Stated Preference Modeling of the Demand for Ohio River Shipments

October 2005

by
Nino Sitchinava
University of Oregon

and
Wesley Wilson
University of Oregon
and
Institute for Water Resources-Army Corps of Engineers

and
Mark Burton
University of Tennessee

A Draft Report prepared for the
Institute for Water Resources
U.S. Army Corps of Engineers

Nino Sitchinava
Department of Economics
University of Oregon
Eugene, Oregon 97403
(541) 346-4674
(541) 346-1243 (fax)
nino@uoregon.edu

Professor Wesley W. Wilson
Department of Economics
University of Oregon
Eugene, Oregon 97403
(541) 346-4690
(541) 346-1243 (fax)
wwilson@uoregon.edu
http://darkwing.uoregon.edu/~wwilson

Mark L. Burton
Director Transportation Research
Center for Transportation Research
309 Conference Center Building
University of Tennessee - Knoxville
Knoxville, TN   37996-4133
865-974-4358
Mburton3@utk.edu

Executive Summary

Recent reviews of the U.S. Army Corps of Engineers Upper Mississippi River and Illinois Waterways Feasibility Report recommend that empirical studies be performed to analyze the behavior of shippers and their demand for waterway transportation. This study uses survey data from a sample of 179 shippers that use or could plausibly use the Ohio River Waterway System for transportation. The data reflect a wide range of commodities and shipper locations. Shippers provide information on how their quantities would respond to changes in transportation rates and transit times. These "stated preference" responses allow the estimation of a TOBIT model of annual shipments and responsiveness. The results provide demand estimates for different modes and different commodities. High value commodities shipped by truck are the most responsive to rate changes, while low-value bulk commodities shipped by barge are the least responsive to rate changes. The results also suggest that shippers respond to shipment characteristics i.e., transit times. The results are comparable to rates, although they are not as large.

TABLE OF CONTENTS

1. INTRODUCTION

The behaviour of transportation demand with respect to transportation rates is of central importance to Army Corps of Engineer (ACE) planning models. These models rest on individual shipper demand structures that, in the primary model used, are perfectly inelastic to a reservation price at which point all demand flows to another mode. The National Research Council (2001, 2004a, 2004b) and Berry *et al.* (2001) have questioned this methodology, holding that shippers have alternatives and do react to rate changes. Further, that the demand structures used have not been grounded in empirical studies of transportation demand. Anderson and Wilson (2004a, 2004b, 2005) theoretically examine shipper demands, competition, and welfare in a series papers that development a full spatial equilibrium model. They find that shippers have multiple options; each of which may be a source of responsiveness to rate changes. These alternatives include the choice of mode, market, intensity of production, and the level of production. Train and Wilson (2004) examine shipper mode/location/quantity choices. In their switching model, they find that substantive responses of shippers to changes in both rate and transit times in terms of mode and location choices as well as in the annual volumes produced. Their model was applied to a sample of grain elevators in the Upper Mississippi and Illinois River basins (UMISS). This market is characterized by shippers with a number of alternative choices and direct competition from alternative modes.

In this study, we examine Ohio River demands. Ohio River shippers are much different from the agricultural shippers that dominate southbound traffic on the UMISS that were analyzed by Train and Wilson. Specifically, while agricultural movements dominate the UMISS, coal and, to a lesser extent, primary manufactured goods (steel) dominate the Ohio. To examine demands on the Ohio, information was gathered from a sample of 179 shippers located in states that span the Ohio River Waterway System. These data include both shippers that use and do not use the river. For the latter, care was taken to include shippers that do not use the river but plausibly could. The results suggest, however, that few shippers in the sample have alternatives other than those used. Thus, the sample is dominated by shippers that report they have no mode/market alternatives than those chosen. As such, in the context of Anderson and Wilson, there is but one source of responsiveness: Shippers may adjust production levels to rate changes i.e., the "intensive" margin. In the sample, we observe shippers that do adjust and shippers that do not adjust when confronted with rate changes. Empirically, this forms a limited dependent variable, and a demand function for transportation is estimated as a TOBIT model. The demand model is framed around transportation rates and service attributes, as well as shippers' individual characteristics. The result provides a model of individual shipper decisions related to annual volumes of shipments and allows direct estimation of the impact that changes in both rates and transit times. The model is motivated by the inventory theoretic demand model of Baumol and Vinod (1970) which integrates into a logistic cost function the role of rates and service characteristics. The cost minimizing quantity shipped is a function of rates (or, rates as a function of shipment attributes), shipment attributes, and, of course, shipper characteristics. Based on this model, an empirical relationship between the volume of annual shipments and shipment characteristics is derived. This is based on stated preference data wherein shippers are asked of their responsiveness to rate and transit time changes. While the theoretical model holds that rising rates and transit times translate into either no change or into lower shipment volumes, all else held equal, for both rates and transit times, we observe in the data a limited dependent variable in which shippers do not respond, respond, or shutdown. This implies a limited dependent variable which we estimate with a "Tobit" model. The results suggest that shippers are quite responsive to rate changes, and the level of responsiveness varies across the commodities and shipper characteristics. The responsiveness to time changes appears to vary across commodities, but be invariant across shipper and other shipment characteristics. The shippers are less responsive to time changes than to rate changes.

The report proceeds in the following fashion. In the next few sections we provide a brief overview of transportation demand modeling and transportation in the Ohio River Valley. In Section 4, we summarize the survey, survey instrument and descriptive statistics. The demand model we use to frame the empirical work is developed in Section 5, with results presented in Section 6.

2. BACKGROUND ON DEMAND MODELING

There is a long history of transportation modeling. Over the years, a wide range of alternative approaches to demand models have arisen. In this section, this history and alternative approaches are summarized. Following this review, short subsections are provided that profile Army Corps of Engineer (ACE) treatments of demand in evaluating lock improvements are presented and followed by a description of issues that have been raised with ACE's treatments.

2.1 History and Evolution of Freight Demand Modeling[1]

Modeling of transportation demand goes as back as far as 1840's and is extensively explored in the academic research literature. Some of the earliest developments in studies of transportation economics discuss such topics as pricing of transportation infrastructure, congestion of roads, and optimal pricing of public transportation facilities. A number of the tools used in the earlier analyses of the transportation problems are still widely used today, for instance Ramsey pricing by Dupuit (1844,1849), economies of scope and joint production by Wellington (1887), and economies of scale by Lorenz (1916), as noted by Clark *et al.,* (2005) are examples.

Economic theory yields several features that lay the ground work to the study of transportation demand. These features include: (1) the interrelated decisions of transportation purchasers and providers, (2) the large number of distinct services differentiated by location or time (spatial and temporal aspects), and (3) the shipper's sensitivity to service quality (Small and Winston, 1998). These properties prompt many of the discussions on the building blocks of transportation demand, for instance on the determinants of shippers' choice of mode, the role of reliability and travel time in shippers' decisions, and the influence of input or output price changes on a firm's activities. Ultimately, each of these areas requires empirical Treatment. As a result, much of the work on transportation demand over the last 30 years has focused on developing methods for empirical estimation.

2.1.1. Aggregate vs. Disaggregate Data Models

The freight demand literature has, over the years, evolved into two distinct categories: studies that employ aggregate data often delineated by commodity (aggregations of shipments and shippers) or shippers (aggregations of shipments), and, more recently, those that use disaggregate data, where the level of disaggregation is at the individual shipment level. The aggregate demand models of 1960s are classified as modal split models and use data that described some behavioral aspects of a large group of shippers. These models were criticized for a variety of reasons, most of which focused on the lack of explicit emphasis on the behavioral aspects of decision-making and the implied structure on shipper preferences. These criticisms along with the development of duality methods, led to the development of the neoclassical aggregate demand model. Generally,

[1] This section draws heavily from Clark *et al.* (2005)

these later models, use standard microeconomic theory to derive transportation demand models usually from a logistic cost minimization problem. An advantage of this approach over modal split models are that the former are based on standard microeconomic theory and that they have the ability to use flexible functional forms in estimation that are directly tied to the underlying technology of the shipper. Flexible functional forms do not place any *a priori* restrictions on the nature of substitution across modes.

Oum (1979) was the first to identify the weaknesses of the modal split models in having restrictive functional form, ad hoc specification, exclusion of service-quality attributes, and the use of highly aggregated data over heterogeneous commodities. He measures the price and quality responsiveness of demand using three different derived demand models. The formulation of the models is based on the relation between production and a translog cost functions (duality theory). Thus, instead of imposing restrictions on the model by specifying a functional form, Oum derives a route-specific unit transport cost function for shippers as function of freight rates, service quality attributes of various modes, and the distance of the link. The data used include eight different commodity groups, and consists of the distance of each link, total tons moved, average freight rate, transit time and its variability by mode on each link. Data is for the year 1970 from the Canadian Freight Transport Model database. The author finds high substitutability between modes for most of the seven commodities groups.[2] Additionally, truck mode was found to be less price elastic than rail mode for all commodities except for chemicals and fuel oils.

Friedlaender and Spady (1980) extended Oum's (1979) models of neoclassical aggregate demand by using a cross-section of 96 manufacturing industries in 1972 to estimate the input share equation for truck and rail service. They estimate that the own-price elasticities for rail vary from -1.681 for stone, clay, and glass to -3.547 for electrical machinery.[3] The own-price elasticities of demand for truck, however, vary considerably less and range from -1.001 for food products to -1.547 for wood products. The cross-elasticities are quite low and range between -0.129 and 0.025. These elasticities imply a high degree of interdependence between rail and truck modes.

Oum (1989) broadens his 1979 analysis and explores how changes in the specification of the model affect the elasticity estimates. He compares elasticity estimates for models that use four different functional forms: (1) Linear demand model; (2) Log-linear demand model; (3) Logit model; and (4) Translog demand model. Oum asserts that changes in the estimated elasticities are a direct and sole result of changes in the functional form of the model, since the data used is the same for each specification. He finds that the Translog demand system is the best model for aggregate freight. Moreover, the author points to three notable findings. First, the ordinary cross-price elasticities from the logit

---

[2] The elasticity of substitution between rail and truck was lowest for lumber, 1.04, while that for other commodities ranged between 1.40 and 1.57, implying that a one percent increase (decrease) in rail freight rates would cause a more than one percent increase (increase) in the use of truck transportation and vice versa.

[3] An elasticity with absolute value greater than one implies that a one percent change in the price results in a more than a one percent change in the quantity demanded.

model are negative, but that is counterintuitive. Second, the own-price and own-quality elasticity estimates from both the Box-Cox and Log-linear forms are higher than expected, while the Translog and Linear forms generate demand elasticities that are closer to the expected value. Third, the author suggests that the theory-based Translog model is not only robust but produces the most favorable elasticity estimates.

The neoclassical approach uses aggregate data wherein, generally, total tonnages shipped over some period of time are aggregated over shipments. This approach may make it difficult to capture variation in shipment characteristics. This may result in either an overstatement or understatement in the sensitivity of demand to price and service qualities. Further, while the use of duality methods to generate transportation demands is "theoretically" grounded, the underlying structure of technology is usually taken as generally appropriate. Underlying the logistic cost minimization (or profit maximization) for shipments over some time period is a set of individual decision-making, the context of which may be lost in the aggregation. Given these drawbacks to using neoclassical aggregate demand models, economists developed disaggregate approaches to estimating freight transportation demand. A disaggregated model uses the characteristics of the individual decision-makers as well as a set of service attributes of different modes. Therefore, it yields richer empirical specifications which are more firmly grounded in the realities of decision-making.

Disaggregated demand models can be classified into two categories: inventory and utility maximization (choice models) (Clark *et al.*, 2005). Inventory-based models analyze freight demand from the perspective of an inventory manager who deals with a number of production decisions, while the choice models typically deal with only one decision, the choice of mode (Abdelwahab and Sargious, 1992).

The groundwork on inventory-based approach to analyzing freight demand was performed by Baumol and Vinod (1970). In explaining freight shipment decisions, the authors consider shipping cost per unit, mean shipping time, variance of shipping time, and carrying cost per unit of time while in transit. Shipper's indifference curve is specified with respect to the above-mentioned attributes by deriving a cost function under perfect certainty, a cost function where uncertainty of demand forecasts and delivery times are introduced, and a firm's profit function. As a result they arrive at an equation that explicitly defines annual tonnage shipped as a function of determinants of the mode choice. This result is cited in most of the empirical freight demand specifications, and is the foundation for the estimation of demand in this document.

Over the last several years, choice models wherein transportation demands are based on the decision made at the individual shipment level have become dominant. In particular, a typical model has a shipper considering the rate and service characteristics of different alternatives (mode/location) on a utility (profit) basis. Such models use logit/probit techniques to estimate the probability of making a choice given the attributes of the choice and the alternatives along with, in some cases, attributes of the shipper. To illustrate, Inaba and Wallace (1989) use a choice-based methodology to examine the demand for transportation by agricultural shippers in the Pacific Northwest. In addition to the standard approach described above, they amend the procedure to address two additional issues in transportation demand estimation. These are the simultaneity between mode choice and shipment size decisions and the effects of spatial competition on the demand for freight transportation. A switching regression model is used to account for the possible endogeneity of the shipment size with respect to the mode choice. The optimum mode choice and shipment size are determined through a profit function, which is a function of distance between a supplier and the firm, the firm's storage capacity and the *entire* set of mode-specific characteristics. The authors use survey data from grain elevators that included questions about capacity, loading facilities, service and handling charges, costs, loading times, service characteristics, destination prices for wheat, and shipment costs of mode used and their alternatives. They find that there is simultaneity between shipment size and mode choice. The results also indicate that higher service costs for a given mode lower the probability of the mode being chosen. The estimated demand elasticities suggest that transportation demands are relatively rate inelastic due to the short-run nature of the mode decisions studied.

2.1.2. Survey Studies

There have been a number of survey articles on transportation demand. One such survey by Oum, Waters, and Yong (1992) provides a comprehensive documentation of demand elasticites. Their survey covers both passenger and freight demand, and includes rail, truck and airfreight. They document a wide range of elasticities across commodities, functional forms, and methodology. The study finds elasticities of aggregate commodities to most likely range from –1.20 to -0.40 and –1.10 to –0.70, for rail and truck respectively; of coal from –0.40 to –0.10 for rail; of petroleum from –1.00 to –0.50 and –0.70 to -.50 for rail and truck, respectively; of primary manufactured commodities from –2.20 to –1.00 and –1.10 to –0.30 for rail and truck respectively.

2.1.3. Stated Preference Modeling

Stated preference modeling has been a relatively recent development and has received much attention in modeling consumer demand for passenger transport. Standard stated preference modeling confronts the survey respondent with a set of hypothetical alternatives with pre-programmed attributes. The choice made by the respondent is then modeled, generally, with a standard logit framework. The advantage of this approach is the analyst has control over the choice set and its attributes. The disadvantage is that the choice set is a constructed choice set and the behavioral response is a hypothetical. Nevertheless, this approach has been used extensively in modeling passenger transportation demands, and more recently, to model freight transportation demands.

Bolis and Maggi (2003) used a survey of thirty-one firms that provided a sample of 1271 hypothetical, stated preference, choices to estimate the effects of freight services such as price, time, reliability, and flexibility on the choice of freight transport. The objective of the research was to produce realistic estimates of the determinants of service choices in order to guide rail-related strategies in trans-Alpine freight transport. They found that firms place much value on transport qualities in general, and more specifically they give great importance to reliability and flexibility aspects.

Bergantino and Bolis (2003) carried out an adaptive stated preference[4] experiment to collect an appropriate database to analyze consumers' preferences for the maritime alternative and to identify the service attributes which most influence freight-forwarders' attitudes towards short-sea shipping. The analysis has been carried out using a revealed preference study to obtain data on the characteristics of the "typical" transport performed by the company and a stated preference survey user preference for the hypothetical alternative. The Tobit estimation technique was used to arrive at the conclusion that when evaluating the maritime alternative, freight forwarders seem to assign a higher ranking to frequency than to reliability property of a transportation mode.

In the United States, Train and Wilson (2004) estimate transportation demand functions for agricultural shippers that use or could use the Upper Mississippi and Illinois waterways (UMR-IWW). They design and implement a revealed and stated preference survey instrument and model shipper's transportation choices as a function of rates and transit times. The model estimated recognizes that the parameters of the underlying utility function of choices are linked, and both revealed and stated preference data are combined in their estimation. In a separate analysis, they frame a stated preference model of the responsiveness of annual shipment volumes to changes in transportation rates and transit times. They find that annual volume adjustments to rate and service characteristics depends on the level of the change and a set of individual shipper characteristics. This latter model is extremely useful in the analysis reported below in that the survey data do not suggest much in the way of mode/location choices with most of the adjustments by shippers being related to the quantities produced i.e., the "intensive" margin.

2.2 Summary of U.S. Army Corps of Engineers Demand Modeling

The U.S. Army Corps of Engineers (ACE) has a long history of managing navigation, flood control, and other waterway-related issues. Their tasks range from planning, designing, building and operating water resources and other civil works projects, to designing and managing the construction of military and other facilities for the Army, Air Force, Defense and other federal agencies. The projects the ACE embarks on are warranted by the long-run cost-saving benefits that prevail over the project economic life. In recent years some of the tools used by ACE in the benefits assessment have come under considerable scrutiny and have been evaluated by the National Research Council (NRC) and others. To develop a better suite of tools, the Navigation Economic Technologies (NETS) program was established to provide ACE with independently verified, objective economic models, tools, and techniques for evaluating current and future navigation needs. One focal point of NETS is on the integration of more complicated demand structures into the ACE models (NETS).

The general economic approach to valuing benefits of a project is to value the "economic surplus" generated. Ordinarily, this means that the cost of any improvement would be compared to the expected net present value of economic benefits that will be generated

[4] The choice of survey questions is adapted to the respondents' answers to the previous questions.

by the project (Berry *et al.*, 2001). ACE relies on a generalized methodological document referred to as the "Principles and Guidelines" (P&G). The P&G defines a wide array of benefit categories. Historically, however, it has been the National Economic Development (NED) benefit, one of many P&G considerations, that has weighed most heavily in any decision-making process. NED benefits generally stem from welfare-enhancing efficiency gains and exclude the impact of income transfers. The P&G identifies four potential sources of NED benefits in association with inland navigation projects. They include: 1) Savings to Existing Waterway Traffic; 2) Savings Due to Shift of Mode; 3) Alternation of Commodity Flows; 4) Project-Induced Changes in Output Quantities (Burton, 2001). In brief, in each period, the economic benefit of the waterway improvements is the net value of the additional transportation services received by shippers. The value received by shippers can be summarized by the "demand for barge transportation" (Berry *et al.*, 2001).

The traditional application of P&G recognizes the savings to the shippers from lowering the costs of transportation to be the easiest to evaluate. Current traffic volumes are readily available and estimates of navigation costs under "with" and "without" project conditions can be made with relative ease. With regard to benefits that may be attributable to the other three potential sources of NED benefits, the spatial nature of the benefit analysis challenges the calculation process. The savings attributable to modal shifts appear to be investigated with much inconsistency in the analytical procedures employed. The other two sources of benefits are, almost without exception, ignored within the NED calculation process (Burton, 2001).

In view of the fact that a solvable general equilibrium model that fully encompasses both spatial relationships and all downstream market activities is impossible to develop due to its complexity, an alternative measure is to incrementally improve the understanding and treatment of transportation demand relationships. With this purpose in mind, in 1988, the ACE instigated *Spatial Price Equilibrium Based Navigation System NED Model for the Upper Mississippi River-Illinois Waterway Navigation System Feasibility Study* (UMR-IWW Feasibility Study). The Economics Work Group in charge of the UMR-IWW Feasibility Study took on the task of investigating the benefits and costs of extending several locks on the lower portion of the Upper Mississippi River-Illinois Waterway (UMR-IWW) in order to relieve increasing waterway congestion, in particular for grain moving to New Orleans for export (NRC, 2004a). One factor contributing to the congestion is that the length of tows on the river has increased over time. The draft report of the UMR-IWW Feasibility Study released in the Fall of 1999 proposed an expansion of locking capacity on the UMR and IWW. That is, to increase the length of locks at selected locations to 1200 feet instead of 600 feet (Berry *et al.*, 2000). In July 2002, the ACE issued an interim report of the Restructured UMR-IWW Feasibility Study, in which it addressed navigation improvements along with the ecological degradation that has accompanied Mississippi and Illinois River lock and dam construction and operations.

Spatial price equilibrium theory suggests that the maximum contribution to NED of each potential origin, destination, and commodity group movement is the minimum willingness-to-pay to avoid all other alternatives to waterway transportation. In the draft report of the UMR-IWW Feasibility Study, the Economics Work Group incorporated the notion that changes in barge rates may significantly alter the ways in which shippers operate. Specifically, the work group examined four alternative shipper responses to water rates that may constrain willingness-to-pay: (1) a shift of transport mode, (2) a geographical shift of destination, (3) a geographical shift of origin, and (4) a no long-haul transportation or local consumption alternative (USACE, 2002). These alternatives exactly parallel those suggested by the P&G sources of navigation improvement benefits. The Spatial Price Equilibrium Based Navigation System NED Model (SEM) distributes willingness-to-pay for water transportation between the maximum willingness-to-pay for the first ton moved and the minimum willingness-to-pay for the last ton. With the exception of agriculture, SEM distributes willingness-to-pay linearly. Agricultural products are believed to experience a more rapid decline. In the case of corn, the Work Group notes that Gervais and Baumel survey data indicate that there is a significant local demand for grain in the state of Iowa. Also, negligible quantities of corn produced in the state of Iowa move by rail to the same ultimate destinations as those served by the Mississippi River. They conclude that for corn currently moving to the Mississippi River, utilizing a different mode of transportation to the same ultimate destination is not a real alternative to waterborne transportation. It appears to them that a change in destination is the real alternative for corn destined to Mississippi River terminals (Dager *et al.*, 2004).

Two primary economic models have been used in recent years to provide a basic measure of NED benefits. These are the Essence Model and the Tow Cost/Equilibrium Model (TCM/EQ). We note this latter has now been subsumed in the Ohio River Investment Navigation Model (ORNIM). For the present purpose, the treatment of demands in TCM/EQ and ORNIM are symmetric, and, hereinafter, we refer to each as TCM/EQ. A key difference of TCM/EQ and Essence is relates to differences in the demand functions used. The demand function of TCM/EQ is perfectly inelastic to a threshold price above which demands for barge revert to zero. In the Essence model, demands erode continuously from the same quantity as the TCM/EQ to zero at the same threshold price. As described below, the treatment of demand can and does have an important effect on the size of the benefits from a given waterway project.

TCM/EQ

For the Upper Mississippi, the TCM/EQ operates on a sample of 1900 barge movements that are taken as inputs. For each of these barge movements, the best rail alternative is identified, and the cost of sending the shipment by rail is calculated. Forecasts are obtained under scenarios for barge costs (i.e., with and without the project). For each of the 1900 barge movements, the cost of sending the shipment by barge under the scenario is calculated. The shipment is predicted to stay on barge as long as the barge cost is less than the least cost alternative usually taken as the cost by rail. If the barge cost under the scenario is higher than the rail cost, then the shipment is predicted to switch to rail. Based on this assumption a demand curve for barge shipments is constructed within TCM/EQ, and applied to each of the 1900 shipments. The predictions for each shipment are then added up to obtain the prediction of the total quantity shipped by barge. This prediction is done twice, with and without the proposed project. The difference between the two sets of predictions provides the estimated impact of the project on the volume of barge shipments. This difference in shipments with and without the project can be used to calculate an arc elasticity of barge volume with respect to change in barge costs. Note, however, that this elasticity is the outcome of the demand curve constructed within TCM/EQ model for each of the 1900 shipments. It is not an input to the model. Also, the arc elasticity does not affect the calculation of impacts or benefits; rather, it is an implication of the demand curve applied to each of the 1900 shipments (Curlee *et al.*).

Essence

Essence addresses the first of the two "stark" assumptions of the TCM/EQ demand construct. In the Essence model, barge quantity decreases as barge costs increase even when the barge cost is less than the rail cost. For barge costs below rail costs, the demand curve is downward sloping rather than, as in TCM/EQ, perfectly vertical. The curvature of the demand curve is determined by a parameter, "N". As practiced in early studies, the value of N is not determined from data analysis, but rather assumed. In principle, N allows for a wide class of functional forms that allows for convex, concave and linear demand functions, and, in principle could be estimated. Further, in the more recent UMISS study, different values of elasticity are assumed and then the value of N that would imply the values is inferred from a mathematical expression. Thus, instead of a specific N assumed for simulations, there are specific elasticities assumed each of which yield a different value of N. While Essence allows for downward sloping demand equations at the ODC level (origin, destination commodity), it maintains the second "stark" assumption of TCM/EQ. That is, when the barge cost exceeds the rail cost, the entire quantity of the shipment is assumed to switch to rail. Essence runs on the same sample of about 1900 barge shipments for the UMISS as for the TCM/EQ. That is, the demand curve is applied to each of the 1900 shipments, using the rail cost R0 and the "N" value for that shipment. The total quantity on barge is obtained by summing the predictions for the 1900 shipments (Curlee *et al*.).

Both TCM/EQ and Essence are designed to measure the benefits of relatively small infrastructure improvements –e.g., the extension of one or more locks, the rehab of specific parts and components at locks, the adoption of new approaches to maintain and repair locks. Each of these models has been heavily criticized, as described in the following section.

2.3 Criticisms and Issues with Corps Demand Modeling

In February 2000, the Department of Defense requested that the National Research Council (NRC) convene a committee, "Phase I committee", to review the ACE draft report of UMR-IWW Feasibility Study and issue a single report, Inland Navigation System Planning: The UMR-IWW. This committee was requested to focus its review on the ACE's economic analysis of proposed navigation system improvements, but also to comment upon other relevant water resources planning issues (NRC, 2004a). The NRC was called again in 2003 to form a "Phase II committee" to review the interim report of the Restructured UMR-IWW Feasibility Study and the drafts that followed. A series of three reports, the Review of the Restructured UMR-IWW Feasibility Study, were scheduled to be released in 2004 and 2005 and concentrated on several topics on which the Phase I committee had commented and for which the ACE had proposed responses in its restructured study plan. In these NRC reports, the reviewers found the methodology used in the study to be basically sound, but, among others, they reached several unfavorable conclusions regarding the elasticity component of the SEM: The committees commended ACE for adopting a model where barge demand is modeled with users having a distribution of willingness-to-pay. However, the fact that this distribution is assumed rather than measured was troubling, especially considering that the ACE has stated that no study resources were directed toward identifying the distribution of willingness-to-pay for commodity movements. Obtaining data on the actual willingness-to-pay distribution is of high priority, because so much of the estimated benefit comes from the willingness-to-pay calculations. This benefit estimate should be based on data, not just unsupported theory. Additionally, the NRC review offers strong criticism of the ACE's approach to constructing a spatial equilibrium model (SEM) in relying on TCM and ESSENCE models (Dager *et al*. 2004).

According to NRC, the TCM suffers from three primary limitations in that the quantities demanded are fixed to a threshold, the model fails to consider alternative modes and alternative markets; and it fails to recognize explicitly the spatial placement of products. Neglecting these issues makes TCM an oversimplified representation of the demand for waterway transportation. To generalize the first limitation, the TCM assumes that shipments will be unaffected by rising transport cost (due to increasing congestion) until it reaches the cost of the least cost alternative mode (presumed to be rail shipment). At that point, all traffic is assumed to move from the waterway to rail. In economic terms, the TCM assumes that demand for water transportation is perfectly inelastic for prices below the cost of rail shipment and perfectly elastic at that point. The other two issues refer to the "boundary conditions", that there is no single alternative shipping cost – it depends on rail capacity, proximity of shippers to railheads, proximity of shipper to barge loading points, and so on. Yet even if more realistic boundary conditions could be provided, the assumption of perfectly inelastic demand for all shipping costs below the boundary (alternative cost) remains at odds with reality. The NRC committee concludes that TCM "therefore produces results that are of only marginal use in the feasibility study. For this reason, the TCM cannot be used to accurately estimate the benefits of reducing congestion. Instead, it estimates an approximate upper bound on economic benefits" (NRC, 2004b).

The committee also noted several limitations of the ESSENCE model. The model represents a significant simplification of the spatial equilibrium concept, in that it incorrectly assumes that the cost of transport is always proportional to distance. Additionally, there is no way to know whether any value of N that is used in Essence actually provides a plausible demand curve shape, since the value of N is not determined from data analysis. This is a crucial omission, since the values for the parameters used in the elasticity estimations should be based on empirical demand and supply data for the UMR-IW. However, even if such data is available, the present specification of the ESSENCE model does not allow for "an independent choice of demand elasticity", whether or not it is empirically determined (NRC, 2004a).

Through the course of the NRC committee's study, several academic and other experts and practitioners in the fields of grain production, shipping, and commercial transportation provided comments regarding grain shipments and multiple end uses, markets, and shipping options available to farmers. These comments indicated a strong consensus that small changes in market prices as experienced by grain producers (driven, for example, by changes ins hipping costs) are sufficient to transfer significant amounts of grain from one market to another. The NRC committee concurs with this consensus and further notes that similar factors also influence non-grain shipments. This reality is not represented in any way by SEM models that assume unchanging barge movements for all shipping costs below the relevant boundary conditions (NRC, 2004a).

In 2003, U. S. Department of Agriculture (USDA) funded the Department of Agricultural Economics at Texas A&M University to examine barge grain transport demand on the UMRIWW. In the resulting study, Yu and Fuller (2003) argue that, for the studies underway to evaluate the feasibility of new lock construction on the UMR-IWW, the benefits of new lock construction should be based on demand schedules for barge transportation service. They develop and estimate various demand models using monthly data on aggregations of traffic by river (and river segment). Their findings suggest that the demand for grain barge transportation on the UMR and IWW is inelastic, with estimated demand elasticities of –0.50 and –0.20, respectively. The results also suggest that foreign grain demand, as measured by quantities of grain exported at lower Mississippi River ports, has an important influence on grain barge demands. The export grain demand elasticity is found to be elastic (1.2 to 1.6) for the UMR and inelastic (0.7 to 0.9) for IWW.

It is noted that in the Yu and Fuller, barge rates were statistically significant in only two of the six equations on the Mississippi River. And, of these, significance was found at only the 20 percent level. Results were more positive for the Illinois River; for all six equations, the elasticity values were significant at the five percent level and all were near -0.21. These results point to inelastic demands, a finding that seems to run with the use of aggregated time series data.

A recent study by Dager *et al.* (2004) also estimates demand elasticities for different aggregation on the UMR-IWW. In this research, they examine the four axioms suggested in the UMR-IWW Feasibility Study defining the maximum willingness to pay for barge transportation related to modal choice. The findings provide evidence to indicate that the last three axioms, a geographical shift of destination, a geographical shift of origin, and a "no long-haul" transportation alternative, are less likely to occur than the first one, implying that the most likely alternative to barge transportation is switching of modes. The authors estimate the rate elasticity for the lower Mississippi River to be -0.7. For the middle Mississippi River, the upper Mississippi River and the Illinois Waterway, the elasticity values are estimated to be, respectively, -0.3, -0.57 and -0.42. These results are consistent with the work of Yu and Fuller, augmented by the fact that the elasticity values are statistically significant. The authors attempt to explain high maximum willingness to pay and inelastic demand of barge users by the ability of shippers to use barges for storage to a depth of 12 feet, the economies of mid-stream transfer at export ports, and flexibility in the servicing of terminals on different river systems and at export ports.

The current work differs dramatically from the models that use time series data. In particular, cross sectional survey data are used to model the demand for transportation by mode using stated preference methods. The result allows a demand function to be created at the individual shipper level. Aggregation to the pool level is plausible and may allow direct integration into the planning models. This topic is considered in greater detail later in the paper.

3. BACKGROUND OF OHIO RIVER RESOURCES

The inland waterway system of the U.S. is vast both in geographic area and tonnages of goods carried. The total network consists of nearly 12,000 navigable miles, offering the benefit of direct access from and to ocean ports and from the nation's interior and connecting to all but nine of the fifty states. Several river systems, most notably the Mississippi and Ohio, serve as major arteries that draw traffic from other smaller, tributaries, and connect remote regions to the waterway system as a whole.

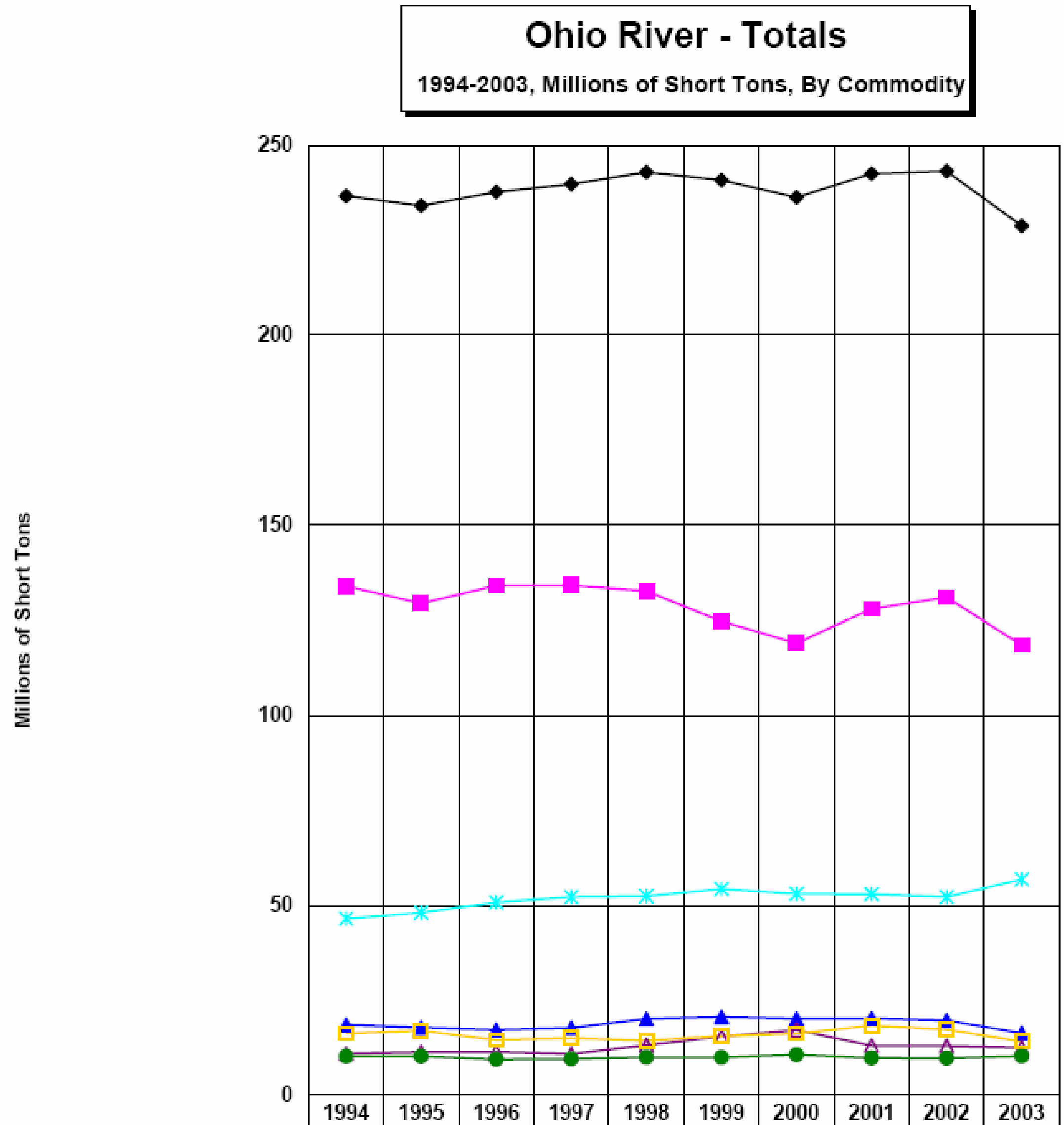
The entire system, from ocean ports inward, falls under the jurisdiction of the USACE, whose responsibility is to operate and maintain all waterway infrastructure needs, such as constructing and maintaining navigation channels and harbors and regulating water levels on inland waterways. USACE delineates the entire waterway system into four geographic sections: 1) Atlantic Coast, 2) Gulf Coast, Mississippi River System and Antilles, 3) Great Lakes, and 4) Pacific Coast, Alaska and Hawaii. For purposes of this report, both the Ohio and Mississippi River systems are incorporated within the bounds of the Gulf Coast, Mississippi River System and Antilles division (WCSC, 2003a).

Encompassing 2800 miles of navigable waterway, the Ohio River Basin (ORB) is a major system for inland barge commerce. In addition to the Ohio River, the Basin is composed of the Ohio River's seven navigable tributaries (Tennessee, Cumberland, Monongahela, Allegheny, Green, Kanawha, and Big Sandy Rivers). This allows the system to cover nine states, namely: Alabama, Illinois, Indiana, Kentucky, Mississippi, Ohio, Pennsylvania, Tennessee and West Virginia. Moreover, barges that operate within the ORB can be found originating from or terminating at 12 other states: Arkansas, Florida, Georgia, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, Oklahoma, Texas and Wisconsin. In 2003 alone, the Basin was responsible for transporting a total of 261 million short tons[5] of commodities to these and other states (WCSC, 2003a).

Needless to say, the Ohio River itself represents the central artery within the Basin system, both in a static and dynamic sense. As the backbone of the ORB system, the Ohio's 981 miles of navigable waterway stretch westward from Pittsburgh to convergence with the Mississippi River near Cairo, Illinois. This endpoint connection at the Mississippi River and the convenience of having seven navigable tributaries are the key reasons for the Ohio's attractiveness to the inland barge commerce. Naturally, the river acts as a funnel for the commodity traffic traveling within the area and will remain so for years to come. Figure 1 shows the volume of commodities traveling through the Ohio River alone in years 1994-2003. As can be seen, the river has gone through business cycles fluctuation of commodity flows, corresponding to ups and downs of the U.S. economy. Commodity tonnages reach a maximum of approximately 243 million tons in 1998 and 2002, and drop down to around 230 million tons in 1995, 2000, and 2003 (WCSC, 2003b).

[5] One short ton is 2000 pounds. From here on short tons will be referred to as just tons.

Figure 1: Commodity flow on the Ohio River in years 1994-2003[6]



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Total	236.65	234.06	237.69	239.76	242.90	240.79	236.30	242.50	243.15	228.77
Coal	134.02	129.46	134.14	134.19	132.69	124.75	118.93	128.00	131.04	118.46
Petro & Petro Products	18.59	17.84	17.27	17.75	20.16	20.64	20.19	20.28	19.75	16.38
Crude Materials	46.49	48.05	50.76	52.21	52.42	54.28	53.02	52.93	52.22	56.85
Manufactured Goods	10.98	11.39	11.47	10.91	13.20	15.49	17.19	13.08	13.00	12.58
Food & Farm	16.25	17.04	14.58	15.07	14.39	15.60	16.23	18.34	17.33	14.17
Other	10.32	10.29	9.47	9.62	10.04	10.02	10.73	9.86	9.81	10.34

[6] WCSC 2003b, page 34

The ORB system economy resembles the Ohio River commodity flow trends described above. Table 1 shows the most prolific commercial traffic of 1998, 2001, and 2002 to attain volumes as high as 280 million tons per year, while the national recessions to be reflected in low volumes of 1995 and 2003 (268 and 262 million tons, respectively). It is notable to mention, however, that over the period of 1994 to 2002 the traffic flow on ORB has increase at an average rate of 0.48% per year.

Table 1: Comparative Statement of Traffic on ORB (in millions of short tons)[7]

Year	Total	Year	Total	Year	Total	Year	Total
1994	270,539	1997	274,859	2000	274,372	2003	261,277
1995	267,604	1998	278,811	2001	281,801		
1996	270,932	1999	277,902	2002	280,878		

Of the 261 million tons carried within the system in 2003, approximately 40 million tons ebbed out of the ORB, while 43 million tons flowed into the system from outside (upbound and downbound combined). Most significantly, approximately 178 million tons, about 68%, traversed and remained within the Basin itself (WCSC, 2003a pg. 69) The commodities shipped via the system can be grouped into six categories: coal, crude materials, petroleum, primary manufactured goods, chemicals, food and farm products, and other. The following section of the report provides a brief account of each commodity group hauled within the ORB system.

3.1 Coal

Coal constitutes the dominant share of the cargo, approximately 142 million tons or 54% of total barge traffic in 2003.[8] Most of the shipments, 90%, remained in the system. These coal shipments tend to originate from coal reserves in the states adjacent to the Ohio River such as Illinois, Indiana, Kentucky, Pennsylvania, and West Virginia. Furthermore, the Ohio River is home to 49 coal-fired power plants, 20 percent of nation’s coal-fired generating capacity (USACE, 2005). Twelve others reside in the neighboring states connected via waterways.

3.2 Crude Materials

Crude materials form the second largest commodity classification with 64 million tons or 24% of all cargo hauled within the system. Of those, 35 million tons (55%) were destined for locations within the Ohio River Basin and 14 million tons were exported out and imported into the Basin each.[9] The major commodity group shipped in this category is aggregates (74%), a common term for soil, sand, gravel, rock and stone. Kentucky retains the position of both the largest shipper and receiver of aggregates. Not coincidently, Reed Quarry located on the Tennessee River in Kentucky is the largest limestone quarry in the world. Limestone is also utilized by coal-fired power plants for

[7] WCSC 2003a, page 69

[8] While coal tonnage has stayed reasonably constant at a system level, there are often significant flow changes at a more disaggregated level. These changes reflect the always volatile nature of fuel markets.

[9] These figures do not report waterway improvement material, accounted separately by the USACE

desulfurization, which adds to the system-wide, interconnected nature of demand for barge traffic.

3.3 Petroleum and Petroleum Products

Petroleum and allied products comprise the third largest commodity classification (6.9% of all barge traffic). Of the 17,223 million tons transported in 2003, 43.9% was imported from outside the Basin, while 50% was transferred intra-system. This may be the result of the fact that many Basin cities are without a connection to the national petroleum pipeline and petroleum products have to be transported via other modes. In addition, some products such as asphalt and residual fuel oils cannot be moved via pipelines, simply due to their physical properties. To meet this demand, ORB hosts 250 tank farms, terminals or affiliated facilities for petroleum products, including the nation's largest refinery operated by Marathon Ashland in Catlettsburg, Kentucky (Huntington).

3.4 Food and Farm Products

The ORB states clearly contribute the national grain production. Unlike the other commodities reviewed above, the majority of farm production within the region is destined for export via the Lower Mississippi. Specifically, over 10 million tons (71%) are exported (10.2 million tons), while only 3.6 million tons are imported (24%) into the Basin. Due to large transactions of grains and oilseeds, the waterway infrastructure supports 145 grain facilities that are available for barge access.

3.4 Primary Manufactured Goods

This category of commodities ranges from primary paper, glass, and steel goods to wood, cement and others. They comprise 5% of barge cargos, where approximately 6 million constituted imported goods, and the remaining of the 13 million tons represented intra and outbound traffic. Manufactured iron and steel products constituted most of the imports, reflecting weak production capacity for such products across some portion of the ORB system.

3.5 Chemicals

Attracted to the Basin by cheap electricity, abundant inputs (coal and salt deposits) along with close proximity to down-stream manufacturers (plastic and auto parts, for instance), chemical cargo contributed nearly 12 million tons to commodity traffic in 2003. The trend for chemical shipments has remained nearly constant over the last decade at around 10 million tons annually. The 231 chemical facilities clustered largely on the Lower Monongahela and Upper Ohio Rivers may provide for a relatively stable demand for chemicals will continue to persist in the region (Huntington).

The wide variety of commodities shipped via the ORB system could not be sustained if not the elaborate infrastructure constructed and maintained by the USACE and other private parties. In particular, there are approximately 1000 facilities, docks and terminals that comprise the system that also includes 60 lock and dam facilities overseen by the USACE. From this description, it should well be noted that industries have developed and have incurred sunk costs to persist in the Ohio River Valley.

4. SURVEY

The data employed in the analysis are the result of telephone survey conducted by the Center for Business and Economic Research (CBER) at Marshall University. The survey instrument is provided in Appendix A. It was designed to solicit responses to questions that would enable both revealed and stated preference models to be estimated. As discussed below, the results of the survey suggest that choice methods cannot be employed with this population, and thus, our empirical model and results focus on stated preference questions related to the reaction of production levels to changes in transportation rates and service attributes.

The sample was stratified by location and commodity from a list of shippers provided by USACE and Dun and Bradstreet. The list of shippers with locations on the Ohio included 628 dock listings from which non-shippers (e.g., fuel docks, repair docks, etc.) were removed. This provided a list of 535 shippers located on the river. Off-river shippers were identified within counties that border the Ohio River. Six different commodity groups were identified (coal, aggregates, chemicals, iron/steel, ores/minerals, and petroleum) for the sample. The survey was conducted during March, April, and May of 2004. Shippers sampled were each telephoned up to three times to solicit participation and completion of the survey. The telephone calls continued until the closure of the survey. By commodity, the contact rates were: 106 of 106 coal shippers; 351 of 594 aggregate shippers; 250 of 556 chemical shippers; 204 of 782 iron and steel shippers; 61 of 61 ore and mineral shippers; and 94 of 331 petroleum shippers.

Of the 972 shippers contacted, CBER was able to successfully interview 191 shippers. Of these, 179 surveys were used. The remaining surveys provided extremely sparse information and were not usable. The number of barge shippers along with total tons shipped by the firm is listed in Table 2.[10]

Table 2: Number of Barge Shipments and Annual Tonnages by Commodity Type

	Shippers (#)	%	Annual Tons (millions)	%
Chemicals	5	10.87%	0.03	0.01%
Coal	12	26.09%	311.04	86.28%
Crude	10	21.74%	14.75	3.94%
Food	10	21.74%	16.59	4.61%
Prim. Manufactured	3	6.52%	2.60	0.72%
Petroleum	4	8.70%	12.00	3.33%
Other	2	4.35%	4.00	1.11%
Total	46	100.00%	361.01	100.00%

[10] There may be some cause of concern on these statistics. For example, the annual tonnages shipped by coal are more than is shipped on the Ohio as presented earlier. However, the question of the survey on which this is based, simply asks for firm size in terms of tons produced. It does not ask how much tons do they ship from that location by barge per year.

Table 3 provides the frequency of shippers in each state. Nearly all shippers, 98%, come from the states in the Basin, with Alabama, Mississippi, and Tennessee not represented in the sample. The three states included in the sample that are not in the system, Georgia, Missouri, and Texas, comprise the rest of the shippers.

Table 3: Location of Shippers By State

State	%
GA	0.56
IL	7.82
IN	20.11
KY	21.23
MO	0.56
NY	0.56
OH	22.35
PA	15.08
TX	0.56
WV	11.17
Total	100

There are a number of key variables reported in Table 4. These include average commodity prices and logistics costs as a fraction of the commodity value by modes used. The means of the responses are presented in Table 4. As can be seen, the average price of the commodity usually shipped by truck is substantially higher than ones shipped by rail or barge, $23,297 vs. $275 and $132 per ton, respectively. The commodities shipped by truck are usually final goods, the price of which reflects the value-added, whereas commodities shipped by rail and barges tend to be raw materials and agricultural crops. The fraction of commodity value represented by logistics costs appears somewhat uniform across modes, averaging at 20-22%. The annual volumes of shipments (not reported here) are lower for barge, reflecting the seasonal patterns in shipment of agricultural crops and construction materials.

Table 4: Firm Specific Data

Choice	Average Commodity Price (per ton)	Share of Logistics Costs
Barge	131.72 (32)	21.44 (26)
Rail	274.50 (3)	22.25 (4)
Truck	1275.14 (54)	23.41 (70)
All Modes	836.43 (88)	22.85 (100)

The survey instrument included a question about the availability of the loading/unloading equipment at the shippers' premises. Table 5 displays the distribution of such equipment among the sampled shippers. As can be seen, majority of the shippers have loading equipment for truck, either alone (43%) or in combination with barge and rail equipment (47%).

Table 5: Availability of Loading Equipment

Options	%
None	2.79
Barge Only	3.91
Rail Only	0.56
Truck Only	43.02
Barge & Rail	2.79
Barge & Truck	15.64
Rail & Truck	10.06
Barge & Rail & Truck	21.23
Total	100

The shippers were also asked to provide specific information about their last shipment. The last shipment information was used to restrict the number of alternatives for which data would need to be gathered and still allow a switching model to be estimated. These data provide information about the commodity shipped, the origin and destination, the shipment size, modes used, transportation rates, and transit times for the last shipment and the shipment that would have been made in lieu of the shipment made.

Table 6 shows the frequency of states from which shipments originated and their destination states. It can be seen that shipments take off from states bordering the Ohio River and terminate predominantly in neighboring states. Such pattern in shipment travel is in part due to the limitations of transporting freight via Ohio River.

Table 6: Origins and Destinations of Shipments

		Destination State																				
		AL	CA	FL	GA	IA	IL	IN	KY	LA	MD	MI	NC	NJ	NY	OH	PA	TN	TX	WV	Oth.[11]	Tot.
Origin State	AR						1															1
	FL																			1		1
	GA																	1				1
	IL			1			3	2	2	4							1				2	15
	IN				1	1	1	12	2	4		2	1				3	2	2	1	2	34
	KY		1	1	1	1	1	1	14	1		1				8	1	1	2	1		35
	LA								1							2						3
	NY														1							1
	OH	2	1		1		4	1	4	4				1		15	6			1	1	41
	PA		1				3			1	4			1	2	2	7		1	1	1	24
	TX							1													1	2
	WV								2		1	2	1			3	4	1		6	1	21
	Total	2	3	2	3	2	13	17	25	14	5	5	2	2	3	30	22	5	5	11	8	179

[11] The states in this category were shipped to only once. They include: AZ, CT, ID, KS, MA, MO, MS, OK.

Statistics provided in Table 6 present means of the rates, speed, and distance and median of size of the sampled shipments, by mode. The differences across modes are generally as expected, but a few inconsistencies in the responses of the six rail shippers as they comprise such a small fraction of the sample. Barge movements cost the least and truck the most per ton-mile, while rail shipments take the longest, followed by barges and then trucks. This, of course, is consistent with expectations. Miles traveled is also as expected, with barges traveling the furthest. Finally, rail and barges haul the largest shipment volumes, and trucks the smallest values.

Table 7: Last Shipment Specific Data
Rate, Speed, Distance, and Size of Shipments by Mode

Choice	Rate per ton-mile (cents, mean)	Miles per hour (mean)	Miles (median)	Shipment Size (median)
Barge	1.20 (19)	9.88 (44)	500 (46)	1700 (46)
Rail	4.49 (3)	9.25 (6)	233 (6)	10000 (6)
Truck	55.41[12] (63)	35.97 (126)	175 (127)	19.5 (120)
All Modes	41.50 (84)	28.93 (176)	250 (179)	22.43 (172)

Note: Number of observations in parenthesis

Of considerable importance to modeling transportation is the identification of shippers' alternatives. The survey instrument was designed to obtain information on the "next-best" alternative that was available to the shipper for its last shipment. After the shippers described their last shipments, the shippers were asked what they would have done if the mode choices used for the last shipment were no longer available. For example, if the last shipment was by barge, shippers were asked what they would have done if sending the shipment by barge were not an option. The responses are summarized in Table 8. About 15% of the shippers said that they would use a different mode, without changing origin or destination. About 16% said that they would choose a different origin or destination. An astounding 70% of the shippers noted that they have no alternatives and would have to shut down. There are a number of different explanations for this result. First, if firms are working on a small margin, small changes in costs can impeded their competitiveness. Discussions with analysts suggest that much of the traffic in the Ohio River Valley may of such a nature. Second, the lack of alternatives may reflect the notion that the alternatives are outside the "consideration set". That is, while options

[12] Some of the commodities transported by truck are light in weight, but occupy much volume or cannot be transported in large quantities, such as glass sheets. The truck rates for such commodities tend to be high due to high volume and value. High rates apply to such commodities as sheet metal, custom packaging, iron castings, metal, furnaces, plastic, rolls, and thermo-foam, and such difficult to transport goods as glass sheets. Omitting these rates from the survey data (8 observations) yields a mean rate of $0.25 per ton-mile and a median of $0.07 per ton-mile which are much more in line with expectations.

might theoretically exist, if they are not considered by the shipper, they are irrelevant.[13] What is clear, however, is that majority of the shippers would not change the location if the mode they currently use was no longer available, a result that is consistent with the findings of Dager *et al.* (2004). These shippers posed a number of problems in the estimation of a "choice" model. Specifically, if shippers have no mode/location options, no such decisions can be estimated. Instead, the only mode of adjustment is through production decisions.

Table 8: Availability of Alternatives

Alternative	Frequency	%
Original Location	26	14.77
Different Location	28	15.91
Shutdown	122	69.32
Total	176	100.00

If there is little opportunity for shippers to choose modes and locations from discrete alternatives, the primary mode of adjustment (if any) to changes in rate and service characteristics is through adjustments in production levels. The survey results provide information on annual production levels as well as the responsiveness to rates and time to transit. The latter forms the basis for the empirical work developed in the next two sections. Shippers were asked how their production plans would change in response to a randomly generated percentage increase in rates and transit times, ranging from 10% to 60%. Questions of this variety represent stated preferences of the shippers, as opposed to revealed preferences of observing changes in annual volumes of shipments from rate and transit time changes that happened in actuality. In some settings and research designs, stated preference research offers an excellent way to examine decision-making. That is, for extremely complex decision processes, the researcher designs the experiment and the problems of modeling actual outcomes are alleviated. In the present case, data do not exist that allow the estimation of demands for the wide classes of commodities and settings of shippers. The stated preference approach is ideally designed for such cases. In the present case, Table 9 provides a summary of these results overall and by commodity. Basically, the answers to the question fall into three categories that are no adjustment, some adjustment and shutdown (quantities fall by 100%).

[13] In other surveys of a similar nature e.g., Train and Wilson (2004), a high number of "no alternative" shippers was also reported. In their case, the data consisted by agricultural shipments – a commodity for which there are ample markets and markets that are commonly arbitraged in the grain trade. For the bulk of commodities in the Ohio River Valley, the number of alternatives may be smaller and arbitrage is not as prevalent.

Table 9: Percent Shippers that Adjust Some or Completely and Mean Adjustments

Adjustment to Rate Increase	% Some & Complete Adjustments	Avg. Volume Adjustment	Adjustment to Time Increase	% Some & Complete Adjustments	Avg. Volume Adjustment
Chemicals	33.33%	35.00%	Chemicals	29.41%	40.00%
Coal	18.75%	56.67%	Coal	43.75%	17.86%
Crude	45.45%	44.00%	Crude	58.33%	27.14%
Food	34.50%	40.83%	Food	31.25%	33.00%
Prim. Manufactured	33.80%	31.67%	Prim. Manufactured	25.00%	30.50%
Petroleum	44.44%	42.50%	Petroleum	22.22%	27.50%
Other	37.50%	46.11%	Other	25.00%	16.33%
All Commodities	34.55%	38.42%	All Commodities	30.12%	27.64%

As shown in Table 9, the number of shippers that reduce their annual shipment volumes in response to rate or time changes is larger for the former. However, this trend varies across commodities. More shippers are likely to reduce the annual volumes of coal and crude materials in response to time changes, with the number of coal shippers more than double. For all commodities combined, the average magnitude of annual volume reduction is once again higher in response to a rate change. This is not true for chemicals shipments, whose volumes adjust in greater proportions in response to transit time increases.

In the next section, we develop a model of this variable (the percentage change of quantities) for rates and transit times, and report the empirical results in the following section.

5. CONCEPTUAL FRAMEWORK

In this section, we develop the foundation for the empirical estimations. This work follows directly from a model of transportation demands developed by Baumol and Vinod (1970). Their model defines demand for transportation on the basis of the characteristics of the individual decision-makers and a complete set of service attributes of different modes. Baumol and Vinod (1970) develop a model of demand through a cost minimization optimization framework. Costs include transportation, handling and inventory costs. Their initial cost function can be written as:

$$C = R(q, Q, Z)*Q + h(Z, q)*Q+I(q, Q, Z),$$

where *q* is the shipment size; *Q* is the total volume of annual shipments; *Z* is the vector of transport mode characteristics, i.e. transit time (*T*), reliability (*G*), safety (*S*), frequency (*D*), and flexibility (*F*); *R(q, Q, Z)* is transportation cost per unit of commodity shipped; *h(Z, q)* is freight handling costs of loading, unloading, and transhipments; and *I(q, Q, Z)* is inventory costs, defined as a function of the cost of the cycle stock, cost of the in-transit inventory, and the cost of the safety stock (Baumol and Vinod, 1970). Individual shippers choose *Q* to minimize costs. The solution can be written as:

$$Q^* = Q(q, Z, \frac{\partial R}{\partial Q}, \frac{\partial I}{\partial Q}) \tag{1}$$

The equation states that the total volume of annual shipments, *Q*, is a function of shipment and transport service characteristics (*q* and *Z*, respectively), transportation rates($\frac{\partial R}{\partial Q}$), and handling rates ($\frac{\partial I}{\partial Q}$).

From the data, the dependent variables are the result of a stated preference questions. The adjustments in annual shipment volumes given by shippers as a response to hypothetical changes in rates and transit times can be motivated by equation (1) with the adoption of a specific functional form. To illustrate, suppose annual shipments are determined by shipment characteristics at a base rate as:

$$Q_0 = A_0 x_0^{\alpha} r_0^{\beta}, \tag{2}$$

where A_0 is all non-shipment characteristics related effects, x_0 represents a set of shipper and shipment characteristics, r_0 refers to transportation rates; and α and β reflect unknown parameters. These parameters can be regarded as elasticities with respect to *x* and *r*, respectively.

Now, suppose that holding all else constant, transportation rates change from r_0 to r_1, where $r_1 = r_0(1+\Delta)$ and Δ refers to the percentage change in the rates. The volumes of annual shipments at the new price can be written then as:

$$Q_1 = A_0 x_0^{\alpha} r_1^{\beta} = A_0 x_0^{\alpha} r_0^{\beta} (1+\Delta)^{\beta} \quad (3)$$

Given (2) and (3), the changes in variables *Q* and *r* from period *0* to period *1* can be simply derived from equations (2) and (3) to have the following form:

$$\frac{Q_1}{Q_0} = (1+\Delta)^{\beta} \quad (4)$$

Taking logarithms of both sides of equation (4) and simplifying provides a convenient econometric model:

$$\log(\frac{Q_1}{Q_0}) = \beta \log(1+\Delta) + \varepsilon\,, \quad (5)$$

where ε is a disturbance term that accounts for other unobserved factors influencing the extent of the changes in annual shipment volumes.

Equation (5) applies to a specific shipper. Of course, there may be dramatic differences across shippers and across commodities. Thus, it is plausible that that the elasticity (β) is in fact also a function of other shipment characteristics, shipper characteristics, or commodity characteristics, i.e. $\beta = \beta(x_0) = \beta_1 + \beta_2 x$. Indeed, to obtain estimates across different shippers and commodities, the regression model is expanded for these variables and is given by:

$$\log(\frac{Q_1}{Q_0}) = \beta_1 \log(1+\Delta) + \beta_2 \log(1+\Delta) x_0 + \varepsilon \quad (6)$$

Thus, theoretically and intuitively, equation (6) allows for the relative change of quantities from a rate change to be determined by the degree of change in the transportation rate as well as by shipper and commodity characteristics. An identical formulation can be made with respect to transit time changes.

The following section describes the econometric methodology used in the estimation as well as the variable description. For the econometric results see the subsequent section.

6. ECONOMETRIC ANALYSIS OF DEMAND

6.1 Econometric Methodology and Variable Description

The left-hand side variable of equation (6), $\log(\frac{Q_1}{Q_0})$, represents the log of the ratio of the shipment volumes after to the shipment volumes before the hypothetical change in transportation rates or transit times, as reported by the shippers in the survey instrument. The minimum value the ratio can take is zero, since the maximum decrease in volumes as the result of an increase in rates or transit times cannot exceed 100%. Since the logarithm of zero is undefined, three observations were excluded although it is noted that in other modeling efforts the exclusion of these did not materially change results (using this approach). As a result, the minimum value $\log(\frac{Q_1}{Q_0})$ can attain in a model for rate changes is –1.301, corresponding to a logarithm of the next lowest ratio of 0.05. In a model for transit time changes, the minimum value corresponds to -0.699, or a logarithm of 0.20. Furthermore, the upper bounds for both, the rate and transit time, models are equal to one, as to shippers who stated that their volumes would not decrease as a result of those changes. Such behavior can be represented through a Tobit model with truncation on both sides.

As noted from equation (6), x_0 represents a set of shippers', shipment, and/or commodity characteristics, as described the Baumol and Vinod (1970) demand model. These variables only enter into the current modeling effort if elasticities vary with the levels of these variables. To explore the possibility of variations in elasticities, the variation of quantity adjustments is explained in terms of barge, rail, and truck as a share of modes used; rates as a share of product value; and a set of dummy variables identifying commodity (chemicals, crude materials, coal, food, petroleum, and primary manufactured good).

Reported in the data are the percentages of shipments involving barge, rail, and truck. From these variables, we constructed a measure of mode utilization. There are three variables truck, rail and barge. Truck was the omitted category. As noted earlier, if shippers have alternatives, then a choice model is implied and these variables should be treated as endogenous. However, the data are dominated by shippers that report they have *no alternatives*. In such a case, the mode choice is exogenous. The data offer an excellent opportunity for a robustness check. In particular, we estimated the model for the usable sample, and a subset of the data containing only shippers with no alternatives. The results were numerically similar and qualitatively equivalent. Second, we included a dummy variable for shippers that had alternatives. The idea is that shippers with more alternatives have different options of adjustment, while shippers without alternatives have only the intensity of production. The coefficient did not suggest any statistical differences.

The dummy variables, coal, manufactured, and crude, take a value of one when a commodity is coal, a primary manufactured good, or crude, respectively.

Two sets of results are presented. These include a set of results relating to rate increases, and a set of results relating to transit time changes. In both sets, we present a base model in which only rates or transit times appear, and, a derived model. In the case of the latter, we take the notion that elasticities may vary by commodity and mode as an empirical possibility. Estimation proceeds by first including the full set of commodity dummies, i.e. chemicals, crude materials, coal, food, petroleum, and primary manufactured good and mode utilization measures (rail, barge, and truck (the base mode). Upon estimation, we then test individual commodity coefficients for statistical significance, and include on those for which there is statistical importance. The only exception is that rate and transit times and mode utilization measures remain in the model, as they constitute the key variable of interest.

As discussed above, a feature of the data is that large fractions of shippers do not adjust to rate changes. The empirical results allow the probabilities of no adjustment and adjustment to be calculated. For the models selected, we present a detailed evaluation of whether shippers adjust or not (by commodity and mode) and then present a table of elasticities *given an adjustment occurs.*

6.2 Estimation Results for Transportation Rate Increase

Column I, II and III of Table 8 display the Tobit estimation results of the hypothetical increases in transportation rates on volumes of annual shipments, applying equation (6). Column I has results on a model with only rate changes; Column II has results on a model with rate changes, a full slate of commodity dummies and mode utilization; and Column III has results on a model with rate changes, mode utilization measures, and statistically important commodity dummies. The marginal effects are elasticities associated with the model in the preceding column. The dependent variable is the log of the shippers' annual shipment volumes after the rate increase as a share of the volume prior to the rate increase. Similarly, the key variable of interest is expressed as the log of the transportation rates after the increase took place as a share of rates the shipper faced prior to the rate increase (r_1/r_0). As developed in Section 4, the observables are the ratio of quantities before and after the rate change and the ratio of rates before and after a change.

The econometric model of Column I is a pure replica of equation (5), where the change in the volume of annual shipments is explained solely by the change in the transportation rates. The coefficient on the $\log(r_1/r_0)$[14] is statistically different from zero, indicating that a hypothetical increase in transportation rates indeed results in a decrease in volumes of annual shipments. From the elasticities, one can surmise that a rise in rates by 1% leads

[14] In the context of the theoretical model the variable $\log(r_1/r_0)$ is equal to $\log(1+\Delta)$. If not a censored distribution, this would be the standard elasticity in a double log specification. However, as discussed later, due to the censoring of the dependent variable, the coefficient estimate must be multiplied by the probability of a rate change to arrive at the elasticity.

to a 1.225% decrease in volumes of shipment annually.[15] Moreover, the magnitude and the statistical significance (at the 1% level) of this result points to downward-sloping demands that are elastic.

TABLE 10: Estimated effects of changes in transportation rates on annual shipments volumes (from equation (6))

	I	Marginal	II	Marginal	III	Marginal
log(r1/r0)	-3.915	-1.225	-5.349	-1.652	-4.992	-1.548
	(4.60)***		(5.44)***		(5.29)***	
barge*log(r1/r0)			1.552	0.479	1.257	0.39
			(2.00)**		(1.69)*	
rail*log(r1/r0)			1.1	0.340	1.314	0.408
			(0.64)		(0.74)	
Coal*log(r1/r0)			2.031	0.627	2.031	0.63
			(1.82)*		(1.86)*	
Mfg*log(r1/r0)			1.498	0.463	1.301	0.403
			(2.25)**		(2.16)**	
Petro*log(r1/r0)			0.8	0.247		
			(0.69)			
Crude*log(r1/r0)			-1.868	-0.577		
			(1.45)			
Chem*log(r1/r0)			0.793	0.245		
			(0.86)			
Constant	1.323	0.414	1.328	0.410	1.291	0.4
	(5.06)***		(5.33)***		(5.18)***	
Observations	163		163		163	

The results in Column I hold that elasticities are invariant with respect to both commodity and mode. The results in Column II introduce modes used and commodities carried. The coefficient of interest (on the change in rates) is larger in magnitude than that from column I. In Column II, there are controls for all commodities and "other" commodities is the base. There are also controls for mode utilization. Specifically, the modes included are barge and rail, and truck is the excluded category. The coefficient estimate on log(r1/r0) is the coefficient estimate for truck and other commodities. This simply indicates that once there are controls for commodities and mode utilization, the level of responsive i.e., that for other commodities shipped by truck, is higher. The interpretations of the other coefficients simply segment this coefficient by commodity and mode. The coefficient on barge is positive and statistically significant (at the 10% level). This suggests that adjustment of barge users to changes in rates is smaller (in magnitude) than the adjustment by truck users (the base). The coefficient on rail is not

[15] The coefficient is not the elasticity. In equation (5), the coefficient is the elasticity, and our estimation is built on equation (5). However, because the distribution of errors is truncated, TOBIT must be used. The elasticity calculated is the change in volumes divided by the change in rates multiplied by *the probability that the shipper will adjust.*

statistically significant, but has a magnitude and sign similar to that of barge.[16] The coefficient estimates for coal and manufactured products are also positive and statistically significant. This points to smaller elasticity estimates *vis a vis* other products shipped.

Column III represents a model wherein non-statistically important commodity dummies are removed from the model. Both the coefficient estimates and associated elasticities are comparable to those of Column II. The coefficients on the commodities are statistically important and are positive in sign. The base dummy represents commodities other than coal and manufacturing. These latter two are central to the Ohio River basin. Most coal flows to coal-fired electricity plants and a large number of these are located on the river. Further, coal is a low-value bulk commodity. By and large these attributes point to the use of barge, and since, barge is generally the least cost in terms of both rates and inventory costs, it stands to reason that the reaction of shippers to rate changes is muted *vis a vis* other commodities. Manufactured commodities follow the same line of reasoning although the extent of each is less so. From a limited set of information available in the survey, the average value of the commodity shipped and the percentage of logistics costs to value are smallest for coal, then manufactured goods, followed by "other".[17]

As noted above, elasticities vary according to mode and commodity. In Table 11, we present arc elasticities for each commodity and mode pair *given the shipper adjusts*, and using the results in Column III. These are provided for values corresponding to prompts of the survey instrument (a 10, 20, …, 60 percent change in rates). Our specification is a double log specification so that the elasticities given a rate change are constant.[18] As we discuss below, the changing elasticities reflect the fact that higher rate changes, change the probability of adjustment. That is, it does not reflect the standard textbook example that demands are relatively more elastic at higher rate levels. In the present case, for small rate changes (10%), elasticities range from -.1 to -.67. There is only a modest change in volumes per one percent change in rates. However, for larger rate changes, the arc elasticities range from -.4 to -4.59 per one percent change in rates.

For all commodities, truck elasticities are largest (in magnitude) for all commodities and rate increase levels. Truck elasticities range from -4.59 for other commodities with a 60 percent increase in rates to -.25 for coal with a 10 percent increase in rates. Rail and barge elasticities range from -2.75 for other commodities with a 60 percent increase in rates to -.1 for coal shipment with a 10 percent increase in rates. These finding adhere directly to the predictions of the coefficient estimates in Table 10 and what is commonly known about the behavior of the users of each of the modes. Of specific interest to the Ohio River Basin are the elasticities presented with respect to coal. Coal is the commodity mostly produced and shipped within the ORB system and is central to the

[16] Technically, we find that the truck and rail users are the same i.e., the coefficient is zero. However, in our estimation, this is a result of a relatively low cell count for rail.
[17] In specifying these results, we did explore the inclusion of other commodity dummies. Generally, our results are only slightly different. Non-significant auxiliary effects were not included in the final estimations.

river economy. By and large, coal traffic in the system does not have sizable adjustments to rate changes. At all levels of rate adjustments, coal elasticities are lower than for the corresponding other commodities, regardless of mode.

TABLE 11: Arc Elasticities of Annual Shipments Volumes to Transportation Rates Changes by Commodity Type and Shipment Mode

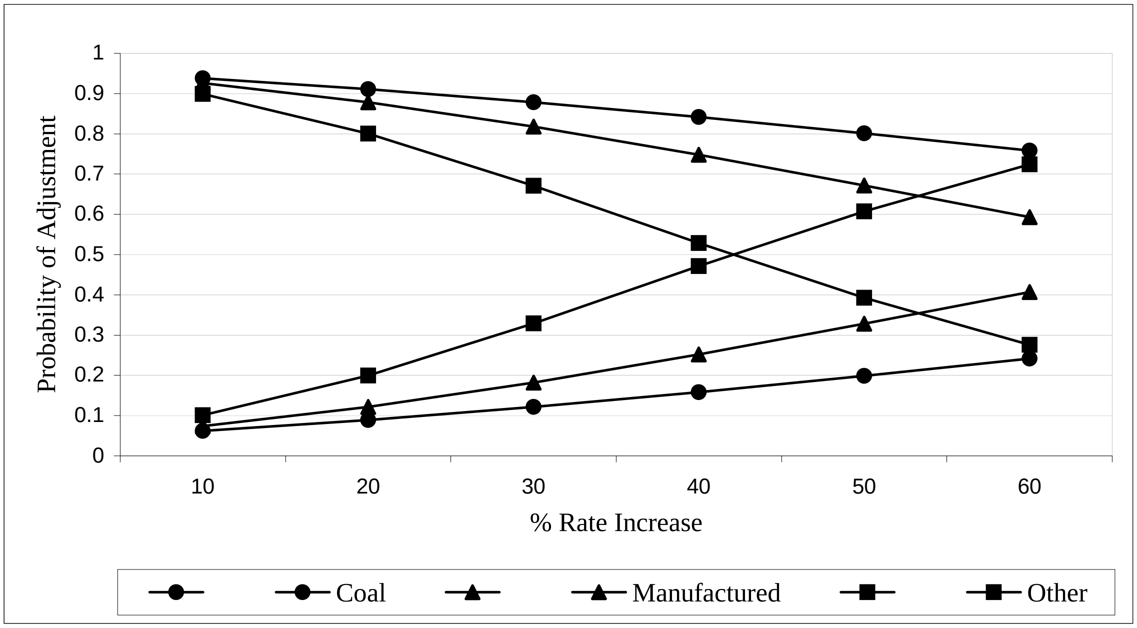
Coal				Primary Manufactured				Other Commodities			
Rate	Rail	Barge	Truck	Rate	Rail	Barge	Truck	Rate	Rail	Barge	Truck
10%	-0.10	-0.11	-0.25	10%	-0.18	-0.18	-0.37	10%	-0.37	-0.38	-0.67
20%	-0.15	-0.16	-0.46	20%	-0.29	-0.30	-0.74	20%	-0.73	-0.76	-1.51
30%	-0.20	-0.21	-0.72	30%	-0.43	-0.46	-1.22	30%	-1.21	-1.26	-2.55
40%	-0.26	-0.28	-1.02	40%	-0.60	-0.63	-1.75	40%	-1.73	-1.80	-3.50
50%	-0.33	-0.35	-1.34	50%	-0.78	-0.83	-2.25	50%	-2.23	-2.31	-4.19
60%	-0.40	-0.43	-1.64	60%	-0.97	-1.02	-2.68	60%	-2.66	-2.75	-4.59

As can be observed from Table 10, the coefficients estimated by the Tobit estimation technique do not translate into the elasticities of the annual volume shipments to transportation rate changes directly. The elasticities, or marginal effects of the rate changes on annual shipments, are reported in the adjacent columns. The difference between the coefficients and the elasticities reported in Columns I, II and III can be attributed to the marginal effect of the rate changes on the probability of responding to the rate change given shipper, shipment, and commodity characteristics and the extent of the rate change. For example, it can logically be expected that the probability of responding to a transportation rate increase of 10% is lower than the probability of adjustment as a result of a rate change of 20%. Conversely, the probability of no adjustment, that is no change in shipment volumes, is higher if the rate increase is relatively small, i.e. 10%-20%, compared to 50%-60% rate change. Lastly, one would expect that the probability of not shipping at all to remain at zero regardless of the rate increase.

This behavior is illustrated in the graphs below (Figures 2, 3, and 4), where we again distinguish the probabilities across the commodity types within each shipment mode used. Within each transportation mode, it can be observed that coal has the lowest probability of adjustment and, alternatively, the highest probability of no volume decrease in response to each transportation rate increase. And, even for large rate changes, the results coal shippers do not adjust to rate changes. That is, the likelihood of NO adjustment for a 10 percent change in rates is over 90 percent for rail and barge. As expected, this effect does fall with progressively larger increases in rates. Over the effect is very modest with the probability of adjustment only about 75 percent for 60 percent increases. For trucks, the effect is more pronounced as expected. But, again, the likelihood of no adjustments is high and remains high for large rate changes. Primary manufactured commodities follow similarly. Generally, the likelihood of NO adjustment is high for small rate changes, and decreases modestly for larger changes.

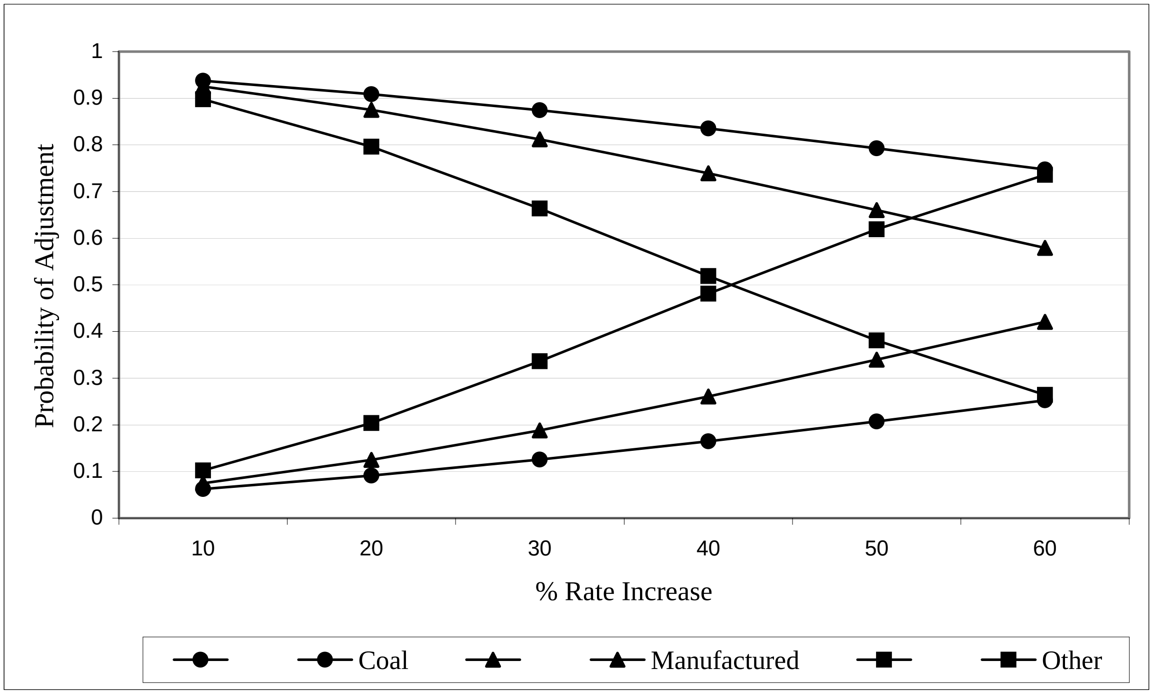
Generally, other commodities and truck probabilities are more sensitive as expected for higher valued commodities and a more flexible mode of transportation. Comparing effects by mode of transportation, truck exhibits the lowest probability of no adjustment or the highest probability of adjustment for each commodity type and rate change. Barge and rail are virtually the same. These findings conform to the patterns observed in, and, indeed, underlie the arc elasticity estimates of Table 11.

Figure 2: Probabilities of Adjustment with Respect to Rate Changes For Rail Users



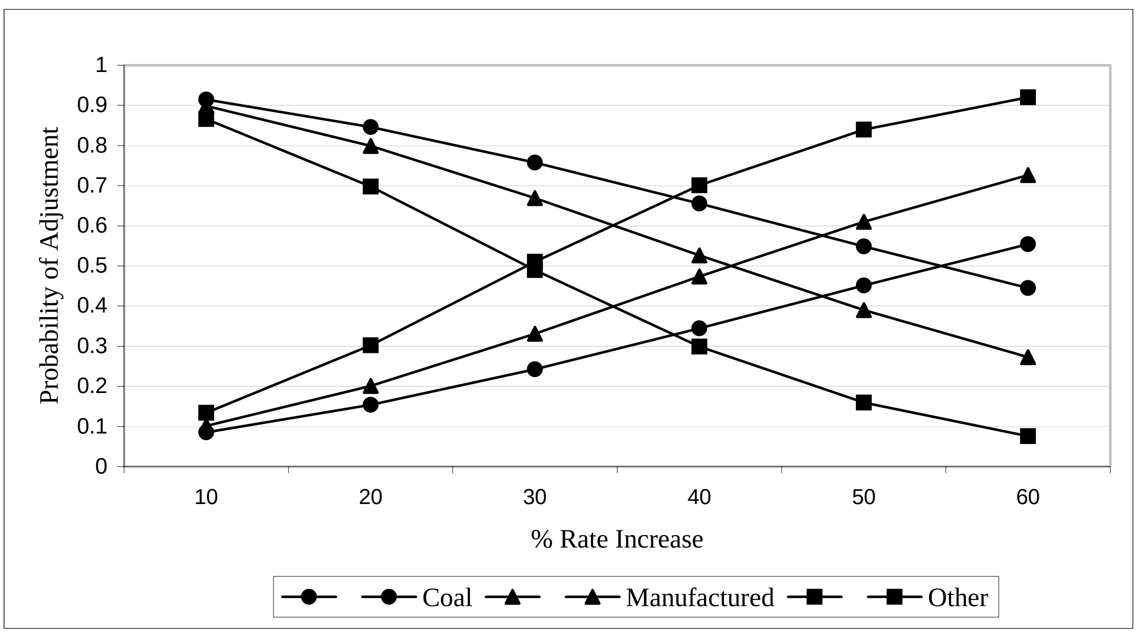
Note: Downward sloping lines refer to Probability of % Decrease in Quantities=0
Upward sloping lines refer to Probability of 0<% Decrease in Quantities<1

Figure 3: Probabilities of Adjustment with Respect to Rate Changes For Barge Users



Note: Downward sloping lines refer to Probability of % Decrease in Quantities=0
Upward sloping lines refer to Probability of 0<% Decrease in Quantities<1

Figure 4: Probabilities of Adjustment with Respect to Rate Changes For Truck Users



Note: Downward sloping lines refer to Probability of % Decrease in Quantities=0
Upward sloping lines refer to Probability of 0<% Decrease in Quantities<1

6.3 Estimation Results for Transit Time Increase

The estimation results of the response of the annual shipment volumes to changes in transit rates as modeled by equation (6) are displayed in Table 12. These results somewhat parallel those in rates changes, as a hypothetical increase in transportation times also reduces the volume of annual shipments. Again, we present three sets of coefficient estimates along with corresponding marginal effects. In Column I are the results of a model with only the time change ($\log(t_1/t_0)$; Column II adds a complete set of mode utilization and commodity dummies; while Column III has only the statistically important commodity dummies. The comparison across Columns in this table is analogous to that of rates i.e., the coefficients estimates yield the same qualitative results albeit the estimates themselves are somewhat more sensitive across Columns.

In this case, both crude and chemical products are statistically different from other commodities. In this case, the coefficients are negative. This means the corresponding volumes are more sensitive to transit time adjustments than for other commodities shipped. Both crude and chemical products tend to be higher valued commodities, and, therefore carry with it higher inventory costs. Thus, it seems natural to expect they would be more responsive to transit time changes. Unlike rate changes, we do not find any statistical difference across the modes. Thus, the service characteristic, transit time, is symmetric across the modes.

As before, we are able to calculate elasticities by commodity and mode. These are provided in Table 13. There are modest differences across modes owing to the fact that the coefficient estimates, while statistically not different from zero, are different in magnitude. As with rates, the elasticities get larger (in magnitude) with the level of the change in transit times. Comparisons across commodities suggest that other commodities are less responsive than chemical or crude commodities. The values of the elasticities depend on the level of transit time change. For small changes, these range from -.19 to -1.1 for barge shipments of other commodities and rail shipments of crude. For larger changes, these range from -.67 to -3.88 for barge shipments of other commodities and rail shipments of crude.

A notable feature of the results is that the time elasticities are smaller than the rate elasticities. While Column III results for rates and time are not comparable, Columns I and II have the same variables, and therefore, can be compared. The central point can be made through a comparison of the marginal effects for Column I in Tables 10 and 12. We do note that this is reinforced by Column II results, but expositionally more cumbersome. The marginal effect in Column I for rates (Table 10) and for times (Table 12) are -1.225 and -.47. These are elasticities for the pooled (across mode and commodity) elasticities. The rate elasticity is larger in magnitude than the time elasticity. This suggests that shippers are more responsive to rate changes than to transit time changes. Additionally, unlike the elasticity of the volume of annual shipment with respect to rate changes, the shippers' elasticity with respect to time changes does not appear to depend on the mode.

TABLE 12: Estimated effects of changes in transportation times on annual shipments volumes

	I	Marginal	II	Marginal	III	Marginal
log(t1/t0)	-1.633	-0.47	-1.142	-0.32	-1.536	-0.44
	(3.64)***		(1.75)*		(3.46)***	
barge*log(t1/t0)			0.377	0.11	0.353	0.10
			(0.64)		(0.78)	
rail*log(t1/t0)			-1.521	-0.43	-1.571	-0.45
			(1.21)		(1.28)	
Coal*log(t1/t0)			-0.962	-0.27		
			(1.24)			
Mfg*log(t1/t0)			-0.480	-0.14		
			(0.89)			
Petro*log(t1/t0)			-0.229	-0.07		
			(0.24)			
Crude*log(t1/t0)			-2.373	-0.68	-1.966	-0.56
			(2.77)***		(2.51)**	
Chem*log(t1/t0)			-1.399	-0.40	-0.999	-0.29
			(2.01)**		(1.66)*	
Constant	0.652	0.19	0.653	0.19	0.658	0.19
	(4.77)***		(4.88)***		(4.95)***	
Observations	165		165		165	

Absolute value of t statistics in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

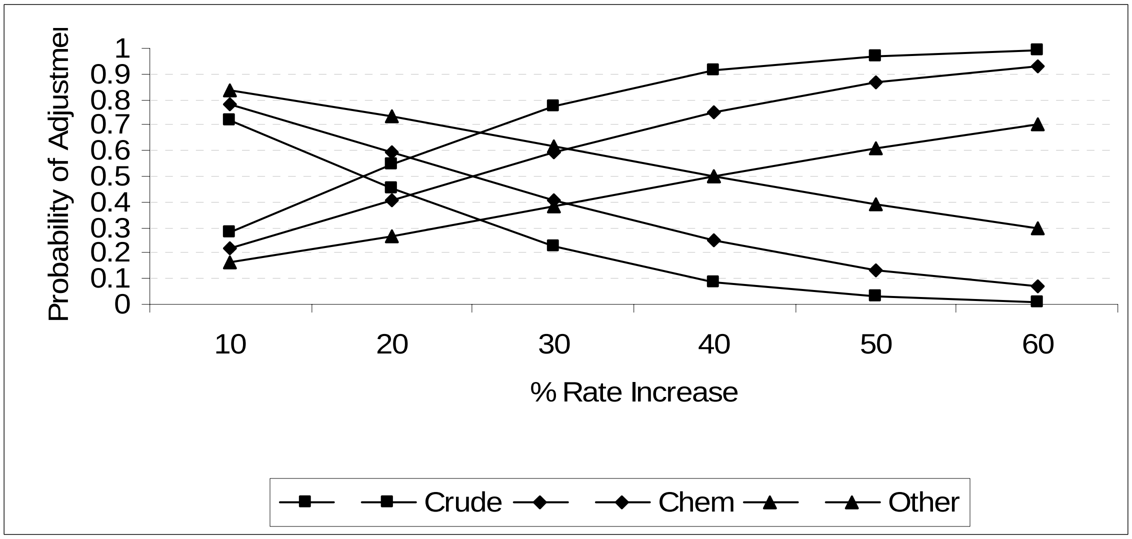
Table 13.—Time Elasticities by Commodity and Mode

Crude				Chemical				Other Commodities			
Time	Rail	Barge	Truck	Time	Rail	Barge	Truck	Time	Rail	Barge	Truck
10%	-1.10	-0.81	-0.89	10%	-0.65	-0.45	-0.50	10%	-0.32	-0.19	-0.23
20%	-2.14	-1.53	-1.70	20%	-1.19	-0.76	-0.87	20%	-0.52	-0.28	-0.34
30%	-3.04	-2.24	-2.47	30%	-1.75	-1.11	-1.28	30%	-0.74	-0.37	-0.46
40%	-3.57	-2.77	-3.00	40%	-2.22	-1.45	-1.66	40%	-0.97	-0.47	-0.59
50%	-3.80	-3.08	-3.30	50%	-2.55	-1.74	-1.97	50%	-1.18	-0.57	-0.72
60%	-3.88	-3.23	-3.43	60%	-2.75	-1.96	-2.19	60%	-1.37	-0.67	-0.85

As noted earlier, the probability of an adjustment weighs heavily in the calculation of elasticities. In Figures 5, 6 and 7, we present the probability of adjustment (and no adjustment) by mode and commodity. Since there is little difference across mode, the general shape and positions of the probability plots are remarkably similar. However, there are marked differences across commodities. For all commodities, small transit time changes do not lead to quantity adjustments. Based on Figure 6, for crude commodities, the probability of adjustment (no adjustment) increases (decreases) so that it takes about a

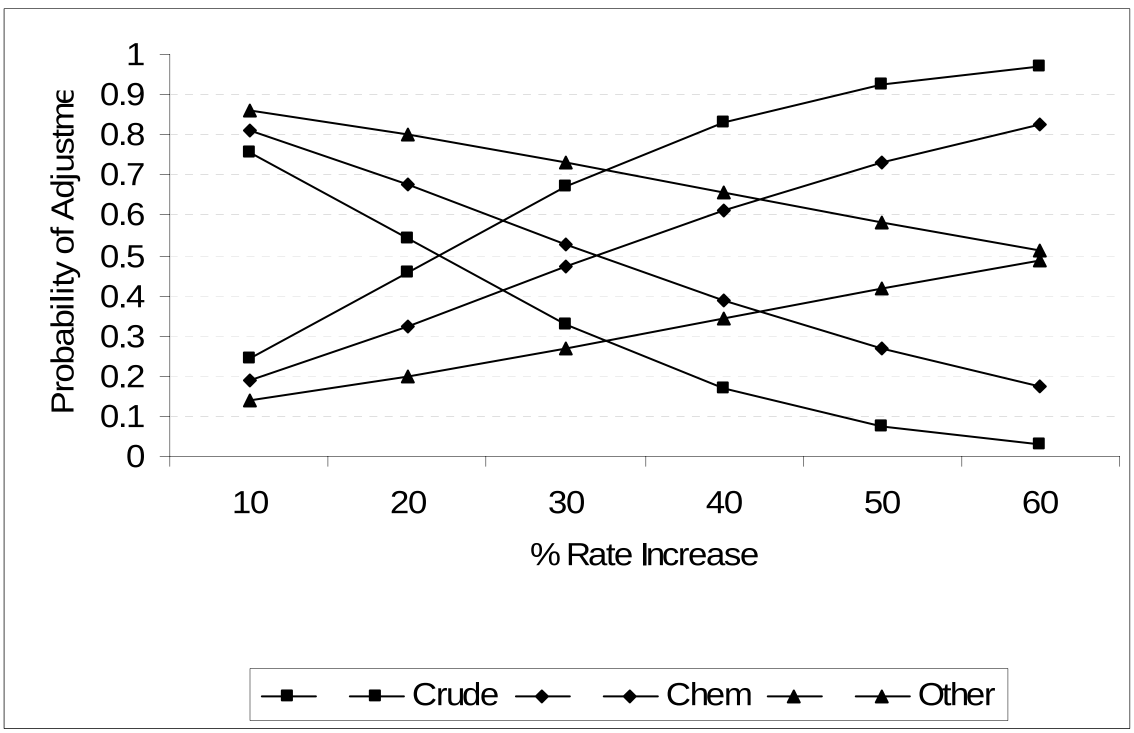
25 percent change in transit times before the probability of adjustment is larger than no adjustment. For other commodities, it takes values of about a 60 percent change in transit times before an adjustment occurs. Other commodities, in this case, are, for example, coal, manufactured goods, etc.

Figure 5: Probabilities of Adjustment with Respect to Time Changes for Rail Users



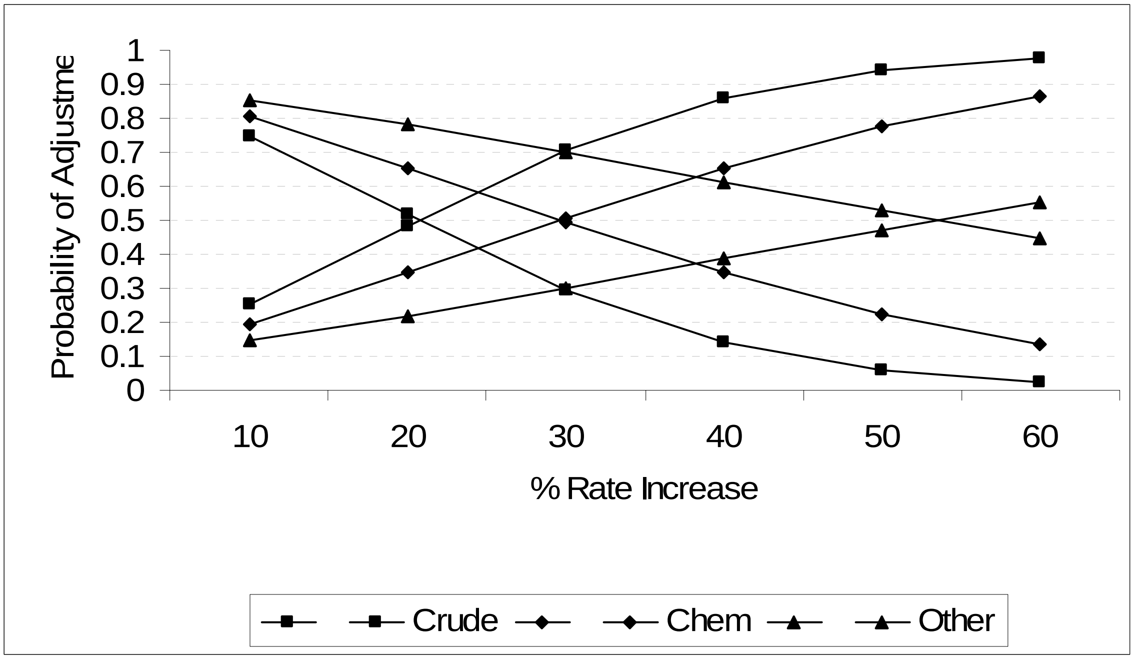
Note: Downward sloping lines refer to Probability of % Decrease in Quantities=0
Upward sloping lines refer to Probability of 0<% Decrease in Quantities<1

Figure 6: Probabilities of Adjustment with Respect to Time Changes for Barge Users



Note: Downward sloping lines refer to Probability of % Decrease in Quantities=0
Upward sloping lines refer to Probability of 0<% Decrease in Quantities<1

Figure 7: Probabilities of Adjustment with Respect to Time Changes for Truck Users



Note: Downward sloping lines refer to Probability of % Decrease in Quantities=0
Upward sloping lines refer to Probability of 0<% Decrease in Quantities<1

6.4 Sensitivity Analysis

A major issues with the results presented above is that modes used appears on the righthand side. Of course, in the choice literature such variables are typically the choice (endogenous) variable. Inclusion of an endogenous variable on the righthand side can impart bias on the data. The endogeneity of the variables would arise if both the volume of annual shipments and the transportation rates were determined simultaneously as a result of the shipper having no other alternatives, in other words making them jointly dependent. In the present case, the sample consists of 179 shippers. But, 122 of these shippers reported that they have no alternatives. We examined the endogeneity issue by restricting the sample to shippers that have no alternatives. A large difference between the estimation results based on these shippers and the results displayed above would point to the possible endogeneity problem. The results from this experiment yielded results that were nearly identical to those reported with no qualitative differences. We also introduced a dummy if the shipper had alternatives in the full set of results. The coefficient on this term was not statistically significant. These results suggest that either the modes used are exogenous or treating them as exogenous does not impart significant bias on the results.

The results of several specification tests warrant noting. The Cobb-Douglas model specification of equations (4) and (6) makes a strong assumption of constant elasticity where the responsiveness of the volume of annual shipments does not vary with the magnitude of the transportation rates and transit times changes. The authors test this assumption by allowing the elasticity to vary with the rate and time changes linearly and logarithmically. None of these additional terms entered significantly.

Other shipper, shipment, and commodity characteristics used included distance to and from the loading facility, availability of loading equipment, rate to value share, firm size, annual revenues, and other. None of the variables entered statistically significant. The variables included in the models above, such as barge and rail as the share of modes used, as well as coal and primary manufactured commodity types account for such differences across shippers.

7. SUMMARY AND CONCLUSIONS

Demand models are of central importance in evaluating transportation infrastructure investment decisions. Generally, planners evaluating the associated costs and benefits need estimates over a wide range of rates and commodities. The use of revealed choice data (in either choice or aggregates) limits the range or rates and often is serious hampered by the lack of appropriate commodity level data. The use of stated preference data, on the other hand, allows the researcher to control the environment of the shipper and the reaction of the shipper to changes. In this research, the stated preference approach is used to assess shipper reactions to both rate and transit time changes. These changes range from a 10 percent change to a 60 percent change. The reported elasticities differ by commodity and mode and range from relatively elastic for truck shipments of higher valued commodities to relatively inelastic for rail and barge shipments of relatively low valued bulk commodities.

The data used reflected a limited dependent variable. That is, shippers reported the change in annual volumes from a change in rates. The responses ranged from no change to total shutdown (i.e., a 100 percent reduction). These responses mandated the use of an estimation technique that reflects the censoring of the dependant variable. We used a Tobit model to estimate the demand functions. This allowed a decomposition of the elasticity into source of change. Specifically, we found that small changes in rates and service characteristics do not appear to induce changes in annual volumes shipped (a zero effect), but that as the size of the change increased, shipper volumes did adjust. Second, given there is a change in annual volumes, the model allows estimation of the size of the change. Thus, there are two sources of shipper level responses, each of which are presented in the research which is not found elsewhere in the literature.

Finally, this procedure allows direct estimation of shipper demand functions. The demand functions presented are for a range of commodities on an annual basis. We have not been successful in identifying shipper characteristics that influence demands apart from mode and commodity, however, the research can easily be extended to capture such effects. The results can be used in the ACE planning models e.g., ORNIM, ESSENCE through a modification of the algorithms through which equilibriums are established.

8. REFERENCES

Abdelwahab, Walid and Michael Sargious. (1992). "Modeling the Demand for Freight Transportation." *Journal of Transport Economics and Policy*, 26(1), 49-70.

Anderson, S, and W. Wilson. 2004. *Spatial Modeling in Transportation I: Congestion and Mode Choice.* Institute of Water Resources, Department of the Army Corps of Engineers.

Anderson, S, and W. Wilson. 2005a. *Spatial Modeling in Transportation II: Railroad Pricing, Alternative Markets, and Capacity Constraints.* Institute of Water Resources, Department of the Army Corps of Engineers.

Anderson, S, and W. Wilson. 2005b. *Spatial Modeling in Transportation III: Infrastructure, Planning, and Welfare*. Institute of Water Resources, Department of the Army Corps of Engineers.

Basin Profile. 2004. Huntington, WV: Huntington District, Department of the Army Corps of Engineers.

Baumol, W. J. and H.D. Vinod. 1970. *An Inventory Theoretic Model of Freight Transportation Demand.* Management Science, Vol. 16(7), pp. 413-421.

Bergantino, Angela, and Simona Bolis. 2003. *An Adaptive Conjoint Analysis of Freight Service Alternatives: Evaluating the Maritime Options*. Preliminary Version. http://www.ersa.org/ersaconfs/ersa03/cdrom/papers/428.pdf

Berry, S., G. Hewings, and C. Levin. 2001. *The Adequacy of Research on Upper Mississippi-Illinois River Navigation Project.* Washington, D.C.: Northeast-Midwest Institute,

Bolis, Simona and Rico Maggi. 2003. *Logistics Strategy and Transport Service Choices: An Adaptive Stated Preference Experiment.* Growth and Change, 34(4) 490-504.

Burton, Mark. 2001. *The Past and Future Treatment of Transport Demands in Navigation Project Evaluations.* Institute of Water Resources, Department of the Army Corps of Engineers.

Clark, Chris, Helen Tammela Naughton, Bruce Proulx, and Paul Thoma. 2005. *A Survey of the Freight Transportation Demand Literature and a Comparison of Elasticity Estimates.* Institute of Water Resources, Department of the Army Corps of Engineers.

Curlee, T. Randall. *The Restructured Upper Mississippi River –Illinois Waterway Navigation Feasibility Study: Overview of Key Economic Modeling Considerations.* Undated. Mississippi Valley Division, Department of the Army Corps of Engineers.

Dager, C.A., L.G. Bray, M. Murphree, and C.A. Leibrock. 2004. *Elasticity of Demand for Barged Grain Shipments on the Upper Mississippi River and Illinois Waterways*. U.S. Army Corps of Engineers Planning Center of Expertise for Inland Navigation, Huntington, WV.

Friedlaender, Ann F. and Richard H. Spady. 1980. *A Derived Demand Function for Freight Transportation.* The Review of Economics and Statistics, 62(3), 432-41.

Fuller, Stephen, Fellin, and Grant. 2003. *Grain Transportation Capacity of the Upper Mississippi and Illinois Rivers: A spatial Analysis*. Transportation Research Forum.

Inaba, Fred S. and Nancy E. Wallace. 1989. *Spatial Price Competition and the Demand for Freight Transportation.* The Review of Economics and Statistics, 71(4), 614-25.

National Research Council. 2001. *Inland Navigation System Planning: The Upper Mississippi River-Illinois Waterway*. Washington, DC: National Academy Press.

National Research Council. 2004a. *Review of the U.S. Army Corps of Engineers Restructured Upper Mississippi-Illinois Waterway Feasibility Study*. First Report. Washington, DC: National Academies Press.

National Research Council. 2004b. *Review of the U.S. Army Corps of Engineers Restructured Upper Mississippi-Illinois Waterway Feasibility Study*. Second Report. Washington, DC: National Academies Press.

Navigation Economic Technologies (NETS). Accessed August 15, 2005; http://www.corpsnets.us/aboutNETS.html

Oum, Tae H. 1979. *A Cross-Sectional Study of Freight Transport Demand and Rail Truck Competition in Canada.* The Bell Journal of Economics, 10(3), 463-82.

Oum, Tae H. 1989. *Alternative Demand Models and Their Elasticity Estimates.* Journal of Transport Economics and Policy, 5, 163-87.

Oum, Tae H., W.G. Waters II, and Jong-Say Yong. (1992). *Concepts of Price Elasticities of Transport Demand and Recent Empirical Estimates: An Interpretative Survey*. Journal of Transport Economics and Policy, 26(2), 139-69.

Train, K. and W. Wilson.2004. *Shippers' Responses to Changes in Transportation Rates and Times: The Mid-American Grain Study.* Institute of Water Resources, Department of the Army Corps of Engineers.

U.S. Army Corps of Engineers (USACE). 2002. *Interim Report for the Restructured Upper Mississippi River-Illionois Waterway System Navigation Feasibility Study*. Rock Island, IL: Rock Island District of Engineers.

U.S. Army Corps of Engineers. 2005. *Ohio River Navigation.* http://www.lrd.usace.army.mil/_kd/go.cfm?destination=Page&Pge_ID=1226: accessed August 15, 2005. Great Lakes and Ohio River Division.

U.S. Army Corps of Engineers (USACE). *Petroleum and Petroleum Products*. Huntington District.

Waterborne Commerce Statistics Center (WCSC). 2003a. *Waterborne Commerce of the United States. Part 2: Waterways and Harbors, Gulf Coast, Mississippi River System, and Antilles.* Publication IWR-WCUS-03-2. Available on-line at http://www.iwr.usace.army.mil/ndc/wcsc/pdf/wcusmvgc03.pdf; accessed August 15, 2005. Institute of Water Resources, Department of the Army Corps of Engineers.

Waterborne Commerce Statistics Center. 2003b. *Final Waterborne Commerce Statistics for Calendar Year 2003.* http://www.iwr.usace.army.mil/ndc/wcsc/pdf/final03.pdf; accessed August 15, 2005. Institute of Water Resources, Department of the Army Corps of Engineers.

Wooldridge, Jeffrey. 2001. *Econometric Analysis of Cross Section and Panel Data.* Massachusetts Institute of Technology.

Yu, Tun-Hsiang and Fuller. 2003. *Estimated Grain Barge Demands for the Upper Mississippi and Illinois Rivers: Tentative Findings*. U.S. Department of Agriculture, Agricultural Marketing Service, Washington, D.C.

APPENDIX A

TRANSPORTATION CHOICE AND SATISFACTION SURVEY

SURVEYOR INITIALS: ____________ **FIRM NAME:** ____________________________

DATE SURVEYED: ____________ **RESPONDENT:**____________________________

SURVEY LIST: ______________**PHONE #:** ______________________________

Introduction

1. Where is your firm or facility located: (where does the firm receive to or ship from)

   City ______________ County _____________ State _____________ Zip ____________

2. What is the primary commodity your firm or facility transports: ______________

Shipment Characteristics:

3. Consider the very last shipment of __***refer to question 2***___you made. Where did this shipment travel to and from (in the US)?

   From: City _______________ State ______________

   To: City_______________ State_______________

4. On this last shipment, what mode(s) did you use?

Barge	Yes	No
Rail	Yes	No
Truck (for hire ____ or your own ____)	Yes	No

5. How large was the shipment? ***(just one needed)*** __________ tons

   __________ bushels

   __________ cwt (hundred weights)

6. How long did the shipment take (to reach its terminal point, US)?

   Days __________ Hours ____________

7. Did the shipment arrive on time? Yes No

   If not, how long was it delayed? Days ________ Hours _______

8. Approximately, how far did the shipment travel? __________miles

9. What was the rate for barge? $_________
What was the unit (per ton___, per cwt____, per bushel___, other ____specify_________)

What was the rate for rail? $_________
What was the unit (per ton___, per cwt____, per bushel___, other ____specify_________)

What was the rate for truck? $_________
What was the unit (per ton___, per cwt____, per bushel___, other ____specify_________)

Total rates for all modes _____________ Unit of measurement ______________

If a private (they own the trucks) shipment, what is your estimate of per unit cost?

$ ___________

Is that	Per ton	_________
	Per bushel	_________
	Per cwt (hundredweight)	_________
	Per mile	_________

Now, we would like some information about the alternatives you have. Suppose you could not ship to or from (SURVEYOR INSERT location from Q3) by (SURVEYOR INSERT mode from Q4),what would you have done?.

10. Would you ship by other modes to and from the same locations or would you choose other locations.

Other mode to same location ___________ Other locations ___________ Shut down ________

If other location, where? From: City _____________State_______________

To: City _____________State_______________

11. For this alternative shipment, what mode or modes would you use?

Barge	Yes	No
Rail	Yes	No
Truck (for hire___ or your own___)	Yes	No

FOR QUESTION #12, REFER TO QUESTION #11 FOR THE MODES TO ASK:

12. a. What would be an approximate the rate for barge? $_________

What was the unit (per ton___, per cwt____, per bushel___, other ____specify_________)

b. What would be an approximate rate for rail? $_________

What was the unit (per ton___, per cwt____, per bushel___, other ____specify_________)

c. What would be an approximate rate for truck? $_________

What was the unit (per ton___, per cwt____, per bushel___, other ____specify_________)

$_____________ Unit of measurement ________________

13. How long would the alternative shipment be expected to take (to reach its terminal point, US)?

Days __________ Hours ____________

14. How often do similar shipments arrive on time? _________ %

15. Approximately, how far would the alternative shipment travel? __________miles

16. How large would this alternative shipment be?
__________ tons
__________ bushels
__________ cwt (hundred weights)

We now like you to consider what conditions, if any, might cause you to switch from your original shipment to the alternative. Your last shipment was to/from (***insert question 3 response)*** by ***(insert question 4 response)***. You said your alternative was a shipment was to/from ***(insert question 10 response)*** by ***(insert question 11 response).***

17. If the rate of the original choice was ____ percent higher than what you paid, would you make the original choice or the alternative? Original Alternative

If original, by what percentage would rates have to increase to induce a switch to the alternative? _________%

18. If the transit time of the original choice was ____ Percent higher than what you paid, would you make the original choice or the alternative? Original Alternative

If original, by what percentage would times in transit have to increase to induce a switch to the alternative? _________%

19. If the reliability of the mode your chose (i.e., the percentage of time shipments arrived on-time) fell by ____ percentage points, would you make the original choice or the alternative? Original Alternative

If original, by how many percentage points would reliability have to increase to induce a switch to the alternative? _________%

Location decisions

20. How important are or were logistics costs in determining your plants location?
(logistics costs = shipping, handling, inventory)
(1= very important, 3=somewhat important, 5=not important) (Circle the best choice) 1 2 3 4 5

21. How long has your plant been at its current location? ____ years

22. If you were offered another plant location at lower logistics and transportation costs, what percentage lower would these costs need to be to cause you to relocate?

____% lower

23. Suppose you were a start-up business and you were offered two locations with different logistics costs and different investment costs. Location A has ____ lower logistics costs than Location B, but Location A has a ____ higher investment cost.
Investments have a 25-year life and all other relevant factors are the same.
Which location would you choose? (circle either A or B) A B

Perceptions

Now we'd like to ask about the factors that most influence your shipping decisions. Please answer the following with respect to ALL SHIPMENTS YOU MAKE.

24. In order of importance, what the most important factors influencing your shipping decisions?

Most important ____

2nd most important ____

3rd most important ____

25. If the average transportation rate you pay increased by ___ percent, would your annual volumes decrease? Yes No

If yes, by how much? _____%

26. If the average transit time you incur (by all modes) increased by ___ percent, would your annual volumes be affected? Yes No

If yes, by how much? ____%

27. What do you consider to be the most important issues facing transportation shippers today?
____

Shipper Characteristics

28. How large is your firm or facility? (THEIR LOCATION ONLY)

Revenues per year _________________

Tons shipped per year _________________

Number of employees _________________

29. What modes do you use to ship your ________ **(*insert commodity listed in question 2)***

Barge	Yes	No
Rail	Yes	No
For-Hire Truck	Yes	No
Private (your) truck	Yes	No

30. What percentage of your shipments involve:

Barge:	_______%
Rail:	_______%
For-hire Truck	_______%
Private Truck	_______%

31. What is the average price or value of the ______ ***(insert commodity from question 2)*** you pay or receive?

Price __________ Unit of measurement ________ (ton, bushel, cwt (hundred wt.))

Is this the value at your location or at the location being transported to or from? Yours Other

32. How far is the nearest rail loading facility? ___________miles

33. How far is the nearest barge loading facility? ___________miles

34. Do you have loading and unloading equipment for:

Barge Shipments	Yes	No
Rail Shipments	Yes	No
Truck Shipments	Yes	No

35. What fraction of the delivered value of your commodity represents logistics costs (i.e., rate + inventory + handling/landed price)?

____

Thanks so much for your help with this survey!