SECTION 3 - SYSTEM ANALYSIS

INTRODUCTION

A system approach is required to evaluate the National Economic Development (NED) benefits of potential navigation improvements to the Gulf Intracoastal Waterway System. This analytical approach explicitly recognizes that individual locks are only components in a complete navigation system, and that alterations of the traffic processing characteristics of specific components will have impacts throughout the navigation system. The General Equilibrium Model described below is used to perform the systems analysis.

GENERAL EQUILIBRIUM MODEL RATIONALE AND METHODOLOGY

The General Equilibrium Model (GEM) is used to evaluate the existing conditions, the future without-project conditions, and the future conditions with alternative system configurations in effect. GEM is a tool used for the economic evaluation of potential changes to various components of a navigation system. The model estimates the total transportation costs, including congestion costs, incurred by individual movements desirous of using all or portions of a navigation system. System transport costs for these individual movements are then compared to the total transport costs of that movement via the least-cost alternative mode or alternative non-system water route. If the alternative means of transport has lower costs than water system transport for a given movement, then that movement is presumed to be diverted from the navigation system to the alternative mode/non-system route. This potential movement enjoys no transport cost reductions resulting from the navigation system. Conversely, movements enjoying less costly transportation on the navigation system are presumed to use the navigation system, realizing net savings of the difference between the costs of system transport and the next least costly alternative means of movement. The sum of all these transportation costs savings represents the total resource savings to the Nation attributable to the navigation system.

The navigation system transport costs are dependent on three general classes of parameters: first, the operating characteristics of waterway carriers and shippers; second, the operating characteristics of the navigation system itself; and, third, the physical traffic carrying capacities of the components of the navigation system. For the purposes of this study, the first two parametric classes are assumed to be fixed through time. This analytical effort focuses exclusively on the impact on the levels of navigation system transport costs of carrying capacity constraints at system locks.

For a given level of traffic, the greater the carrying capacity of the navigation system the lower the total unit transport costs. This is a consequence of decreased levels of congestion in the system, allowing potential movements quicker and more efficient transport from origin to destination. Hence, the navigation system transportation costs of individual movements are explicitly dependent on total system traffic. In other words, individual movement system transportation costs depend not only on the economics of each individual movement, but also on the levels of congestion on those portions of the transportation system used by each individual movement. The levels of congestion for each component of the navigation system are increasing functions of the total volume of traffic processed by each component of the system.

Each individual potential system movement is assumed to transit the navigation system if, and only if, it has economic incentive to do so. Here, economic incentive to use the navigation system means that a movement is assumed to use the navigation system if system transport provides the least cost total transportation costs including the congestion costs resulting from carrying capacity constraints.

The input requirements of the GEM model are as follows:

a. Individual Movement Data: For individual potential system commodity movements, this input requires a waterway routing vector (indicating which system locks the movement will transit if it utilizes the navigation system), the annual volume of the movement measured in kilotons (ktons), the gross transportation cost savings of the movement (defined as the difference between the total uncongested system transportation costs and the total transportation costs of the next least costly non-system alternative means of transit for that movement), and an indication of whether or not alternate system water routings are possible.

b. Congestion Costs: Costs per kton per hour of delay for each commodity movement at each system lock transited are inputs required by the GEM model. The model allows these costs to be input by aggregated commodity groupings for each system lock.

c. Lock Delay Parameters: Capacity in annual ktons and expected delay in hours per ton at 50 percent utilization for each lock in the system are required by the model. For solution, the model requires that delay be a monotonic nondecreasing function of tonnage. The configuration of the delay function used in the model is:

$$D = k * T / (C - T);$$ where

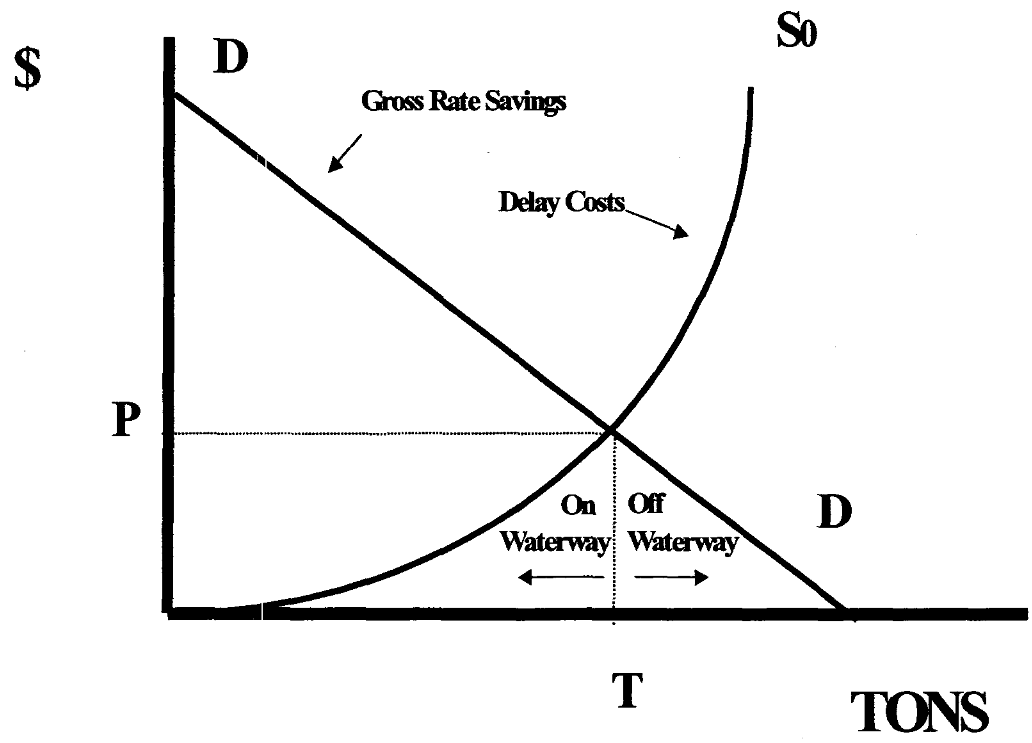
D = delay per ton in hours; k = delay per ton in hours at 50% utilization of capacity; T = annual lock tonnage; and C = annual lock capacity in tons.

To use this formulation, Capacity (C) and expected delay at 50 percent utilization (k), for each lock in the system, are required input parameters.

Output from the GEM model includes total system transportation costs including congestion costs, expected delay times at each modeled system lock, annual tonnages moved through each lock, and the net system transportation cost savings for each movement. The net system transportation cost savings are defined as the transportation resource cost savings attributable to the navigation system for that movement accounting for the effects of system congestion on system transportation costs.

Benefits for navigation projects consist of two distinct components: first, transportation resource cost savings to existing system traffic from reduced levels of systemic congestion; and, second, transportation savings over an alternative means of transport for movements now induced to utilize the navigation system because of the reduced total transportation costs. This idea is graphically demonstrated in Figure 3 - 1. The demand curve DD shows for each potential ton of commerce the difference between system total transportation costs (with no congestion costs) and the total costs of movement via the next least costly alternative non-system means of shipment. This difference is termed the gross cost savings of that ton's potential movement via the waterway system. The curve

Figure 3 - 1
Conceptual Model For
Waterway Economic Analysis



S0 represents the congestion costs incurred by each movement as different levels of tonnage transit the system. It is upward sloping to represent the notion that as more tons pass through the navigation system, greater levels of congestion occur, and, consequently, higher unit costs of transportation are incurred by each ton transiting the system. The system equilibrium congestion cost is given at P with tonnage of T actually transiting the system. All tonnage to the "left" of T find it still cheaper to move on the system than by the next cheapest alternative means, whereas all tonnage to the "right" of T find it economically more advantageous to use some non-system alternative. Hence, in equilibrium, T tons will pass through the lock and incur delay costs of P dollars.

Now, consider the impact of a system change (such as the installation of a new lock chamber at one lock) on the level of system traffic and shipping costs. Figure 3 – 2 illustrates the effect of the change and the measurement of resulting benefits.

The provision of the new chamber increases the carrying capacity of the system and reduces the unit cost of congestion for any given level of system traffic. The curve labeled S1 depicts the with-project relationship between system traffic levels and the reduced with-project levels of congestion. The new equilibrium level of traffic increases from T0 to T1, with a reduction in congestion costs due to the improvement from P0 to P1. The resulting benefits for this system change may be broken into two components: (1) the cost savings on the pre-improvement level of traffic, T0 x (P0 - P1) (the shaded area to the left of T0); and (2) the benefits to the new traffic that can now move on the waterway, [(T1 - T0) x (P0 - P1)] (the shaded triangle to the right of T0).

The difference in the total transportation costs between with and without-project conditions represents the NED benefits of the proposed inland navigation improvement.

The important analytical assumptions employed in this analysis are:

(a) Movements will divert from the waterway when the total system transport costs including expected congestion costs exceed the total costs of shipment via a non-system alternative means; and

(b) The expected levels of delay and traffic for each component for the system must be logically consistent with the delays and traffic computed for all other components in the system. This requires that the equilibrium calculation at all system locks take place simultaneously.

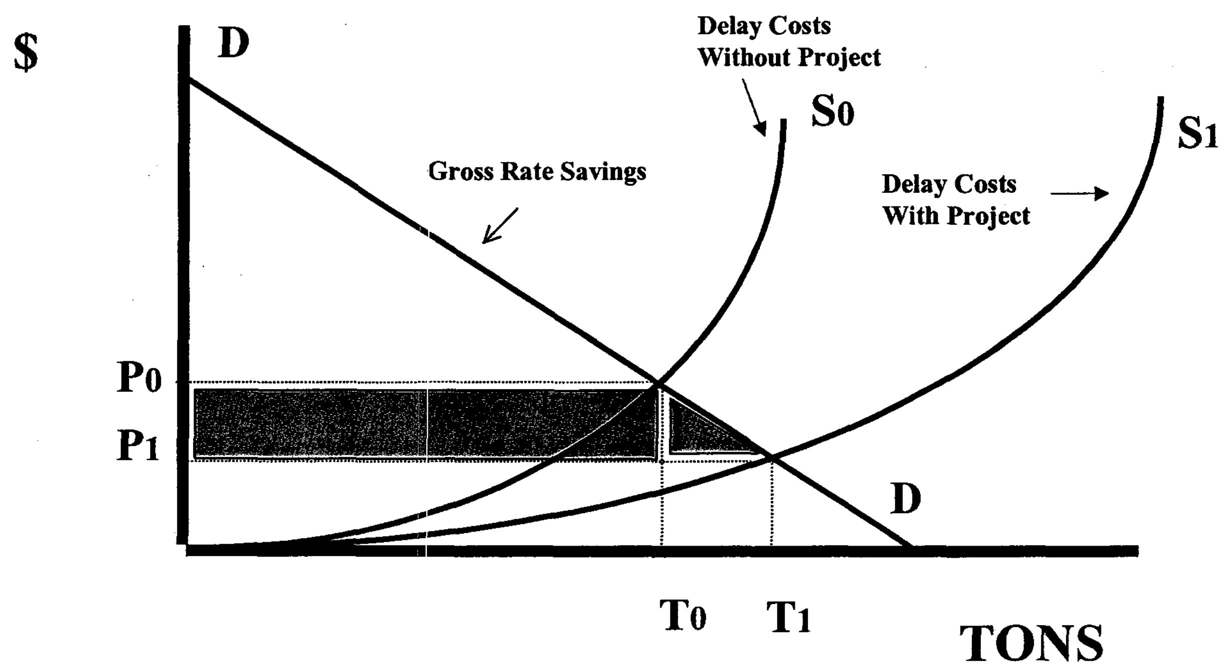
DATA REQUIREMENTS AND SOURCES

COMMODITY MOVEMENT DATA BASE

a. Transportation Cost Analysis: The benefits of a navigation improvement are computed as the difference between the transportation costs to the shipper by the various modes available to the shipper, hence the determination of transportation costs is of the highest importance in this economic study.

In brief, this process involved the development of transportation costs for a sample of movements,

Figure 3 - 2
System Benefits For Lock Improvement



which traveled any portion of the waterways within the defined system and represented a wide cross section of system movements.

The transportation costs were then expanded to the population of movements. This entailed several levels of matching sample movements to population movements based on common attributes. When a match occurred, the transportation costs associated with the sample movement would be applied to the population movement.

A more detailed discussion of the procedures and methods used in this analysis is contained in Section 4 of this appendix.

b: Alternative System Routes and Movement File Aggregation: Due to the configuration of the mainstem GIWW and the GIWW Morgan City - Port Allen Alternate Route, alternate water routings are possible for virtually all movements operating on the GIWW west of the Mississippi River and the IHNC.

The waterway "triangle" formed by the Mississippi River between Baton Rouge and New Orleans (approximately 130 miles), the mainstem GIWW between New Orleans and Morgan City (approximately 94 miles) and the GIWW Morgan City - Port Allen Alternate Route between Morgan City and Baton Rouge (approximately 64 miles) provides the basis for multiple routing possibilities for through traffic as well as for traffic that is strictly local. For a local movement, i.e., a movement with an origin or destination on the "triangle", transit can be achieved by two alternate water routes in addition to the original route. This is so because Port Allen, Algiers and Harvey locks all provide for access from the Mississippi River to the western GIWW. For a through movement, i.e., traffic moving between a point above Baton Rouge and west of Morgan City, in addition to Port Allen, Algiers and Harvey routings, the Atchafalaya River (an Old River lock routing) also represents a viable alternate route. The Atchafalaya River provides access between the Mississippi River at mile 304, approximately 76 miles above Baton Rouge, and the mainstem GIWW at Morgan City, a distance of approximately 123 miles.

The availability of these alternate routings is important for system modeling. As tonnage in the system increases over time, so will congestion costs. The likely result of increased congestion costs will be a change in the relative desirability of one route over another for at least some movements. If alternative routings are specified for each movement within the movement file, the model will be able to evaluate all possibilities and select a route based on the costs associated with each choice.

In an effort to control the size of the problem to be solved by the model, alternative routings were limited to those that represented the most reasonable candidates; however, all original routes that had potential alternate routes were provided at least one alternate. In constructing the system alternate routings the following rules were used. (1) For through movements using the GIWW Morgan City - Port Allen Alternate Route, one alternate was constructed, the Atchafalaya River. (2) For through movements using the mainstem GIWW via Algiers or Harvey Locks, two alternatives were constructed, one via Harvey Lock and the mainstem GIWW and the other alternate via Port Allen Lock and the GIWW Alternate Route. (3) For GIWW West movements with an original route including Port Allen, Algiers or Harvey Locks, two alternatives were constructed, one each involving the use of either Port Allen, Algiers or Harvey locks depending on the original routing. (4) For local movements with an original route not including Port Allen, Algiers or Harvey Locks, two alternatives were constructed, one each involving the use of Port Allen and either Algiers or Harvey Locks depending on the original routing.

The assignment of transportation cost to the alternate water routings was accomplished in the following manner. Barge costs per mile were calculated for all original movements having alternate routings. This barge cost per mile was multiplied by the mileage associated with the alternate route to produce an adjusted alternate barge cost for the alternate route. Given the mileages of the original routing and the associated alternate, the adjusted alternate barge cost could be higher or lower than the original route barge cost. Using the alternate route barge cost and the same least cost non-system alternative associated with the original movement (since this in unchanged for the system alternate), the transportation cost savings for the system alternate route was computed.

When all alternative routings were constructed, the movement file consisted of 18,944 total records representing 8,081 original movements.

The next step in the development of the movement file was to aggregate the file to a level more suitable for the analysis. Reducing the size of the movement file lowers the level of complexity that a large number of records can create for modeling purposes. To accomplish this, while still maintaining a level of detail necessary for realistic traffic routing, movements with common origin Port Equivalent, destination Port Equivalent, 10-group commodity code and system lock usage were aggregated into individual movements, with their transportation rates becoming a weighted average figure. The result of this process was a movement file that consisted of 7,102 total records representing 3,126 unique movements.

To further improve the efficiency of model operation, records of less than 1,000 tons, generally less than one full barge load, were deleted from the file as well as those movements where a non-water mode of transport was costed less than the original water mode. The total number of records deleted was 848 records. Removing these movements only reduced lock system tonnage by approximately 775,000 tons representing 0.1 percent of original movement tonnage.

c. Future Traffic Levels: From the final movement file, additional movement files were constructed to estimate future traffic demands by applying commodity group specific high, medium and low annual growth rates, to the 1992 movement tonnages. The medium annual rates of growth were used to generate the most likely future system traffic demands at system locks.

CONGESTION COSTS

At this point, the transportation cost savings estimated for each of the movements in the WCSC database include any congestion costs movements may have encountered as they traveled through the modeled locks. However the GEM requires these gross savings to be delay free, as the model itself calculates these costs. As a result an adjustment needs to be made to these estimates before proceeding any further.

To make the adjustment to gross savings estimates it is necessary to calculate a costs per hour of delay. There are three components that comprise the commodity-specific hourly delay costs at system locks. These components are barge cost, towboat cost, and commodity or inventory cost.

The first component, barge cost, is determined by the tow sizes and barge types employed in the movement of specific commodities. Tow size and barge type affect delay costs due to the differing capital and operating costs of the distinct equipment.

The average number of barges per tow for each commodity type transiting each lock was estimated and hourly barge costs for covered hopper barges, open hopper barges, and tank barges were used for the appropriate commodity groups in determining average barge costs per ton. Hourly barge costs were obtained from the Corps of Engineers Institute for Water Resources shallow draft vessel costs for Fiscal Year 1997.

The second major factor in estimating delay costs is the hourly cost of the towboat. The hourly cost of the towboat is directly related to its horsepower. Therefore, average towboat horsepower for each commodity type transiting each system lock was estimated and the operating costs were obtained from the Corps of Engineers Institute for Water Resources shallow draft vessel costs for Fiscal Year 1997. A significant adjustment to full towboat operating costs was necessary to more accurately estimate towboat costs accrued while waiting. Full operating costs are inappropriate for measuring delay costs since full costs contain a fuel component that reflects underway operations. To adjust for this, the fuel component of towboat costs was reduced by 75 percent to more accurately reflect the costs of tows idling while waiting to lock through.

Using this information, an average tow operating cost was determined for each system lock for the ten commodity groupings used in this analysis.

The final component of the hourly cost of delay is commodity or inventory costs. These costs are typically such a small percentage of tow operating costs (less than 1 percent) that they have been ignored in this analysis.

For each of the ten commodity groups, barge and towboat cost per tow hour of delay were converted to costs per ton per hour by using average tons per tow. The final step in calculating cost per ton per hour of delay was to adjust for the empty backhauls of dedicated movements. The commodity mix of traffic on the GIWW is heavily weighted towards crude petroleum, refined petroleum products, and chemicals. For these commodities it was assumed that all traffic has empty backhauls. As such, delay costs are incurred twice, once with loaded barges and once with returning empty barges. The cost per ton per hour of delay was therefore doubled to reflect the empty backhaul. A 70 percent empty backhaul was assumed for the rest of the commodities so that delay costs are incurred 1.7 times, therefore the cost per ton per hour of delay was multiplied by 1.7 to reflect the appropriate level of empty backhaul. These calculations represent the estimates utilized by the GEM as it calculates lock congestion costs for each movement transiting each system lock. These hourly cost per kiloton by commodity and lock are shown in table 3 - 1.

In order to calculate delay free gross cost savings for each of the movements in the WCSC file, the original water transportation cost estimates were decreased (which increased the gross cost savings) by the product of these hourly wait cost per ton estimates and the average delay per hour the movement had to incur as it traveled through the modeled locks from its origin to destination.

Table 3 - 1

Hourly Costs of Delay for Commodities at System Locks (Dollars per 1,000 Tons)

Commodities	Old River	Port Allen	Bayou Sorrel	IHNC	Algiers	Harvey	Bayou Boeuf	Leland Bowman	Calcasieu
Farm Products	56	59	56	50	59	59	56	56	56
Metallic Ores	47	50	47	50	50	50	47	47	47
Coal	47	50	47	50	50	50	47	47	47
Crude Petroleum	46	48	46	48	48	48	46	46	46
Non-Metallic Minerals	42	46	42	46	46	46	42	42	42
Forest Products	42	45	42	45	45	45	42	42	42
Industrial Chemicals	76	81	76	81	81	81	76	76	76
Agricultural Chemicals	64	70	64	70	70	70	64	64	64
Petroleum Products	46	48	46	48	48	48	46	46	46
Miscellaneous	61	66	61	66	66	66	61	61	61

LOCK CAPACITY AND DELAY ANALYSIS

Essential to the economic analysis of improvements to the lock structures on the navigation system is the ability to quantify the relationship between tonnage moving through a lock and the resulting delays at the lock. In this study, a simulation analysis, which can detail any number of specific operational practices on the traffic – delay relationship, was employed for this purpose. The discussion of this analysis can be found in Section 5.