INLAND NAVIGATION ECONOMICS WEBINAR SERIES

#10 Navigation Economic System Modeling

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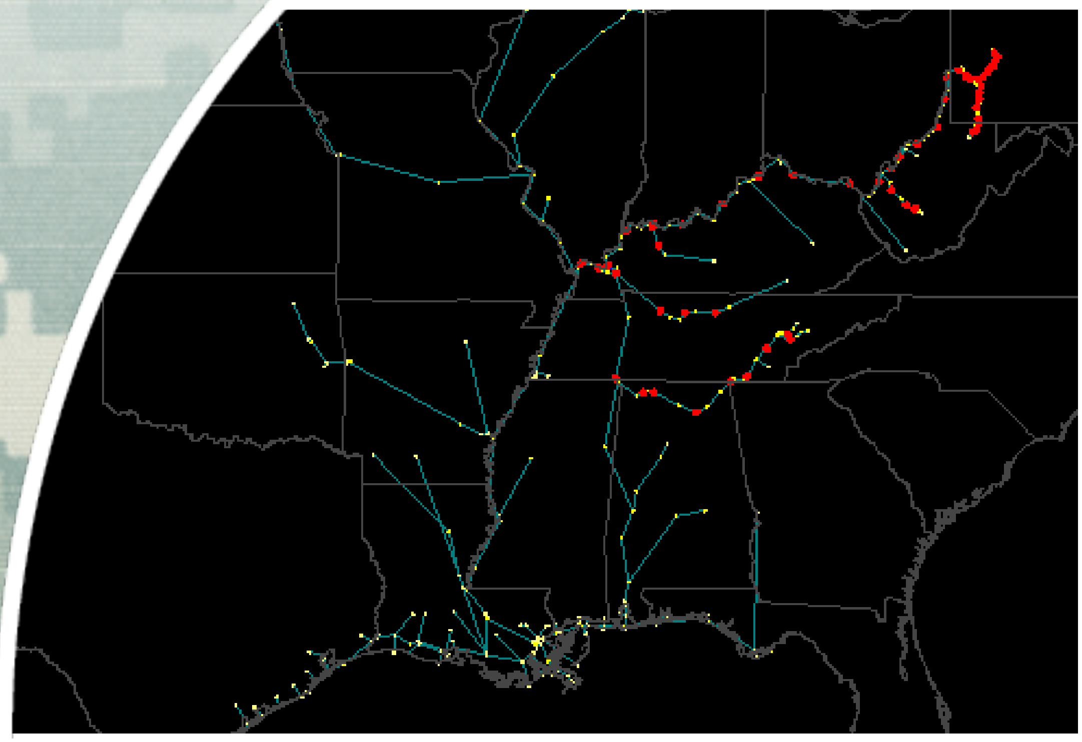


US Army Corps of Engineers

BUILDING STRONG®

Inland Navigation Economics 101
(Mark Hammond)

Transportation Rate Analysis & Externalities
(Lin Prescott)

Navigation Data Resources
(Dick Ash)

Waterborne Traffic Demand Forecasting
(Wes Walker)

Lock Capacity & Engineering Reliability
(Mark Lisney)

Navigation Component Engineering Reliability
(Gabriela Lyvers)

Elasticity of Demand
(Mike Hilliard)

Vessel Operating Costs - Inland
(Gabe Stala)

Corps Inland Navigation Mission

Provide a safe, reliable, efficient, and environmentally sustainable waterborne transportation system for movement of commerce, national security needs, and recreation.

Inland Shallow Draft

Six Step Planning Process

1 – Identify Problems & Opportunities
2 – Inventory & Forecast Critical Resources
3 – Formulate Alternative Plans
4 – Evaluate Alternative Plans
5 – Compare Alternative Plans
6 – Select Recommended Plan

Outline

- Inland Shallow-Draft Navigation Economic Modeling Background, History, & Guidance
- Model Calculations (NIM)
- Outputs

Background :

Inland Shallow-Draft Navigation Development History

- ❑ Founded on framework established in the 1950's.
- ❑First model North Central Division for the Illinois Waterway in the 1960's.
- ❑ Simulation Models – TOWGEN / WATSIM → WATSIM IV - 1970's.
- ❑ Inland Navigation Systems Analysis (INSA) Coordination Group within the Office of the Chief of Engineers (OCE) 1975-1976. (WAM, Flotilla, Commodity Flow, Multi-Modal)
- ❑ Transportation Systems Center of the U.S. DOT sponsored model expansion in 1977 of the Flotilla Model for user charges, called Waterway Cost Model.
- ❑ Waterway Cost Model evolved to Tow Cost Model (TCM) & Marginal Economic Analysis Model (MEA) 1979-1980 by Huntington District.
- ❑ Tow Cost / Equilibrium (TC/EQ) model mid-1980s.
- ❑ ERDC modified the Waterways Analysis Model (WAM) 1982-1999.
- ❑ ORNL **TC/EQ Model** → Java object oriented **NIM** 1996-1999, added relational database management (C++) 1999-2005, modified for Upper Ohio analysis (C#) 2006-2009, HQ Corporate certification 14 Feb 2012, modified for Bayou Sorrel alternative waterway routing equilibrium 2012.

Background : # Inland Shallow-Draft Navigation Application History

❑ TCM/MEA & TC/EQ Models (and WAM)

- ✓ *Gallipolis (1982) online Jan 1993*
- ✓ *William Bacon Oliver (1986) online 1991*
- ✓ *Gray's Landing & Point Marion (1986) Monongahela River on line June 1995 / Sept 1994*
- ✓ *Winfield (1986) online November 1997*
- ✓ *London (1998) online July 2003*
- ✓ *Marmet (Dec 1993 & May 1996) online Jan 2008*
- ✓ *McAlpine (Aug 1994 & 1996) online May 2009*
- ❑ *Olmsted (April 1985 & Oct 1990) under construction*
- ❑ *Markland (Aug 1999) under construction*
- ❑ *Kentucky (1992 & 1996) under construction*
- ❑ *Lower Monongahela (1992, 1994) under construction*
- ❑ *Upper Tennessee Recon (1991) & Feasibility (1993)*
- ❑ *TCM vs GEM (1986), Comparison to ESSENCE (----)*

❑ NIM 5.1-5.2 & WAM

- ❑ *ORMSS-SIP (May 2006)*
- ❑ *Greenup (April 2000 & June 2006)*
- ❑ *Myers (April 2000) under construction*
- ❑ *Olmsted (May 2008) under construction*

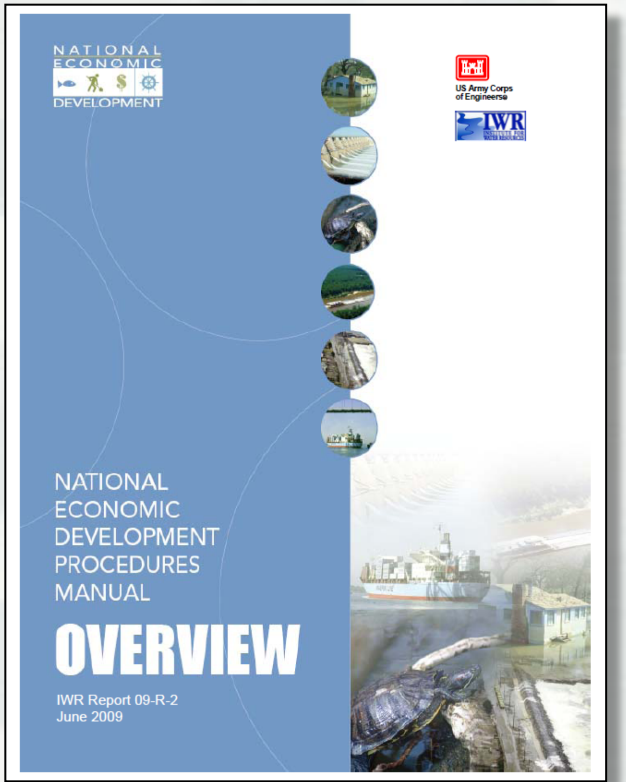
❑ NIM 5.3 & WAM

- ❑ *Upper Ohio Navigation Study (in review)*
- ❑ *Calcasieu Lock (underway)*

❑ NIM 5.4 & WAM

- ❑ *Bayou Sorrel Lock (underway)*
- ❑ *Greenup Locks (underway)*

Background : **Analysis Guidance**



NED benefits are defined as "*… increases in the net value of the national output of goods and services, expressed in monetary units …*"

1. Introduction

1.1 Background

The Civil Works Program of the U.S. Army Corps of Engineers (Corps) includes a variety of program areas that involve different activities concerned with the management of water and related land resources to serve the nation's needs. Corps decision-making within these program areas necessarily confronts choices among possible alternative courses of action that involve tradeoffs in economic and other opportunities. The Corps uses economic analyses for the evaluation of economic tradeoffs in order to reach decisions that promote the efficient allocation of scarce societal resources. For example, the Corps uses economic analysis to support planning and decision-making for new or modified civil works projects; for decisions relating to the operation of existing water civil works infrastructure, such as dam regulation and the dredging of harbors and inland navigation channels; and for decisions relating to the decommissioning and rehabilitation of aging water infrastructure. The Corps has also sometimes relied on economic analysis to support permit decisions within the Clean Water Act Section 404 permit program involving proposed public water supply projects.

The primary guidance document that sets out principles and procedures for the formulation, evaluation, and selection of civil works project plans to recommend for federal involvement is the *Principles and Guidelines* (P&G).[1] Another guidance document, the *Planning Guidance Notebook* (PGN), provides Corps policy guidance for implementing the P&G and other Corps policies.[2] The P&G states, "The Federal objective of water and related land resources project planning is to contribute to national economic development consistent with protecting the Nation's environment…" It further explains, "Contributions to national economic development (NED) are increases in the net value of the national output of goods and services, expressed in monetary units…" With regards to plan selection, the P&G states, "A plan recommending Federal action is to be the alternative plan with the greatest net economic benefit consistent with protecting the Nation's environment (the NED plan)…" The P&G thus directs the Corps to formulate, evaluate, and select alternative project plans based on their estimated net economic benefits (plan benefits less and plan costs) expressed in dollars. The Corps refers to such economic analysis as "NED analysis."

In the civil works project planning context, NED analysis can be generally defined as economic benefit-cost analysis for plan formulation, evaluation, and selection that is used to evaluate the federal interest in pursuing a prospective project plan. The P&G analytical framework for the use of NED analysis relates specifically to civil works

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[1] U.S. Water Resources Council. 1983. *Economic and Environmental Principles and Guidelines for Water and Related Implementation Studies*. It is important to note that Congress, in the Water Resources Development Act of 2007, directed the Secretary of the Army to revise this guidance document to conform with a number of planning concepts, considerations, and tools enumerated in the act. At the time of this writing, Corps Headquarters had published in the *Federal Register* (on September 12, 2008) proposed revisions to the "principles" part of the guidance document for public review and comment.
[2] ER 1105-2-100 (22 April 2000).

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Background : **Analysis Guidance**

Section 219 of that act directed the Secretary of the Army to calculate the NED benefits for nonstructural flood damage reduction projects using methods similar to those used in calculating the NED benefits for structural projects, while avoiding the double-counting of benefits. To comply with this directive, current Corps policy says that PDA for the properties to be evacuated can now be claimed as an NED benefit of evacuation plans. However, for the NED evaluation of the net benefits of such plans, planners are to use a measure of plan costs that reflects the market value of flood-free properties that are comparable to the properties to be evacuated. That is, for evacuation plans, the measure of NED cost should reflect the market vale of comparable properties that lie outside the floodplain, rather than the appraised value of the evacuated properties.[27]

This new policy guidance would be directly comparable to the P&G approach for using PDA in the case of structural flood damage reduction plans in cases where the market value of the properties to be evacuated equals the market value of comparable flood-free properties used in the NED evaluation. Any equivalence between the market value of the floodplain properties to be evacuated and comparable flood-free properties would imply that market traders have complete ignorance (i.e., the opposite of complete information) regarding the flood risks for the floodplain properties. But if the market value of the floodplain properties were less than the market value of comparable flood-free properties, then the new guidance would employ measures of NED costs (market value of flood-free properties) and NED benefits (PDA for floodplain properties to be evacuated) that overstate actual economic costs and benefits. The implicit assumption within the new guidance is that these inflated measures of NED benefits and costs will serve to cancel each other out, and thus satisfy the WRDA directive to use PDA measures of benefits in the case of nonstructural evacuation plans, without double-counting benefits.

4.2.2 Transportation: Inland and Deep Draft Navigation Benefits

The P&G defines the primary economic benefit of inland and deep draft navigation projects as the reduction in the value of resources required to transport commodities. The specific categories of benefits set out in the P&G for inland navigation include:

1) Cost reduction benefits,
2) Shift in mode benefits,
3) Shift of origin-destination benefits, and
4) New movement benefits.[28]

Cost reduction benefits are the principal benefit category; the other benefit categories reflect the different ways that cost reduction can give rise to non-marginal changes in the use of inland navigation.

Figure 4-1 uses a hypothetical project example to illustrate benefits estimation corresponding to three of these categories of inland navigation benefits. It depicts the

[27] The policy guidance states, "Note that this adjustment in costs is intended for use in the economic evaluation only and should not otherwise affect the financial cost associated with evacuation of the floodplain."
[28] The P&G lists similar benefit categories for deep draft navigation planning.

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calculation of benefits to shippers[29] from expanding locks along a specific origin-destination route as a means to alleviate barge traffic congestion and associated passage delays at the locks. The vertical axis represents the unit prices (rates) for transport, and the horizontal axis shows the total quantity of commodity units transported in response to different rates.

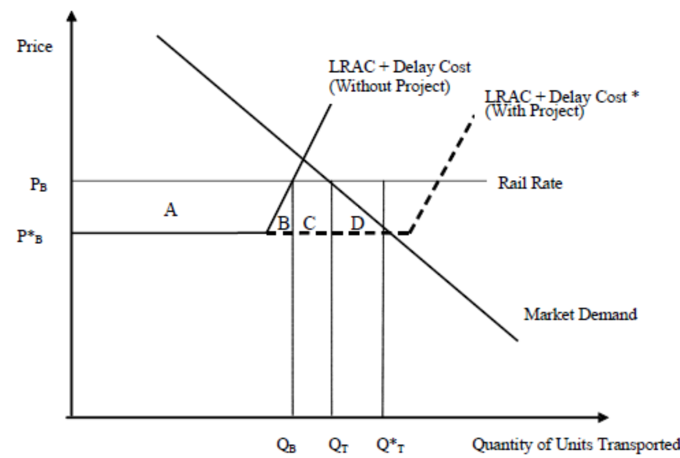

Figure 4-1 Benefits to Shippers from Lock Expansion

The downward sloping line shows shippers' total market (derived) demand function for transporting a specific commodity from a given origin to a given destination. The slope of the demand function, or Market Demand for all available transportation methods, represents the response of the quantity of the commodity transported to changes in transportation rates. For simplicity, it is assumed that this market is served by only two transport modes--waterway barge and railroad, and there is no qualitative difference between the services they provide.

In the Figure 4-1 example, it is assumed that, because of the open access nature of the barge industry, competition forces barge rates to the level of the long-term average costs

[29] Shippers include grain elevators and other entities that purchase barge services to transport commodities to buyers.

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Done in a system context !

Background : **Analysis Guidance**

DEPARTMENT OF THE ARMY
U. S. Army Corps of Engineers
Washington, D.C. 20314-1000

ER 1105-2-100

CECW-P

Regulation
No. 1105-2-100

22 April 2000

Planning
PLANNING GUIDANCE NOTEBOOK

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This engineer regulation supersedes ER 1105-2-100 dated 28 December 1990

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ER 1105-2-100
22 Apr 2000

(a) All reasonably expected nonstructural practices within the discretion of the operating agency, port agencies, other public agencies and the transportation industry are implemented at the appropriate time.

(b) For deep draft navigation studies, alternative harbor and channel improvements available over the planning period (in place and under construction) and authorized projects are assumed to be in place. For inland navigation, only waterway investments currently in place or under construction are assumed to be in place over the period of analysis.

(c) Normal operation and maintenance practices are assumed to be performed over the period of analysis.

(d) In projecting commodity movements involving intermodal movements and in projecting traffic movements on other modes, sufficient capacity of the hinterland transportation and related facilities and the alternative modes is normally assumed.

(e) For inland navigation, user charges and/or taxes required by law are part of the without-project condition.

(f) Advances in technology affecting the transportation industry over the period of analysis should be considered, within reason.

(3) With-Project Condition. The with-project condition is the most likely condition expected to exist in the future if a project is undertaken. The same assumptions as for the without- project condition underlie the with-project condition.

(4) Evaluation Procedure for Inland Navigation. The following ten steps are used to estimate benefits associated with improvements of the inland navigation system. The level of effort on each step depends on the nature of the proposed improvement, the state of the art for accurately estimating the benefits and the sensitivity of project formulation and justification to further refinement. Appendix E provides additional guidance for each of these steps.

(a) Step 1 - Identify the Commodity Types. The types of commodities susceptible to movement on the waterway segment under consideration are identified for new waterways and existing waterways, as applicable. For new waterways, commodity types are identified by interviews of shippers and by resources studies. For existing waterways, commodity types are identified by analysis of data on existing use of the waterway segment.

(b) Step 2 - Identify the Study Area. The study area is the area within which significant project impacts occur. The origins and destinations of products likely to use the waterway are normally included in the study area.

(c) Step 3 - Determine Current Commodity Flow. This step identifies the total tonnage that could benefit from using the waterway. This information is primarily obtained by interviews of shippers. Potential commodities that might use the waterway in response to reduced transportation costs are also identified.

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Background : **Analysis Guidance**

ER 1105-2-100
22 Apr 2000

(d) Step 4 - Determine Current Cost of Waterway Use. Current cost of waterway use is determined for all commodities that could potentially benefit from the waterway improvement. This cost includes the full origin-to-destination costs, including handling, transfer, demurrage and prior and subsequent hauls for the tonnages identified in the prior step. Costs are estimated for the without-project and with-project conditions. The difference between the with and without-project costs represents the reduction in current delays and gains in efficiencies with the project in place.

(e) Step 5 - Determine Current Cost of Alternative Movement. The current cost of alternative movement is estimated for all commodities under consideration. This cost includes full origin-to-destination costs, including costs of handling, transfer, demurrage and prior and subsequent hauls. The product of this step, combined with the products from the two previous steps, generates a first approximation of the demand schedule for waterway transportation. In the case of rail movements, the prevailing rate actually charged for moving the traffic shall be used to estimate the alternative movement cost. A "competitive" rate may be used if there is no prevailing rate. Appendix E provides a definition and guidance on how to compute "competitive" rates.

(f) Step 6 - Forecast Potential Waterway Traffic by Commodity. Projections of potential traffic are developed for selected years from the time of the study until the end of the period of analysis, for time intervals not to exceed 10 years. Normally, independent studies are undertaken to develop these projections. Available secondary data supplemented by interviews of relevant shippers, carriers and port officials, opinions of commodity consultants and experts and historical flow patterns are used to develop these projections.

(g) Step 7 – Determine Future Cost of Alternative Mode. The future cost of alternative mode per unit of each commodity will normally be the same as the current cost.

(h) Step 8 – Determine Future Cost of Waterway Use. The potential changes in cost of the waterway mode for future years for individual origin-destination commodity combinations are estimated in this step. Also, an analysis of the relationship between waterway traffic volume and system delays is conducted. This analysis generates data on the relationships between total traffic volume and the cost of transportation on the waterway.

(i) Step 9 – Determine Waterway Use, With and Without-Project. The data developed in previous steps is used to determine waterway use over time with and without the project. This determination is made based upon a comparison of costs for movements by the waterway and by the alternative mode and of any changes in the cost functions and demand schedules. The "phasing in" and "phasing out" of shifts from one mode to another are also considered in this analysis.

(j) Step 10 – Compute NED Benefits. The information produced in previous steps is used to compute total NED benefits for each category described in Paragraph 3-2c(1), as applicable. Total NED benefits are annualized and discounted using the applicable discount rate (published annually by HQUSACE).

3-7

ER1105-2-100
22 Apr 2000

(5) Use of Rates For Benefit Measurement. It is currently more difficult to accurately compute the long-run marginal costs of particular rail movements on the basis of cost estimation studies than to determine the rates at which railroad traffic actually moves. In competitive markets, rates (prices) correspond to marginal cost, and, given market stability, prices will settle at long-run marginal costs. Moreover, the rates actually charged determine the distribution of traffic among modes. For these reasons, rates will be used to measure shift of mode benefits. Section 7a of the Department of Transportation (DOT) Act of 1966 (Public Law 89-670) requires the use of prevailing rates, as described in paragraph E-9d(5). In the case of new waterways, this rate may or may not represent the best estimate of long-run marginal costs. In the case of existing waterways, prevailing competitive similar rates are the best available approximation of long-run marginal costs.

(6) Risk-based Analysis Procedure. Institute of Water Resources and HQUSACE staff are currently in the process of developing risk-based analysis procedures for inland navigation studies. Although these efforts are ongoing, preliminary indications are the following variables should be explicitly incorporated in risk-based analysis; 1) commodity forecasts, 2) alternative mode costs, 3) reliability of existing and proposed structures, and, 4) system delays associated with capacity constraints. Additional variables can be incorporated if appropriate for individual study areas. Districts are expected to incorporate risk-based analysis procedures in all inland navigation studies. Until risk-based procedures are fully developed, districts are expected to, at a minimum, perform sensitivity analysis of key variables.

c. Planning Setting.

(1) Without Project Condition. The without project condition is the most likely condition expected to exist in the future in the absence of the navigation project or any change in law or public policy. The without project condition includes any practice likely to be adopted in the private sector under existing law and policy, as well as actions that are part of broader private and public planning to alleviate transportation problems. The following specific assumptions are part of the projected without project condition:

(a) Assume that all reasonably expected nonstructural practices within the discretion of the operating agency, including helper boats and lock operating policies, are implemented at the appropriate time. Substantial analysis is required to determine the best combination of nonstructural measures to ensure the most effective use of an existing waterway system over time. This analysis should be documented in project reports to assure the reviewer that the best use of existing facilities will be made in the without-project condition and that the benefits of alternative with project conditions are correctly stated. The criteria for the best utilization of the system are overall public interest concerns, including economic efficiency, safety and environmental impact.

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Navigation Investment Model (NIM) Description

- System Economic Model – spatially-detailed partial-equilibrium period-based (annual) waterway movement transportation cost & equilibration model … given a defined waterway system. Calculations include infrastructure service reliability (results are expected values)
- Calculates & summarizes benefits & costs over a life cycle
  - Benefits are a function of barge transportation demands, barge transportation characteristics, waterway characteristics *(lock capacity & reliability, taxes, towsize limits, vessel costs, etc)*, and shipper willingness-to-pay for barge transportation *(e.g., least-cost all-overland rate)*
  - Costs are a function of investment costs and condition *(scheduled & unscheduled / probabilistic repair costs)*
- Optimizes investments for the system
  - What – component, rehab, or new construction
  - When – year
  - Where – by lock site

NIM Sectorial, Spatial, & Temporal Simplifying Assumptions

- ❑ Incremental transportation investment changes to the waterway transportation system can be analyzed under a spatially detailed partial-equilibrium waterway transportation cost & equilibrium model framework.

- ❑ Link only traffic experiences and creates no congestion effects; traffic not moving through a lock (intra pool traffic) is inconsequential to the analysis of lock investments. Non-lock traffic flows are not modeled.

- ❑ Annual simulation of movements and av. costs & system equilibrium provides adequate cost-benefit analysis of ORS investments, assuming: a) shipments are scheduled well in advance with a carrier motive to fully employ their transportation equipment (with scheduled waterway system service disruption events scheduled 2 years in advance through Notice to Navigation process); b) insignificant seasonal variation; and c) unscheduled service disruptions are uniformly distributed throughout the year.

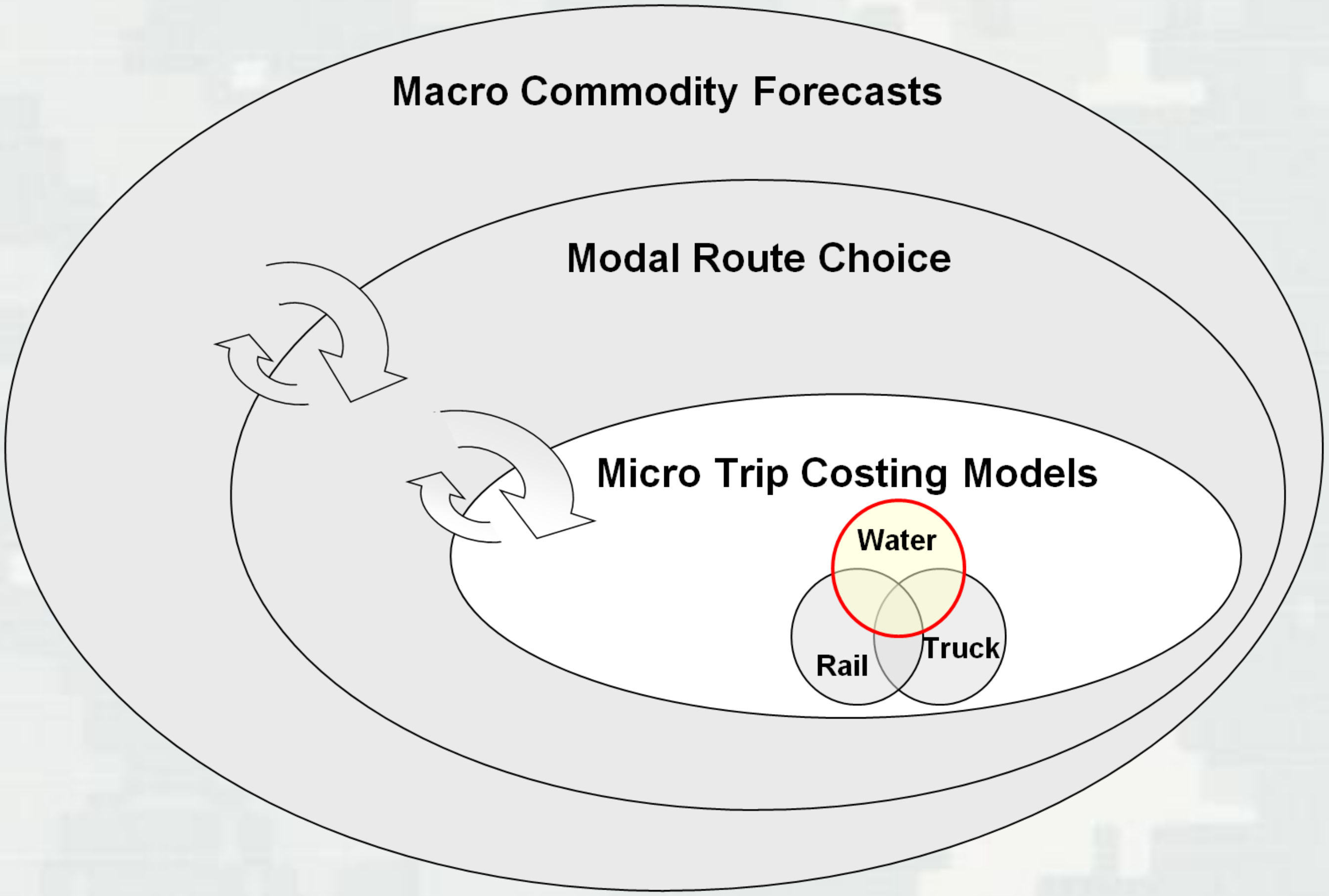
- ❑ All shipments of all movements are assumed to experience the same av. transit time through a constraint node. There is no seasonal variation beyond the seasonal variation endogenous to the tonnage-transit curve. In short, the model actually assumes that any seasonal variation in the tonnage-transit curve remains constant through time, tonnage level, and tonnage mix.

- ❑ Assumptions regarding the level of resolution for the waterway transportation network is user specified. Typically only one or two pick-up / drop-off nodes are assigned to each navigation pool.

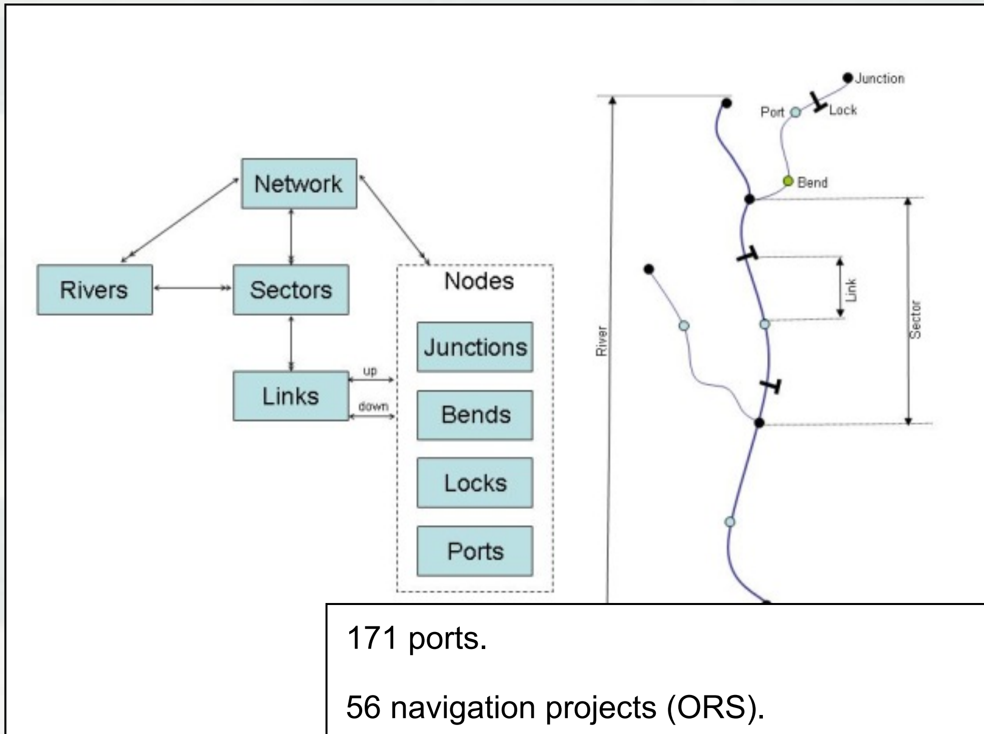
- ❑ Assumptions regarding the level of resolution for movement commodity, barge type, & towboat class is user specified.

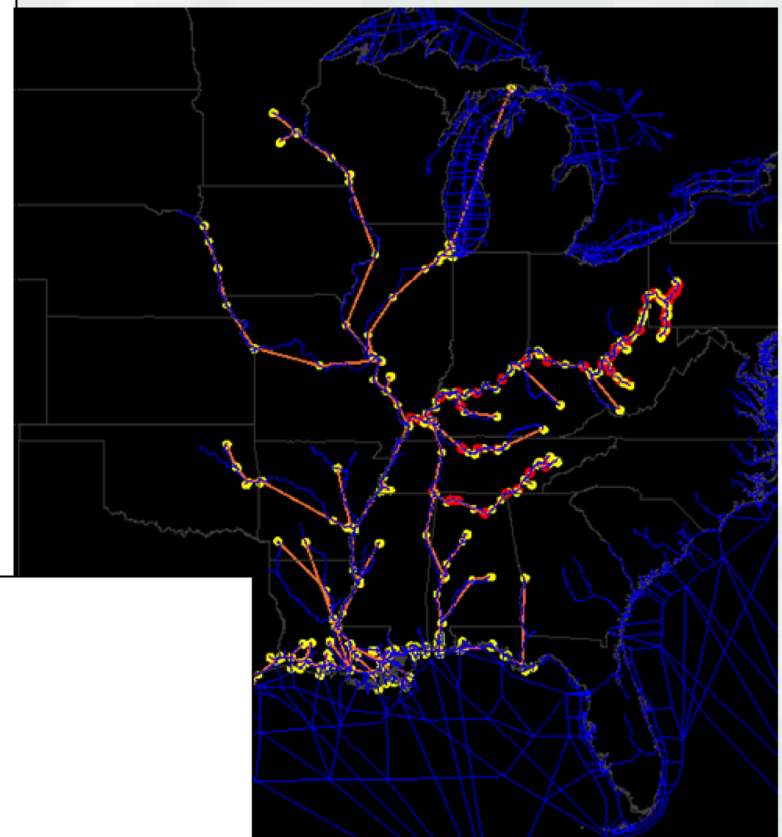
Models / Calculations:

NIM Sectorial, Spatial, & Temporal Simplifying Assumptions



NIM Sectorial, Spatial, & Temporal Simplifying Assumptions





171 ports.

56 navigation projects (ORS).

12 barge types.

8 towboat classes.

9 commodity types

16,948 unique origin-destination-commodity-barge mvts.

Link-Node Network (granularity user defined)

NIM <u>Barge Transportation</u> (movement) Demand Assumptions

- Technology assumptions are user defined through the traffic demand forecasts. Typically it is assumed in the forecasted demand development that technology is fixed at the time of the analysis, however, the economic and population growth rates, and environmental policies are often varied between forecast scenarios.

- Waterway forecasted demand (whether defined as inelastic or elastic) represents future waterway traffic given the endogenous technology assumptions, current water transportation cost and current land transportation cost. Since the model is calibrated to the current shipping-plans and a current waterway transportation cost is calculated from which to determine waterway transportation price change (into the future and between different system performance characteristics), the demands should be based on the current water and land transportation costs.

- Unmet waterway barge transportation demand <u>can be</u> assumed to be transported overland at the long-run least-costly all-overland rate. This assumption is based on the assumptions that:

    - any waterway diverted traffic to the land modes would represent a insignificant increase in the land transportation tonnage; and

    - land mode utilization in the future will approximate current utilization rates (i.e. land transportation capacity will grow with land transportation demand).

NIM <u>Barge Transportation</u> (movement) Demand Assumptions *(continued)*

- Waterway movement demand can be defined by the user as either fixed quantity (inelastic) or price-responsive (elastic).

  - For fixed quantity (inelastic) demand movements, the willingness-to-pay for barge transportation is assumed fixed through time (unaffected by demand or land congestion). The proxy for the fixed demand willingness-to-pay is typically set as the least-costly all-overland transportation rate (noting that this value is externally derived and input to the model by the user).

  - For price-responsive (elastic) demand movements, we have sufficient exogenous information to allow a unique demand curve to be calculated. The exogenous forecasted tonnage for each movement for each year corresponds to the given long-run least-costly all-overland rate, which establishes one point on each demand curve.

Models / Calculations:

NIM Equilibrium Assumptions

- Shippers’ decisions on waterway movement volume are determined by an economic equilibrium based on an annual cost of waterway transportation and an annual cost-demand relationship (demand function) assigned to the movement. As discussed under the movement demand assumptions, this cost-demand relationship can either be defined by the user as fixed or elastic.

- When multiple scheduled closures occur in a given year at a lock, the closures are assumed to be spaced far enough apart for queues to dissipate to normal levels before the next closure occurs. The model combines the service disruption tonnage-transit curves.

- The supply of land transportation for feeder legs of the waterway routing are perfectly elastic at the given long-run base rate. Only congestion changes on the waterway leg are considered in the equilibrium process.

- Shippers have complete knowledge of annual waterway transportation prices which incorporates the cost of scheduled lock closures. Shippers do not estimate or consider expected costs for unplanned closures; they are not risk adverse and they do not have knowledge of unscheduled service disruption probability or transportation cost effects.

NIM Equilibrium Assumptions

- ❑ Individual shippers will not restrict waterway usage to the social optimal level, but will continue to expand waterway volumes to the level at which their average towing costs equal their marginal rate-savings (ATC = MRS). This occurs because each individual carrier pays only its own average cost for moving on the waterway system, not the true marginal costs, which include the costs imposed on all shippers.

- ❑ Each movement is considered to be continuously divisible (i.e. tonnage values are not limited to discrete barge loads or full tow configurations).

- ❑ Equilibrium in a year is independent of preceding year equilibrium (i.e. movements can change transportation mode each year). Note that scheduled and unscheduled service disruption is not independent from one year to the next and that equilibrium is a function of scheduled service disruption and that equilibrium is probabilistically adjusted (not determined) for unscheduled service disruptions.

- ❑ Unmet equilibrium waterway demand <u>can be</u> assumed to be transported overland at the long-run least-costly all-overland rate (note that this is not the same as traffic diverted during unscheduled service disruption).

NIM Reliability Assumptions

- Survivability of all components is assumed to the user defined analysis base year (decision point).

- Components are assumed independent and fail independently of each other. Note however, that with event-tree state change option the user can lump components into a model-level component and thus model joint components.

- Components can only fail once in a year, however, multiple reliability closures from different components are allowed to occur in a year.

- When multiple reliability closures (from different components) occur in a given year at a lock, the closures are assumed to be spaced far enough apart for queues to dissipate before the next closure occurs. The model combines the service disruption tonnage-transit curves.

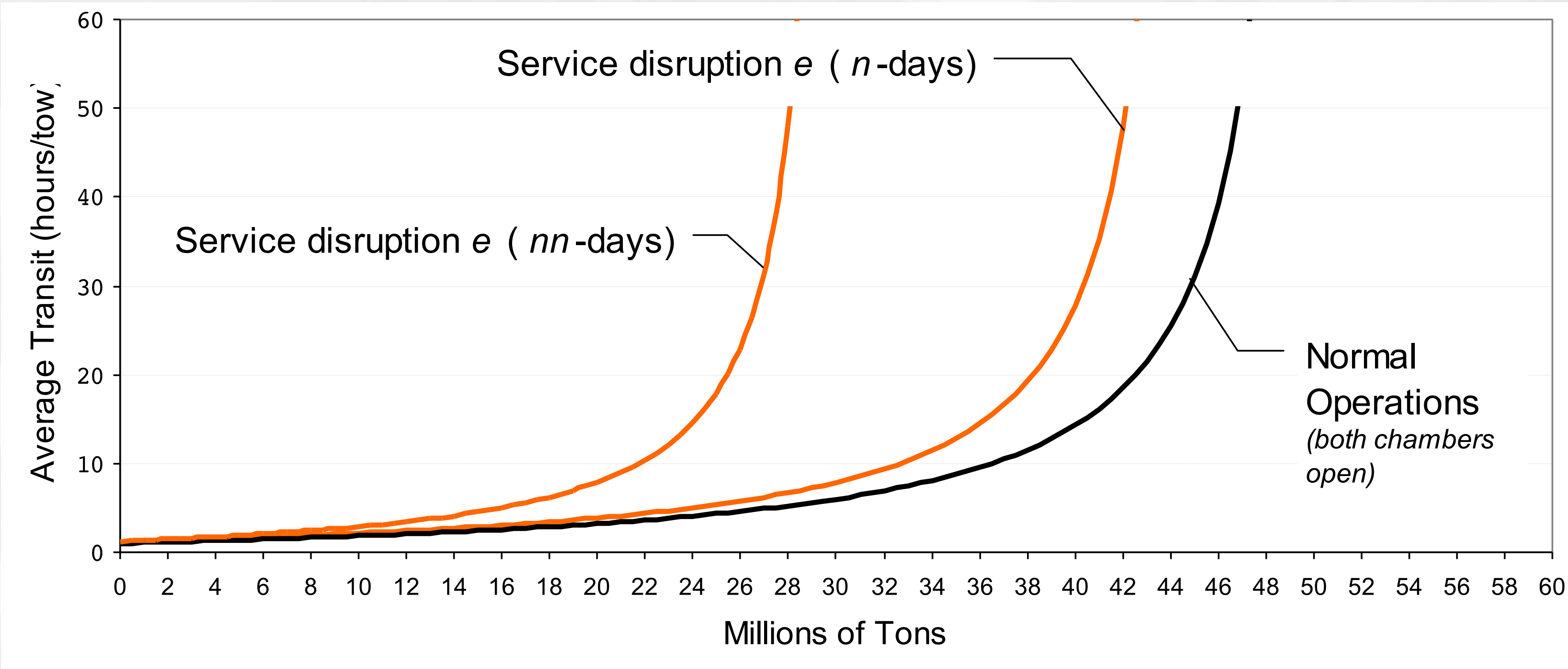
Models / Calculations:

NIM Unscheduled Service Disruption Assumptions

- ❑ Equilibrium traffic levels are determined with shipper knowledge of scheduled service disruption but without knowledge of unscheduled service disruption probabilities
    - ❑ When calculating the impacts of an unscheduled service disruption event, equilibrium traffic can be diverted from the waterway because the traffic level exceeds the annual capacity of the lock with the outage, or because movements have been defined with a river closure diversion response.
        - ❑ Unscheduled service disruption over capacity tonnage diversion is assumed to move at the long-run least-costly all-overland rate (and not at the river closure response diversion rate).
        - ❑ Unscheduled river closure service disruption tonnage diversion is assumed to move at a user specified spot-rate.
    - ❑ Except for unscheduled over capacity diversion and / or river closure response diversion, equilibrium traffic will be assumed to move on the waterway at a higher unscheduled service disruption lock transit time (as specified in the service disruption tonnage-transit curve).
- ❑ Movement river closure diversion response percentage assumed constant through time and between forecast scenario.

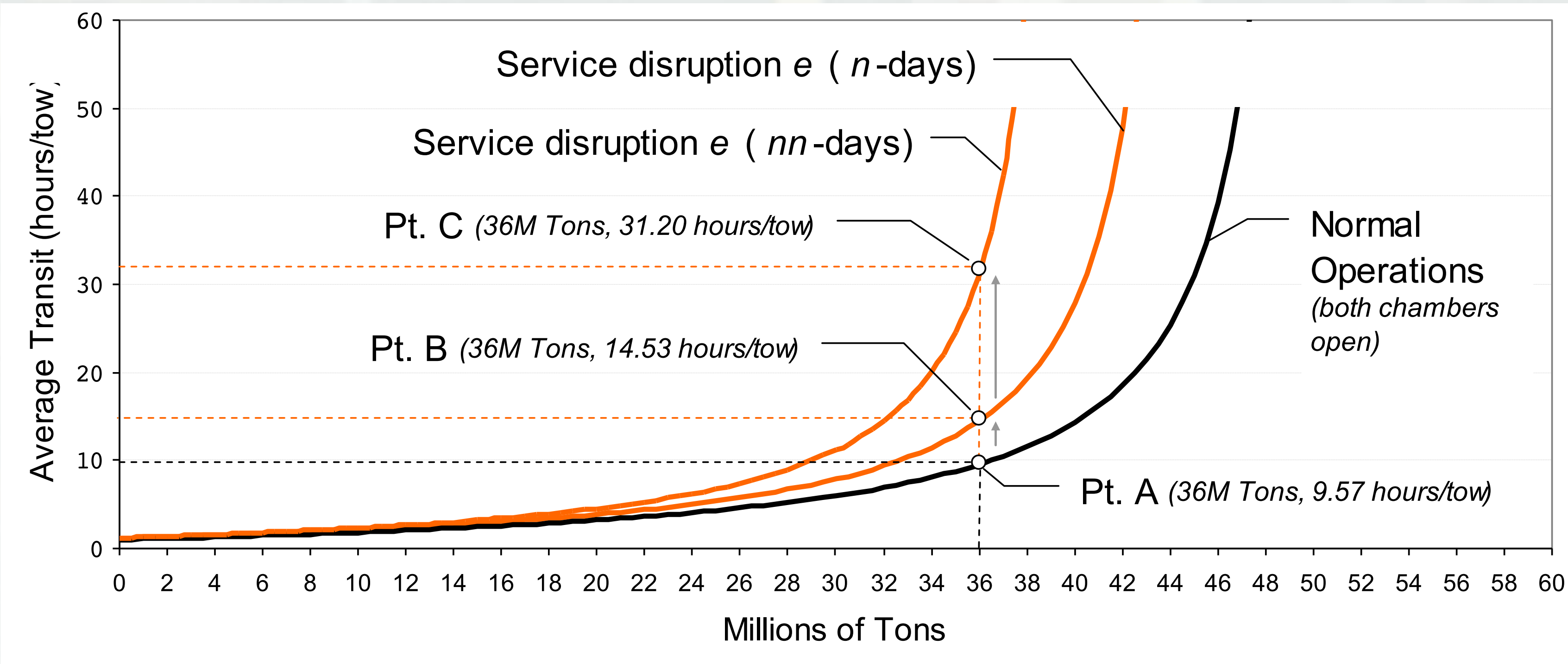
Models / Calculations:

Adjustment for Unscheduled Service Disruption



Adjustment for Unscheduled Service Disruption

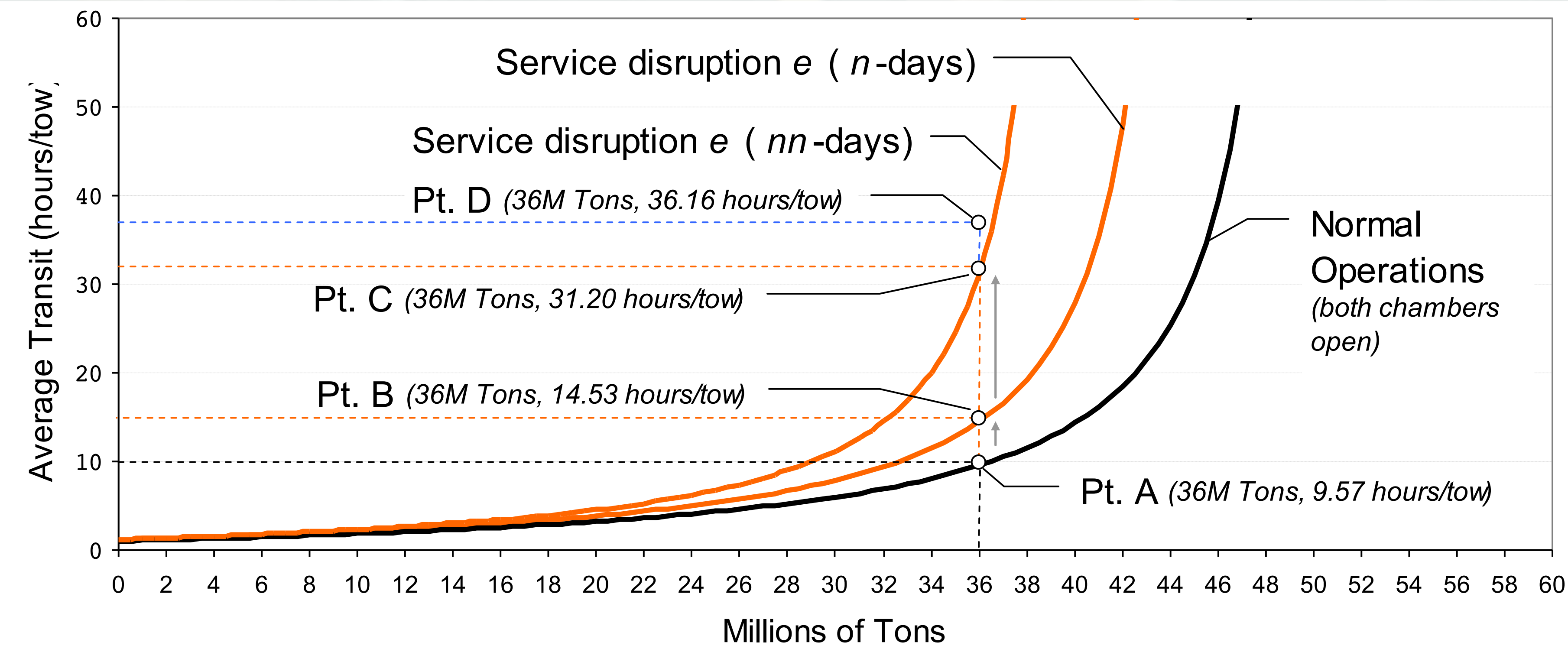
Transit Time Adj. – no traffic diversion.



Models / Calculations:

Adjustment for Unscheduled Service Disruption

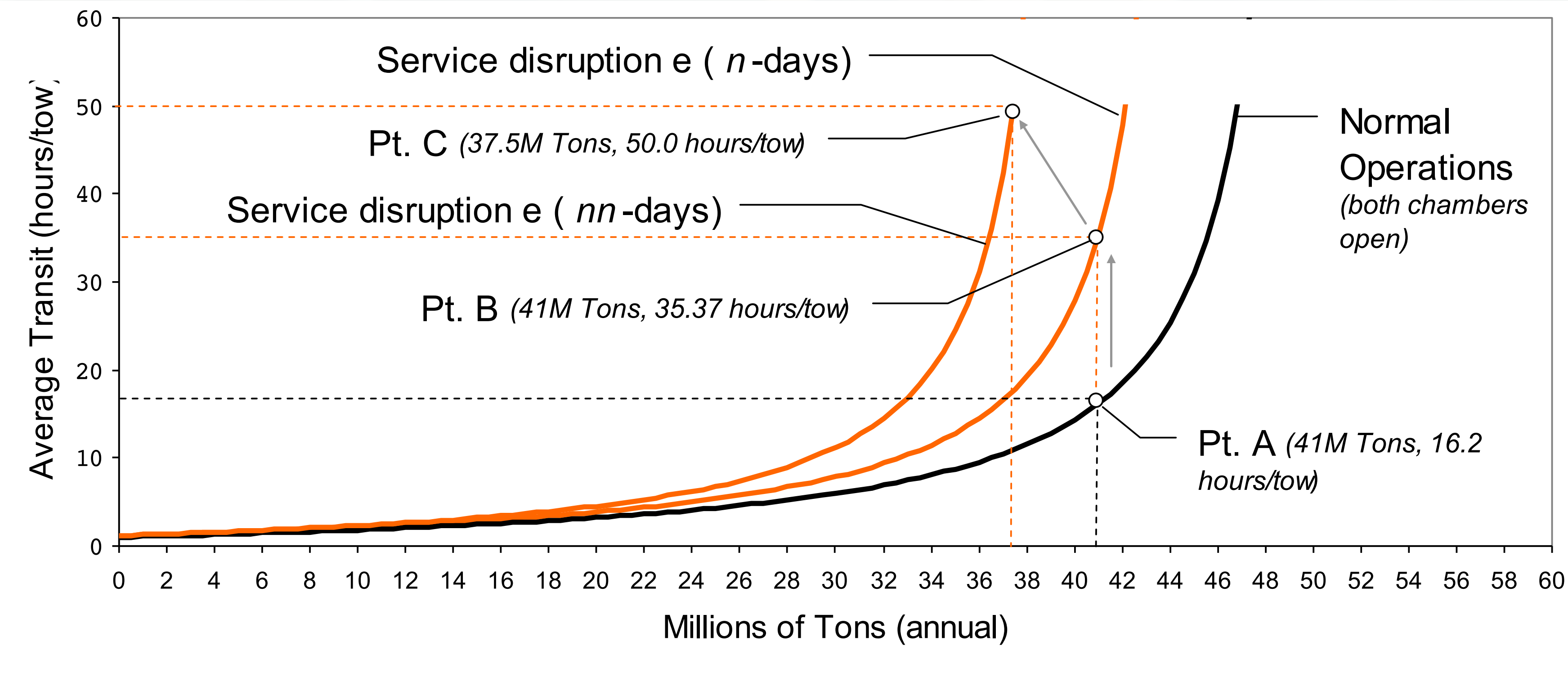
Transit Time Adj. – no traffic diversion (multiple events in same year).



Models / Calculations:

Adjustment for Unscheduled Service Disruption

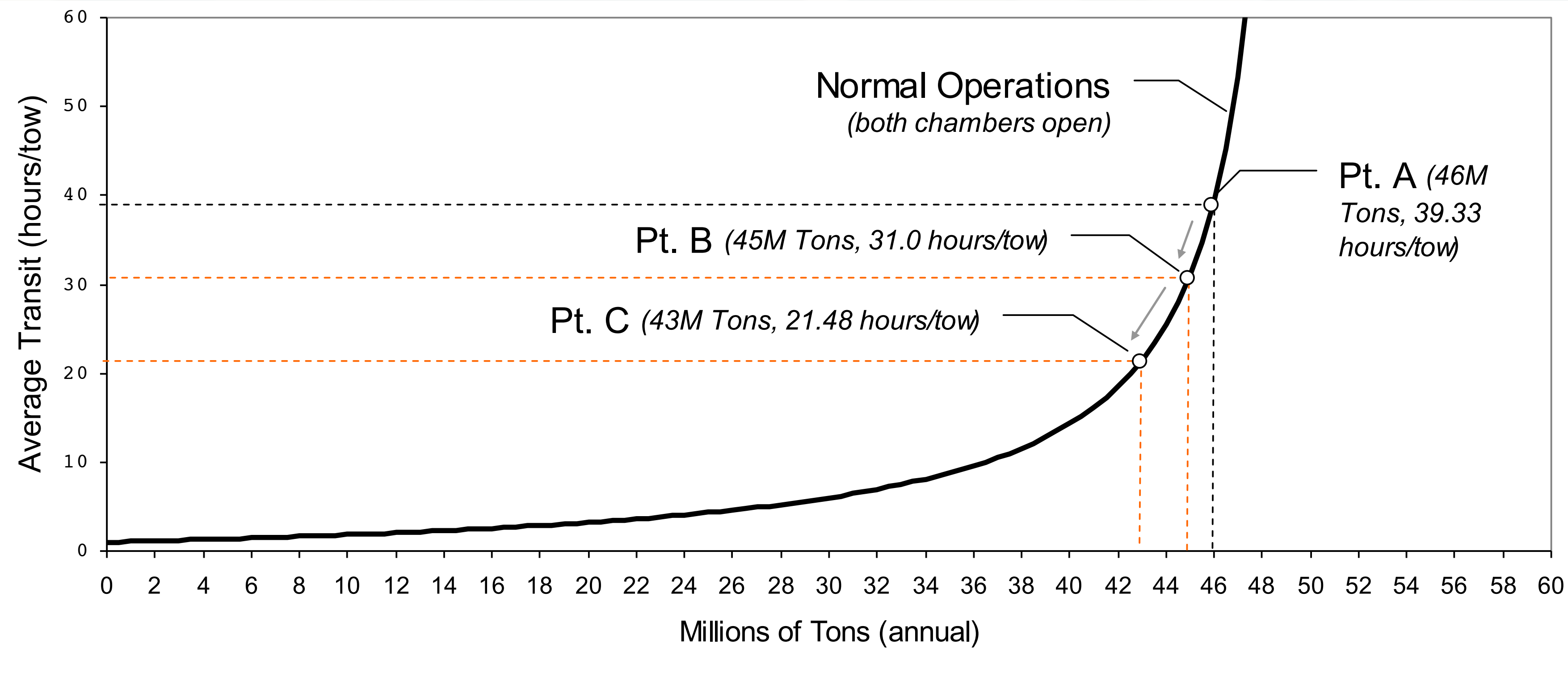
Transit Time Adj. – no traffic diversion vs. over capacity diversion.



Models / Calculations:

Adjustment for Unscheduled Service Disruption

Transit Time Adj. at adjacent project.



Models / Calculations:

Adjustment for Unscheduled Service Disruption

LRM Service Disruption Event probabilities

System Equilibrium Statistics given known Average Towing Cost

1.2.4.4.5.5 Adjustment 1 – River Closure Response Traffic Adjustment

1.2.4.4.5.6 Adjustment 2 – RCR Diversion Transportation Cost Calculation

1.2.4.4.5.7 Adjustment 3 – RCR Diversion Externality Cost Calculation

1.2.4.4.5.8 Adjustment 4 – Over Capacity Traffic Adjustment

1.2.4.4.5.9 Adjustment 5 – OC Diversion Transportation Cost Calculation

1.2.4.4.5.10 Adjustment 6 – Waterway Transportation Cost Recalculation, no diversion

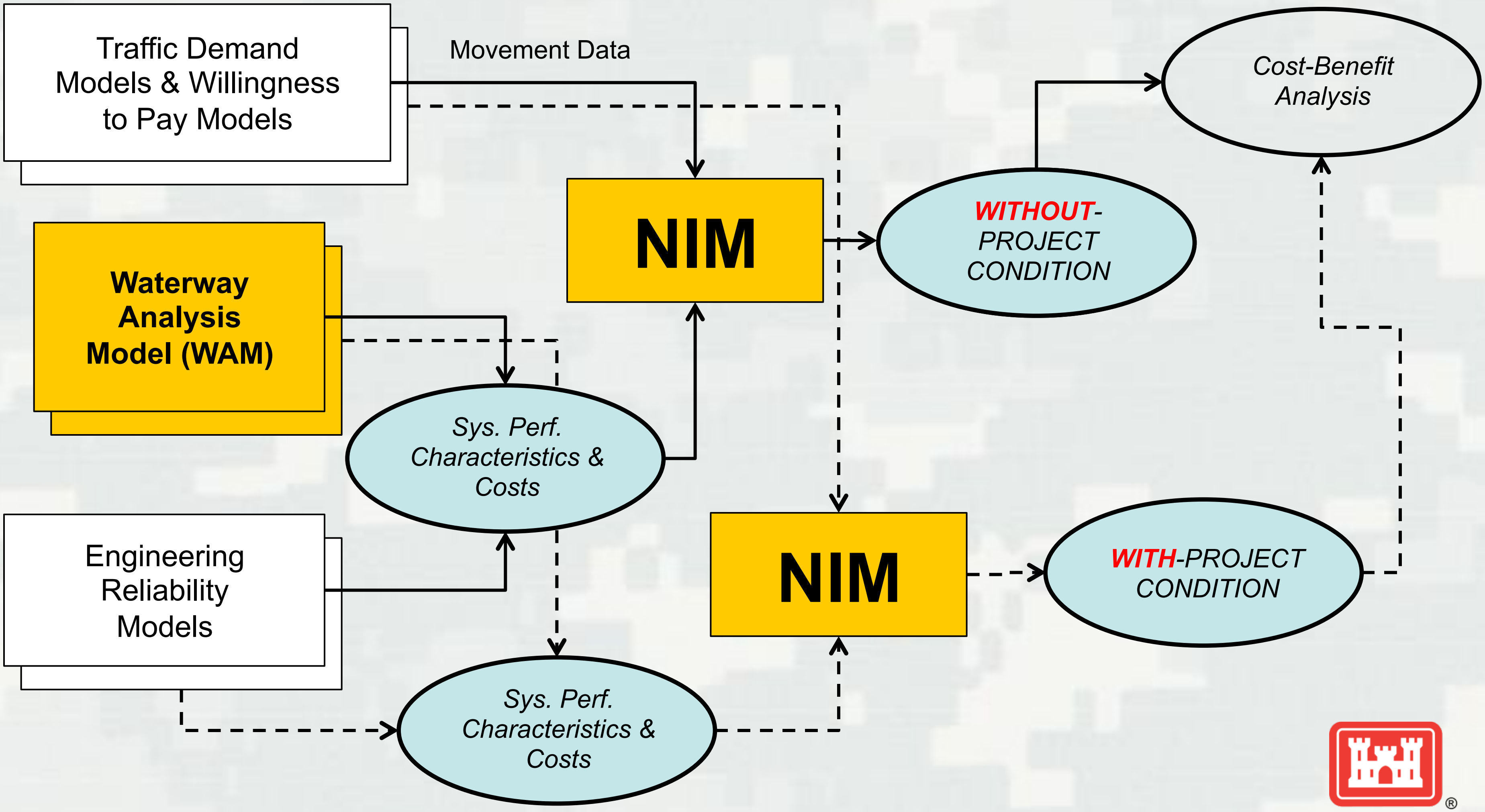
1.2.4.4.5.11 Adjustment 7 – Waterway Transportation Cost Recalculation, with diversion

1.2.4.4.5.12 Adjustment 8 – Expected Waterway Transportation Costs

EXPECTED Equilibrium Statistics

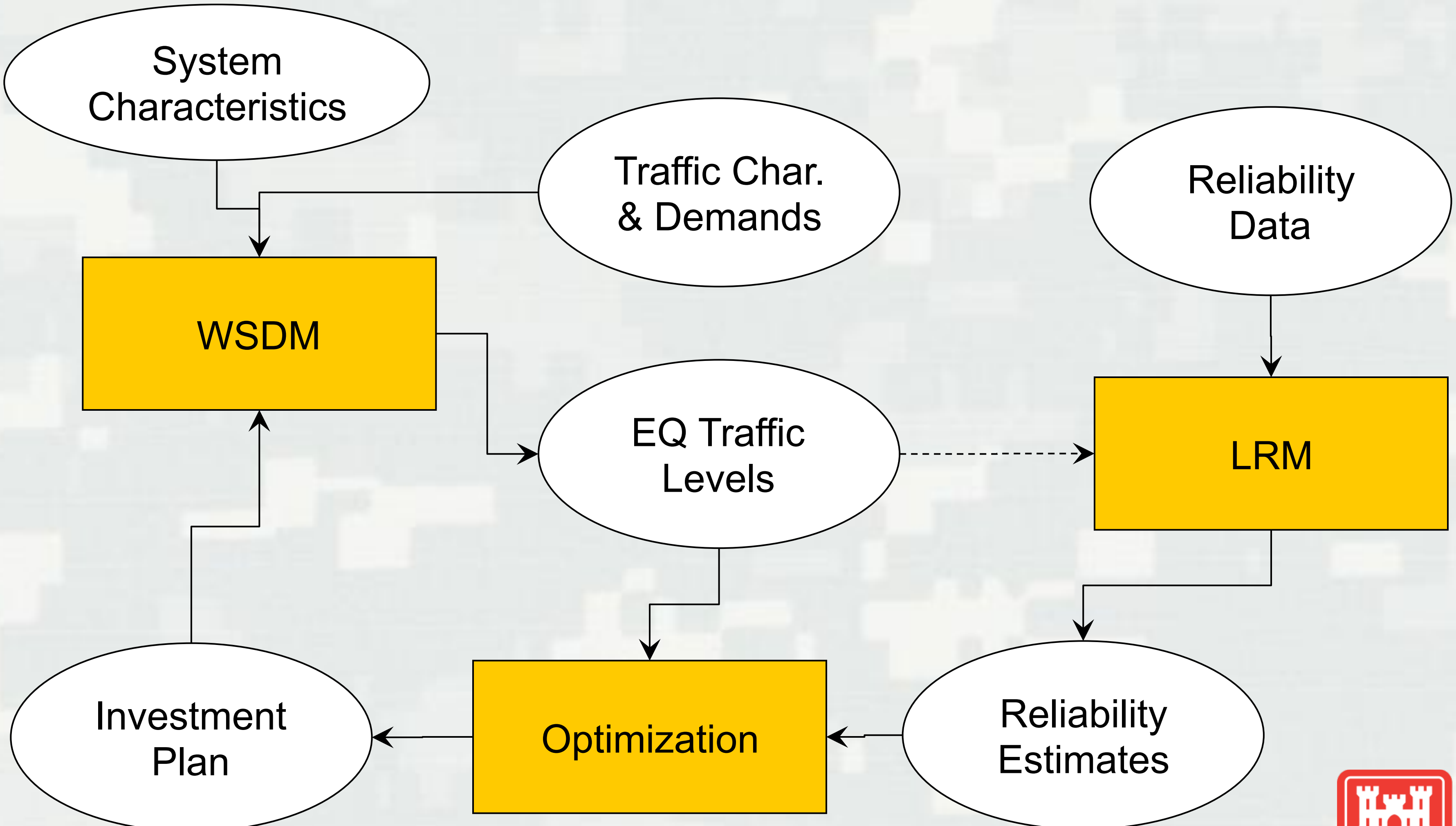
Models / Calculations:

Navigation Investment Model (NIM) Process



Models / Calculations:

Navigation Investment Model (NIM) Primary Modules



Models / Calculations:

Navigation Investment Model (NIM) Primary Modules

While there are three primary modules, the model is much more complex. The model structure is best described and understood through the following nine separable modules:

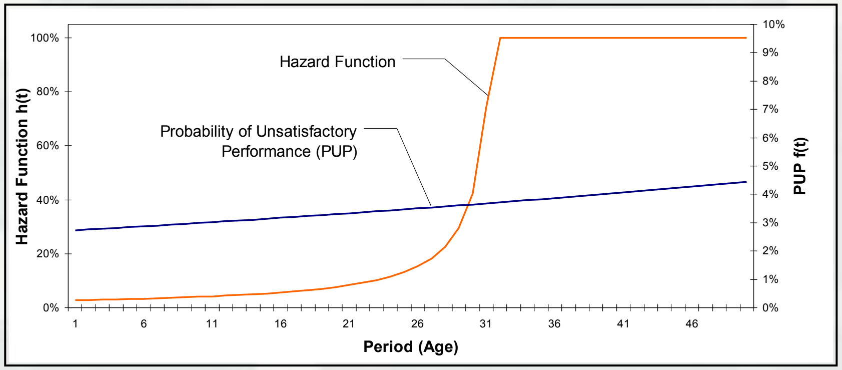
- **Water Supply and Demand Module (WSDM)**
  - Calibration Sub-Module (Calibrate.exe)
  - Equilibrium Sub-Module (WSDM.exe)
- Set-Up Component Alternatives and Runs Module
  - Generate All Component Replacements Sub-Module (GenAllCompRep.exe)
  - Generate Component Replacement Curve Sets Sub-Module (GenCompReplaceCurveSet.exe)
  - Build Transit Time Curve Set Sub-Module (BuildTransitTimeCurveSet.exe)
  - Copy Run Sub-Module (CopyRun.exe)
- **Lock Risk Module** (LRM.exe and runLRM.exe)
- Summarize Closures Module (SummClosures.exe)
- **Optimization Module** (ORNIMOptim.exe)
- Build Investment Plan Module (BuildInvestmentPlan.exe)
- Build Investment Plan Closures Module (BuildInvestmentPlanClosure.exe)
- Calculate Costs Module (CalculateCosts.exe)
- Output Utility Module

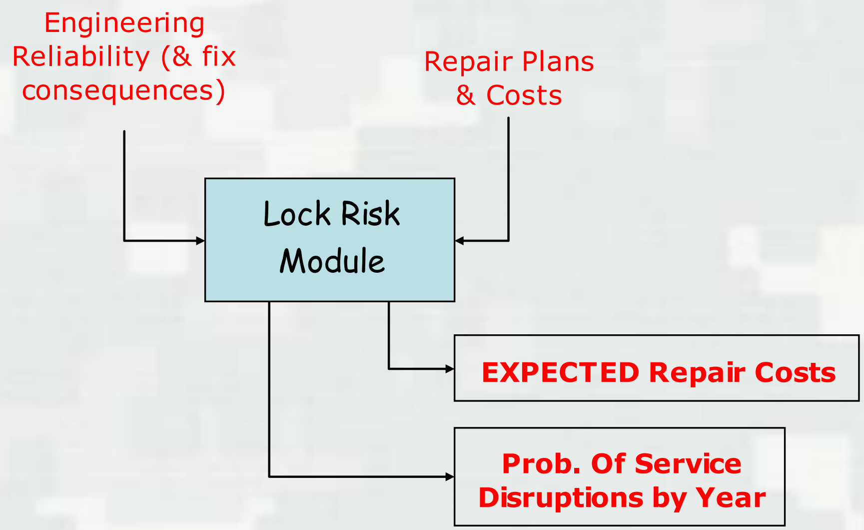
Navigation Investment Model (NIM)

Lock Risk Module

Simulation of the Engineering Reliability Data

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





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

Component	Annual Time Dependent Probabilities	Prob. Degree of Failure	Repair Level	Prob. Repair Level	Year of Repair	Cost	Year of Failure Closure Days	Following Year 1/2 Spd Days	Effect on Reliability
Main - Gate Event Tree	Satisfactory Table Values								
	Annual Unsatisfactory Table Values	Major 100%	New Gate	5%	1	$13,150,000	365	0	R=1 all future years
					2	$3,150,000	90	0	
			Major Repair	35%	1	$1,575,000	45	0	Back 5 years
					2	$1,575,000	45	0	
			Temporary Repair with New Gates 60%	60%	1	$3,575,000	45	0	R=1 all future years
					2	$3,575,000	45	0	
					3	$5,050,000	30	0	
		Minor 0%							

Scheduled Replacement Year 1 = 30 - closure days and cost $5,050,000
Year 2 = 30 - closure days and cost $5,050,000
Future Reliability will be equal to 1.0 for all future years after replacement

…estimates the probability of each potential closure in each year of a component's life given equilibrium traffic levels, hazard functions and event trees.

Models / Calculations:

Navigation Investment Model (NIM)

Component	Annual Time Dependent Probabilities	Prob. Degree of Failure	Repair Level	Prob. Repair Level	Year of Repair	Cost	Year of Failure Closure Days	Following Year 1/2 Spd Days	Effect on Reliability
Main - Gate Event Tree	Satisfactory Table Values								
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			Temporary Repair with New Gates 60%	60%	1	$3,575,000	45	0	R=1 all future years
					2	$3,575,000	45	0	
					3	$5,050,000	30	0	
		Minor 0%							

PUP

Varies by yr.

Scheduled Replacement Year 1 = 30 - closure days and cost $5,050,000
Year 2 = 30 - closure days and cost $5,050,000
Future Reliability will be equal to 1.0 for all future years after replacement

Can now go to different PUP curve and event-tree.

Models / Calculations: **Navigation Investment Model (NIM)**

Prob. Of Service Disruptions by Year

Lock Risk Module Output

Project A Component A

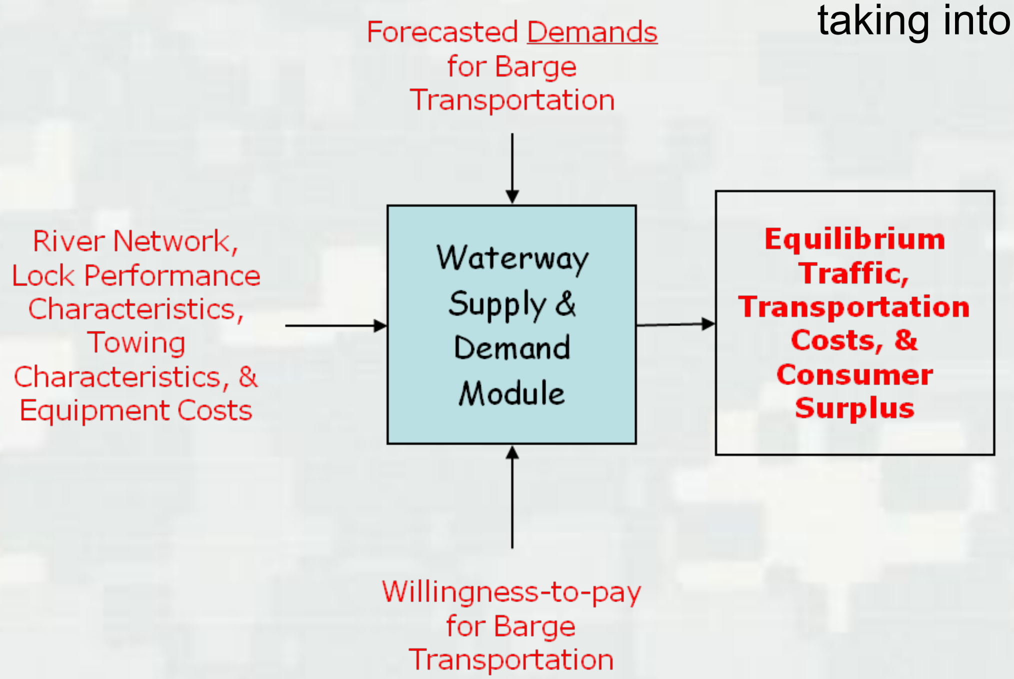
	Probability of Service Disruption by Year					EXPECTED Repair Cost				
	closureID					closureID				
Age	**1**	**2**	**3**	**…**	**n**	**1**	**2**	**3**	**…**	**n**
1	2.00%	0.00%	5.00%	…	0.10%	$ 248	$ -	$ 620	…	$ 12
2	2.10%	0.00%	7.00%	…	0.15%	$ 260	$ -	$ 868	…	$ 19
3	2.20%	0.00%	11.00%	…	0.20%	$ 273	$ -	$ 1,364	…	$ 25
.	.	.	.	…	.	.	.	.	…	.
.	.	.	.	…	.	.	.	.	…	.
.	.	.	.	…	.	.	.	.	…	.
50	10.00%	0.00%	67.00%	…	0.90%	$ 1,240	$ -	$ 8,308	…	$ 112

closureID 1 = 5-day main closed
closureID 2 = not used
closureID 3 = 15-day auxiliary chamber closed
closureID n = 30-day main chamber 1/2 speed fill / spill

NIM Waterway Supply & Demand Module

(WSDM) Determination of Equilibrium Traffic Levels and Transportation Costs

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



Step 1 – Determine Shipping Plans

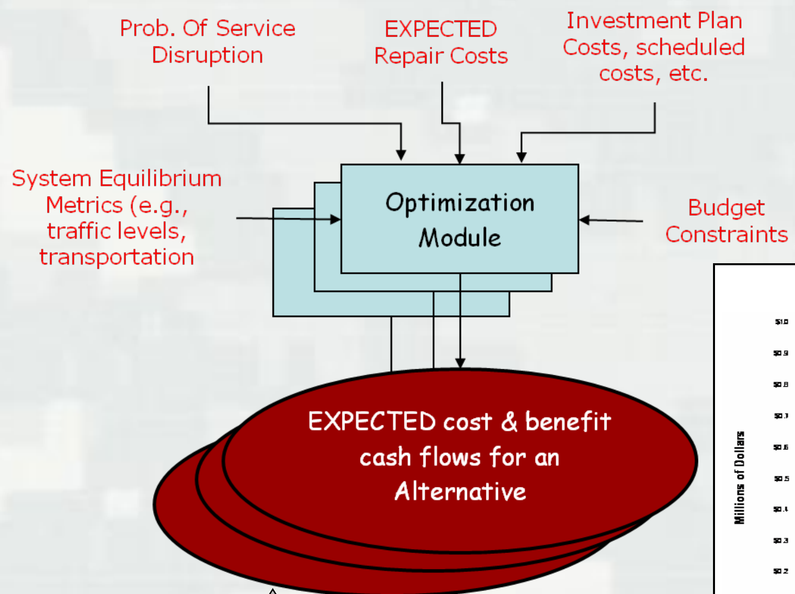
WSDM calculates the towing costs and determines the cost-effective tow configurations to move the port-to-port tonnage on the waterway network honoring tow and operating characteristics.

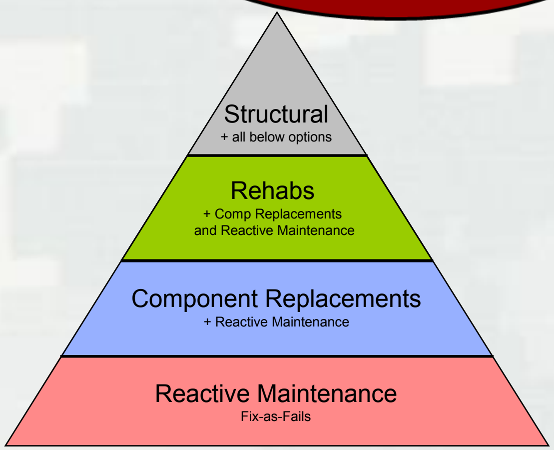
Step 2 – Equilibrate Traffic Levels

Ranks mvts by base rate savings…adds mvts and Iterates until savings are stable with no negatives.

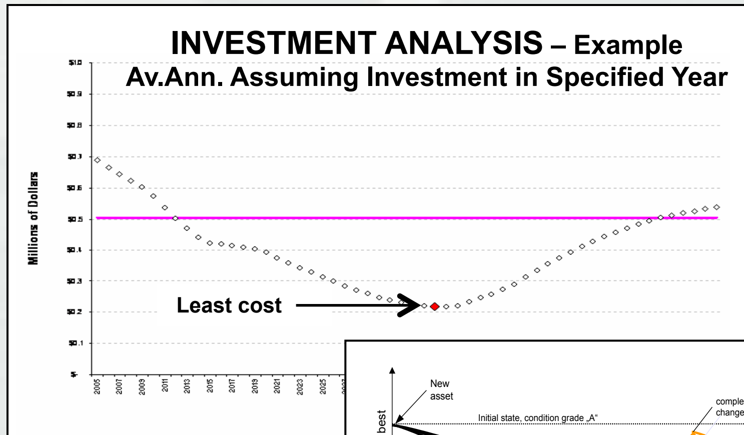
Models / Calculations: **Navigation Investment Model (NIM)**

NIM Optimization Module Qualify & Compare Investment Options

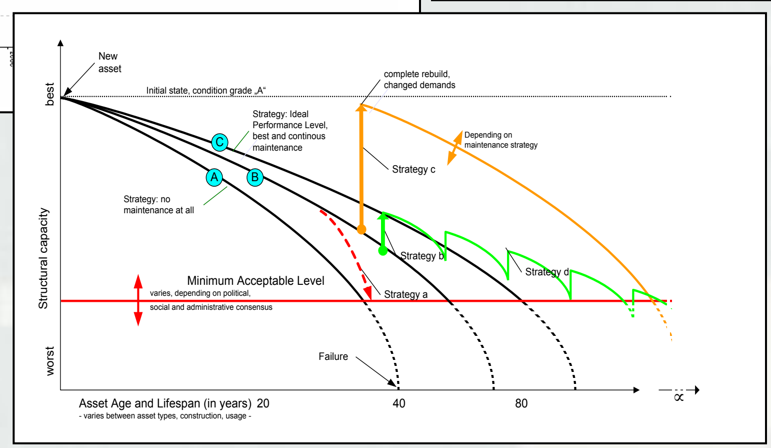




…systematically compares investments and selects the optimal investment strategy and summarizes the results.



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



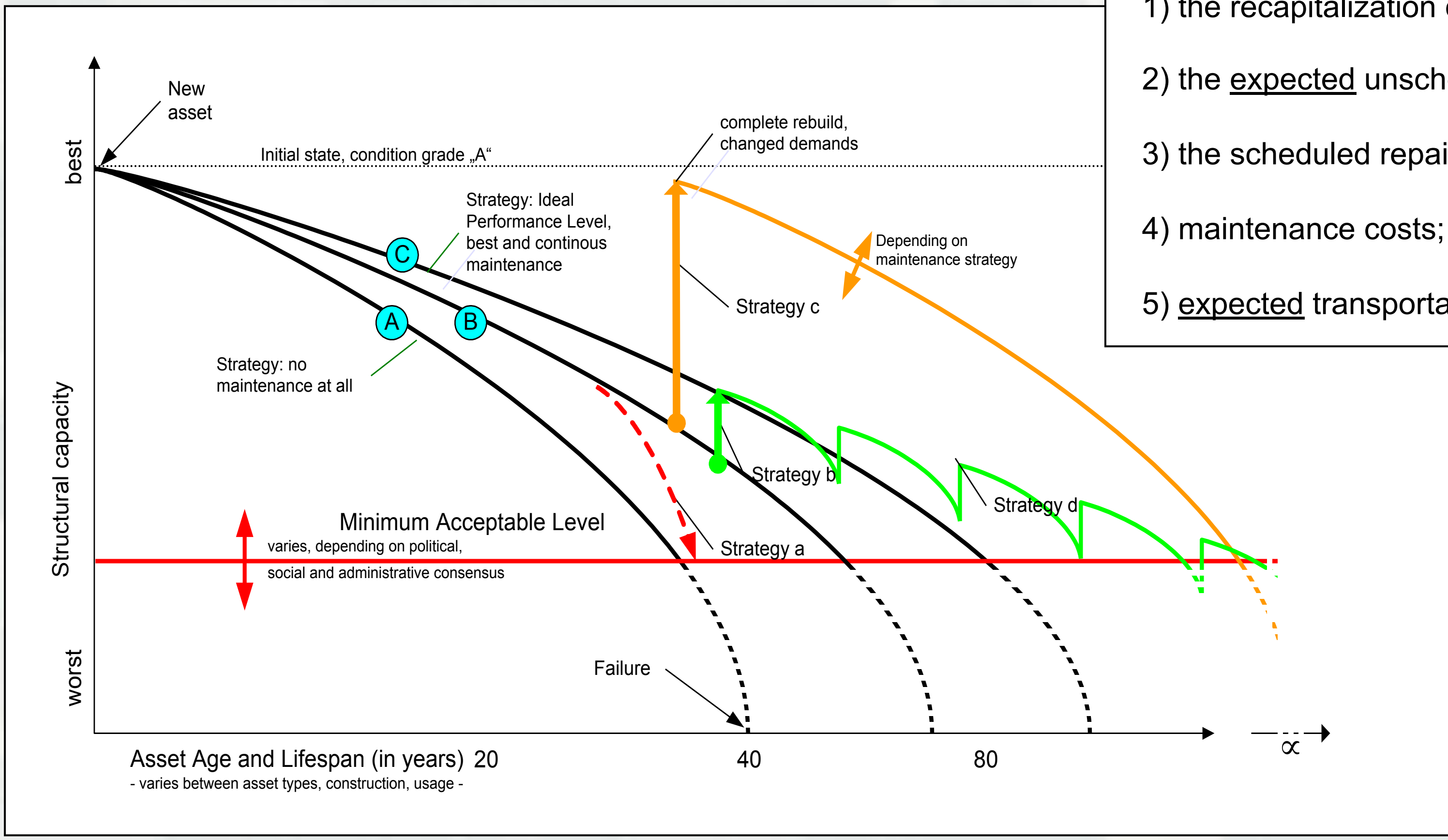
Models / Calculations:

Navigation Investment Model (NIM)

Quantify & Compare "Structural Capacity" Strategies

Investment Plan

1) the recapitalization cost (if there is one);
2) the expected unscheduled repair costs;
3) the scheduled repair costs;
4) maintenance costs; and
5) expected transportation impact costs etc.



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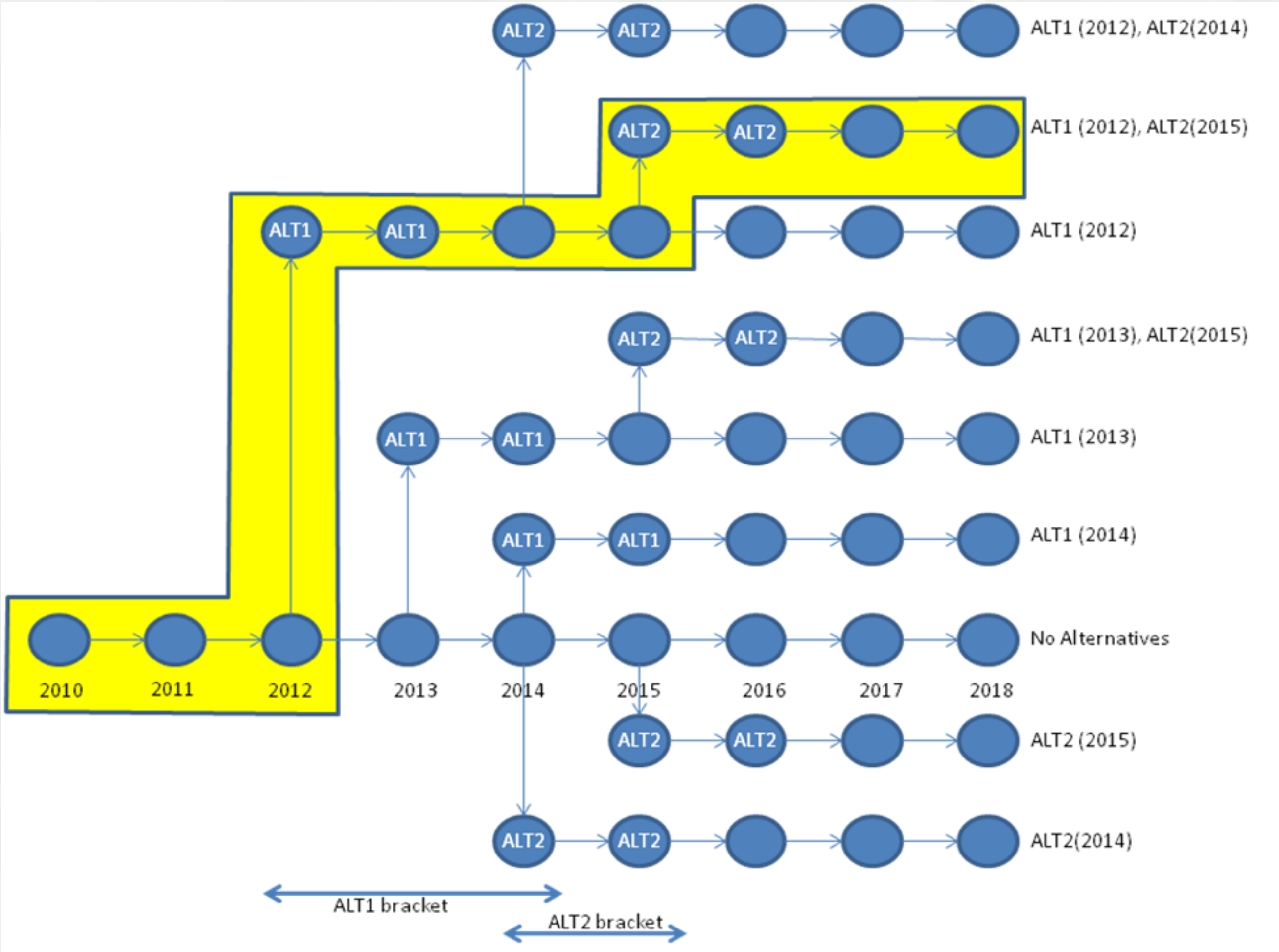
Navigation Investment Model (NIM)

NIM Optimization Module Qualify & Compare Investment Options



Outputs :

Navigation Investment Model (NIM)

(Millions of dollars, Average annual 3.75% discount/amortization rate, 20

Elastic Movement-Level Demand, NIM Selected Water

ITEM	Without-Project Condition (Alt.6 Build-In-Place Floodgate) Cap.= 30.968M tons first cost = $75.410259			WIT			
				Alt. 2 New 75' x 1200' Cap.= 69.054M tons first cost = $328.050950			
	Forecast Scenario			Forecast Scenario			
	Low	Reference	High	Low	Reference	High	
Benefits							
Base Transportation Savings (no service disruptions) *	$ 1,429.2	$ 1,725.6	$ 2,104.2	$ 1,431.8	$ 1,728.4	$ 2,107.1	$
Reduced Surplus frm Scheduled Disruptions	$ (2.5)	$ (2.5)	$ (3.2)	$ (1.0)	$ (1.1)	$ (1.2)	$
Total System Benefits	$ 1,426.7	$ 1,723.1	$ 2,101.0	$ 1,430.7	$ 1,727.3	$ 2,105.9	$
Incremental System BENEFITS	na	na	na	$ 4.0	$ 4.3	$ 4.9	$
WOPC Cost Foregone - Constr	na	na	na	$ 3.2	$ 3.2	$ 3.2	$
WOPC Costs Foregone - Sch Repair	na	na	na	$ 1.7	$ 1.7	$ 1.7	$
WOPC Costs Foregone - Unsch Repair	na	na	na	$ -	$ -	$ -	$
WOPC Costs Foregone - normal O&M	na	na	na	$ 0.3	$ 0.3	$ 0.3	$
TOTAL Incremental BENEFITS	na	na	na	$ 9.2	$ 9.4	$ 10.1	$
Costs **							
With-Project Improvement Cost	$ -	$ -	$ -	$ 13.3	$ 13.3	$ 13.3	$
Scheduled Repair Cost	$ -	$ -	$ -	$ 1.1	$ 1.1	$ 1.1	$
Unscheduled Repair Cost	$ -	$ -	$ -	$ -	$ -	$ -	$
Normal O&M Cost	$ -	$ -	$ -	$ 0.3	$ 0.3	$ 0.3	$
Total System Costs	$ -	$ -	$ -	$ 14.6	$ 14.6	$ 14.6	$
Incremental COSTS	na	na	na	$ 14.6	$ 14.6	$ 14.6	$
INCREMENTAL Net Benefits	na	na	na	($5.4)	($5.2)	($4.5)	(
ALT. BENEFIT-COST RATIO (BCR)	na	na	na	0.63	0.65	0.69	

** Includes construction impacts. Only Alt. 4 and Alt. 6 have construction / implementation impacts to transportation.*
*** While NIM can track costs for each lock modeled in the system, only Bayou Sorrel costs have been entered.*
SOURCE: SUMMARY_BayouSorrel-Sys_noHR_2013-01-31.xlsx

Questions ?