other. I interpret that the "System Network Model" (SNM) and its component models become the foundation of NaSS. The "Investment Optimization Model" (IOM) using Genetic Algorithms, as described in this document, is too sketchy for detailed comments. However, gleaning from several presentations and this write-up, I perceive it to be in the very, very early proof of concept stage as applied to transportation investment decision-making. I would suggest the parallel pursuit of alternative optimization models which have a higher probability of fielding by 2008.

Expectations for NaSS are that this program will actually be solving many of the intractable problems worked on by modelers and by the inland waterway economics community for the past 35+ years. This work is to be completed within two years. **Redacted eight lines due to personal or sensitive nature of content.**

To accomplish the art of the possible in the two year time frame I suggest the following:

- The NETS team must take on another intense review of the proposed work for SNM, using a decision matrix approach, and evaluate the level of importance of improving an existing product, developing a new model or program, verification of actual practices, data quality and completeness work etc., and weigh these against resources available. The outcome will be where to place today's priorities. The lists of actions at each level in the spiral stage of development will need time frames and some probabilities of success attached. On page 17 in the paper it is said that models are "…pitched at the maximum level of detail…within the network model". It will be these assumptions which must be carefully weighed before work at specific levels in the spiral is undertaken.

- Prepare, as simply as possible, what will, with a high level of certainty, and what may be (lesser level of certainty) completed, with limitations spelled out, in the time frame remaining. **Redacted six lines due to personal or sensitive nature of content.**

A life cycle for a model is never clear, however what is clear is the fact that after the NETS program is complete that there must be a program in place to correct, enhance and modify the modules, that is to continue their evolution. This means funding. What plans are in place for the 2008 budget process to include funding, not for primary research, but maintenance of the suite of models and other economic technologies?

Terminology coming from the past 30+ years means something different for one model, for one data base, for one lock, and for one district versus another. In the document it became clear that terms that HQ, NDC, then OMBIL and its initial IDEF models tried to resolve include such terms as basin, waterway, river, port, and dock; the lockage processing terminology; vessel definitions; commodity descriptions (LPMS nests within the WCSC structure); and others. These command a significant level of effort to insure uniformity across the uses. There are often owners of terms and it is their definitions that should be used. It is understood in the modeling world that a term may represent something that is an abstract of the real world, therefore a new term, or one adopted from earlier modeling, such as "port equivalent (PE)" may be warranted.

The choice of the term "microscopic" (pg 11) relating to the SNM creates another expectation of replicating the real world in the entire SNM. It needs to be made clear that no modeling of transportation and forecasts can ever, ever fall into this category. I strongly suggest in your rationalizing of each module and its parts that no reference is made to microscopic. Tier 3 (Figure 4) abstractly represents what I believe the paper calls microscopic, and it is clearly communicating that a greater level of detail than in Macro and Meso-Economic Modeling will be involved, that is all. The aim of maximizing microscopic detail feeds, once again, expectations. The paper's description of modeling components, such as gates and filing systems may be useful, particularly for decisions on rehabbing a lock, but if it can imply, and I believe it does, that that will be the level of detail in the entire SNM, it is creating expectations which will not, nor should not, be fulfilled. The suggestion that the model uses "linear spatial representations" is another microscopic proposal. Based on 15 years of work on this, it too is an unrealistic data pursuit for the entire system. **Redacted seven lines due to personal or sensitive nature of content.**

Reviewer 3

In general, the design document is well organized and well constructed, and the concepts presented are valid. The idea of using genetic algorithms (GA) to search large solution spaces, coupled with a simulation model to evaluate individual solutions, has been used successfully in other design domains with considerable success. Perhaps one or two references from that body of literature would be helpful. The detailed description of the proposed System Network Model will be helpful for the next stage of model development. The description of the Investment Optimization Model is not at the same level of detail, and leans too heavily on supposed reader familiarity with the SIMOPT model, but is useful nonetheless. The description of how the NaSS relates to the NETS global forecasting and regional routing models is good. Finally, the early text promises a discussion of agent-based modeling of shipper response to lock outages, but this topic does not appear in Section 3.

One generic comment is that the entire architecture of the NaSS, and nearly all of the details of the System Network Model, are very similar to ORNIM. It would be worthwhile to acknowledge more emphatically this heritage, especially since ORNIM itself was founded on years of experience with predecessor models, and then point out the differences or advances proposed for NaSS. Specific comments on the design document follow.

Section 4
Individual Comments and Issues for Resolution

Reviewer 1

1. Section 2.2, Paragraph 3. "It is anticipated that the primary programming language will be C++ and C# and the database will be Microsoft Access." I would suggest that this decision be reconsidered. There are many good, commercial software products designed specifically to perform discrete event simulation with animation. These products have the potential to significantly reduce model development time and costs and foster transparency. This would be especially beneficial because, as the document points out, there are many areas where prototype development is needed. Finally, if desired, C++/C# could be used to produce the final "production" model, after the spirals of development are complete. In this case the models produced in the proprietary software could also serve as important benchmarks for quality control purposes.

2. Section 4.4.7, Paragraph 1. Stochastic simulation models typically require a large number of runs to generate enough output for valid statistical analysis. The number of runs necessary is usually determined through experimentation with the model itself. It is the case, however, that if low-probability rare events are modeled, many runs are required to generate valid output because of the rareness of events. Because lock failures (or component failures) are, for any given lock or lock component, rare events many model runs will be necessary to produce valid results. Some effort should be dedicated to estimating the number of runs, along with the resources required for a single run for a typical application.

3. Section 3.7. The document indicates that separate probability distributions will be provided to simulate the lockage time for each component of the lockage process (i.e. approach, entry, chambering, and exit). I suggest it would be more computationally efficient to build probability distributions for the entire lockage time (based on the lockage type and entry type). This would mean only one lookup per lockage as opposed to multiple lookups. For many runs of a multi-lock system this could prove to be a significant savings.

4. Section 3.2, Paragraph 8. "No trip is ever prevented from moving by virtue of lack of equipment in the reservoir…" This is a mistake. One of the benefits of a simulation model is that it can account for the fact that there is only a finite set of equipment available. Further, since the output is based on multiple model runs, there is a logical inconsistency to combining runs that have simulated different equipment levels. An approach worth considering is to make model runs with some defined infrastructure and defined set of floating equipment. Further runs could then be made changing the infrastructure and/or the set of floating equipment. In this way the production possibilities could be mapped which could then feed the spatial equilibrium model.

5. Section 3.5. The approach of including all anticipated investments in the original model design has a severe downside namely that only those solutions which are anticipated can be evaluated. The better approach, at least initially, is to focus on the existing and without-project future

conditions for initial model runs. The results from these analyses will suggest a range of possible improvements for evaluation.

6. Section 3.12.1.2. "- clearly, an older gate that has undergone more operating cycles should be more susceptible to failure than a newer gate with the same number of cycles." The stated concept may be incorrect. Corps studies have suggested that age and cycles are only weak predictors at best of lock component failures. Further, it is often the case that newer components (especially at those at brand new facilities) are more likely to fail than older components.

Reviewer 1, References

Michael C. Fu, Glover, Fred W and April, Jay 2005. *Simulation Optimization: A review, New Developments, and Applications.* Proceedings of the 2005 Winter Simulation Conference, M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, eds., Piscataway, New Jersey: IEEE.

Robert G. Sargent 2005. *Verification and Validation of Simulation Models*. In Proceedings of the 2005 Winter Simulation Conference, M. E. Kuhl, N. M. Steiger, F. B. Armstrong, and J. A. Joines, eds., Piscataway, New Jersey: IEEE.

Wesley Wilson and Train, Kenneth 2004. *Modeling Preferences for Upper Mississippi Grain Movements: The Mid-American Grain Study*. The Institute for Water Resources, U.S. Army Corps of Engineers, November 2004.

Reviewer 2

1. Section 2, Page 5, Paragraph 1; Page 7, Paragraph 1, Bullet 1 & Paragraph 2, Bullet 1. These offer examples of several uses of the term "commodity demand" or "demand" when the text implies only "volume". Given historic negative criticism of the use of the term "demand", I recommend taking great care when using that term throughout this document.

2. Section 2, Page 5, Table 1. Auxiliary tool development should tap into WCSC (Waterborne Commerce Statistics Center) support as well as from the Lock Performance Monitoring System (LPMS) management team. Pre- and post-processed data should also be reviewed by knowledgeable operations personnel and by those who understand the functioning of the greater inland waterway system.

3. Section 2, Page 5, Paragraph 2. Bullet 1 - What is "agent-based" modeling in reference to shipper responses? Bullet 2 - Regarding tow configuration dynamics during a trip, the designers need to know how configurations have been changing over time and what the drivers of these changes have been in order to predict the future's potential array of configurations.

4. Section 2, Page 6, Figure 1. LPMS and OMNI have now been unified into one data base/warehouse with all historic data from 2000 to current month's data. All extractions for these models should be taken from that source, not from data prepared for earlier NETS analysis. The differences in the two collection systems have been minimized in this warehouse. Also, for Corps users the OMBIL (Operations and Maintenance Information System) has on-line

access to selected data from the LPMS warehouse as well as from WCSC at the site, project, river, district, division and by now other geographic areas. All OMBIL data aggregates from the bottom up, from site to the nation, and displays information for both fiscal (FY) and calendar (CY) years. I do not recommend using year 2000 data from LPMS given the massive transition problems from the old LPMS collection system to the new in that year.

5. Section 2, Page 6 & 7. Shipper responses to unscheduled outages for the frequent (high probability low duration) and for the infrequent (very low probability and high duration) need more research. These events should be consolidated at a river as well as at the interdependent systems level. The unscheduled events and their probabilities should then be consolidated with the probabilities of scheduled events. Lock reliability will need several series of data to capture the combined probabilities: 1) Total number of outage events per quarter and annually; 2) Number of events associated with scheduled outages (must normalize across locks and districts); 3) Number of events associated with unscheduled outages and 4) For 1-3, durations of each outage must be associated with the events. What would be illuminating would be the number of stalls associated with the lockage. How have stoppages and stalls changed over time?

   Redacted fourteen lines due to personal or sensitive nature of content.

6. Section 2, Page 8, Last Paragraph. Is rehabilitation (it is currently in the CG [construction general] budget) going to be placed under O&M or project investments in the model's assumptions? Rehabilitation may extend the life of a component; therefore it seems to fit into your O&M investment category. It only changes reliability, not capacity.

7. Section 2, Page 10, Paragraph 1. "This dynamic interaction results in modal choices by shippers based (in part) on cost…". I would modify this to read "costs and reliability" rather than "costs and congestion" since "congestion" can be converted into "costs". For "costs" I would ideally include total transport costs to include items such as congestion-induced costs, lock processing costs, line haul and handling costs, as well as inventory costs.

8. Section 2, Page 12, Paragraph 2. "…forecast commodity demands (export and import) at ports along the waterway…" should not use the terms import and export, but should use the terms such as inbound, outbound and local by direction since this network is related to an inland network reach or specific waterway. For strictly port generated movements the terms "shipments" and "receipts" may be the appropriate to substitute for import and export.

   Supplemental recreational information can be critical since its use peaks in the third FY quarter (season runs from Memorial Day through Labor Day) mostly on Saturday and Sunday, some on Friday, and principally during daylight hours.

   It is good that traffic is developed from a set of trips based on O-D-C and the availability of equipment; however this should also become a factor in the Regional Routing Model reflecting availability, time and costs of equipment from all alternative and connecting modes (Figure 5).

9. **Redacted thirteen lines due to personal or sensitive nature of content.**

10. Section 2, Page 13, Bullets 2/1. Expand the single lock prototype to "lock site with one and two chambers".

11. Section 2, Page 13, Bullets 2/2. System network model prototype. It says add shipper response to outages at a later time. Does later mean after this initial concept is prototyped? This item becomes critical and should be scheduled early in the process. Isn't "willingness to wait" modeled differently than "uncertainty" in the shipper decision model? Also, in the short-run the "carrier" decisions regarding outages also play a role in decision making.

    Shouldn't the model incorporate the probability of outage events and their durations and distributions in the supply side as input to lock supply (availability)?

12. Section 2, Page 13, Bullets 2/3. "…shipper response to scheduled/unscheduled outages and long term congestion…" could well be mixing the shipper response to short and long run lock outages and increasing stalls. These can be, I would hypothesize, quite different actions. Just as I postulate that in the short run the carrier is also a participant in selecting a response to an unscheduled outage. Regarding responses to congestion, long term response information is essential, but how will this be collected and verified? Also, how are the shipper decisions being made (or have been made) for the long run with the *intersect* of congestion (perhaps this has already peaked) and reliability (this may have grown to become the dominant determinant impacting selection of the waterway mode).

13. Section 2, Page 14, Paragraph 1, Bullet 8. Reliability by component (gate, filling system, etc.) suffers from lack of nationally collected and consistent data base on the age and date of rehab of components. Creating a benchmark for components for a few locks, let alone the entire system, requires a separate effort with an extensive field (operations) role in design and review.

14. Section 2, Page 14, Paragraph 1, Bullet 9 and Page 15, Paragraph 5. I have concern with shipper response in how stated and revealed preferences change over time in both short run, and most importantly, in the long run (15-25 years). The long term preferences and how they evolve is information that becomes an imperative for useful NETS modeling. Also, the latest Wilson-Train work was for a system with shippers moving 85% food and farm products. It will be important to test whether a significant sample can be selected, afforded and executed for the major non-farm/food shippers elsewhere in the inland system (try the Illinois Waterway for mixed [over half of movements are non-farm] and the GIWW for heavy petroleum and chemicals). In very short run scenarios it appears that the carriers make choices usually assumed for the shipper (choices in response to unscheduled outages for example).

15. Section 2, Page 14, Bullet 11. Modeling of each cut will necessitate evaluation of actual processes and results. Historic lock data can skew interpretation of line-haul flotilla size. For the pre- 2000 period, and probably some time after that, the LRD rule of no double cuts at 1200′ locks falsely implied that all tows were 15 barges or less. Has this been resolved? The post 1999 LPMS attempted to accommodate the LRD practice while capturing the data with naming assisting vessels in the Lockage Log and specifying "Entire" Flotilla Dimensions in the Vessel Log.

16. **Redacted ten lines due to personal or sensitive nature of content**

17. Section 2, Page 14, Bullet 14. The development of generic cost curves is important. It is essential to also develop a range of commodity values for use in developing inventory costs.

18. Section 3, Page 18 Table 2. Modify to read "*Commercial* Fishing Vessel" and "*Commercial* Non-Cargo" to align with LPMS.

19. Section 3, Page 18, Paragraph 1.a.i.1&2. Besides LPMS definitions which are often abbreviated, refer to definitions in Waterborne Transportation Lines of the United States (WTLUS). Recommend substituting WTLUS definition for towboat and tugboat: "Towboat/Pushboat: Self-propelled vessel designed to tow/push barges and pontoons (skip sentence). A pair of knees of ample strength and height engages barges of various depths to maneuver the tow."

    "Tugboat: Self-propelled vessel with a V-shaped bow designed for the towing and pushing) of ships or other floating structures such as barges (delete 'in ports and harbors')". NOTE: I would not include "in ports and harbors" in your definition since that would exclude ocean towing, their definition was oriented only to inland tugboats.

20. Section 3, Page 18, Paragraph 1. a.i.4. The Ship/Self-propelled Commodity Carrier is a newly coined term. Do you intend to capture all self-propelled vessels under this grouping? If so, the vessel costs will be all over the map, as will their dimensions and uses. At certain locks and along certain waterways the crew boat and the fishing vessel are very significant.

21. Section 3, Page 19, Paragraph 1.a.ii.2. For simulation you will not need to break out the integrated barge since they are so few in number, and operate primarily on the Great Lakes and Ocean. Distribution of barges by type, age and year constructed are readily available from WTLUS, Vol.1.

22. Section 3, Page19, Paragraph 1.b. Tow and Flotilla terms are used interchangeably. The term flotilla is sufficient since it includes "tow". The phrase "or for reporting purposes…" is confusing and inaccurate, even through it may have been extracted from some official source. The phrase is not on the LPMS forms or in its glossary of terms.

23. Section 3, Page 19, Paragraph 2. Definition of the waterway: b. Node, since this term incorporates subsequent port (c) and re-fleeting point (d) I would array these as "i" and "ii" under paragraph (b) and delete c & d. In (b) the term "system" is introduced. It should have a separate definition as should the terms basin, region and waterway. You may want to discuss the various nesting geographical areas that the OMBIL data system uses. More about the use of the term "port"; in past models, statistical reporting, and surveys the Corps, Federal Government, and the world community have muddled-up the term so a user or reader needs a dictionary to decipher each use of the term. It may be difficult to change terms because of its "common" use in your past models, but I strongly suggest another term other that the singular term "port". In the INSA program they had WCSC create "port equivalent" or "PE" which is more representative of your definition than any of the existing "port" definitions. The PE may be the appropriate reporting term. You would have a Louisville PE, for example.

24. Section 3, Page 20, Paragraph 3. Is the term "port" used here the same as in paragraph 2, or does this represent a true O&D with mile points and latitudes and longitudes attached.

25. Section 3, Page 21, Paragraph 4. Lockage description entry and exit types are noted, but what about the 11 "lockage types" used in LPMS (e.g. Setover)?

26. Section 3, Page 21, Paragraph 5. Under Lockage Policies, verification of lockage policies applied on the various waterways, districts and locks is necessary in order to accurately benchmark a model's output against existing policies. Not only what policies are current, but when were they implemented, and what were the practices before and for what duration. The compilation of existing rules as noted, plus those which impact passenger and government vessel priority rules should be obtained.

27. Section 3, Page 21, Paragraph 6.1. The model should consider all 13 LPMS vessel types and where appropriate, aggregate them. There may well be different aggregation options for different locks and waterways.

    The phrase "…temporarily reconfigured to enter a lock" recalls the LRD policy of only allowing a single cut through the 1200′ locks and the unfortunate interpretation for past models that the line-haul flotilla size equaled that reported at the lock. See my comment on Page 14 bullet 11.

28. Section 3, Page 21, Paragraph 7. The term "basin" has now been introduced; see my comments on Page 19 Paragraph 2 regarding definitions of geographical terms.

29. Section 3, Page 21-22, Paragraph 8. "Pool" is known but needs a definition as it relates to your "port". The proof-of-concept proposed should probably incorporate a review of inter-tow and inter-line operating practices and the economic drivers behind these, and assess how these practices have been evolving over time.

30. Section 3, Page 22, Paragraph 9. Reliability. The unscheduled outages for major and minor maintenance and unscheduled minor events rightfully should be internalized. In order to calibrate any lock model, "reliable" district records should be used. Part of assessing data is verification of rules of data capture used at lock chambers which will then be used for calibration. Both lock managers and lock personnel must cross verify rules actually applied. The previous NETS study, as reported by study manager, seemed to check OMNI versus log's outages, which did not uncover the root "rules" of stalls and stoppages (only suggested that the locks used the same rule for OMNI as for their logs). Any interviewer must know lock operations, the data collection system and its official rules and have a rapport with lock and operations personnel.

31. Section 3, Page 22, Paragraph 10. Shipper Response: The statement that shippers are assumed to have advance knowledge of scheduled outages raises the consistency issue again—at locks, districts and divisions. Conversations with lock personnel over time found a wide variance in interpreting the term "scheduled". This is very important. A day, week, month, quarter, or year advanced notice will produce differing capabilities in responding. Verification with lock personnel and district lock operation's managers is needed to understand the data pertaining to the term "scheduled' actually captured in OMNI/LPMS.

32. Section 3, Page 22, Paragraph 9/10. The use of the Train-Wilson probabilistic approach to shipper response begs for testing with a broader number of shippers beyond those shipping primarily food and farm products. Determining a means to assess how preferences of shippers have changed over time, and why, deserves not only a water-focused assessment, but one

involving all relevant modes. Again we are trying to differentiate between short and long run. Long run is where we need to end up in this modeling.

(Also, see comment made for Page 14, Paragraph 1 and Page 15, Paragraph 5.)

The metric that defines reliability and the shipper's response to that should be assessed from a regional perspective across all modes. It is wiser to step away from "water only" in analyzing shipper LONG term responses to reliability, as well as defining reliability across commodity classes. Look at the significant shift from west coast ports to the east coast after the west coast lock-out.

The willingness to divert concept must be for a system and corridor (needs a definition). One issue not yet raised is the impact on shippers and carriers of the probability of multiple events (scheduled + unscheduled + stalls) on closely interconnected systems (e.g. Upper Miss, Up Miss + Ill., and Up Miss + Ill.+Ohio).

33. Section 3, Page 22-23, Paragraph 11. Cost Benefit Considerations: Need to continue to improve knowledge base of the probability of stoppages per site, per waterway and per interconnected system(s). **Redacted two lines due to personal or sensitive nature of subject.** Data and information capture of the quarterly variances of the outages is important. Assessment of the historic carrier's response to downtime should consider: 1.Increase dwell at docks; 2 Increase reach time and/or 3. Increase queues and delay time at locks. Decisions on where time is spent impacts fuel consumption rates and costs of operations.

    Great care must be taken to differentiate between short run and long run shipper responses. Most industry response research has focused on the short run. Looking at the Up Miss/Ill Waterway over the last 5 decades can be useful in as much as no capacity expansion has taken place above St. Louis, the back log maintenance has continued to grow, and reliability, as captured in outages and stall events, and total duration of cumulative events within the waterways has grown.

34. Section 3, Page 23-24, Paragraph 3.3 Bullet 6, Locks. Locks as a "reach" makes sense in as much as fleeting, port loading and unloading may take place within a lock's reach. Also, consideration of locks in close proximity to each other such as Brandon Road and Lockport on the Illinois, may suggest their treatment in a model as a joint reach. The area above Brandon Road had served as the fleeting area to downsize flotillas to Chicago Sanitary and Ship Canal and Little Calumet River dimension towboats and tows, and conversely, to make up down bound river tows. Some approaches, such as down river of Brandon Road, and upriver channel at Marseilles Lock involve lengthy "no passing" approaches of about a mile each.

35. Section 3, Page 24, Paragraph 1. Alternate routes are captured in WCSC detailed statistics and can be used to design and test the trip generator. The towing equipment and tow size configuration in place may well preclude short term congestion-dictated route choices. This "locked-in" route situation will need to be assessed (e.g. an alternate choice of the Cumberland River may be immediately precluded by the Tennessee River tow size).

Another research issue is "what have been the historic alternate route growth rates over time for all commodities, for specific ones including haz-mat and for O-D pairings? Any statistically significant drivers to help with future routing should be evaluated?

Before accepting historic WCSC and LPMS data inquire of the NDC data specialists about their knowledge of data quality in capturing alternate routes. Some years may not be as complete as others. This has also been true in the past at Barkley and Kentucky locks. The problem is only important when an investment decision is being studied for these impacted locks—but the model should have the design capability to handle alternates.

Remember at locks, the approach time, which is neither queue nor chambering, but is truly an approach, may contribute as much time or more than chambering itself. The old Bonneville Lock had a very long approach, just as does Marseilles.

36. Section 3, Page. 24, Paragraph 3. Reach rules for transits will need to take congestion responses into account as well as events at locks which cause vessels to slow or tie-off well beyond the normal lock approach.

37. Section 3, Page. 25, Paragraph 3.4. "Region" as a term is yet undefined.

38. Section 3, Page 25, Figure 6. Figure 6 has two titles "System Representation" and "Basin Network Representation". I believe "system" is the one you want, however, on page 20 you incorporate the term "basin" into your description. Does a system have to be a river basin? Figure 6 incorporates what appear to be two connecting river basins.

39. Section 3, Page 26, Paragraph 1. It is my understanding that each river mile with latitude and longitude and river bank for most all inland, intracoastal and coastal waterways are included in NDC's 2005 National Waterway Network. NDC also has, for most docks and locks, the lat/long/river bank as well as county and state. NETS should use the 2005/6 versions of the NDC geocoded files. The national waterway network will be of immeasurable help in providing reach lengths. P1. The statement "A lock separates two pools, so it is not really "in" one pool or the other." seems to be an unnecessary sentence at this point.

40. Section 3, Page 26, Paragraph 1. It has taken a decade to establish the U.S. National Waterway Network with consistent miles, lat/long/river bank etc. and still no attempt has been made, due to complexity and costs, to use anything beyond linear. "It is proposed that, at least initially, separate polyline representation of a reach be storable…" may be desirable for project level analysis, however to consider data acquisition beyond a test, and possibly a prototype would be prohibitively expensive. Careful not to give out too many expectations when one knows that data is a killer, such as in this case.

41. Section 3, Page 27, Paragraph 3.5. Programming the "possible" may be quite a guessing game, however, programming for the known such as Olmsted and the decommissioning of locks 52 and 53 on the Ohio is good planning. I suggest programming for what is on the books, that is, in the construction pipeline.

42. Section 3, Page 27, Paragraph 3.6/1. Question, when should a lock domain instead become part of a lock reach with docks and fleeting and rules? Keep in mind that there are times that factors external to the lock or waterway, such as bridge openings, above or below a lock, need to be incorporated into the operating rules.

    It will be prudent to support a review with lock managers and operators on the approach points and to cross check these with both districts and NDC's LPMS records. Before assuming, for consistency, checking on the reality may we most worthwhile to avoid future claims of not accurately representing lock characteristics. Again, an overly lengthy approach may simply be a geographic necessity.

43. Section 3, Page 31, Paragraph 3.7/1--Lockage Processing.

    Lockage processing you say is from the perspective of a vessel. How, then, are locking operations to clear ice, debris, or animals handled since these are operations which are recorded in LPMS and they do consume available chambering time, but not necessarily all of the other times associated with a vessel lockage? Are these treated as reductions in the available chambering time and given distributions by season? They can however, leave a chamber open for some entrance types.

    Turnback entry: add one phrase for clarification to your definition "…chamber must be turned back [add] *'with no vessels in the chamber'* before the gates can open." Also, according to LPMS Glossary, I would add "*The arrival time of the entering vessel may be before the exiting vessel's end-of-lockage [EOL].*"

    Entry bullet. LPMS uses "...and the gates are clear" rather than your words "begin to close" Your definition overlaps with your chambering definition. I recommend the LPMS wordage.

    Chambering bullet. This is defined by LPMS as "Calculated time from end of entry [EOE] to start of exit [SOE]". This uses entry and exit definitions and avoids embedding those definitions into "chambering time" definition. For the model one can spell out all definitions. This would read: "'Time from when the vessel is clear of the gates and is secured' until 'permission is granted to begin to exit.'" Given the model's operation you may want to add after exit "and when the gates begin to open".

    Exit bullet. Defined by LPMS as "Time from start of exit [SOE] to end of lockage [EOL]". To embed SOE and EOL into the definition you end up with this definition: "From time permitted by lock operator to proceed from chamber and gates are open until such time as another vessel can be served by the lock or when the stern of the vessel is abreast of the Approach Point [AP]". The definition you propose misses the SOE and doesn't link to the other vessel's position.

44. Section 3, Page 32, Table 3. Approach and Entry definitions are generally clearer here than those on page 31.

    Chambering: I would modify all three, the fly, exchange and turnback to read "Begin closure of gates" to "permission granted to exit and gates begin to open".

Exit: I would modify fly and exchange to read "From time permitted to proceed and gates are open to point where stern passes the approach point." Under Turnback#1 I would insert "stern" before "clearing" and in #2 insert "stern clearing" before approach point and delete the words "opposite direction". NOTE: I do not see the "opposite direction" terminology necessary in any of the definitions.

45. Section 3, Page 33, Paragraph 2. What plans exist for capturing the reach, load and unload, re-fleeting and of most concern, the intentional slowdowns or stoppages in a reach due to lock unavailability, scheduled or unscheduled, or even stalls. Also, working with industry, how have practices changed over the decades?

46. Section 3, Page 33, Figure 12. You may want to insert "approach" in space between "Gate Wait Point" and "Gate Point" for the turnback.

47. Section 3, Page 33, Paragraph 1. It is an imperative that existing lockage policy be verified, not only at a district level, but at the lock level to insure effective calibration of a model with actual practice.

48. Section 3, Page 34, Paragraph 4. "…and permanently reconfigure at a re-fleeting point…" is of concern since most reconfigurations before and after locking (except where forbidden by district or lock rules) occur in the entrance/exit area. (See your P, Vessel at Arrival Point, it seems to acknowledge this). The practices and rules need to be examined.

49. Section 3, Page 36, Paragraph 2. I believe the "Vessel Lockage Types" should be added to your list of 7.

50. Section 3, Page 37, Paragraph 3. Your NOTE: You mentioned tow haulage units are used on the Up Miss. You will want to insure your inventory of tow haulage units and their functionality is current, not all chambers have these. Also, check data "Mechanical Assistance-J" in LPMS to assess frequency and condition of use. Also, need to evaluate whether field is filled in.

51. Section 3, Page 37, Paragraph 7 Start Chambering. Historically, certain locks, due to turbulence during the filling and emptying processes, or due to clogged screens, have had to slow down for all chambering and sometimes only for the small craft lockages.

52. Section 3, Page 38, Paragraph 2. Agree that "head differential" as a continuous variable is too complex to include.

53. Section 3, Page 38, Paragraph 4. The statement "If gates don't work, the chamber is shut down" isn't universally true, but most often that is true. The Chicago Lock operated with one gate off for a while and for the John Day Lock I believe they used stop logs when the gate was off. Your statement that at times gates must be opened and closed more slowly is appropriate but it is not easy to verify this in the data sets. Data does not support breaking out gate from total chambering and this should not be done in the model either.

54. Section 3, Page 38, Paragraph 6 Cut Exit. Assess the latest full year, 2005, lock by lock in the LPMS data on code "K" Interference by other vessels" to assess relevance of interferences at each multiple lock situation. This "K" isn't necessarily caused by multiple chamber interference and

should be spot-checked with lock operators. Also, checking on completeness of use of this code by districts and locks is another QC issue.

55. Section 3, Page 39, Paragraph 1. Again, the "vessel lockage type" such as setover, knockout, etc. would yield different durations and should be included.

56. Section 3, Page 39, Paragraph 2. The direction of travel and current flow impacts on the time estimation can be extracted from LPMS. The variance of current impacts over time would be worth assessing and also, should be studied for seasonal differences.

57. Section 3, Page 40, Table 4 and Page 42, Table 7. Replace "Tug" with "Towboat"

58. Section 3, Page 40, Paragraph 6. The sentence "It may be desirable to be able to reference the value of commodity…" probably should show up in the later commodity discussion rather than in this vessel section.

59. Section 3, Page 40 Last Paragraph and Paragraph 41. Refer to WTLUS for abbreviated descriptions of all U.S. commercial vessels. Ingram's association of tonnage and draft by vessel is valuable when it comes to the channel depth issue and the cost of light-loading. Some of the tons per barge recorded by vessel operating companies to WCSC had been averages rather than actuals in the past (and I suspect now as well). Education has encouraged accurate reporting, but be cautious of historic tons per barge if you are doing a time series.

60. Section 3, Page 41, Paragraph 1. You need to test the hypothesis that each barge is completely full (that is filled to capacity) or empty. Data show that most new barges are being built to a 12′ draft, however, when operating on 9′ channels the carriers will load them more heavily when water depth conditions allow. Flood, ice, drought and O-D all impact the load level of a vessel.

61. Section 3, Page 41, Table 6. In the deep draft world, both WCSC and EIA use crude oil densities depending on the source of the oil which impact the tonnage. Also, product densities vary considerably and this is reflected by WCSC in its tonnage conversions.

62. Section 3, Page 41, Paragraph 2. Drop the term "forecast" and substitute '"movements". Units of measure are tons for WBCUS, however the # of containers, loaded and full, is captured for domestic movements.

63. Section 3, Page 41, Paragraph 3. Add in "flotilla configurations" after "dimensions".

64. Section 3, Page 41, Paragraph 4. Vessel Movement Descriptions. It is important to allow a tow to contain barges with differing O-Ds (multiple legs).

65. Section 3, Page 42, Table 7. Replace the term "tug" with "towboat".

66. Section 3, Page 42, Paragraph 2 Re-fleeting. Substitute "loaded/unloaded" for "imported/exported", the latter implies foreign imports and exports.

67. Section 3, Page 42, Paragraph 3. A sample of industry vessels re-fleeting in re-fleeting areas such as the mouth of the Kanawha and the Brandon Road Pool should be undertaken. The decision

to "…have the model wait on equipment availability or not…" may be an important factor. If equipment supply gets short due to heavy use or because it is captive to lock, dam or channel conditions then these all could restrict the free flow of equipment. As outage events become more frequent and dredging less timely, one would think that reliability of timely equipment at re-fleeting areas would closely follow the waterway systems reliability. Cargill reported that after Green-Up closing and the Mc Alpine failure the market prices for barges surged on the national system.

68. Section 3, Page 43, Paragraph 1. Careful in trying to capture a single company's policy and possibly extrapolating to the industry, let alone the long term practice of that company. Company changes have been rapid with the merger of companies. A whole new set of operating policies went into effect after the Hollywood-Kirby merger a few years ago. Logical development of generic rules from actual practice is logical; therefore one has to capture these rules from the many operating companies in order to formulate general procedures.

69. Section 3, Page 43, Table 9. Change "tug" to "tow".

70. Section 3, Page 43, Paragraph 3, Sentence 2. "1 barges" is not necessary in sentence.

    I am sure the writer knows not to assume a large HP towboat stays with its barges after either dropping enough off where it could proceed up or down on a constricted waterway. Generally a small HP towboat will pick up the small tow.

71. Section 3, Page 43, General Vessel Movements. I understand time-of-day for start, however given the interruption factors in anyone barge O-D, does specific time itself fall out as unnecessary and could random starts from any one port be just as realistic.

72. Section 3, Page 44, Paragraph 1. The process of both pick-up and drop-off of barges at multiple "ports" is closer to reality, but how widespread is this? Do certain areas have a higher frequency of occurrence? Has this been changing over time? Once an industry survey review is carried out perhaps this practice may be isolated to specific reaches and waterways.

73. Section 3, Page 44, Paragraph 1. You are absolutely right about changes. Just observing the Illinois River over 20 years found no significant change in total tonnage, but some major changes in commodity specific quantities and O-Ds took place. For example, over 20 years the nearly 6 million tons of internal upbound coal has disappeared (Clear Air Act consequence) and over a million tons today moves upbound from outside the basin. Iron and Steel (I&S) in this same period nearly doubled, but shifted from 50/50 up and downbound to primarily inbound, again coming from outside the basin. Petroleum O-D was opposite the I&S and became 50/50 rather that predominately upbound. Food and Farm tied to land seemed to stay constant in volume and in proportion, about 45% of the whole, and in its outbound movement. Global developments along with Federal policies for steel, energy and the environment have been major drivers for changes in consumption, production, and sourcing.

74. Section 3, Page 47, Paragraph 3. Generic Movement Statistics. Seasonality of commodity flows is critical to the assessment of capacity, congestion and reliability impacts for peak periods. Non-water transportation studies judge capacity, congestion and reliability on peak period analysis,

so should water. Distributions within the period are, at times, crucial as well. Studies of recreational usage at locks from LPMS capture the Memorial-Labor Day, Friday-Sunday, daylight distributions.

75. Section 3, Page 47, Paragraph 4. Re-fleeting generation can be determined from historical patterns by commodity, and past rates of change of patterns over time can be assessed by commodity. The future range of patterns is extrapolated from past practices and trends.

76. Section 3, Page 50, Paragraph 3. "Recreational lockage schedules are defined and change seasonally…" Is this a statement about the model's vessel generation or offered as fact? If fact, policies by district by lock need to be verified.

77. Section 3, Page 52, Paragraph 2. The barges from a trip will become available only when all have been unloaded. Has such a convention in the real world been determined to be the predominate practice?

78. Section 3, Page 54, 3.12.1.2. State Transitions and Associated Events. I suggest adding a fourth bullet, surface conditions, after time, cycling, and lockage. Surface conditions such as ice and flood events directly impact the state of a component.

    For detailed rehabilitation studies the component's state transition probability curves are important and affordable to analyze. However, for a basin or larger system the analyst may want to treat component probabilities for multiple locks using aggregated surface conditions, tow related stoppages and stalls, and lock condition stoppages and stalls or/and the age factor.

    PUP curves for multiples can offer greater statistical confidence levels.

    It has not been noted in this section, but beyond the defined events plus surface conditions which can precipitate a component's state transition, is the level of intensity of usage and hardware cycles during peak periods.

79. Section 3, Page 56, 3.12.1.4 Scheduled Outage. It has been a challenge in LPMS to insure uniformity in defining and reporting scheduled and unscheduled outages. See my comment on Page 6/7. Actual practices coinciding with the LPMS period of data capture will need to be confirmed in order to use the statistics to design and calibrate the models.

80. Section 3, Page 57, Paragraph 2 Performance Penalties. "…performance degradation should…function of the combined state of the components…" This is true for not only a single chamber, but for double chambered lock sites as well as a waterway's total collection of locks and all their components. Weak links of one or more components in a system impacts the whole lock and the whole interconnected system.

81. Section 3, Page 57, 3.13.1 Potential Movement. How often on the major waterways are shippers even consulted, or even advised by vessel operating companies regarding unscheduled waterway outages? When unscheduled events occur and the tow is in transit, or possibly even in the loading or unloading process, I have observed that it is the carrier that chooses among options, not the shipper (the shipper may be informed, or offered a veto). For scheduled, and

significant unscheduled, shippers will probably be the ultimate decision makers. The distinction is important and should be further evaluated.

82. Section 3, Page 58, Paragraph 1. The assumption that "scheduled" outages are known at the beginning of each season may not be supported in practice (see 3.12.1.4 Page 56 comment).

83. Section 3, Page 58, Paragraph 4. Even though this is a quote you will want to insert definitions for WTW, WTS and WTD.

84. Section 3, Page 58, Paragraph 5/3 Divert. Shift in mode, shift in source and route (may or may not include water mode), and curtailment of any shipment from any source are distinctively different and should be treated as such. It is worth assigning probabilities to these. Obviously research is needed here.

85. Section 3, Page 59, Paragraph 1. How are the number of days determined?

86. Section 3, Page 60, Paragraph 3. "A method of continuously calculating system 'reliability' will need to be developed…" is so true. Once a basin or waterway seemed to be a large enough system for reliability calculations, but in the post 2000 period it seems that the interconnectivity of systems impacts vessel distributions and has become a significant factor in the decision process. To have open hoppers and towboats captive on the Ohio at the beginning of the peak Up Miss/Ill grain transport season has demonstrated today's complexity in determining nationwide waterway system's reliability.

87. Section 3, Page 61. NOTE: Using an alternate to avoid "a" delay may be one reason for use, but may not be compelling to a vessel operating company due to factors of reliability and total trip costs.

88. Section 4, Page 67, Last Bullet and 4.1.4. This capacity reduction should be expanded beyond construction period. The capacity reduction ratio can be very important in assessing impact of NOT carrying out maintenance, rehabilitation and timely construction. Could one do optimal withdrawal of service to prioritize maintenance and rehabilitation dollars?

89. Section 4, Page 67, 4.4.6. The issue is not just reduction during construction period, but the reality of not increasing practical service capacity due to constraints at up- and downstream bottlenecks, usually locks.

    Lock and Dam 26 capacity was expanded, however the traffic growth is still constrained by the declining capacity and reliability of the up-river locks.

90. Section 4, Page 68, 4.4.8. Agree that adjacent (and many that are not adjacent, but are interactively connected as part of a servicing system) locks and other channel projects should be considered jointly.

91. Section 5, Page 69. Because of the unique towboat distribution by season I suggest two test areas, the Ohio and the Illinois (latter because of Up Miss winter impacts and the broad mix of commodities moved).

Because of the role of carriers in short-run decisions pertaining to unscheduled outages, the shipper-only (Wilson-Train) approach is incomplete for the short run, and for the long run needs much more research, especially from the non-grain shippers that dominate the U.S. commodity movements.

Reviewer 3

1. Section 2.1, Page 3, Paragraph 1. Point out that there are many other previous models that have contributed to the general state of the art in navigation system modeling. A review of much of the work prior to WAM is provided by Bronzini (1976a). Also, the first bullet below this paragraph should include "given vessel fleet characteristics."

2. Section 2.2, Page 4, Paragraph 3. A stronger case needs to be made for the choice of software. There are several powerful simulation-oriented languages that might be used, and C++ is not known as a particularly simulation-friendly language.

3. Section 2.3, Page 5, Paragraph 3. The first bullet suggests exploration of "use of agent-based modeling techniques to examine shipper responses," but this topic is not pursed later.

4. Section 2.4.1, Page 6, Paragraph 1. This paragraph introduces the notion of hierarchical levels of lockage modeling detail, which is probably the most useful version of the proposed model. More should be made of this, and more plans for incorporating this into the model should be detailed. This topic does not reappear with sufficient emphasis later in the text.

5. Section 2.4.1, Page 7, Paragraph 1. The fourth bullet should have appended to it: "and generation of empty barge and light boat movements."

6. Section 2.8, Page 13, Last Bullet. Same as comment for Section 2.3, Page 5, Paragraph 3.

7. Section 3.1, Page 18. Provide a reference for Table 2.

8. Section 3.1, Page 30, Item 3f. The last word should be "movement" rather than "shipment," unless empty barges are defined as a commodity.

9. Section 3.2, Page 21, Line 2. Some locks have three or more chambers.

10. Section 3.2, Page 21, Item 4. Many undefined lockage terms are introduced here, so it would be wise to refer the reader to section 3.6 for the definitions. Also, somewhere in the document there should be a more extensive discussion of multiple chamber locks, the difference between main and auxiliary chambers, and that many sites have single chambers.

11. Section 3.2, Page 21, Item 8. It should be noted emphatically that the problem discussed here is a central and difficult problem. There is, at present, no accepted theory or set of standard decision rules governing equipment dispatching and repositioning. Only one or two large towing companies have attempted to develop computer-based scheduling models, and the success of those ventures is not known. No prior navigation system simulation model has successfully

solved this problem. The "equipment reservoir" idea was a concept introduced in the initial version of the (system level) WAM. Trying to set the initial pool of equipment at each port led to the development of the Flotilla Model, which was the precursor to the TOWCOST Model. Even with initial equipment pools defined, WAM operation s led to "swarms" of empty barges being dispatched toward empty barge deficit ports, leading to severe model calibration problems. The whole approach was eventually scrapped in favor of the port-to-port and dedicated empty percentage concepts now used in WAM, and at least partially inherited by ORNIM.

12. Section 3.2, Page 22, Item 10. The Train-Wilson approach and the WTW-WTS-WTD concepts need a more in-depth treatment, since they are recommended for implementation. Any information on validation of the concepts would be particularly welcome.

13. Section 3.2, Page 23, Item 11. The last sentence of this item (lines 2 to 4 on the page) is a very ambitious specification. There should be some information here on how to develop al of these data, ancillary models needed, reliance of other parts of NETS, etc.

14. Section 3.5, Page 27. It really isn't possible to foresee all of the projects that might be suggested for analysis. Years of modeling experience, of both navigation and other systems, suggests that such an idea is impractical and unwieldy, and will inhibit use of the model. A more reasonable strategy is to insist on standardized documentation of network database changes, with reference to a base configuration, which itself should be allowed to be reset periodically.

15. Section 3.6, Page 30, Last Line. To the definition of "Sill" add: The sill is also the physical end of the lock chamber.

16. Section 3.7, Page 31, Paragraph 2, Fourth Bullet. Modify the definition of "exit" to read: "…time required for the stern of the tow to reach the gate…"

17. Section 3.7, Page 31-33. This section needs a detailed discussion of setover (including jackknife and knockout) lockages, multiple-cut tows/lockages, multiple vessel lockages, and recreational craft locking through with commercial vessels or separately. Chamber assignment logic also deserves a discussion.

18. Section 3.7.1, Page 33, Paragraph 2. Tows rarely encounter any operating time "loading and unloading at ports." The barges are usually loaded/unloaded with no towboat present. Exceptions are unit tows, typically comprising chemical or petroleum tank barges. Tows do, however, spend time picking up and dropping off barges (a.k.a. making/breaking tow). SPCCs, of course, do have load/unload time. Also, this discussion seems to be misplaced, since the topic is lockage processing.

19. Section 3.7.1, Page 34, Last Paragraph. For standard tow configurations, i.e., 8 or 17 jumbo barges, the lockage type for each size of chamber is easily determined, and could be carried as a tow attribute when the tow is configured for it trip. This could be recomputed for each remaining type of chamber in the tow's itinerary each time the configuration changes (e.g., at fleeting points). Odd size tows will require special algorithms or preprocessed table look-ups. In fact, a look-up table of lockage type by tow size and chamber size should not be too difficult to construct (not simple, but not overly difficult). The lockage type could even be probabilistic if

some tow sizes split across two or more lockage types. The hard case is a mixed tow, with barges of two or more types (e.g. a tow of jumbo barges with one odd-size tank barge as an outrider). While mixed tows occur in the real world, whether to accommodate such traffic in the model should be an explicit model design decision.

20. Section 3.7.1, Page 35, Paragraph 1. This is an abrupt transition from a narrative style to a sort of pseudo code directed at the simulation model designer.

21. Section 3.7.1, Page 35, Paragraph 2. Tow reconfiguration sometimes occurs during the interval between arrival and start lockage. This happens, for example, under lockage policies that utilize mooring cells and helper boats as traffic management tools. The model will need explicit mechanisms to handle tow assist operations. In previous WAM applications (e.g., the Winfield Locks study) such strategies were simulated by adjusting the approach and exit times, and the extra times for setover and multiple cut lockages.

22. Section 3.7.1, Page 37, Start Entry, Last Paragraph. The rule that other vessels cannot be added to a tow that has reconfigured is too strict. Recreational craft can often fit into the chamber with a setover or knockout lockage.

23. Section 3.7.1, Page 37, Last Paragraph. It is not strictly true that chambering time is independent of the contents of the chamber. Skilled lock operators know how to introduce a cushion of water under an upbound tow before opening the valves fully, and this may differ for loaded and empty barges, and single vessel vs. multiple vessel lockages. Likewise, presence of vessels waiting near the lock culvert intake or discharge points may affect achievable culvert flow rates. Analysis of LPMS data should reveal any such differences.

24. Section 3.8.1, Page 40, Second to Last Paragraph. Value of cargo should be a commodity attribute, not a barge attribute.

25. Section 3.8.2, Page 42, Tables 7& 8. Previously in the text the point was made that towboats are sometimes referred to erroneously as “tub boats” or “tugs.” Hence those entries in these two tables should be corrected. The associated text must also be changed.

26. Section 3.8.2.2, Page 43, Table 9. Same error as for Tables 7 and 8.

27. Section 3.9, Page 43, Table 10. Movement ID 1234 occurs twice, with different movement dates. This appears to be an error. If it isn’t further explanation is needed.

28. Section 3.9, Page 44, Paragraph 1. The original design of WAM allowed a tow to pick up barges as it moved along its route if the maximum tow size for that particular tow had not been reached. Company I.D. flags on both towboats and barges also had to match. The logic did not go beyond this level of detail, so that version of the model proved to be too difficult to calibrate. Perhaps further exploration of these concepts would be useful.

29. Section 3.9.1.1, Page 46, Paragraph 1. Direct shipment list specification is also used in WAM and ORNIM and, in fact, has been the method of choice in nearly all previous navigation simulation models.

30. Section 3.9.1.2, Page 46, Last Paragraph. The assumption of a negative exponential distribution of the tow departure intervals (i.e., random departures), either at each port or system wide, has also been used. This is easily combined with a set repeating schedule cycle for some of the shipments.

31. Section 3.9.1.3, Page 48, Paragraph 1. The second sentence is not a sentence, so the meaning is not clear.

32. Section 3.9.1.3, Page 49, Paragraph 2. The ORNIM Shipping Plan algorithm for generating tow movements should also be examined.

33. Section 3.11.1.1, Page 52, Paragraph 2. The logic described is also used in ORNIM.

34. Section 3.11.1.1, Page 52, Paragraph 3. Given the initial O-D-C rips and the data on dedicated barges, the residual repositioning problems (by barge type) can easily be solved as a set of standard Linear Programming Transportation Problems, which will yield a reasonable and feasible set of empty barge movements for further analysis and adjustment. This method has been used by others (see, for example, Bronzini 1976b).

35. Section 3.12, Page 52 to 56. The whole section on reliability is nearly identical to the comparable concepts used in LCLM and the Lock Risk module of ORNIM.

36. Section 3.13, Page 57. More discussion of the Wilson-Train model is needed.

37. Section 4, Page 63. Somewhere in this section there should be a discussion of how this is different from the optimization approach used in ORNIM.

38. Section 6, Page 81. Most of the references are incomplete (publication data are lacking).

Reviewer 3 References

Bronzini, M.S., et al. 1976a. *Inland Navigation Systems Analysis, Volume V, Waterway Analysis*. CACI, Inc., for Office of the Chief of Engineers, U.S. Army Corps of Engineers, Washington, DC,

Bronzini, M.S. 1976b. Optimal Cargo Vehicle Flow Patterns for Inland Waterway Systems, *Transportation Research Record* 577: 1-12.