CALCULATING THE VALUE OF UPPER MISSISSIPPI RIVER NAVIGATION: METHODOLOGICAL REVIEW AND RECOMMENDATIONS

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1. Introduction and Executive Summary

1.1 Research Motivation

Efficient transportation policy requires that responsible policy-makers expend federal funds for the construction and maintenance of competing infrastructures based on the relative benefits potential projects will provide to the national economy. Thus, in order to evaluate the desirability of proposed navigation improvements to the upper Mississippi's system of navigation structures, it is necessary to assess how the proposed improvements might impact the costs incurred by the shippers of goods to, from, and within the region.

In a simple setting, developing hypothetical policy-induced scenarios to compare with baseline forecasts is, at best, tedious work. The upper Mississippi basin inland navigation system, however, is not a simple setting. Instead the billions of ton-miles of barge transportation observed each year represent a fragile confluence of immense and disparate economic forces. Any policy decision that materially alters relative transport costs will simultaneously lead to many economic actions and reactions that may, in turn, significantly alter barge traffic volumes.

The complexity of upper Mississippi transportation and its role in a remarkably diverse set of related transport and product markets mandates analytical structures and empirical techniques that extend well beyond the traditional methods used to calculate navigation project benefits in simpler settings. Specifically, it is essential that study methods preserve the myriad economic relationships that lead to currently observed commodity flows. Any defensible long-run analysis of upper Mississippi barge traffic must include a more careful accounting for both spatial and product substitutes than has typically occurred in similar studies.[1]

In response to the challenges posed by the Upper Mississippi River, Illinois Waterway Navigation System Feasibility Study economic analysis, U.S. Army Corps of Engineers (Corps) personnel have significantly modified the analytical framework in which the Corps' principles and guidelines are applied. The new framework successfully embodies the economic relationships alluded to above. In its current form, however, the methodology requires data describing demand relationships that are not immediately available. Without these demand data, it is not possible to produce practical estimates of project benefits. Thus, additional analytical measures are necessary to bridge the gap between current model requirements and available information. It is this need that has given rise to the current investigation.

In response to the informational needs fostered by the upper Mississippi study, the Center for Business and Economic Research (CBER) at Marshall University, in conjunction with Bicentennial Volunteers Incorporated, has agreed to investigate the nature of transportation

[1] Any specific consideration of the impacts of the upper Mississippi study on future studies elsewhere is beyond the scope of the current analysis.

demands in the upper Mississippi River basin and to provide additional information where available. Specifically, CBER has:

I. Conducted a thorough theoretical review of methodologies currently used within the upper Mississippi economic analysis;

II. Developed additional information, where possible, to supplement currently available data; and

III. Combined existing information with data developed under Task II to yield recommendations of specific input values to be used in subsequent calculations of upper Mississippi navigation project benefits.

1.2 Summary of Findings – Modeling Efforts

In the course of the upper Mississippi analysis, there has been considerable discussion of the appropriate theoretical treatment of economic consequences of potential changes in transportation costs. These discussions have been extended to also consider how the theoretical treatment might be translated into reliable empirical estimates to be used in further calculations. At the heart of these discussions lie a theoretical model and an empirical counterpart both developed by the Corps' St. Louis District. The theoretical construct is referred to as the *Spatial Equilibrium Model* or (SEM). The empirical companion model is referred to as the *Inland Navigation Excel Spreadsheet Spatial Equilibrium Nascent Concept Execution* or (INESSENCE). Within the current document, the SEM and the INESSENCE will be referred to collectively as the St. Louis Model.

The St. Louis Model represents a significantly more complex approach to the calculation of navigation project benefits than has typically been evidenced in similar studies. Specifically, in the case of non-grain commodities, it allows for the quantities of barge transportation demanded to decline as barge rates increase well in advance of any modal substitution. Similarly, in the case of grain movements, barge traffic is allowed to decline gradually as barge rates increase rather than being held constant up to the point where all traffic is lost to some transportation alternative. Additionally, the St. Louis Model can be modified to incorporate the impacts of industry self-help or the imposition of congestion tolls.

The demands for the movement of all commodities are “derived” from the role the commodities play in subsequent production processes. Consequently, the incremental declines in the demand for barge services associated with increased barge rates are driven by the profit-maximizing behavior of the firms that use the shipped commodities in subsequent production. Profit-maximizing behavior – under any market structure – predicts that producers will base output quantities on the demand for their products and the prices of the inputs necessary to the production process. Thus, even though a producer may continue to source an input from the same location in the face of increased barge rates, the increase in barge rates will typically lead that producer to reduce output quantities and, thereby, the quantity of barge transportation demanded.

In application, the St. Louis model utilizes a parametric demand construct for all commodities. Demand curves are defined for each origin-destination-commodity triplet and are anchored by the observed rate/quantity combination and the point on the vertical axis that corresponds to the next-best alternative transportation price. These curves can then be made convex or concave depending on the parametric value that is appropriate . Parametric values less than one result in concave demand curves; values equal to one produce linear demand curves and values greater than one yield convex demand curves.

In the case of grain movements, barge traffic is gradually lost to other transport modes and/or destinations because of the spatial proximity of farm production to navigation facilities. This clearly suggests that the anchor points employed in the St. Louis Model are appropriate so long as the best alternative price is effectively captured and assuming that there is no local constraint on the maximum distance over which grain can be drawn to the river. With regard to the concavity or convexity of demands, a circular drawing area and constant motor carrier rates would suggest an exponent value of 2.0. However, for reasons discussed below, it may be desirable to modify this value slightly.

In the case of non-grain commodities, the demand construct currently embodied within the St. Louis Model may or may not fully capture the relationship between barge rates and the quantities of barge transportation demanded in various markets. Specifically, the model's vertical intercept – clearly supported in the case of grain -- is more suspect when the relationship between rates and quantities demanded is dependent on downstream production decision rather than distance between production and the river. Likewise, even if the currently employed intercept is appropriate, the absence of any significant variation in the proximity of producers to the river makes the determination of the appropriate parametric value more difficult. Ultimately, in the case of non-grain commodities, the shapes of the derived demands for barge transport are an empirical rather than theoretical matter.

1.3 Summary of Findings – Development of Additional Information

As indicated above, in the case of non-grain commodities, the St. Louis Model requires specific information detailing demand relationships in order to generate the set of empirical estimates necessary to carry the analysis forward. Ideally, this would be addressed through the simultaneous estimation of long-run demands for motor carrier, rail, and barge transportation. Unfortunately, the data necessary for such an analysis are currently unavailable. It was, however, possible, to use existing data to shed *some* additional light on the nature of the demand for the barge transport of non-grain commodities. Specifically, data describing the relationship between observed railroad rates and quantities demanded were used, in combination with other data, to estimate short-run derived demands for rail transport. With some significant assumptions, it is possible to combine the estimated derived demands for rail transport with observed barge rate and quantity data to obtain a rough approximation of short-run barge demands. Estimated short-run own-price elasticities for railroad transport are reported in Table 1.1 along with estimates of the elasticities of demand, with respect to proximity to available barge transport.[2] The methods used to obtain these estimates are fully described in Section 4.1.1 and the means by which they may be applied to develop approximations of short-run barge transport demand curves are detailed in Section 4.1.2.

Finally, economic theory suggests that long-run demands for transportation are likely to be more price-elastic than short-run demands. Consequently, NED estimates based on short-run demands would probably overstate the actual value of new facilities. In the current setting it is not possible to remedy this deficiency empirically. It is possible, however, to at least identify the magnitude of the potential bias in the case of one commodity relative to that bias in the case of other commodities.

[2] Own-price elasticity is defined as the percentage change in the quantity demanded of a good given some percentage change in that good's price. More generally, any elasticity is defined as the percentage change in one variable given some percentage change in some related variable. Thus, the elasticity of rail quantity demanded with respect to

Table 1.1

SHORT-RUN ELASTICITIES OF DEMAND FOR RAIL TRANSPORT

Commodity Group	Own-Price Elasticity of the Demand for Rail Transportation	Elasticity of Demand for Railroad Transportation with Respect to Origin Distance to Water	Elasticity of Demand for Railroad Transportation with Respect to Destination Distance to Water
Metallic Ores	-0.9889		0.0474
Coal	-0.7655	0.0959	0.0287
Non-Metallic Minerals	-0.8126	0.0266	
Food & Kindred Prd.	-0.5035	0.0074	0.0079
Lumber and Wood Prd.	-0.6635	0.0093	0.0090
Chemicals	-0.3380	0.0046	0.0058
Petroleum Prd.	-0.6903	0.0106	
Rubber and Plastics	-0.4387	0.0282	0.0287
Stone and Glass Prd.	-0.7021	0.0145	0.0134
Primary Metal Prd.	-0.5516	0.0097	0.0104
Fabricated Metal Prd.	-0.5539	0.0355	0.0302
Scrap Materials	-0.6565	0.0098	0.0096

Note: Blank cells indicate that estimate was insignificant at a 90% confidence level

Accordingly, efforts were made to estimate the longevity of capital in various production processes. The estimates were then used to rank commodities according to whether the inclusion of long-run considerations would produce more or less of a computational bias. These rankings appear in Table 1.2.

1.4 Summary of Findings – Recommended Values

The upper Mississippi analysis can only proceed when NED benefit values have been calculated. This, in turn, requires specific estimates of the functional relationship between the own-price and the long-run quantity of barge transportation demanded within each market considered by the investigation.

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origin or destination distance to water simply measures how responsive rail quantities are to available navigation.

Table 1.2

RELATIVE LONGEVITY OF CAPITAL

Industry	Relative Longevity of Capital (High to Low)
Electric Utilities	1
Petroleum and Coal Products	2
Primary Metal Industries	3
Printing and Publishing	4
Fabricated Metal Products	5
Food and Kindred Products	6
Lumber and Wood Products	7
Chemicals	8
Paper and Allied Products	9
Stone, Clay, and Glass Products	10
Rubber and Plastic Products	11

For grain, the empirical specification embodied within the St. Louis model is appropriate in its current form. To the extent that time may allow, it may be useful to revisit the prices of the best transport or marketing alternatives that form the intercept for barge transport demand curves. It should be observed, however, that variations in these values impact NED calculations less than it would first seem, so that any examination that entails significant monetary or temporal costs may not be justified.

Regarding the parametric value that determines the concavity or convexity of the demand curves, strict mathematics would imply a value of 2.0. However, agricultural experts elicited by the Corps could only concur that appropriate actual values probably are between 1.0 and 2.0. Given no theoretical or empirical reason to do otherwise, the current analysis recommends that a value of 2.0 be used as the exponential value in subsequent simulations.

For non-grain commodities, estimates of the derived demands for railroad transportation can be used in a variety of ways to supplement the current methodology. At the very least, these demand curves further restrict the area in which the long-run demands for barge transport can actually lie. Used in this fashion, the railroad demand elasticity estimates limit the parametric values to some minimum without necessitating any modification in the structure of the St. Louis model.[3] This approach makes the most conservative use of the estimated demands for rail transport.

Alternatively, as described in Section 4.1.2, with the appropriate simplifying assumptions, it is possible to modify the structure of the St. Louis model so that estimated rail demands can be used, in conjunction with barge price/quantity data, to directly approximate demand curves for barge transport. This latter approach would yield much more specific estimates of the demands for barge transportation. It does, however, represent a significantly more aggressive use of the rail demand estimates. This approach would also require modifications to the St. Louis Model that make it modestly more restrictive in its economic assumptions. Ultimately, it is the author’s judgement that the more conservative application is the most defensible.

1.5 Cautions and Caveats

The development and application of the St. Louis Model in the assessment of project benefits in the upper Mississippi basin is a watershed event in the arena of transportation policy-making. As might be expected, however, the adoption of a new and significantly different

[3] Specifically, the estimated derived demands for rail transport are based on a construct that implies a constant elasticity of demand for each demand curve. The demand curves embodied with the St. Louis Model feature a constant exponential parametric value that allows elasticities to vary throughout the length of any given demand curve. In the case of non-grain commodities, it is not clear that one form is superior to the other. It should be noted, however, that allowing elasticities to vary is less restrictive.

methodology, has lead to a number of uncertainties and misunderstandings in its initial application.

The results and economic theoretical foundations of the St. Louis Model are demonstrably superior to similar results obtained under other methodologies both from a theoretical and an empirical standpoint. However, these results could be improved through the development of additional data. The Model requires large volumes of, heretofore, unnecessary information about specific demand relationships and this requirement has proved to be problematic for analysts.

The explanations, research, and recommendations contained in the remainder of this document are intended to remedy the paucity of empirical information that has plagued the initial application of the St. Louis Model. Current efforts should not, however, be viewed as providing definitive results that will stand unaltered through future applications. To the contrary, the application of the St. Louis Model in the upper Mississippi basin clearly points to the need for additional research in the areas of spatial equilibria and transportation demands.

2.Theoretical Basis

Like all input demands, the demand for transportation service is derived from the demand for the shipped commodity in subsequent production processes. It is, therefore, possible to use traditional microeconomic theory as a basis for formulating and estimating transport demand functions, so long as the spatial nature of transportation is incorporated within any analytical framework.

Within the current framework, it is also important to distinguish between the short-run demands exhibited by shippers who face a limited range of transportation / production alternatives and the long-run demands evidenced when shippers may choose to relocate or discontinue production.

The remainder of this section provides an overview of the economic principles that are applicable to the development of barge transport demand curves in the Upper Mississippi basin. This includes a full exposition of derived demand and a lengthy discussion of spatial equilibria.

2.1 Optimal Transportation Use and Derived Demand[4]

The demand for transportation service in any particular market is comprised of the individual demands of the shippers who participate in that market. These individual demands, in turn, reflect the attempts of shippers to maximize some stream of current and future firm profits.

[4] The discussion of derived demand is based on the treatment of this topic within Walter Nicholson, Microeconomic Theory: Basic Principles and Extensions, Sixth Edition, Dryden Press, 1995.

A demonstration of the relationship between profit maximization and factor demands is relatively simple. Imagine a firm that uses variable quantities of two inputs T and F to produce variable quantities of some output, Q that it then sells at a market price of P. Let T be a transportation input and F be some other composite input. The firm's profit function may be specified as:

$$\pi = P(Q) \times Q - C(Q)$$

Where P(Q) reflects the demand for the firms output and C(Q) represents the cost of producing various quantities of that output. Further, Q is a function of inputs T and F which the firm purchases at P_T and P_F. Assuming well behaved functional forms, there is an optimal (cost minimizing) combination of T and F for every quantity Q that is determined by the manner in which T and F can be combined in production and the respective prices of these two inputs. Consequently it is possible to re-specify the profit function as:

$$\pi = \pi(P, P_T, P_F)$$

This is commonly referred to as the indirect profit function. It embodies the same relationships evident in the direct profit function, but makes explicit the fact that the magnitude of profits available to the firm in any time period is a function of the price it can attain for its products and the prices it must pay for its inputs. Assuming that there is some maximum level of profits per time period, this maximum (π^*) can also be expressed as a function of input prices and the price of the firm's output. That is.

$$\pi^* = \pi(P, P_T, P_F)$$

Finally, a very powerful application of the envelope theorem known as Hotelling's Lemma makes it possible to recover the demand for the two factors, T and F from the indirect profit function. Specifically,

$$\frac{\partial \pi}{\partial P_T} = -T^*(P,\ P_T,\ P_F)$$

and

$$\frac{\partial \pi}{\partial P_F} = -F^*(P,\ P_T,\ P_F)$$

are the negatives of the two factor demand functions, so that it is possible to identify the derived demand for transportation that stems from the profit maximizing process (T*) where:

$$T^* = T^*(P, P_T, P_F)$$

While there is nothing novel about this derivation, the link between profit maximization in output markets and the price of inputs has powerful implications within the current context. Specifically, profit maximizing behavior, in the face of an input price increase, forces producers to consider reducing output quantities and the quantities of inputs demanded as well as evaluate opportunities for factor substitution. Within the current example, where no transportation substitute is available, this implies that an increase in P_T would lead to a reduction in Q, F, and T. In short, the derived demand curve for T is downward sloping.

2.2 Short-Run Substitutes

The spatial nature of transportation, combined with the assumption of profit maximization described in Section 2.1, yields derived demands for transportation that are significantly more complex than the demands for other productive inputs. In particular, the demand for transportation within a specific market is often affected by available transportation to and from alternative locations. Thus, while there are product substitutes for most physical factors of production, opportunities for spatial substitution add a dimension to transport demands that is absent in most other factor demands.

The availability of spatial substitutes greatly complicates the decisions that shippers must make and their resulting demands for various transportation services. The combined effect of product and geographic substitutes on the demands for transportation is underscored by a representative example. Low sulfur, low Btu coal is shipped by rail from the Powder River Basin (PRB) of Wyoming and Montana to a number of electricity generating facilities throughout the mid-west. Based on Section 2.1, one would expect that the demand for the transportation of Powder River coal is a function of the mine-mouth coal price, the price the generating firm receives for its electricity, and the price of railroad transportation. These factors do, in fact, directly affect the quantity of coal transported from the Powder River basin in any given time period, but this quantity is also affected by the availability and pricing of spatial substitutes.

Low sulfur coal with a higher Btu content is mined in Colorado and Utah. This coal has a higher mine-mouth price and is more expensive to move by rail to mid-western locations, but the higher Btu content also makes it more productive in the process of generating electricity. Similarly, the coal mined in the central Appalachia has a relatively low sulfur content and high Btu content. Like Colorado and Utah coal, central Appalachian coal is relatively expensive to mine and to transport by rail, but it is also more productive than Powder River coal. Additionally, unlike western coal, central Appalachian coal can often be transported by barge.

In this example, there are potential spatial and modal substitutes. It may also be possible for the producer to substitute fuel oil or natural gas for coal – particularly in a long-run setting. All such substitutes can affect the profit-maximizing decisions of the power producer in this example. Therefore, the price of each of these substitutes may affect the profit-maximizing quantity of Powder River coal and, therefore, serve as an argument within the derived demand for the transportation of PRB coal.

Section 2.1 makes it clear that, by affecting profit-maximizing output quantities, changing transportation prices can lead to changes in the quantity of transportation demanded - even when there is no opportunity for substituting another form of transportation. It is also clear that the potential substitution of alternative carriers, modes, routings, or products is of paramount importance to the proper treatment of the demand for transportation services.

2.3 The Short-Run / Long Run Distinction

The example described above considered possible modal, spatial, and product substitutes that might require the producer in question to modify its production process and desired level of output. Thus, one might reasonably question the effects of these substitutes on the short-run demand for transportation. Efficient policy-making requires, however, that the costs used to evaluate navigation project benefits be those costs observed in a competitive long-run equilibrium. In addition to increasing the number of potential product, modal, and spatial substitutes available to producers, this necessary long-run vantage has further implications for the derived demands described in Section 2.1.[5]

In the short-run, the quantities of some inputs are, by definition, fixed. Typically, this fixed capital is embodied in the firm's physical plant found at specific geographic locations. In the long-run, producers can modify physical facilities to accommodate alternative modes of transport or modify production processes to use different commodity inputs or, if they desire, do both.[6] There are also two additional alternatives available to firms in the long-run. First, they may choose to cease production altogether. Second, and more importantly, in the long-run, firms may elect to place necessary new capital in an alternative location that provides them better access to input and output markets.

Within the context of the Section 2.1 discussion, imagine that at some point in time, the profit-maximizing seller suddenly has a set of transportation prices over which to make its decision and that each of the elements in this set or vector of prices represents a different location decision. The producer now must choose its output quantity, input quantities, <u>and production location</u> based on the price of the composite

[5] In addition to being long-run in nature, the competitive costs described here are also: 1) forward-looking; 2) based on least-cost technologies; 3) incremental; and 4) traceable to underlying causes. See *<u>Reconciling Prices and Costs in NED Benefit Calculations</u>*, U.S. Army Corps of Engineers, Huntington District, September, 1997.

[6] It is tempting to suggest that the modification of facilities represents a cost that should be included in the calculation of project benefits. It would, however, be inappropriate to do so. In the long-run, if the producer wishes to continue production, it will have to replace existing facilities. Thus, the only relevant question is whether replacing current capital assets with facilities that can accommodate other modes or commodity inputs is more or less costly than duplicating current facilities.

input factor, expected output price, and the various transportation prices available at alternative locations.[7]

To summarize, the relationship between the quantity of transportation demanded from a particular mode and the prices various modal providers can charge is derived from the long-run profit-maximizing decisions of shippers and is, therefore, affected by:

- The price of the “downstream” product for which the shipped commodity is an input;
- The pricing of other inputs used in the “downstream” production process;
- The availability and pricing of modal substitutes;
- The availability and pricing of transportation alternatives over different origins and destination pairs;
- The availability and pricing of substitute inputs; and
- The long-run locational alternatives available to the producer.

Attention to each of these factors is important to both the theoretical and empirical treatment of transportation demands in the Upper Mississippi River basin.

2.4 Freight Transport in the Upper Mississippi Basin

While containing a few specific examples, the theoretical discussion, to this point, has be sufficiently broad to allow application to any freight transportation setting. There are specific conditions observable in the

[7] The process of intertemporal profit-maximization is actually far more complex than represented here. For a comprehensive discussion of intertemporal optimization techniques see: Morton I. Kamien and Nancy L. Schwartz, Dynamic Optimization: The Calculus of Variations and Optimal Control in Economics and Management, 1981, North Holland .

upper Mississippi basin that allow further modifications to the theoretical constructs offered so far. Treatment of these specific conditions helps to ensure that any ensuing estimates of transport demands are as accurate as possible.

2.4.1 Grain Transportation

Grain – particularly corn and soybeans – is the commodity that is transported most frequently on the upper reaches of the Mississippi River. In fact, in 1997, roughly 50% of all commercial navigation ton-miles reflected grain movements.[8] The importance of this commodity group, combined with the highly variable, highly versatile structures of the markets in which grain is transported and consumed, makes the effective treatment of this commodity group essential within the current context.

Because the production of grain occurs, more or less evenly, over an extraordinarily large space, it must be gathered over this space for subsequent use. This gathering process imposes costs that are fundamental to any treatment of the demands for rail and barge grain transport. Specifically, rail loading facilities and opportunities for local use are much more evenly dispersed throughout the principal grain-producing regions of the U.S. than are the locations at which grain can be loaded to barge. Thus, while the line-haul costs for barge transport are usually significantly lower than line-haul costs over some alternative mode, the competitive influence of commercial navigation and the benefits it confers to barge users are limited by the relatively high cost of transporting grain to the river.

Generally, grain will be gathered to one of three locations – a location where it can be processed or consumed locally, a location where it can be loaded for rail shipment to a final market, or a location where it can be

[8] Though technically inaccurate, grain is here defined to include soybeans.

loaded to barge. The combined gathering and shipping costs for these three alternatives can be specified as:[9]

$$C(\text{Local}) = \sum_{d=0}^{D} Q_d(T)d$$

$$C(\text{Rail}) = \sum_{d=0}^{D} Q_d(T)d + (R)\sum_{d=0}^{D} Q_d$$

$$C(\text{Barge}) = \sum_{d=0}^{D} Q_d(T)d + (B)\sum_{d=0}^{D} Q_d$$

where:

- d = a specific distance from the gathering point;
- Q_d = the quantity of grain available at distance "d" from the gathering point;
- D = the maximum distance from the gathering point;
- T = the transport rate per unit distance "d" from the Gathering point;
- (R) = the railroad line-haul cost to final destination; and
- (B) = the barge line-haul cost to the final destination.

The demands for barge and rail transportation can be derived directly from these costs and the relative delivered prices for grain in final markets. Two points emerge immediately from this simple construct. First, in the absence of final market price differentials, all grain would be consumed in

[9] In a strict mathematical sense, because distances are continuous, the above specification is inappropriate. However, given that the empirical treatment that follows is based on one-mile distance increments, this specification is, nonetheless retained.

local use. Second, line-haul rates and maximum drawing distances “D” are bound to be inversely related. What is less clear, but vastly more important, is that Q_d is an increasing function of “d”.

To begin to see the emergence of a spatial equilibrium, imagine that there is no rail transportation and only a single river location where grain can be loaded to barge. Also assume that all grain can be consumed locally where grown at a value of P_L or sold in a barge-served market at price P_B. If the effective price available to producers favors local consumption for any positive distance “d” from the river, that is if:

$$P_B - \left[C(\text{Barge}) = \sum_{d=0}^{D} Q_d(T)d + (B)\sum_{d=0}^{D} Q_d \right] < P_L$$

then all grain would be consumed locally. If, however, either the market price P_B rose sufficiently or the transport prices (T) or (B) fell sufficiently to reverse the inequality, then some portion of grain produced would be loaded to barge. A small differential would produce a small drawing distance, D and a relatively large differential would produce a relatively large maximum drawing distance. This outcome is pictured in Figure 2.1.

In this figure, each circle surrounding the barge facility represents the maximum drawing area for a different value of $P_B - C(\text{Barge})$, where

$$P_B - C(\text{Barge}) > P_L$$

Again, what this figure does not necessarily make clear is that each time “D” is increased incrementally by an amount “d”, the total quantity moving by barge increases exponentially because of the two-dimensional nature of the drawing area.[10]

Figure 2.2 holds all variables constant except for (B), the line-haul cost of barge, then relates decreases in (B) to increases in the drawing area and in the quantity of barge transportation demanded. As the barge rate, (B) falls, at first, a trickle of grain is drawn to the river for barge transport. However, as (B) continues to fall at some constant rate and the drawing area increases at some constant rate, the demand for barge transport increases rapidly. Thus, in terms of own-price elasticity the demand for barge transport based on the current construct is very elastic at relatively high barge rates and very inelastic at lower barge rate levels.

Without belaboring this example, suffice it to say that the same general pattern of barge demand survives when there is more than one barge facility, when rail loading facilities are made available at off-river locations and, when local consumption is not confined to gathering points. [11]

The integration of these additional alternatives does, however, have implications for the shape of the drawing area surrounding each water facility. Specifically, where a rail market, local market, or alternative barge

[10] In the case where the drawing area is a circle, exponential growth takes a quadratic form. However, the collapse of a two-dimensional shape into a single point guarantees that the growth in total quantity will be exponential regardless of the shape of the drawing area.

[11] Local consumption need not be at off river locations, or locations without rail service so long as there is sufficient flexibility in local market prices. On-river processors or processors in rail-served areas could take as much local production as they desire, then allow any remaining grain to be shipped out of the area by barge or rail. This pattern of behavior would, however, necessitate measurable variations in P_L.

Figure 2.1

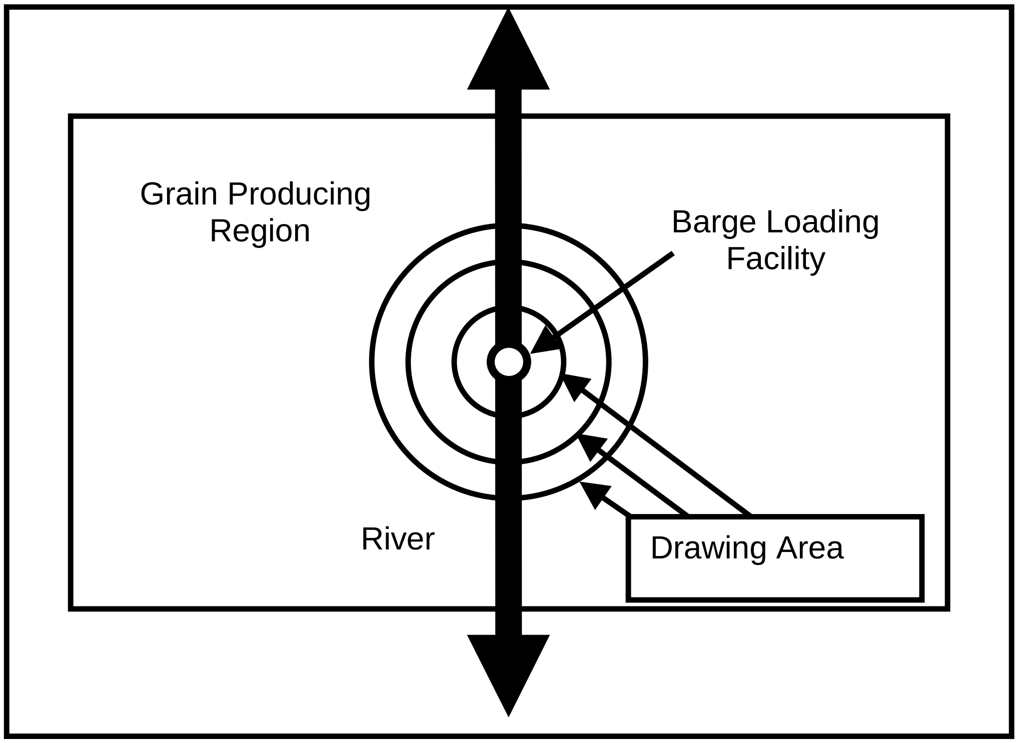
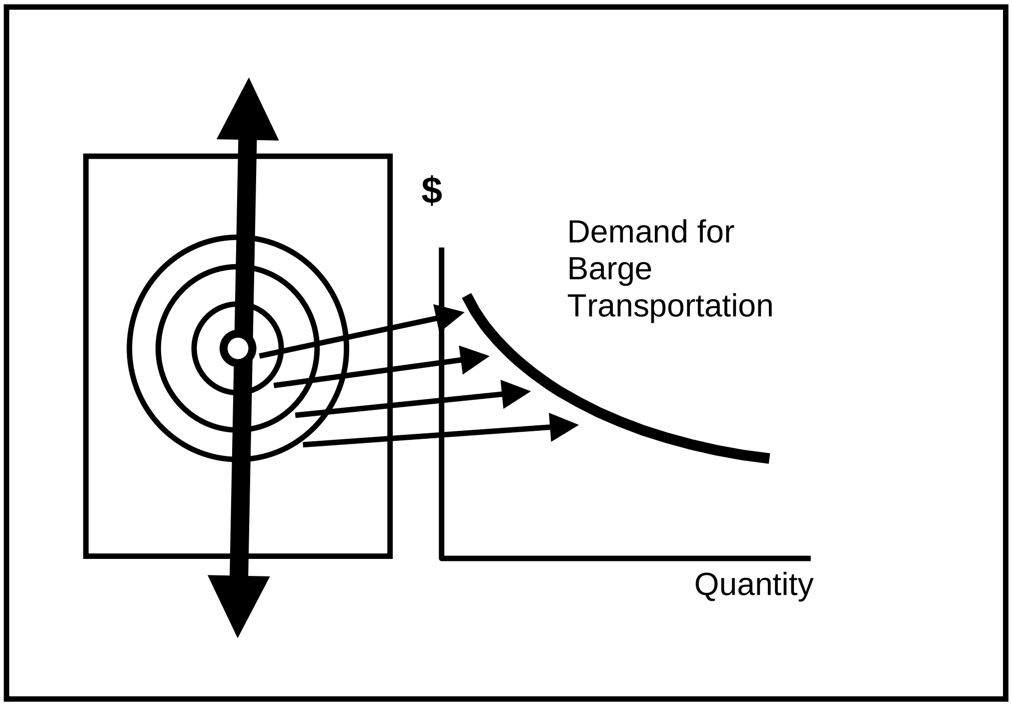

Grain Producing
Region
Barge Loading
Facility
River
Drawing Area

Figure 2.2



market abuts an existing barge market, there is the high likelihood of linear market boundaries. Likewise, natural geographic attributes, market interactions among ports, and spatial asymmetries in production can also distort the drawing area of a particular navigation port facility. Ultimately, the actual shape of a specific drawing area is an empirical question. Nonetheless, the range at which navigation ceases to effectively constrain rail rates combined with the distances between major river terminals tends to support the general application of a circular shape for most drawing areas.[15] This topic is discussed further in Section 3.1.

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[15] Empirical estimates suggest that navigation loses its ability to affect rail rates for grain shipments at a distance of between 50 and 100 miles. Thus, if barge drawing areas are roughly circular, major river facilities should be located between 100 and 200 miles apart. See Rail Rates and the Availability of Water Transportation: The Upper Mississippi Basin, U.S. Army Corps of Engineers, Rock Island District, 1997.

2.4.2 Non-Grain Commodities

Table 2.1 summarizes commodity flows on the Mississippi River for 1997. With the exception of some chemicals used in fertilizer production, it may be reasonably assumed that these commodities had actual origins and destinations that were at or very near the locations where they were loaded to and unloaded to or from barge.[16]

The fact that most non-grain commodities move relatively short distances to or from the river makes the theoretical analysis of the demand for non-grain commodity transportation far simpler than in the case of grain. Essentially, any changes in barge quantities associated with changes in barge rates can be attributed to revisions in the producers' output decisions, so long as barge rates remain below the lowest rate for alternative transport.

Table 2.1

1997 MISSISSIPPI BARGE TRAFFIC

(thousands of tons)

Commodity	1997 Tons
Farm Products	77.66
Petroleum Product	75.52
Coal	52.35
Chemical	35.66
Other	82.20
Total	293.39

[16] This observation is supported by the remarkably short range of distances over which barge transportation is estimated to affect rail pricing for the movement of non-grain commodities. Ibid.

As an interesting aside, the need to draw production from spatially dispersed grain growers gives river grain terminals an incentive to locate away from other terminals. In the case of non-grain commodities, no such incentive exists and, in fact, to the contrary, the optimization processes described earlier in this section suggest that non-grain shippers may well tend to cluster in common locations.

3. The St. Louis Model – A Critical Evaluation

As indicated in Section 1, the spatial model developed thus far in the course of the upper Mississippi study represents a significant departure from similar modeling efforts in other areas. As a consequence, this model has been the object of considerable review. Also, as observed earlier, the actual application of this modeling methodology has been subject to many of the same tortures that invariably plague first-time applications of new methods. It would be inappropriate to represent the St. Louis Model as a mature, well-tested method for assessing project benefits. At the same time, however, the contributions of both the theoretical and empirical approaches embodied within this model are unmistakable.

3.1 Theoretical Construct

The economic theory embodied in the St. Louis model is unassailable. Specifically, the 17 postulates that underpin the model are entirely consistent with the economic theory described in Section 2 of this document.[17]

The documentation of the St. Louis Model suggests two principle deviations from extant methodologies currently used within the Corps. These include:

- A construct that allows the willingness to pay and consequent transacted quantities to decline as barge rates increase in advance of any substitution of alternative transportation; [18] and

[17] See A Spatial Price Equilibrium Based Navigation System NED Model for the UMR-IW Navigation System Feasibility Study, U. S. Army Corps of Engineers, CEMVS-PD, July, 1998.

[18] Ibid, p. 20.

- An explicit accounting for the fact that there is a finite number of available tows at any point in time.[19]

While both modifications represent an approach that is more consistent with economic theory, it is the first of these deviations from the norm that has created the critical need for additional information regarding derived shipper demands for transportation services.

3.2 Empirical Application

Application of the St. Louis Model requires an explicit treatment of shipper demands over the range of prices that separates currently observed barge rates from the rate for the next best transport alternative.[20] It is this requirement and the lack of reliable empirical information that has resulted in a difficult first application of the model.

Because the rate information that is available is focused on the currently observed barge rates and the cost of the next best transport alternative, these data have been used extensively to establish estimates of the derived demand for barge transportation. Specifically, current applications of the St. Louis Model employ the following demand equation.[21]

$$Q = \left[\frac{R - y}{R - W_0}\right]^N * Q_0 \;;\; 0 \le y < R$$

$$Q = 0 \qquad ; y > R$$

[19] Ibid, p. 25

[20] Similar methodologies avoid this requirement by assuming that market quantities are unchanged in the face of higher barge rates until shippers fully substitute a transport alternative.

[21] See supra Note 12, Appendix A, p. 13.

Where:

Q = the quantity of barge transport of an O-D-Commodity triple;

R = the upper bound on barge rates as reflected by the best available alternative over the same O-D pair;

y = barge rate for an O-D-Commodity triple; and

W_0 = observed water rate for movement at quantity Q_0.

This construct anchors derived demand between the currently observed barge price/quantity and the point on the vertical axis that corresponds to the next best available transport cost, R. The shape of the derived demand is determined by the exponent value, N. When the value of N is less than one, the demand curve is concave. N values greater than one produce demand curves that are convex and an N value that equals one corresponds to a linear demand. As described in Section 4, this construct yields demand curves with an own elasticity of demand that varies across their length.

3.2.1 Grain Commodity Movements

In the case of grain, the demand structure employed by the St. Louis model appears to be entirely consistent with the economic theory described in Section 2.4.1. The St. Louis construct mimics the complete absence of barge traffic predicted when the combined costs of using barge transport exceeds the cost transport alternative and also allows the exponential growth in barge traffic associated with incremental declines in barge rates.

To the extent that the drawing areas surrounding barge terminals are circular, an exponent value of two is indicated. This conclusion is not, however, without its critics.

A group of agricultural and transportation experts convened by the Corps in late 1998 seemed to generally embrace the demand construct of the St. Louis model, but was unable to agree on a likely exponential value other than to suggest that the value is somewhere between one and two. Accordingly, some have advocated a solomonic approach that would yield a value of 1.5.

In a document prepared for MARC 2000, Criton Corporation fully rejects the notion that market-specific demands for the barge transport of grain are convex in nature, asserting instead that these demands are, in fact concave.[22] This conclusion is based on the interpretation and manipulation of survey data describing Iowa corn and soybeans flows for 1994.[23] Unfortunately this analysis is severely flawed. It is, in fact, relatively easy to demonstrate that the Iowa data support drawing areas that are somewhat circular and barge demand functions that are unquestionably convex. This latter conclusion is also confirmed by the Tennessee Valley Authority (TVA) field work performed in conjunction with the development of barge and alternative modal costs. Both field and telephone interviews with regional barge facilities lead TVA analysts to conclude that drawing areas for grain are elliptical in shape.

Ultimately, there is neither a theoretical nor an empirical basis to abandon an exponent value of two and there is, in fact, at least one reason to suspect that a higher exponent value is possible. An exponent value of two corresponds to linear gathering rates, but motor carrier rates that form the majority of gathering costs are generally non-linear. The barge

[22] See "Review and Critique of Upper Mississippi Barge Freight Demand Curve Assumptions", Criton, Corporation, February, 1999.

[23] See C. Phillip Baumel, Jean Philippe Gervais, Harold Hommes, and Craig O'Riley, "The Iowa Grain Flow Survey: Where and How Iowa Grain Producers and County Elevators Ship Corn and Soybeans," Iowa State University, September, 1996.

transport cost function from Section 2.4.1 is a useful tool for exploring the topic further. It is, therefore repeated below.

$$C(\text{Barge}) = \sum_{d=0}^{D} Q_d(T)d + (B)\sum_{d=0}^{D} Q_d$$

Because an increase or decrease in (B) affects the maximum drawing area, D is actually a function of (B). When the gathering rate, (T) is constant, the relationship between (B) and D is straight forward. A decrease in (B) increases D at a constant rate. However, if gathering rates become a function of “d”, the relationship between (B) and D gains a new dimension. A decline in the line-haul barge cost still leads to an increase in the maximum drawing distance. However, this impact is magnified by the lower gathering rate (per unit distance) that is paid by the incremental traffic that now moves by barge. In short, gathering rates that are a decreasing function of “d” lead to a derived demand for barge transport that is relatively more elastic.

Criton Corporation also argued that the alternative rates that generally form the intercept of the demand construct in the St. Louis Model fail to account for the incremental costs that are borne by peak-load rail users who must often pay a premium in order to secure adequate car supply. The model’s developers argue that no such premiums were paid for the rail shipments that represent the direct origin-destination analogue to the barge movements in the base sample. This response is not entirely convincing. There are readily available methods for incorporating an estimate of peak-load car capacity costs into the current rate data.

Moreover, affecting this revision would, in no way alter the basic model structure.

3.2.2 Non-Grain Commodities

The demand structure embodied in the St. Louis Model may well reflect the derived shipper demands for the barge movement of non-grain commodities. It is also possible, however, that these demand relationships are somewhat different in form and that these differences could measurably affect the calculations of project benefits. Ultimately, it is an empirical rather than theoretical matter.

In the case of grain, both the intercept of the derived demand curve for barge transport and the shape of that demand curve as it approaches the intercept are dictated by the spatial geometry that determines drawing areas. In the case of non-grain commodities, this is far less the case. As observed in Section 2, most non-grain commodities don't move great distances to or from the river. Thus, the geometric conditions that make it possible to readily estimate the demand for grain transport are absent in the case of non-grain commodities. Instead, in the short-run, the derived demands for the barge movement of non-grain commodities are primarily a function of output decisions. In the long-run these same output decisions, coupled with location choice, appear to be the primary determinants of demand for barge transport.

Functionally, the intercept of actual derived demand curves for barge transport need not intercept the price axis at the point that corresponds to the next best alternative cost. This intercept may occur above or below that point. Moreover, while most empirical studies have found the demands for transportation to be convex, it is not clear from a theoretical vantage that this must be the case. Again, the empirical structure embodied in the St. Louis Model may be appropriate for non-grain commodities, but in the absence of additional information, a defensible, definitive judgement is impossible.

3.3 The St. Louis Model and the Calculation of NED Benefits

The St. Louis Model represents a significant departure from the analytical structures used to evaluate the National Economic Development benefits attributable to other navigation projects. Consequently, the newer framework materially alters benefit calculations. There are, at least, three specific implications of the St. Louis Model with respect to benefit magnitudes. These include:

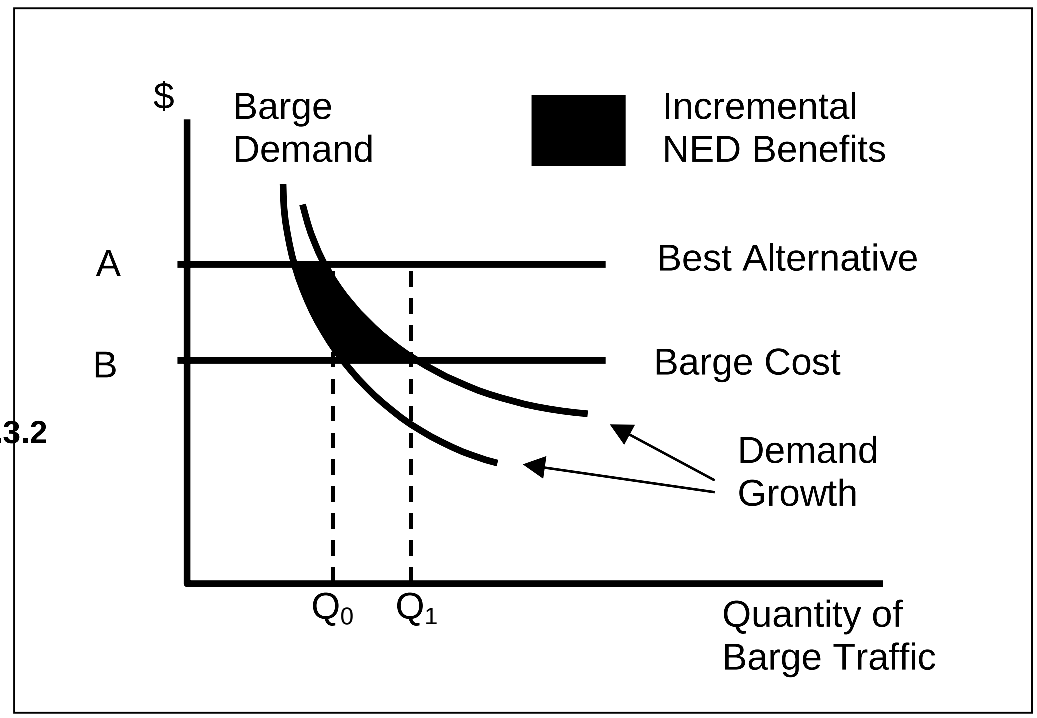
- In the case of projects or operational changes that are only intended to maintain barge costs at current levels, the St. Louis approach will invariably lead to lower estimates of barge shipper savings than would be obtained under a more traditional approach.
- In the case of projects or operational changes that will measurably lower barge user costs, the St. Louis Model will invariably yield greater barge shipper savings than would be obtained under a more traditional approach.
- Unlike other frameworks, the underlying assumption that transport demands are responsive to variations in prices implies that some portion of the water-compelled rate savings attributable to navigation represents a net welfare gain, countable as an NED benefit.

Each of these outcomes is discussed in detail below.

3.3.1 Preserving the Status Quo

Figure 3.1 illustrates market-specific NED calculation in the case of a navigation improvement designed to accommodate increased market demand, while preserving currently observed navigation costs.[24] Under both the St. Louis model and analytical constructs used elsewhere, the increase in the quantity of barge transport demanded at every price is the source of the incremental benefits generally necessary to justify project implementation. Clearly, however, the downward slope of demand used within the St. Louis model leads to lower incremental values. From an economic standpoint, this outcome owes to the fact that the full amount of new barge traffic would only be observed on the waterway *if* barge rates remain at current levels. Under the without project condition, some measurable quantity of emerging new traffic would be withheld as barge rates increase beyond current levels.

Figure 3.1



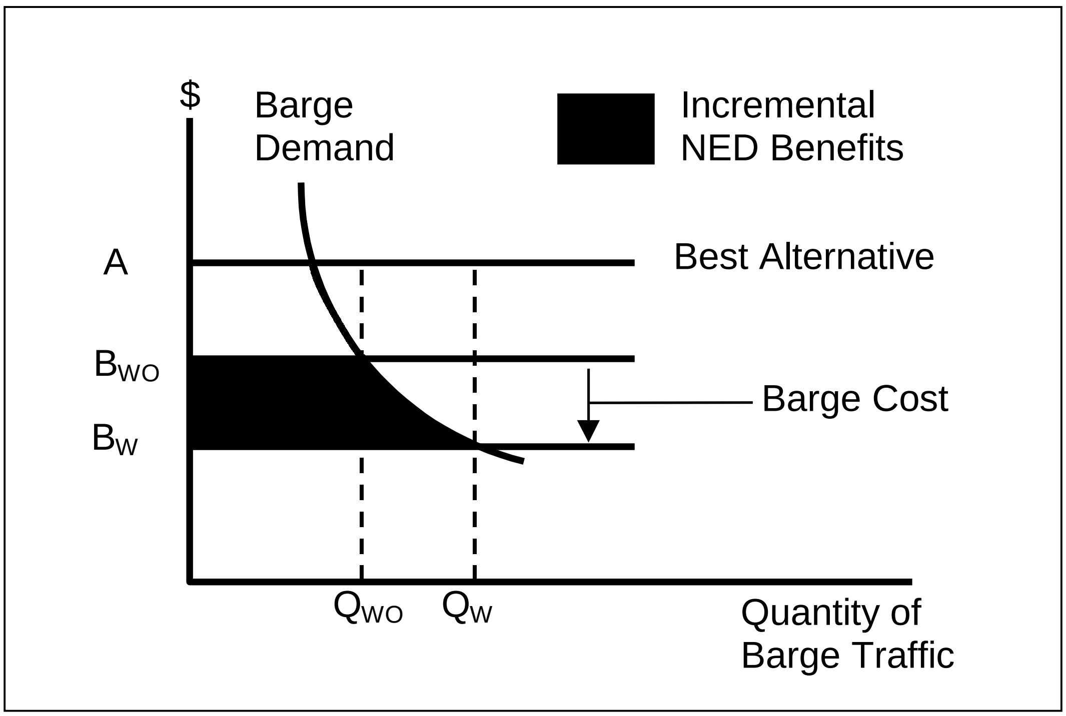
3.3.2

[24] In this particular representation, the demand for barge transport does not have a vertical intercept that corresponds to the lowest available modal alternative. Thus, this depiction is not representative of the demand for grain movements under the St. Louis structure.

Cost-Reducing Measures

The situation posed by a proposed project that would measurably lower barge transport costs is depicted in Figure 3.2. This circumstance differs considerably from the one described in Section 3.3.1. As in all cases, positive incremental benefits would be necessary to justify project implementation. However, in the case of cost reductions, these incremental benefits do not depend on demand growth. Indeed, the demand relationship between barge rates and the quantity demanded is identical under both the with-project and without-project conditions.

Figure 3.2



In the case of cost-reducing projects, the St. Louis construct would clearly lead to incremental NED values that exceed those calculated under models used elsewhere. Moreover, the source of these additional market-specific incremental values is clear. Under a traditional approach, existing shippers would enjoy cost savings, but no additional tonnage would be drawn into waterborne commerce. Under the St. Louis Model, tonnages would increase as barge costs fall. Graphically, the additional NED benefits are reflected by the area bounded by Q_W, - Q_{WO}, B_{WO} - B_W, and the demand curve. Predictably, the difference between benefits calculated under the St. Louis Model and those calculated based on more traditional methods escalates as demands become more elastic.

3.3.3 Water-Compelled Benefits

Relatively early in the Upper Mississippi study, TVA conducted a econometric evaluation of the relationship between available navigation and observed rail rates.[25] The results suggest that rail shippers within the upper Mississippi basin save several hundred million dollars each year because of the competitive influence exercised by navigation. However, all water-compelled benefits attributable to navigation were treated as regional, rather than national, benefits. This treatment resulted directly from the underlying assumption that shipped quantities do not vary with changes in the prices of modal alternatives.

The St. Louis Model, however, relaxes this fundamental assumption. Shipped quantities may respond to changes in own price and to changes in the price of modal alternatives. Thus, the conclusion that all water-compelled benefits are regional transfers is no longer valid.

[25] Supra Note 15.

From a practical standpoint, the insight that some portion of water-compelled benefits reflects an actual welfare gain has no impact on the current analysis, the variations in barge rates under the with-project and without-project conditions are far too small to elicit a change in railroad pricing behavior.[26] However, from a theoretical vantage, this revelation is important. Moreover, it is certainly possible that water-compelled benefits could be non-trivial in other settings.

[26] Under preliminary runs of the St. Louis Model, average, with-project and without-project barge rate projections for the year 2030 vary by only 0.56%. This average increase would likely be imperceptible to rail carriers. Even in the case of soybeans, where the with-project and without-project differential is estimated at 2.38%, it is unlikely that the NED portion of water-compelled benefits would be measurable.

4. Development and Application of Additional Data

Based on the assessment provided in the previous section, the greatest need for additional information appears to be with regard to the derived demands for the movement of non-grain commodities. Accordingly, the remainder of this section provides information that may be used to approximate or, at least, bound short-run demands for the barge transport of several non-grain commodities. It also provides data that may help policy-makers to infer how the movement to a long-run vantage might alter these short-run estimates.

4.1 Short-Run Estimates of the Demand for Barge Transport

The documentation of the St. Louis Model notes that the transportation rate data developed for this project were not designed to provide information about shipper behaviors at prices between the currently observed barge rate and the rate at which the quantity demanded would be zero.[27] Consequently, these data will not facilitate the direct statistical estimation of the derived demand for barge transport. Moreover, there is no immediately available alternative source of rate information for waterborne commerce that can serve as a substitute.

Given the demonstrable need for demand information and the paucity of appropriate barge data, the current analysis has seized on an alternative method that uses rate and quantity information gleaned from railroad shipments to estimate short-run derived demands for rail transport. It is then possible to use these demands to make inferences regarding the shapes of barge demands for transportation of the same commodities in similar markets.

[27] Supra Note 12, p. 22

4.1.1 Estimating the Short-Run Demand for Rail Transport

Based on the theoretical discussion in Section 2, the derived relationship between the quantity of rail transportation demanded in any specific market and the rail rates charged is postulated to be:

$$R = f\,(P_R, P_A, P_F, P_O)$$

where

- R = the quantity of railroad transport of a specific commodity between a specific origin and demanded annually
- P_R = the observed rail rate;
- P_A = the rate of any available modal alternative;
- P_F = a composite measure of other factor prices at the destination;
- P_O = the effective price of the subsequently produced output at the destination;

The empirical specification used to mirror this theoretical construct was:

$$\text{LSUMTON} = \beta_0 + \beta_1(\text{LMRPT}) + \beta_2(\text{LMOD2W}) + \beta_3(\text{LMTD2W}) + \beta_4(\text{LROTON}) + \beta_5(\text{LRTTON}) + \beta_6(\text{LPRIC}) + \varepsilon$$

The dependent variable, LSUMTON, is defined as the natural log of the total tonnage of a particular commodity moving by rail between a specific origin county and destination county in 1996. All variables are, in fact, defined based on this origin-destination-commodity (ODC) triplet. The annual timeframe was selected to match the empirical calculations within the St. Louis Model. This length of time is probably sufficient to capture all shipper decision making except for location decisions. Thus, the resulting estimates must be interpreted as short-run results.

LRMPT is defined as the natural log of the mean rail rate for movements over the ODC triplet in 1996. During calculation, this mean was weighted by shipment tonnage. This variable is intended to correspond to P_R in the theoretical construct.

Trucks do not efficiently move most of the commodities in question over long distances, so that the primary non-rail competitor was judged to be barge transport. Nonetheless, as indicated above, suitable barge rates were not immediately available for inclusion in the estimation. Consequently, two proxy variables, LMOD2W and LTD2W were included in the estimation process. These variables are defined as the natural log of the mean distance to the nearest appropriate navigation facility at origin and at destination, respectively. Again, the mean is over the ODC triplet and was calculated using individual shipment tonnages as a weighting factor. All distances reflect actual highway distances over likely routings from county population centers to either a dry-bulk dock, a liquid commodity handling facility, a general commodities terminal or a coal handling facility, depending on which seemed most appropriate.

Reliable county-specific data describing factor prices do not exist. Consequently, it was necessary to use state-specific data for some factor prices and to develop proxies for others. LROTON and LRTTON were included to reflect the price of the shipped commodity. LRTON is defined as:

$$\ln\left[\frac{\sum_{j=1}^{n} TON_{ij}}{\text{mean}\left[\sum_{j=1}^{n} TON_{ij}\right]}\right]$$

Where i's denote origin counties, j's indicate terminating counties and TON reflects annual tonnage. More simply stated, this variable measures the size of the originating market relative to the average size of all markets that originate rail shipments of the same commodity. The rationale for use of this measure is that, after controlling for transportation costs, any given originating market will only be able to originate a relatively large quantity of traffic if it offers the commodity in question at a relatively low price.

LRTTON was defined in an analogous fashion for terminating or destination markets. Here again, a relatively large value reflects a relatively large destination market. In the case of the destination market, however, the ability to attract greater quantities of the commodity in question suggests a willingness to pay more for those inputs. Based on these rationales, coefficient estimates for both LROTON and LRTTON should be positive.

LEPRIC, a state-specific data measuring average electricity costs, was included to reflect variations in fuel costs.[28] However no similar measure was available to capture variations in capital costs. Also, with the exception of coal, relative variations in downstream product prices were

[28] Electricity rate data were based on U.S. Department of Energy Figures. See Current Electric Sales and Revenue, Table 16, U.S. Department of Energy, Energy Information Administration, 1997.

unavailable and, therefore not included in the empirical estimation. In the case of coal, to the extent that the majority of coal is used in the generation of electricity, LEPRIC represents a downstream price rather than a factor cost.

All rail data used in the development of these variables were drawn from the Surface Transportation Boards annual Carload Waybill Sample.

Probable truncation of the data describing the relationship between rail rates and demanded quantities made Ordinary Least Squares (OLS) inappropriate as method of estimating the empirical model. Consequently, maximum likelihood estimators based on a truncated normal distribution were used to produce all parameter estimates.[29]

Estimation results are summarized in Table 4.1. The first figure appearing in each cell is the estimated coefficient. The second value is the associated standard error. An empty cell indicates that the estimated parameter is not statistically different from zero at a ten percent threshold level. The log-log specification allows each coefficient to be interpreted as an elasticity.

With the exception of chemicals, the estimated model fit for most commodities is what might be expected in a purely cross-sectional estimation. Moreover, where parameters are statistically different than zero at a ten percent threshold, they display the expected sign without fail.

[29] Rates and associated quantities are available where transactions occurred. However, it is virtually certain that additional rail transportation would have been purchased at lower rail rates. Thus, there was concern that the data used in the estimation process would produce biased results. To account for this possibility, maximum likelihood estimators based on a truncated normal distribution were used rather than Ordinary Least Squares. However, a comparison of the OLS and MLE estimates suggests that any bias is minimal. For a description of the estimators used in this analysis see: LIMDEP Version 7.0 Users Manual, Econometric Software, Inc., Plainview, New York, 1998.

Table 4.1

SHORT-RUN RAILROAD DEMAND ESTIMATES

	Metallic Ores	Coal	Non-Metallic Minerals	Food and Kindred Products
LMRPT	**-0.9888489** 0.108861 -9.084 ***	**-0.7655008** 0.0636246 -12.032 ***	**-0.812611** 0.0388994 -20.890 ***	**-0.5034815** 0.0193921 -25.963 ***
LMOD2W	**0.0036693** 0.0423209 0.087	**0.0959353** 0.0273821 3.504 ***	**0.1643365** 0.0265791 6.183 ***	**0.0130475** 0.0074258 1.757 *
LMTD2W	**0.1212984** 0.047446 2.557 **	**0.070206** 0.0286638 2.449 **	**0.0424476** 0.0245274 1.731	**0.0147106** 0.0079241 1.856 *
LROTON	**0.3976662** 0.0424016 9.379 ***	**0.382167** 0.02358 16.207 ***	**0.3422616** 0.0200954 17.032 ***	**0.2408959** 0.0077823 30.954 ***
LRTTON	**0.3923123** 0.0455109 8.620 ***	**0.4716616** 0.0256149 18.414 ***	**0.276218** 0.0175538 15.736 ***	**0.211219** 0.0077022 27.423 ***
LEPRIC	**-0.5057948** 0.3750949 -1.348	**0.4069407** 0.1991001 2.044 **	**-0.4156856** 0.1753877 -2.370 **	**0.1492086** 0.0504799 2.956 ***
Intercept	**14.97836** 0.7364601 20.338 ***	**13.13288** 0.3907342 33.611 ***	**12.55132** 0.3609649 34.772 ***	**10.6189** 0.1115763 95.172 ***
N **Chi2(6)** Log Likelihood	**256** **346.46** **-312.983**	**1320** **728.51** **-2104.9331**	**1577** **1000.32** **-1972.1297**	**6764** **2056.25** **-8687.2283**

Notes: 1. ML is a maximum likelihood estimation for the truncated regression linear form optimization method and a modified Marquardt (1963) algorithm.

2. The first number listed below each coefficient is the standard error. The second number is the t score.

3. Values significant at the .99 level are marked with a "***". Values significant at the .95 level are marked with a "**". Values significant at the .90 level are marked with a "*".

Table 4.1

(Continued)

SHORT-RUN RAILROAD DEMAND ESTIMATES

	Lumber and Wood Products	Chemicals	Petroleum Products	Rubber and Plastics
LMRPT	**-0.6634592** 0.0220446 -30.096 ***	**-0.3379871** 0.0130538 -25.892 ***	**-0.6903047** 0.0376432 -18.338 ***	**-0.4387365** 0.0930493 -4.715 ***
LMOD2W	**0.0401736** 0.0093124 4.314 ***	**0.0197515** 0.0046386 4.258 ***	**0.0559306** 0.0106319 5.261 ***	**0.0648067** 0.0282281 2.296 **
LMTD2W	**0.0280206** 0.0089698 3.124 ***	**0.013219** 0.0057778 2.288 **	**0.0098973** 0.0114755 0.862	**0.0660138** 0.0287395 2.297 **
LROTON	**0.2236657** 0.0096403 23.201 ***	**0.1778377** 0.0055028 32.318 ***	**0.2643267** 0.0152432 17.341 ***	**0.3933066** 0.0469709 8.373 ***
LRTTON	**0.2539804** 0.0093108 27.278 ***	**0.191909** 0.0060742 31.594 ***	**0.2462715** 0.0133221 18.486 ***	**0.3462298** 0.0438449 7.897 ***
LEPRIC	**-0.1052086** 0.0621816 -1.692 *	**0.0329426** 0.040649 0.810	**-0.0374546** 0.0978556 -0.383	**-0.2503933** 0.2358117 -1.062
Intercept	**11.03098** 0.1281973 86.047 ***	**10.30561** 0.0836496 123.200 ***	**11.53855** 0.2128226 54.217 ***	**9.494846** 0.5875132 16.161 ***
N **Chi2(6)** Log Likelihood	**4604** **1719.43** **-5545.3637**	**9115** **1986.42** **-11256.948**	**2272** **873.01** **-3016.7766**	**464** **144.25** **-498.96601**

Notes: 1. ML is a maximum likelihood estimation for the truncated regression linear form optimization method and a modified Marquardt (1963) algorithm.

2. The first number listed below each coefficient is the standard error. The second number is the t score.

3. Values significant at the .99 level are marked with a "***". Values significant at the .95 level are marked with a "**". Values significant at the .90 level are marked with a "*".

Table 4.1

(Continued)

SHORT-RUN RAILROAD DEMAND ESTIMATES

	Clay, Concrete, Glass, and Stone	Primary Metal Products	Fabricated Metal Products	Scrap Materials
LMRPT	**-0.7020671** 0.0312149 -22.491 ***	**-0.5516085** 0.035892 -15.369 ***	**-0.5539172** 0.1068832 -5.182 ***	**-0.6564661** 0.0314187 -20.894 ***
LMOD2W	**0.061904** 0.0145166 4.264 ***	**0.0383295** 0.0097108 3.947 ***	**0.0925124** 0.0354862 2.607 ***	**0.0315302** 0.0097699 3.227 ***
LMTD2W	**0.0634163** 0.0133513 4.750 ***	**0.0232962** 0.0103573 2.249 **	**0.078963** 0.0302062 2.614 ***	**0.0514672** 0.0095882 5.368 ***
LROTON	**0.2764143** 0.0136188 20.297 ***	**0.1743769** 0.0118489 14.717 ***	**0.3981344** 0.0555042 7.173 ***	**0.2186827** 0.011313 19.330 ***
LRTTON	**0.173093** 0.0131786 13.134 ***	**0.2199616** 0.0121443 18.112 ***	**0.3823891** 0.0617235 6.195 ***	**0.239222** 0.0118679 20.157 ***
LEPRIC	**-0.0025987** 0.0926959 -0.028	**-0.2086165** 0.0886551 -2.353 **	**-0.8906775** 0.2965175 -3.004 ***	**-0.0266791** 0.0818695 -0.326
Intercept	**10.96371** 0.1976227 55.478 ***	**11.28381** 0.2013417 56.043 ***	**11.25718** 0.7303207 15.414 ***	**10.55214** 0.1789317 58.973 ***
N **Chi2(6)** Log Likelihood	**2659** **1003.37** **-3555.444**	**2807** **722.77** **-3847.561926**	**411** **7.09-2** **77.7958235**	**43** **1160.46-42** **26.381**

Notes: 1. ML is a maximum likelihood estimation for the truncated regression linear form optimization method and a modified Marquardt (1963) algorithm.

2. The first number listed below each coefficient is the standard error. The second number is the t score.

3. Values significant at the .99 level are marked with a “***”. Values significant at the .95 level are marked with a “**”. Values significant at the .90 level are marked with a “*”.

While there is much of interest within these results, the focus in the current setting is on the estimated elasticity coefficients. These estimates range between –0.98 for the movement of metallic ores and –0.33 for chemicals. Generally, these results suggest two conclusions. First, even in the short-run when information is difficult to acquire and production changes are difficult to execute, firms that face higher railroad rates use less rail transportation. Second, as might be expected, transportation demands for the movement of lower-valued bulk commodities seem to be more sensitive to rates than are the demands for more highly valued commodities. With regard to magnitude, the estimates obtained here are not significantly different from those developed in the path-breaking work of Ann Friedlaender and Richard Spady.[30] Friedlaender and Sapdy estimated railroad demand elasticities for four broadly defined commodity groups in three regional markets. Their results are reported in Table 4.2 for comparison purposes.

It should be noted that, while Friedlaender and Spady characterize their demand estimates as long-run in nature, the estimates developed within the current analysis certainly are not. Based on this distinction, one would expect the Friedlaender and Spady's elasticity estimates to be measurably greater in absolute value than those obtained here. The fact that they are not is likely attributable to the fact that Freidlaender and Spady's work was based on pre-Staggers rail rates and quantities. Post-deregulation research indicates that the demands for the rail transport of many commodities have become more elastic since the implementation of the Staggers Rail Act.[31]

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[30] See, for example, Ann F Friedlaender and Richard H. Spady, Freight Transport Regulation: Equity, Efficiency, and Competition in the Rail and Trucking Industries, MIT Press, 1980.

[31] See, for example, Wilson, William W.; Wilson, Wesley W.; Koo, Won W. "Modal Competition and Pricing in Grain Transport," *Journal of Transport Economics and Policy*; v22 n3 September 1988, pp. 319-37.

Table 4.2

FRIEDLAENDER AND SPADY RAIL DEMAND ELASTICITY ESTIMATES

	Official Territory (east coast and mid-west)	Southern Territory	Western Territory
Durable Manufactured Goods	-0.84	-0.69	-0.51
Non-Durables	-0.70	-0.64	-0.49
Petroleum Products	-1.16	-1.04	-0.84
Mineral, Chemical and Other	-0.59	-0.49	-0.37

4.1.2 Applying Rail Elasticities to the Demands for Barge Transportation

The estimated short-run demand elasticities relating shipper response to changes in railroad rates appear to be of reasonable magnitudes and compare well with similar measures developed independently. The next issue, however, is how to best use these estimates within the context of the St. Louis Model and the upper Mississippi study.

Conceptually, there are a variety of possible ways to bridge between the railroad demand estimates developed in Section 4.1.1 and the barge demand function embedded within the St. Louis Model. One method might assume that the demand elasticity for barge transportation is equal to the elasticity observed in rail-served markets. Given, once again, that the demand for transport by either model is derived from a downstream need for the shipped commodity, this assumption is not entirely untenable.

It should be noted, however, that in empirical studies where both rail and truck demand elasticities have been estimated, the demand for motor carriage is typically more elastic.[33] Thus, if the same relationship is true between barge and rail, applying the rail elasticities to barge demands

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[33] ibid.

would systematically understate the NED values associated with navigation.

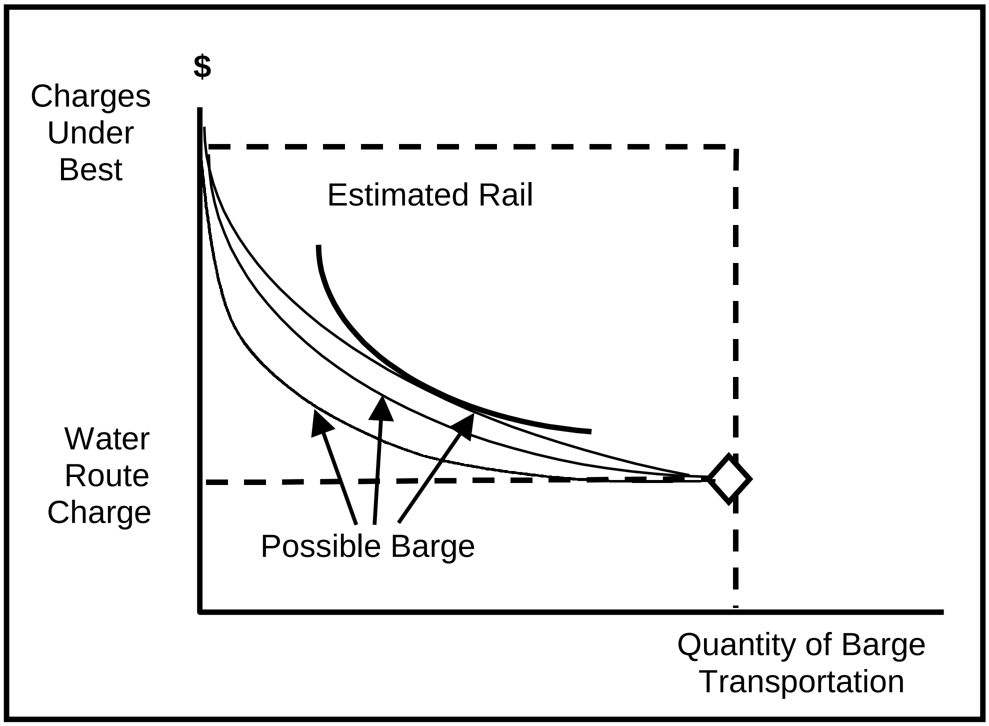
Applying the rail demand elasticities to barge demands would also require a minor modification of the demand structure currently contained within the St. Louis Model. The current demand structure allows the price elasticity to vary over different portions of the demand curve. The estimates developed in Section 4.1.1, however, are based on a demand structure with a fixed elasticity that is uniform throughout each demand curve. Empirical evidence suggests that a uniform elasticity is inappropriate in the case of grain transportation.[34] However, there is no evidence to suggest that the same is true for non-grain commodities.

As an alternative to applying the rail demand elasticities directly to the barge demand equation, it is possible instead to merely use the rail demand estimates to bound the minimum range for the exponent value, N. Because railroad transportation provides both lower transit times, and less variation in transit times, shippers should always be willing to pay more for rail transport than for barge.[35] This implies that the demand curves for these services within any particular market should never cross. This approach is depicted graphically in Figure 4.1

[34] Supra Note 23.

[35] Once again, recall that the current analysis is conducted under the assumption that transportation demands are separable from the demand for storage or other logistic functions.

Figure 4.1



There are two important caveats to be considered in association with this second methodology. First, in the preparation of the current analysis, the author never encountered an instance when the demand for freight transportation is not convex. However, in the event that the premium paid to rail service is large relative to the observed barge rate, it would be possible for the bound imposed by the rail demand curve to result in barge demand curves that are concave rather than convex. In such an instance, the exponent value should not be allowed to become less than one, regardless of the railroad transport demand curve. Second, it should be noted that any demand curves for barge transport derived in this manner will yield estimates of maximum benefits. Just as the first methodology likely tends to systematically understate the value of navigation projects, the second approach will almost certainly overstate these benefits.

Finally, it should be noted that that the two methods for bridging between the estimated rail demands and the necessary barge demand functions suggested here, by no means, exhaust the range of possibilities. There are almost certainly additional methods of relating the two demands. Ultimately, the method chosen may reflect a careful balancing of theoretical and computational concerns.

4.2 Considering the Long-Run

Throughout this document, reference has been made to the need for a long-run perspective in assessment of navigation project benefits. Admittedly, however, the railroad demand functions estimated in Section 4.1.1 represent, at best, an intermediate time frame in which shippers had the chance to consider modal, geographic, or product substitutes, but in which firm relocation was probably impossible. Thus, the methods suggested so far are not fully compliant with the desire to maintain a long-run perspective.

Unfortunately, it is not possible to quantitatively address this deficiency in the current setting. It is, however, possible, to identify those commodities for which the short-run / long-run distinction may be of relatively greater importance.

4.2.1 Longevity of Capital: Methodology and Calculations

Each year firms within an industry engage in a specific level of investment. Some portion of this investment reflects the purchase of new machinery and equipment. The remainder represents investment in new facilities. At any point in time, it is also true that the individual firms within an industry possess a specific stock of capital to be used in the production process. Taken together, annual industry investment represents the inflow of capital necessary to maintain an industry-specific capital stock. The ratio of annual investment to the value of the capital stock provides a measure of the longevity of capital within that industry. For example if annual investment equals the size of the industry's capital stock or the value of the ratio is one, this implies that the all the capital used within the industry must be replaced each year. Alternatively, a value of 0.1 would suggest that, on average, the industry's capital stock is fully replaced every ten years. This methodology is exceedingly imprecise so that the absolute magnitudes of the resulting calculations are likely to be unreliable. Conversely, the relative magnitudes of calculated ratios should provide a reasonably reliable ordinal ranking of firm mobility.

The above relationship was calculated for a set of 11 industries that routinely use products shipped by barge. The actual calculation of capital longevity was based on:

$$\text{Longevity} = \frac{1}{\left(\frac{(E+S+R)}{\text{Equity}}\right)}$$

Where: E = Annual equipment expenditures
S = Annual investment in structures
R = Annual Rental Payments[38]
Equity = Estimated industry equity

Calculations and rankings are provided in Table 4.3.[39] Again, the reader is warned that the absolute magnitudes reported in this table are far less reliable than the ordinal ranking

[38] Rental payments are included to reflect the fact that firms may choose to rent or lease equipment and facilities rather than purchase them. The inclusion or exclusion of this value does not materially affect the value of the calculations.

Table 4.3

RELATIVE LONGEVITY OF CAPITAL

Ranking	Industry	Estimated Longevity of Capital (Years)
1	Electric Utilities	39.6
2	Petroleum and Coal Products	9.0
3	Primary Metal Industries	8.1
4	Printing and Publishing	7.8
5	Fabricated Metal Products	6.5
6	Food and Kindred Products	6.4
7	Lumber and Wood Products	6.2
8	Chemicals	4.9
9	Paper and Allied Products	4.9
10	Stone, Clay, and Glass Products	4.5
11	Rubber and Plastic Products	4.0

4.1.2 Application of Results

Once again, the current setting does not provide the opportunity to integrate these results into the analysis of the demand for barge transport. Clearly, long-run demand curves will be more elastic than those observed in the short-run. The above results suggest that the deviation between short-run and long-run outcomes is likely to be less in the case of shippers who transport coal and metallic ores and, perhaps, greater in the case of the cases of more finished products or products with relatively high values.

[39] Data for these calculations were drawn from the Bureau of the Census' 1992 Business Census series.

5. Recommendations

The notion of offering recommendations in a setting where so many qualified economic, transportation, and agricultural experts have found so little common ground is, at best, quite humbling. As observed in the introduction to this research, the remedies and results pursued herein should not be viewed as definitive. They do, however, represent progress toward a more functional, more accurate application of the St. Louis Model for calculating navigation project benefits.

5.1 Grain Movements

As Described in Section 3.2.1, it is the author's judgement that the demand construct embodied within the St. Louis Model is exactly appropriate as a representation of shipper behavior. Moreover, in the absence of any theoretical or empirical evidence that suggests otherwise, it is impossible to reasonably advocate an exponent value other than two.

There are, perhaps, opportunities to improve the quality of model results by modifying them so that they better reflect the actual cost of the next-best alternative available to shippers. Specifically, it may be desirable to:

- Revisit the issue of peak-load car supply costs and the inclusion of these costs within NED calculations.

- Use per ton-mile rail rates observed at the river, even for shipments that originate at some distance from the nearest available navigation. It has, after all, been demonstrated that proximity to the river constrains rail pricing behavior. Therefore, rail rates at the river more accurately reflect actual costs than rates that are not subject to the competitive discipline navigation offers.

[40] Supra Note 10.

- Update the original rate information to reflect changes in surface transportation that have been observed since those rates were developed. Recalling that efficiency requires that the current assessment be as forward-looking as possible, it seems only sensible to use data that are as current as possible and that are based on the most recent trends in surface transportation.

These recommendations notwithstanding, it should be observed that, given the convexity of grain demand curves and the likely range of barge rate increase, modifying the intercept value in the demand construct is unlikely to result in significant changes to the calculation of NED values. Consequently, a decision to forego the suggested measures is defensible.

5.2 Non-Grain Commodity Movements

While the railroad demand functions provided in Section 4.1.1 are, by no means, pristine, they are reasonable measures of shipper response to variations in rail rates. Moreover, in doing so, they also provide *some* evidence regarding the probable response of barge shippers to barge pricing. As described in Section 4.1.2, there are, at least two ways this rail data can be applied within the upper Mississippi study. These methods each impose a set of necessary assumptions and each has apparent weaknesses. Ultimately, it may be desirable to experiment with both in order to determine which is most reliable. If, however, it is necessary to select a single method, the author would advocate the approach under which the estimated barge demands are simply used to bound the exponent value in the St. Louis demand construct.