The Navigation Economic Technologies Program

October 24, 2005

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TRADEABLE PERMIT MARKETS FOR LOCKS ON INLAND WATERWAYS

US Army Corps of Engineers®

IWR Report 05-NETS-R-11

Navigation Economic Technologies

The purpose of the Navigation Economic Technologies (NETS) research program is to develop a standardized and defensible suite of economic tools for navigation improvement evaluation. NETS addresses specific navigation economic evaluation and modeling issues that have been raised inside and outside the Corps and is responsive to our commitment to develop and use peer-reviewed tools, techniques and procedures as expressed in the Civil Works strategic plan. The new tools and techniques developed by the NETS research program are to be based on 1) reviews of economic theory, 2) current practices across the Corps (and elsewhere), 3) data needs and availability, and 4) peer recommendations.

The NETS research program has two focus points: expansion of the body of knowledge about the economics underlying uses of the waterways; and creation of a toolbox of practical planning models, methods and techniques that can be applied to a variety of situations.

Expanding the Body of Knowledge

NETS will strive to expand the available body of knowledge about core concepts underlying navigation economic models through the development of scientific papers and reports. For example, NETS will explore how the economic benefits of building new navigation projects are affected by market conditions and/or changes in shipper behaviors, particularly decisions to switch to non-water modes of transportation. The results of such studies will help Corps planners determine whether their economic models are based on realistic premises.

Creating a Planning Toolbox

The NETS research program will develop a series of practical tools and techniques that can be used by Corps navigation planners. The centerpiece of these efforts will be a suite of simulation models. The suite will include models for forecasting international and domestic traffic flows and how they may change with project improvements. It will also include a regional traffic routing model that identifies the annual quantities from each origin and the routes used to satisfy the forecasted demand at each destination. Finally, the suite will include a microscopic event model that generates and routes individual shipments through a system from commodity origin to destination to evaluate non-structural and reliability based measures.

This suite of economic models will enable Corps planners across the country to develop consistent, accurate, useful and comparable analyses regarding the likely impact of changes to navigation infrastructure or systems.

NETS research has been accomplished by a team of academicians, contractors and Corps employees in consultation with other Federal agencies, including the US DOT and USDA; and the Corps Planning Centers of Expertise for Inland and Deep Draft Navigation.

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I. PROJECT OVERVIEW

A. Research objective

The objective of the research reported herein was to design a testable mechanism for the Inland Waterway system that allows individuals to reduce their overall transportation cost, reduce uncertainty associated with potential delays and place a dollar value on the benefits of reducing the duration or of even eliminating critical delays.

B. Delays caused by congestion on the Inland Waterways

Lock outages, both scheduled and unscheduled, are one source of congestion leading to delay. Even scheduled outages, can lead to significant delays. For example, scheduled maintenance can lead to the discovery of additional work, unexpectedly lengthening the duration of the outage and perhaps leading to a complete shutdown. Consider the case of the Greenup lock on the Ohio River, where the closure that was planned to last 18 days stretched to over 52 days because of the extensive damage found and the risk of gate failure (Planning Center, 2005). This closure caused an average tow delay of 37.5 hours (Ibid). As the locks have aged, particularly over the last decade or so, the number of scheduled and unscheduled hours of outage has increased (Ibid).

There have also been significant delays on the Upper Mississippi and Illinois River. In 1999, for example, Lock 27 on the Mississippi River was closed for 225 hours, while the auxiliary chamber had an average delay of 25 hours during its peak month (US ACE, 2002). The Midwest Area River Coalition 2000 ("MARC 2000") says that the congestion on only one of the thirty-eight active locks on the Inland Waterways costs $209 million annually (MARC 2000, 2005). These costs are then passed on to those that use the shipping services, e.g., they estimate that delay increases costs for farmers that ship grain over the inland waterways by over $.08 per bushel of grain.

While the costs associated with delay are visible and substantial, the uncertainty associated with delay has more subtle implications. Long run decisions regarding facility location and infrastructure investment can be impacted by the uncertainty. While quantitative measurements of this source of cost do not exist, qualitative evidence can be found.

C. Alternative approaches considered

To address this type of problem a wide array of alternative approaches to a tradable permits program was considered. The alternatives considered can be grouped under the broad headings of (1) lockage fees, (2) scheduling plans and priority permits, (3) command or control regulations, and (4) tradable permits for river access or for fixed time lock use. Each of these is described below in more detail.

1. Lockage fees

Lockage fees are charges for the use of a lock, such approaches may be thought of as including (1) a simple charge system, where each tow pays a fee for each lockage, for example, the system used in the Panama Canal (see, e.g., Stavins (2003)); (2) congestion fees (or peak-load pricing), where a base lockage fee is increased during peak periods, such as the system used in the Washington, DC Metro System (see, e.g., Volpe, (2003)); (3) fees for relatively slow lockages (see Volpe (2003)); and (4) priority fees, where a premium is paid for priority service, like the current system for electrical power (see, e.g., Wilson (1993)).

2. Scheduling and priority

Scheduling regulates the flow of traffic in different ways, including such approaches as (1) reporting requirements, in that a tow is required to publicly report its planned schedule (see, e.g. Stavins (2003)); (2) local appointment system, similar to a train schedule, an appointment at a doctor's office, or air traffic control management (Volpe (2003)); (3) increased Lockmaster authority, where the Lockmasters at each lock on the Inland Waterways have the authority to direct tows in order to take better advantage of idle times at the lock (Volpe (2003)); and (4) priority transit, in which a tow's urgency allows it to skip the line under certain condition, a system that is also used in the Panama Canal (See, e.g., CBFenton).[1]

3. Command and control regulations

Command and control solutions are regulations that require barges to take certain actions in order to reduce congestion, such as (1) a limit on barges, where only a certain number of tows and barges are allowed on the river at any time, and (2) mandated private upgrades, which would require all tows to have a certain level of crew training/qualification and/or technology for cutting, moving, and reassembling tows (Volpe (2003)).

4. Tradable permits for river access and/or fixed-time lock access

Tradable permits for lock access have many different approaches and variations, including (1) seasonal permit trading, where permit trading only matters for certain (peak) months during the year, and in other months there is free access, like a system used with Ozone Transport Commission (OTC) NO_x Budget Program (see, e.g., Anderson (2001)); (2) boat-type-based permit trading, in that because tows are heterogeneous due to variations in configurations and lengths, only certain types of boats can trade with each other (e.g. 1200-foot tows cannot trade with 600-foot tows), like the system used with Chlorofluorocarbons (CFCs) and halons in CFC Production Allowance Trading (Anderson (2001)); (3) geographically varied trading, where permits in one region (less congested) do not equal permits in another region (more congested) on a one-to-one basis, such as the RECLAIM project in Los Angeles (Anderson (2001)); (4) a "quasi-emissions" program, where a regulator assumes that all tows will take a certain amount of time in the lock and charges accordingly; if a boat can prove that it took less time in the lock, it pays a smaller fee, like the program used by Santiago-Chile's environmental agency (Montero (2004)); and (5) a dual permit system in which two permits are issued and traded: one permit for access to the river, a second for the time slot in a given year, allowing companies

[1] Generally, the Panama Canal's priority system uses two principal means of access to the locks: (1) a reservation system for a certain number of slots for priority access and (2) the authority of the lockmaster to let any ship "be moved through the Canal on a priority basis." See CBFenton § 104.5.

that do not need to use the permit, but still require future access to the river, to maintain access, much like the system used in fisheries and water-allocation projects (Tietenberg (2003)).

5. Tradable Priority Permits

As will be discussed in the text below the research became focused on systems of priority permits. Such permits are for a place in the queue for access to the lock. That is, the permit does not guarantee access to the lock but it does establish a system of priority with which boats will access a lock. Boats that have acquired higher permits will be processed through the lock before those with lower permits.

D. Characteristics of the market

Information gathered from public sources, the US Army Corps of Engineers (the Corps) , and industry raised a number of points that highlighted a few broad issues: (1) the industry's need for flexibility in scheduling in order to respond effectively to a variety of external forces, (2) variability in the costs of delay, and (3) the peak-load nature of the upper Mississippi, with high usage in the fall, as capital moves down the river to avoid being iced in for the winter, and in the spring, as the capital moves back up river to serve demand.[2]

External forces also affect operations on the inland waterways and make it more difficult for industry participants to forecast and profitably meet delivery schedules. These include: lock outages (both scheduled and unscheduled), changing demand for transported goods, changing weather conditions, changing river conditions, and changes in staffing and regulatory staffing constraints.

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[2] See also "Briefing Paper on the Upper Mississippi and Illinois Rivers Transportation Corridors: Grain Transportation Rates and Associated Market Area." FAPRI-UMC Briefing Paper #05-04. July 6, 2004 ("Grain barge rates show some seasonality with rates often highest in the spring at river opening and in the fall at harvest. Grain truck rates display similar volatility while rail rates are typically less variable because of the railroad's increased ability to affect its own rate structure.") http://www.fapri.missouri.edu/outreach/publications/2004/FAPRI_UMC_Briefing_Paper_05_04.pdf#search='seasonality%20freight%20mississippi%20waterway%20fall%20spring. Accessed on May 19, 2005.

A variety of products are transported on the inland waterways, including coal, grain, petroleum, construction materials, and chemicals.[3] "The truck, rail, and barge modes play an important role in moving grain and grain products in the north central United States. Over some routes and corridors the modes act in a complementary manner while over other routes they compete."[4] Tables 1 and 2 help illustrate that variation in the products transported on the waterways, albeit within the bounds of bulk products of high weight and relatively low value.

Tables 1 and 2 are also examples of the distribution of products carried in the inland waterways, in this case late in the year. At different points in time, amounts of tonnage carried in each of the categories can vary. Here, in Tables 1 and 2, we are observing the downstream traffic late in 2004. In Table 1, corn, oilseeds and animal feeds are the largest in terms of tonnage; however, there are also substantial amounts of fuel oils, iron, and chemical fertilizers. Table 2 summarizes this product distribution and confirms that most of the products are carried in this example are grains, with substantial amounts of coal and petroleum products.

[3] "Briefing Paper on the Upper Mississippi and Illinois Rivers Transportation Corridors: Grain Transportation Rates and Associated Market Area." FAPRI-UMC Briefing Paper #05-04. July 6, 2004. http://www.fapri.missouri.edu/outreach/publications/2004/FAPRI_UMC_Briefing_Paper_05_04.pdf#search='seasonality%20freight%20mississippi%20waterway%20fall%20spring. Accessed on May 19, 2005.

[4] "Briefing Paper on the Upper Mississippi and Illinois Rivers Transportation Corridors: Grain Transportation Rates and Associated Market Area." FAPRI-UMC Briefing Paper #05-04. July 6, 2004. http://www.fapri.missouri.edu/outreach/publications/2004/FAPRI_UMC_Briefing_Paper_05_04.pdf#search='seasonality%20freight%20mississippi%20waterway%20fall%20spring. Accessed on May 19, 2005.

Table 1: Downbound Waterway Traffic on the Mississippi River from 10/15/2004 - 11/25/2004, by Commodity

Code (a)	Description (b)	Tonnage (c)	Percent of Total (d)
1	empty barges	0	0.00 %
10	coal, lignite & coke	19,500	2.13
20	petroleum & petroleum products	9,000	0.98
21	crude petroleum	0	0.00
22	gasoline, jet fuel, kerosene	0	0.00
23	all fuel oils; lubricating oils & greases	31,612	3.46
24	pitches, asphalt, naphtha, solvents	16,400	1.79
30	chemicals & related products	600	0.07
31	all chemical fertilizers	80,193	8.77
32	all other chemical related products	1,500	0.16
40	crude materials, inedible, except fuels	0	0.00
41	forest products, lumber, logs, woodchips	0	0.00
42	pulp, waste products	0	0.00
43	sand, gravel, all stone & crushed rock	0	0.00
44	iron ore; iron steel waste & scrap	27,024	2.95
45	marine shells, unmanufactured	0	0.00
46	non-ferrous metallic ores, waste & scrap	9,000	0.98
47	sulphur, liquid & dry; clay; salt	0	0.00
48	slag	1,500	0.16
50	primary manufactured goods	0	0.00
51	paper & allied products	0	0.00
52	building cement & concrete; lime; glass	0	0.00
53	primary iron & steel products	6,300	0.69
54	primary non-ferrous & fabricated metal prd	0	0.00
55	primary wood products; veneer, plywood	0	0.00
60	food & farm products	42,000	4.59
61	fresh fish & other marine products	0	0.00
62	wheat	10,580	1.16
63	corn	399,578	43.68
64	rye, barley, rice, sorghum & oats	9,000	0.98
65	oilseeds-soybean, flaxseed & others	157,660	17.23
66	vegetable products	3,035	0.33
67	animal feed, grain mill & processed grains	90,382	9.88
68	other agricultural products incl food, kin	0	0.00
70	all manufactured equipment & machinery	0	0.00
80	waste matl, garbage, landfill, sewage,etc	0	0.00
89	locally designated commodity	0	0.00
99	commodity is 'unknown'	0	0.00
Total		**914,864**	**100.00** %

Source:
RPT06 Waterway Traffic Report (v3.5.1) at - 2005/05/18 13:14:04. Available at http://www.mvr.usace.army.mil/mvrimi/omni/webrpts/omni_gr/landscape.asp?v_seqno=147158 &SRVR=MVD. Accessed on May 18, 2005

Table 2: Downbound Waterway Traffic on the Mississippi River from 10/15/2004 - 11/25/2004, by Commodity Grouping

Commodity Groupings	Tonnage	Percent of Total
(a)	(b)	(c)
Total COAL (10 thru 19)	19,500	2.13 %
Total PETROLEUM (20 thru 29)	57,012	6.23
Total GRAIN (60, 62 thru 66)	621,853	67.97
Total Other (none of the above)	216,499	23.66
Total	**914,864**	**100.00** %

Source:
RPT06 Waterway Traffic Report (v3.5.1) at - 2005/05/18 13:14:04. Available at http://www.mvr.usace.army.mil/mvrimi/omni/webrpts/omni_gr/landscape.asp?v_seqno=147158&SRVR=MVD. Accessed on May 18, 2005

In addition to the variability in the types of product carried, there is variation in industry conditions from other sources as well. Commercial traffic is only one use of the locks. Recreational traffic can affect the availability of the locks for use by commercial traffic, particularly passenger traffic with priority. Table 3 provides another example of the mix of traffic based on downstream traffic in late 2004. While commercial tows account for the majority of traffic, there is substantial traffic from recreational vehicles, as well as some smaller amounts from government traffic and passenger vessels.

Table 3: Vessel Breakdown of Downbound Waterway Traffic on the Mississippi River from 10/15/2004 - 11/25/2004

Vessel Type	Number of Vessels	Percent of Total
(a)	**(b)**	**(c)**
VESSEL TOTALS		
Commercial Towboats (T)	75	55.56 %
Psngr Boats, Ferries (P)	3	2.22
Recreation Vessels (R + addnl Rec boats)	49	36.30
Cargo Carrying Vessels (C)	0	0.00
U S Govt Vessels (G)	5	3.70
U S Govt Contractor (U)	0	0.00
Cmrcl Fishing Boats (F)	0	0.00
Light Comm Vessels (L + addnl Light boats)	3	2.22
Other (remarks) (X or none of the above)	0	0.00
Total	**135**	**100.00** %
BARGES/PASSENGERS TOTALS :		
Number of Empty Barges	281	21.95 %
Number of Loaded Barges	593	46.33
Number of Paying Psgrs on Comm Vessels	406	31.72
Total	**1,280**	**100.00** %

Source:
RPT06 Waterway Traffic Report (v3.5.1) at - 2005/05/18 13:14:04. Available at http://www.mvr.usace.army.mil/mvrimi/omni/webrpts/omni_gr/landscape.asp?v_seqno=147158&SRVR=MVD. Accessed on May 18, 2005

Lock outages, or stoppages, are another, generally, external force that can affect the variability in the market conditions making it more difficult for the industry to forecast and meet delivery schedules. OMNI data tracks lock and vessel "stoppages" on the Inland Waterways for a variety of reasons, including reasons relating to weather, the river surface, tows, and the lock itself.[5] By way of example, an informal review of recent OMNI data suggests that the overall average stoppage on the Mississippi is in the range of 4 to 19 hours, excluding extended closures for more than one month. See Table 4. With regard to longer stoppages, from January 1, 2000 to May 15, 2005, there appear to have been 14 extended stoppages of a lock on the Mississippi River, i.e., stoppages that lasted for more than one month.[6] These 14 closures can be separated into two types of closures: (1) stoppages that amount to a complete closure of the lock but which only occurred in the middle of winter when the upper Mississippi freezes and (2) stoppages that reduces the lock's capacity by closing only one of a pair of alternative locks, leaving the other available for use by river traffic. As the lock is likely to have been effectively closed in any case, the latter case can be set aside. The former case can be interpreted as extended reductions in the capacity to perform lockages of between 33 and 67 percent, depending on the relative sizes of the two chambers at a lock (600 or 1200 feet) and which of them was closed.

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[5] See Stop/Slowdown codes http://www.mvr.usace.army.mil/mvrimi/omni/webrpts/omni_tp/Stoppages.htm.

[6] "Operation & Maintenance of Navigation Installations (OMNI) Reports." US Army Corps of Engineers. http://www.mvr.usace.army.mil/mvrimi/omni/webrpts/omni_gr/omni_criteria.asp?report_name=RPT13. Accessed on May 18, 2005.

Table 4: Average Lock Stoppage for Stoppages Shorter than One Month

Year	Average Lock Stoppage	
	Minutes	Hours
(a)	(b)	(c)
2000	510.48	8.51
2001	1,120.35	18.67
2002	561.50	9.36
2003	632.02	10.53
2004	292.64	4.88
2005 [1]	263.12	4.39

Notes:
[1] Numbers for 2005 range from January 1 to May 15.

Source:
"Operation & Maintenance of Navigation Installations (OMNI) Reports." US Army Corps of Engineers. http://www.mvr.usace.army.mil/mvrimi/omni/webrpts/omni_gr/omni_criteria.asp?report_name=RPT13. Accessed on May 18, 2005

Congestion can reduce performance and increase uncertainty with regard to delivery, which, in turn, can lead to increased demands on a transport system. "[C]argo … has increased 7.1 percent this year with delays creating 'a degree of uncertainty and higher costs for companies' and, without sufficiently close substitutes, '[c]ompanies may have to put more inventory in the pipeline."[7]

[7] Watson, Rip (Bloomberg News) "Rail Congestion halts Michigan plant: Transportation demand increases due to growing economy, Asian imports," *The Detroit News* (July 15, 2004).

In May 2004, the USACE held a meeting with the industry to discuss the temporary closure of the McAlpine Lock on the Ohio River.[8] At that meeting a number of comments by industry participants highlighted both the benefits of having additional time to stockpile for the outage and, for some, the need for a steady and uninterrupted access.

> I'm $$ $$ with Century Aluminum. We have a continuous operation at Rangeland, West Virginia that without the feed stock, we'll shut and would not reopen, given the cost of starting that facility. About seven hundred employees, three hundred retirees at this point. That's our northern most plant. The feed stock that we use along with our metal aluminum is called Alumina, and it's in tight supply world wide, as a matter of fact it's selling at two-and-a-half times what it sold at a year ago. We can't surge and pull ahead very quickly. In our instance, the longer we can put this off, the better, understanding that you do need to get it fixed. So for us, if we were down in June, it would be catastrophic.

> Ms. $$ with Ormet Corporation. It's impossible to mobilize the supply in that time frame. $$'s supply, what he's talking about, is at least thirty days away from that lock right now, even if we were in a position to put enough on the river to basically cover a three-week time frame. First, we have to have our suppliers basically mobilize their supply in order to get the time frame to start moving the product into the river and through the position. If you close that lock, with even a two-week notice, we still have no potential to get the material up the river and through that lock before we would then have – be out of material. So the longer we have, the more notice we have -- you know, basically, ninety days notice would even be better, because it would give our suppliers a chance to get material to us. … Well, we have the same number of employees that $$ has. We have at least a thousand hourly employees between two facilities and if we put both that and a rolling mill in danger, $$'s plant produces product for the U.S. government that they basically need for planes for the materials for the war efforts. So, I mean, this puts the government at risk also for critical materials.

> My name is $$ $$ with Bayer Corporation in Pittsburgh. We have a manufacturing plant in South Charleston, West Virginia. Key raw material will be dock side and we're a hundred percent dependent on that product for manufacture of polypropylene glycol. About ninety plus percent of the content of polypropylene glycol is propylene oxide. We are one hundred percent dependent on the river for this supply. We have no other mode of transportation other than barge. Propylene oxide is also tight around the world at this time and

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[8] Temporary Closure of McAlpine Lock, U.S. Army Corps of Engineers Meeting, Louisville, KY (May 27, 2004).

> it would take us at least until August to build up sufficient inventories of both raw materials and finished goods to get through the fourteen-day outage. Anything beyond the fourteen days, we feel would be – would have a significant impact on our company resulting in millions of dollars of loss for us, shut down of dozens of industries, including key manufacturing companies in the U.S. and the American automotive industry. That industry, we are a key supplier to that and that is an industry that does not have any wide spots in the line to absorb any hiccups in the supply chain.

> I'm $$ $$ with Lyondell Chemical and we supply Bayer with their propylene oxide. We're also the owner and operator of the barges that carry that material from our facilities back to U.S. Gulf. We do have a limited amount of these barges. They are specialized. We have fourteen barges in service. So it is going to be important not only before the closure on the loaded barges coming up from the U.S. gulf, but also getting barges back south, back to our plants to reload the empties. So we are in a situation where we have a limited amount of equipment to move this material up from West Virginia. So -- I think $$ mentioned -- started maybe one of the questions that we have, will there be any prioritization for equipment that is dedicated and needed to keep lines open?

Congestion is a problem affecting many areas of shipping.[9] Predictability is an important demand factor in the choice of carrier and carrier type. "'Each shipper has its own manufacturing schedule, but in general the cutoff date is less material than predictability,' said John Isbell, director of corporate delivery logistics for Nike."[10] "Asian cargo through Southern California has increased 7.1 percent this year with delays creating 'a degree of uncertainty and higher costs for companies,' said Jack Kyser, chief economist at the Los Angeles County Economic Development Corp. 'Companies may have to put more inventory in the pipeline. It will be hard to fall back on trucks because they are short of drivers.'"[11]

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[9] Tirschwell, Peter, "A way to alleviate congestion?," *Journal of Commerce* (March 14, 2005) (port terminals) and Watson, Rip (Bloomberg News) "Rail Congestion halts Michigan plant: Transportation demand increases due to growing economy, Asian imports," *The Detroit News* (July 15, 2004) (railroads).

[10] Tirschwell, Peter, "A way to alleviate congestion?," *Journal of Commerce* (March 14, 2005).

[11] Watson, Rip (Bloomberg News) "Rail Congestion halts Michigan plant: Transportation demand increases due to growing economy, Asian imports," *The Detroit News* (July 15, 2004).

"Looman Stingo, senior vice president of logistics for Holcim Ltd., the world's No. 2 cement maker, said plants in Colorado and Texas may have to shut down because the don't have enough rail-delivered coal to run them."[12]

E. Selection of the basic approach

Based on the characteristics of the marketplace and the nature of the congestion, we were less optimistic about systems that penalizes "slow" lockages, as the length of the lockage may influenced by factors beyond the control of the operators. Some of the same forces that can affect the time in a lock, such as weather, can also affect arrival times. This made fixed appointment based systems less attractive relative to a system that allows greater flexibility. Moreover, the general desirability of allowing for the flexibility of market participants to respond to changing market conditions in a manner, as much as possible, of their own choosing, made command and control systems unlikely to be the most useful line of inquiry. Finally, we decided that a tradable priority permit system was likely to best serve the objectives of reducing the costs of congestion, including costs associated with uncertainty and providing a means to measure the value of increased lock capacity.

Some instances of congestion are likely unavoidable, particularly given the industry concern over lock outages, weather conditions, etc and the seasonal nature of some parts of the system. To assist in reducing the costs during these periods, and to allow some ability to measure the costs of the delays, we propose a system of tradable permits for priority.

The initial grant of permits would be to existing river barge operators in proportion with historical operations. This is not unlike the notion discussed in the NRC report.[13] However, because we are not giving proprietary rights to use the locks for specific times of day, as was

[12] Watson, Rip (Bloomberg News) "Rail Congestion halts Michigan plant: Transportation demand increases due to growing economy, Asian imports," *The Detroit News* (July 15, 2004).

[13] Committee to Review the Upper Mississippi River-Illinois Waterway Navigation System Feasibility Study, Water Science and Technology Board, Division on Earth and Life Studies, Transportation Research Board, and the National Research Council, *Inland Navigation System Planning: The Upper Mississippi River –Illinois Waterway,* Appendix C (Washington DC: National Academy Press, 2001).

discussed there, the historical operations for this purpose can be viewed as the distribution of lockages across operators over a recent historical period, say, the last three years. The permits would be freely transferable. The initial grant of permits would be in such numbers and levels of priority that the cargos with greatest urgency in value could move through the river without costly delay caused by congested traffic.

The initial distribution would a relatively conservative one in that the number of higher level priorities would be relatively low. This conservatism would be in order to avoid the need to downgrade priorities during the preliminary stages in which some adjustment might be required. A conservative starting distribution might, e.g., involve only 5 percent of the priorities being granted at each of the three most preferred levels of priority.

This approach avoids many of the problems associated with other methods, which often fail due to the demand for flexibility by the industry. In fact, the flexibility prized by the industry is increased by allowing vessels to better meet unforeseen difficulties and changing market conditions. As noted above, the principal benefits are those of increased efficiency through a reduction in total transportation costs and a method to value the avoidance of delay.

As a consequence of increasing the efficiency of these river resources and the initial grant being made to existing operators, the profits of these firms should increase as a result of the cost savings. Moreover, entry of new firms and expansion of existing firms will not be prevented because priorities can be bought on the market or, if necessary, additional priorities can be issued (in high price/low trade with low use) scenarios.

The establishment of the priority system does not bar entry; however, for entry to occur for contracts that require some level of priority the entrant would need to purchase priority instruments from those who hold them.[14] However, by observing the prices at which the priorities are trading, prospective entrants and current operators would have better information

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[14] As is discussed below, the priorities are divided into priority permits that can be exercised over a two-week time frame and a master instrument which is essentially perpetual and serves as the source of a stream of the priority permits. An entrant need not buy the master instrument to enter, but may be able to profitably operate only acquiring one or more priority permits.

about the relative scarcity of the lock resources and could better decide whether investment in additional capital was likely to be worthwhile.

Finally, the recommendation is consistent with and similar to self-adopted industry policies to meet temporary difficulties; however, institutionalization of the system will provide for a quicker response time and broader application. Commercial users of the inland waterways are familiar with priority systems and have found them beneficial to help resolve congestion in the past.[15] However, because in the past these solutions have been ad hoc, the benefits are not maximized. Motivations for the use of priorities include limits on the sources of or storage capacity for inputs of some customers and their need for a continuous supply to remain in operation[16] Managing the uncertainty associated with delivery and with the negative outcomes that may ensue, including the closure of some plants dependent on supplies of inputs over the waterways and the exercise "transportation risk management" become of increasing significance.[17] While not an "easy task" for the industry to take on an ad hoc basis, the benefits seem clear.[18]

Delays from congestion, as the result of a stoppage or through other means, can also cause some shipments to shift to alternative modes of transport. For example, "[w]hen the scheduled closure of Greenup Lock turned into a 54-day extended closure (due to extensive unanticipated repairs), Dayton Power had to spend $7 million to find alternative rail transportation and it cost the navigation industry $12-$15 million in lost revenue. [19] Dan Meckleborg, SVP – Ingram Barge Company said, "It was taking 20 times what it normally takes to lock though. It's

[15] See, e.g., the minutes of the USACE meeting "Temporary Closure of McAlpine Lock" on May 27, 2004, pp. 64-5 : "So probably very soon, we'll probably try to put a working group together. We may look to some outside resource also to help manage that process. So, I guess unless we - FROM THE FLOOR: We've done this a lot of times. INGRAM1: Yeah, we have done this before,."

[16] "Temporary Closure of McAlpine Lock." US Army Corps of Engineers Meeting. May 27, 2004. http://www.lrl.usace.army.mil/pa/article.asp?id=83. Accessed on May 19, 2005, p. 61.

[17] "Temporary Closure of McAlpine Lock." US Army Corps of Engineers Meeting. May 27, 2004. http://www.lrl.usace.army.mil/pa/article.asp?id=83. Accessed on May 19, 2005, p. 60.

[18] Ibid.

[19] "The Port of Pittsburg News." Port of Pittsburgh Commission. December 2003. http://www.port.pittsburgh.pa.us/news/nl-dec2003.html. Accessed on April 28, 2005.

symptomatic of all locks. The operative maintenance money the government is allocating is inadequate."[20] Several events occurred in relation to the closure at the McAlpine lock in Illinois. "Mark Devinney, a vice president with Nicholas Enterprises, a barge terminal operator on both the Ohio and Allegheny rivers, says that one of his clients in the Pennsylvania steel industry forked out $300,000 on truck and rail transportation to keep its supplies and products moving when McAlpine shut down."[21]

Uncertainty can not only be costly in that it can reduce the number or types of shipment contracts that a firm may take, but also in the costs of time spent holding a place in the queue. MEMCO Barge Line's river operations losses from the closure at Greenup were estimated at $1.3 million, which translated into 135 boat days and 2,025 barge days lost; "[w]e had four boats sit at Greenup for eight weeks, holding spaces in line," said Mark Knoy, president of Chesterfield, Mo.-based MEMCO."[22]

In sum, the expected improvements from this recommended policy include the following:

- Increases flexibility in shipping schedules as each party is able to decide whether to exercise, sell or hold their priority permits, which were previously not available.
- While not necessarily increasing the number of lockages per day or the number of barges moved through a lock each day, the system allows shipments with costlier delays to move through at a priority, increasing the efficiency of the system.
- Reduces the uncertainty associated with the position one may get in the queue so as to aid in operators' abilities to improve their business arrangements and pursue more time sensitive shipments.
- Increases operator profits by increasing the flexibility of the operator to respond to changing market conditions, allowing the operators to better compete with alternative means of transport by reducing the uncertainties associated with delivery

[20] "The Port of Pittsburg News." Port of Pittsburgh Commission. December 2003. http://www.port.pittsburgh.pa.us/news/nl-dec2003.html. Accessed on April 28, 2005.

[21] "More Disruptions for Industries Reliant on Inland Waterways." Kiplinger Business Forecasts. February 18, 2005. http://www.compassweb.com/cob/kiplinger/200503/waterway_disruptions.html. Accessed on April 28, 2005."

[22] "News Articles on Chickamauga Lock." US Army Corps of Engineers. July 2004. http://www.lrn.usace.army.mil/pao/chickamaugalock/news_articles.htm. Accessed on April 28, 2005.

conditions, and allowing the operators to expand the set of contracts they can profitably undertake.

- Provides a ready means of responding to congestion, including extended or unscheduled outages at a lock.

II. RECOMMENDATION

A. General

The recommendation is to create a system of tradable priority permits that will be issued to existing river barge operators in proportion to existing and historical operations on the river.

B. Details of instruments: tradable priority permits

1. Rights of the holder

A permit will give to the holder the right to move ahead of all barges waiting for access to the lock and traveling in the same direction, up to the holder of a permit in the queue being exercised with equal rights. That is, the function of the instrument is not to govern access to or use of a lock. It only serves to alter the order from one of "first come first served" where there are several potential users in queue for a lock but with different waiting costs. The permits would only alter the order of access among commercial traffic; the existing priorities governing non-commercial traffic would be unchanged.

2. The Master Instrument

The tradable priority permits are instruments with two principal components: (1) the master instrument and (2) the two-week permits. See section II.B.7 below. The master instrument provides the holder a perpetual stream of two-week permits for the life of the program. So, the holder of a master instrument for a given lock (or a given chamber in cases where the lock has multiple chambers) will be reissued each year the same tradable priority permits for the 26 two-week periods unless and until the master instrument is sold.

3. Marketability

The instruments will be marketable and transferable. Either the master instrument or one or more of the two-week permits it generates can be marketed and sold. Sales of the latter do not affect the ownership and control of the master instrument. One may sell priority permits that are not expected to be used or not highly valued to others, while retaining the master instrument and, therefore, the ongoing stream of priority permits in the future.

4. Permit validity and timing

Permits will be designated as "Upstream" or "Downstream." The permits will be lock specific and have a limited life. The life of the permit will be sufficiently long and the grant of permits overlapping so that the flexibility of vessel operators is maintained. For example, a permit might be valid for use within a given two-week period with other permits beginning (and ending) their useful life at the end of the first week. In fact, this "overlapping" structure of instruments will add flexibility for barge owners to meet unforeseen changes that occur during a voyage. Still, the number of permits of a given priority available to be exercised at any time is limited, so savings in delay costs are still achieved.

The queues, "Upstream" and "Downstream," are treated separately. The current procedures by which lockmasters allocate between upstream and downstream traffic is not altered by this proposal, in part, because the congestion is understood to be typically one-way.[23] However, if a priority needed to be viewed as a queue for use of the lock regardless of direction, that can easily be addressed by, as one alternative, avoiding the distinction between upstream and downstream priority and making one unified priority not conditioned on direction. Such

[23] There appears to be some understanding in the industry that multiple one-way locks assist in relieving congestion at locks. "Temporary Closure of McAlpine Lock." US Army Corps of Engineers Meeting. May 27, 2004. http://www.lrl.usace.army.mil/pa/article.asp?id=83 (accessed on May 19, 2005) ("I guess one of the questions that the Colonel asked is do you use traditional first come first serve or do you use[ ]multiple one-way lockages. And my response to that is based on a lot of the queuing theory things that the industry has looked at over the years and worked with the Corps, we have found that multiple one-way lockage permits us to move more cargos through the lock.")

would, of course, risk sacrificing a distinct market for upstream and downstream priorities that adds somewhat to flexibility in planning in making more precise forecasts about river use and relative priority.

A vessel that takes its place in the queue based on the exercise of a permit is envisioned to keep that position, barring the exercise of another permit, even if the permit used to gain that position expires.

5. Priority levels

Unless otherwise determined four priority levels will exist and can be labeled as 1st through 4th. Holders of 1st level priority that present themselves at a lock during a week for which the instrument is valid will be moved ahead of all traffic holding lower level priority. Notice, that under this right a 1st place holder cannot allow a lower level holder in front while holding back another 1st place holder. In general an nth level holder can move ahead of any n+1th level holder.

Given the current tracking of tows between locks in place, this system would add only incrementally to the existing information that is now available to tows on the river. Tows are currently able to access information regarding the number of tows ahead of them in the queue. With the priority system, they would be able to ascertain the number of tows in the queue at each level of priority. In this way, they would be better able to determine whether or not they can profitably accept or compete over delivery conditions in a prospective contract.

6. Limited useful life

The instruments are good only for the time interval and lock for which the instrument was issued. So, in periods without congestion, the permits will expire without being exercised. Unexercised permits whose valid life is past may not ever be subsequently exercised. Of course, the following year, permits will be regenerated for that year according to the ownership of the Master Instrument.

The design of the instruments anticipates the nature of the uncertainty on the river and the associated need for flexibility. Notice that the suggested life of the permit is two weeks and thus allows margins for uncertainty to be built into the scheduling. Vessels for which unexpected delays might be anticipated can acquire permits that expire only well after schedule. In the event that delays are still problematic the vessel can trade for a permit that has a later expiration date. Recall that if the life of a permit is two weeks and the permits are staggered, there are always permits that expire a week later.

7. Determination of number of permits

First, it should be said that the initial allocation, both in terms of the number of permits at each level of priority and in terms of the distribution among carriers, should reflect equity, political and policy considerations that are outside the scope of this phase of the study. However, we do provide the following suggestions. The initial number of permits can be based on historical use. The initial number of permits can be determined by the number of double lockages that have historically been completed at that lock under normal operating conditions.[24] Alternatively, the initial number of permits could be in proportion to the capacity of the lock operating under constrained conditions. The results of the chosen calculation are used to determine the total number of permits that will be issued for exercise in a given period.

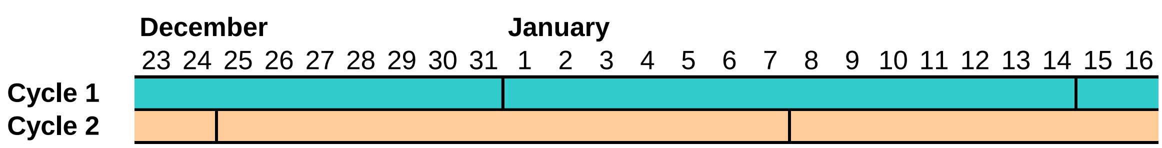
The permit is designed to deal with congestion that occurs because tows operate on their own time schedules or that might need to be cleared as the result of an unplanned outage. The number of permits at each level of priority is associated with the degrees of capacity reduction a lock might experience. The number of first priority permits should reflect the most reduced capacity. In other words, if under the poorest of operating conditions only 5 lockages would be possible in the relevant time frame, then there should be only 5 permits of the highest priority.

[24] Double lockages are those that are required when a vessel's full length, both tug and barges, is roughly twice the length of the lock, and the barges must be put through the lock in two separate parts.

In addition, to this simple relationship, we suggest it would be better to start with a conservative figure for the number of higher priority permits as adjustments then would be to elevate lower priority permits to a higher priority permit, rather than potentially reducing higher level permits to a lower level. See the relevant appendix to the report for an adjustment rule for the number of permits of each priority.

The valid time interval for the priority permits will be a window of two weeks. To provide increased flexibility, the priority permits will have overlapping time intervals. Priority permits will be evenly divided across two cycles that are staggered by one week. Half the master instruments will produce permit streams that have their first two-week permit begin on January 1 and the other half will have their first begin on January 8. See figure 1 below.

Figure 1: Overlapping time intervals



8. Initial Allocation of Instruments to Existing Operators

Again, the initial allocation should reflect equity, political and policy considerations, which are outside the scope of this phase of the study. However, we do provide the following suggestions. The recommended policy includes "grandfathering" the existing operators in the sense that the existing operators receive the priority permits free of charge, or perhaps for a small administrative fee. The allocation should be made according to some measure of past river use, e.g., over the last three years. The percentage of river traffic (in terms of lock use) will be calculated for each firm. Each firm could receive a proportional share of standard portfolios. For example, a firm with *x* percent of the lockages over the last three years will receive *x* percent of the issue of each type of permit. Those whose business models benefit from a greater than proportional share of higher priority permits would be expected to acquire them on the market from those who derive less value from them. However, equity considerations make the precise allocation beyond the scope of this project. We provide this only as a working example.

The number of permits and number of the level of priorities present an interesting tradeoff. With a very high number of priorities and low number of permits of each type, one might observe that, for all intents and purposes, the first group of priorities all to sell for much the same price. Firms may not be willing to pay substantially more to be first as opposed to second. However, this degree of fineness also makes it more difficult to make the initial distribution of instruments more equitable, that is, that all firms with substantial participation get at least one master instrument for each lock they use at each level of priority. If there were 10 firms that all used the same lock and only three master instruments producing permits of the highest priority, an apparently equitable initial distribution might be complicated by a complex balancing of higher priority permits across other locks or other time periods, as well as permits of other priority levels. Note also that a master instrument can provide a mix of priority levels over time for a given lock. So, the number of permits is generally not less than the number of firms with substantial participation at the lock. Moreover, larger numbers of master instruments ease trade among the participants and make pricing more distinct as between priorities.

9. Recording System

Each master instrument and associated two-week permit would be numbered; a record of the owner will be kept by the Corps and made publicly available. These numbers would relate so that each two-week permit can be associated with the master instrument that produced it and the time period for which it is valid. For example, the master instrument might be AAA111 and the two-week permit transfers of ownership are valid only after official notification to the Corps. The record of ownership held by the Corps will be the determining factor in the case of disputes, suspected fraud, forgery, or other suspected misuses.

The particulars of the mechanism by which trades would occur and the data recorded and presented are largely beyond the scope of this project. Use could be made of the existing Corps information system accessible on the Internet, e.g., Operation & Maintenance of Navigation Installations ("OMNI"), which already includes information on the vessels on queue at locks and, so, would likely reduce the amount of incremental infrastructure required. Trades could certainly be made on the fly or based on plans made prior to the journey. We do not exclude the possibility that some of the permits may be held or traded by the customers of the transport companies.

10. Enforcement

The ownership of the master instrument and associated permits will be kept by the Corps and be available to both lockmasters and any vessel that might wish to offer to purchase a priority permit from another operator.

The lockmaster will direct repositioning of tows in accord with the permits held by those who might approach the lock and state they are exercising a priority permit. This can be done in accordance with current practice and the existing tracking and communication systems. The lockmaster will verify the number of the certificate held by the operator using the lock. The nature and punishment for violations and failure to comply will be determined by the Corps.

The exercise of any priority permit is conditioned on it being possible to safely alter the queue based on all the prevailing facts and circumstances.

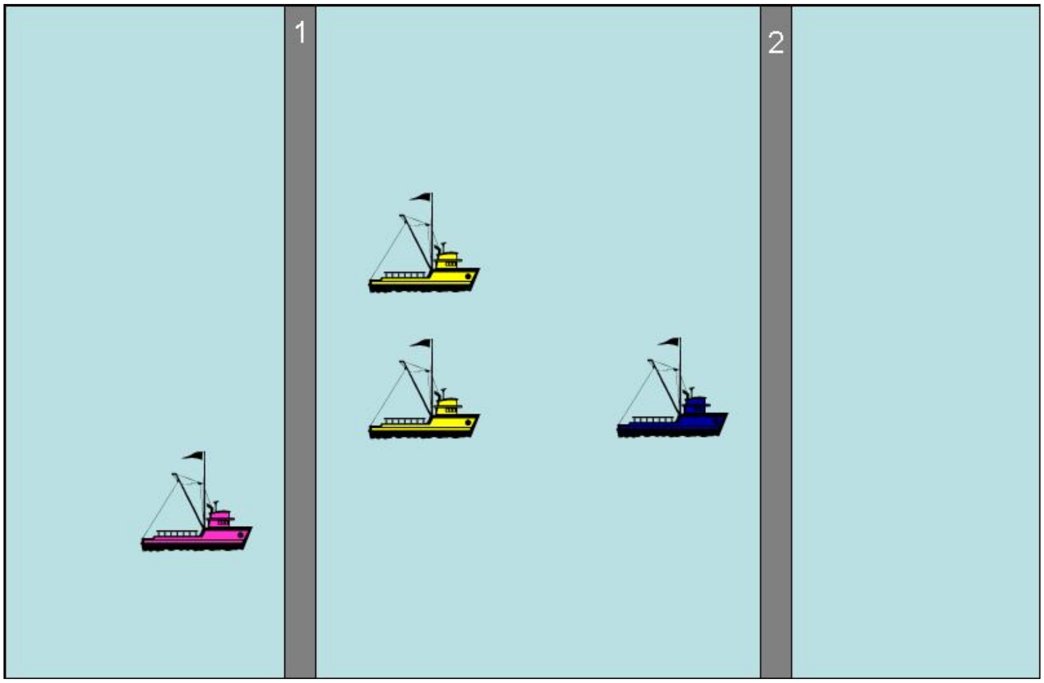
III. ILLUSTRATION

We have outlined the general model of priority permits; however, an example might be useful to illustrate the model. Of course, the model is a general one and its parameters are adjustable to conform to the particulars of each lock or set of locks and with experience. The parameter values were chosen with a mind toward the likely best course for adjustment. Specifically, we chose relatively few levels of priority as it is generally easier to add levels of priority, by elevating those operating without priority, than it is to cut excess levels with little or no market value or to have such levels continue to need to be tracked by the system.

Consider Figure 2 below. The vessel on the far left has priority 2 for lock 2 and is color-coded pink. The three vessels in the pool between locks 1 and 2 have different priorities. The yellow vessels have priority 3 for lock 2 and the blue vessel has priority 1 for lock 2. Upon entering the pool with these three other vessels, the pink vessel can exercise its priority and move ahead of the yellow vessels, safety permitting; however, it may not move ahead of the blue vessel in the queue. Even before the pink vessel reaches the pool between locks 1 and 2, it has a good idea as to the traffic that exists on the river (based on current information systems) and how much traffic it could possibly face in front of it in the queue based on the distribution of priority permits.

Notice that the pink vessel will necessarily have less time waiting in the queue so long as there are limited numbers of priority one and priority two permits for lock 2. Thus, vessels that have acquired higher priority will experience little delay and can thus adjust their cargos to the potential that exist in the marketplace for faster delivery with little uncertainty. Vessels with lower priority will experience longer delays on average but will be compensated by selling the priority rights with which they have been endowed. The value of the priority rights they sell will reflect the profitable opportunities recognized by businesses that buy the permits. Under this system the value of river traffic and profits of operators can only increase. Operators either get the benefit of reduced uncertainty and delay or from the sale price of the permit, whichever they value most.

Figure 2



IV. PRELIMINARY TESTING

A. Policy testbed

While the policy is based on fundamental principles of economics that are fully understood by the scientific community and professional economists, these principles might be unfamiliar to those who will be affected by the recommendation. In order to illustrate the nature of the proposed institution, the problems it addresses and how it accomplishes a solution, an experimental testbed was conducted using students with experience in double oral auction experiments at the California Institute of Technology as subjects. This testbed serves as both an illustration of the recommendation together with an explanation of why and how it is expected to work. The concepts and the setting are complex; so, the testbed demonstration within a highly simplified setting should help to develop an understanding of the recommendation. The simplicity of the setting is necessary to expose the operation of the underlying economics that is not compromised by additional complexity.

B. Questions for the policy testbed

The policy proposal suggests important questions that can be answered in the context of the policy testbed.

- First, can the proposed market system be practical in the sense that it can be put into operation?
- Second, are the principles on which the proposed system is based apparent in the testbed such that the proposed system works for understandable reasons?
- Third, when implemented, does the proposed market system have the expected effects?

The construction and implementation of the testbed requires operational and measurable concepts; so, the very creation of the testbed provides an affirmative answer to the first question. By observing the proposed system at work in the simple case of the testbed, we would hope to see that participants who are unfamiliar with the technical aspects of economics can nevertheless develop a common sense intuition of the proposed system's foundations as evidenced by their ability to successfully use the new market instruments to improve their performance without extensive training. Of course, the final question is answered by the results of the testbed.

C. The Testbed Environment

For simplicity, and without loss of generality, assume that there are 9 operators, each of which own and operate 5 tugs or tug-barge combinations. All of these operators have opportunities to make contracts to move barges of cargo through a lock. The current capacity of the lock, which may be interpreted as an impaired capacity, is insufficient to allow passage of all 45 boats on the same "day." Only 9 lockages are possible on a given day, so the passage of all boats takes 5 days to complete. As all boats are idle and need to move through the lock to complete a contract, there is an excess demand for lockages and a queue will form and most of the boats will experience some degree of delay.

The testbed proceeds in terms of a number of fixed time periods. Each period represents five days and sufficient time to complete all contracts.[25] The first 10 periods of the testbed have the participants operating under a "first-come-first-served" regime. Each subject controls five boats that arrive in random order at the lock.

Table 5

Contract Type	Day on which the boat passes through the lock				
	1st	2nd	3rd	4th	5th
	(value)				
(a)	(b)	(c)	(d)	(e)	(f)
A	1,000	0	-100	-500	-750
B	500	400	0	-100	-200
C	400	300	200	0	-100
D	300	200	100	100	100

Table 5 contains the value of various contracts as depending on delivery time. As can be seen from the values in Table 5, the contracts available differ in payoff and risk dimensions. Contracts of type A have a relatively large payoff if the delivery time is short. Notice, however, that the losses from delays in completing this type of contract are also relatively large and increases with the length of the delay. Contracts of type B produce a substantially lower payoff than those of type A if delivery is relatively quick; however, the loss exposure is also not as great due to delay. For contracts of type C, the payoff for a quick delivery is reduced as are the penalties for delay. Contracts of type D are "safe" contracts, in that it has a similar expected payoff to type C with random delivery times, but does not involve any negative values regardless of the length of the delay.

[25] Of course, if we allowed for the recontracting of vessels that had completed their journey through the lock, we would increase the total number of voyages possible and the profits of the system. However, the increase in the value of those additional lockages would be approximately proportionate to the ones we observe and would not alter the qualitative results of these preliminary tests. Part of the payoff structure in the contracts can be interpreted as relating to opportunities for additional contracts on the other side of the lock.

Opportunities to engage in different forms of contracts differed dramatically across boat operators. In particular, one-third of the operators had the opportunity to engage in type A contracts while others did not. The reason for this experimentally imposed asymmetry was to illustrate how the patterns of profits would be affected across boat owners with different shipping opportunities. Different opportunities may be the result of different business relationships or the particular capabilities of the boats themselves.

Theory tells us, basically, that the benefits of the proposed policy will accrue neutrally in the sense that the benefits of the policy will tend to be equally shared among existing operators regardless of any differences they may have in their opportunity set. The testbed allows a means of supporting this prediction if all the boat owners' profits increase, notwithstanding the fact that only one-third of them had the ability to make contracts of type A. The proposed system includes an even distribution of priority permits to all operators in proportion to historical river use but independent of the nature of that use. Thus, each operator will receive a portfolio that included instruments for all levels of priority. Operators who do not have openings to markets with high payoff contracts are able to sell these priorities to those who do and thereby share in the gains.

D. Testbed Results

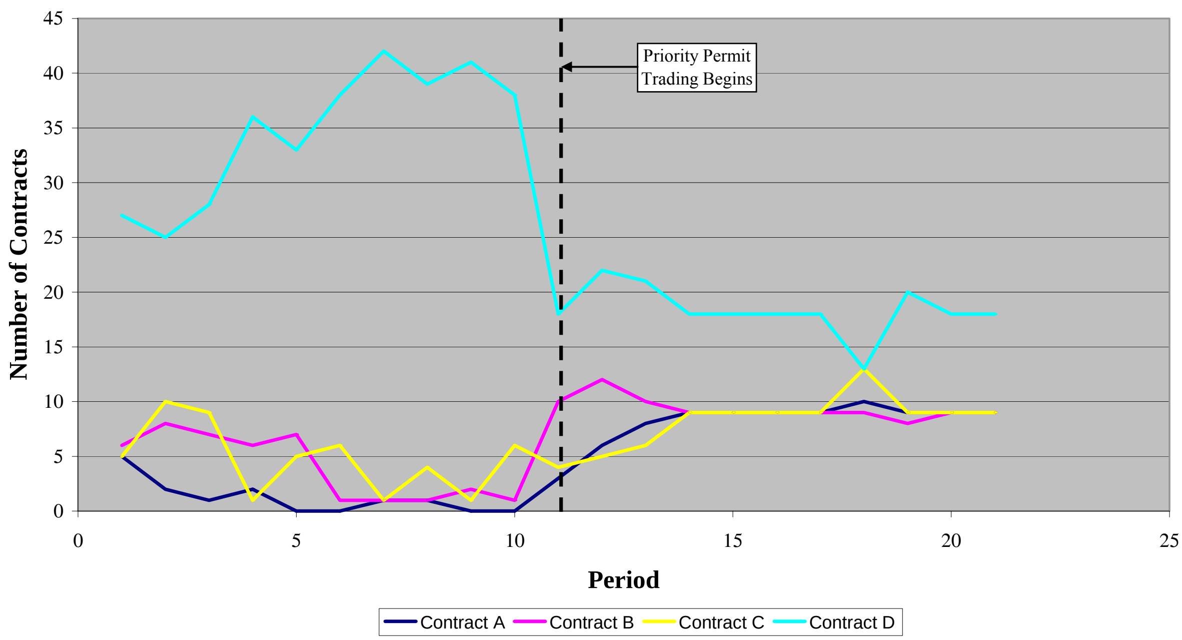
The first 10 periods of the testbed were under a policy of "first-come-first-served." Beginning in period 11, a system of priorities was implemented. The results of this first part of the testbed relative to the second confirm that the delays, directly and through the associated uncertainty, have an impact on the type of contracts made by operators.

Two results summarize the implications of the existing policy of "first-come-first-served" that gives no priority other than the random time of arrival at the lock.

RESULT 1. The risk of lock delay impacts the nature of the cargo and contracts transported through the river system. The "first-come-first-served" policy discourages high value contracts with fast delivery requirements.

Figure 3 demonstrates the contracts chosen over time. During the first 10 periods, the least valuable contracts, those of type D, swell in use while the most valuable contracts, those of types A and B, essentially disappear from use in the market. For our purposes, this diminished use can be thought of as representing business lost to other forms of transportation. In reality this loss comes in the form of technology and location decisions to base businesses on transportation footings other than river traffic.

Figure 3: Number of Contract Types Shipped

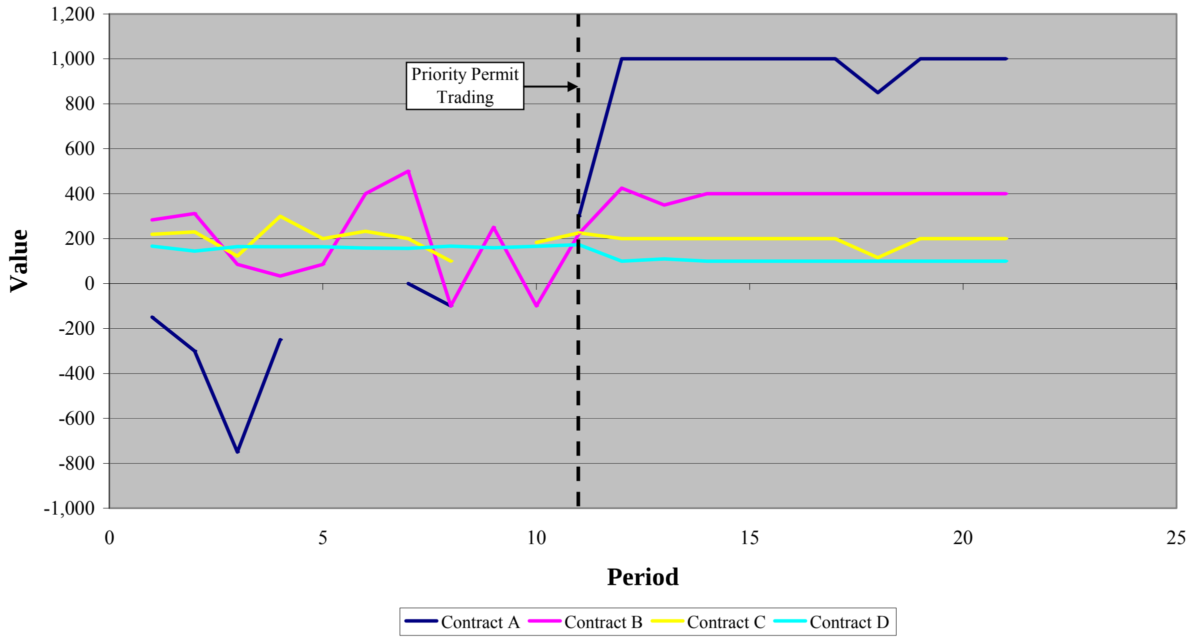


Source: Testbed Data.

Under the "first-come-first-served" policy, then, these contracts of high value and high risk are avoided in favor low value and low risk contracts.

Figure 4 demonstrates the reason for the decay of high risk contracts. In periods of congestion, contracting moves to those types on which the profits are higher. The high risk contracts are not profitable due to the inability of the operators to respond to the congestion so as to limit the uncertainty and their expected delay.

Figure 4: Average Value of Contract Shipped



Source: Testbed Data.

Contracts of type B, which are low risk compared with those of type A, are initially made; however, experience with losses force that type of contract from the market. Contracts of type C, which have still lower risk, are also attempted but contracts of type D have a similar expected payoff and a better downside, evidenced by a steady return. Within the "first-come-first-served" regime there is no mechanism through which operators can capture the value of contracts A, B and C. So, the use of these types of contracts all but disappears.

The introduction of a system of tradable priorities has the clear effect of increasing the frequency with which higher value contract types are used and raising the average value of the contracts made. This leads us to the second result.

<u>RESULT 2.</u> The introduction of a system of tradable priority permits changes the distribution of the types of contracts found in use. Contracting shifts to the more valuable types of contracts and fills the available capacity for such contracts. Use of the least valuable contracts

shrinks to fit the available assets for lower valued contracts. The influx of higher value contracts can be thought of as being attracted from other modes of transportation.

The policy change takes effect for period 12, with period 11 as a period of transition and instruction. As can be seen in Figure 2, above, the shift in the type of contracts characterizing cargo is immediate. The use of the most valuable types of contracts, those of types A and B, are increasing from zero while the use of the least valuable types of contract, those of type D, plummets. Again, such evolution of markets takes place over time reflecting the long range investment decisions.

Since the parameters of the environment are known (due to the construction of the testbed) the economic model can be used to determine the "social optimum" (in a cost-benefit sense) pattern of contracts. The social optimum is almost immediately obtained.

Figure 4 illustrates that with the introduction of the priority contracts, not only does contracting shift to the optimal distribution; the shipments are coordinated in an optimal queue for processing through the lock. Type A contracts are processed on the first day of the period, those of type B on the second day of the period, and so on. The coordination optimizes industry profits and the overall value of river use.

The results of the testbed support the idea that the proposed policy produces exactly the type of results that the underlying principles indicate should result. The following analysis helps focus on exactly how it happened and why it happens.

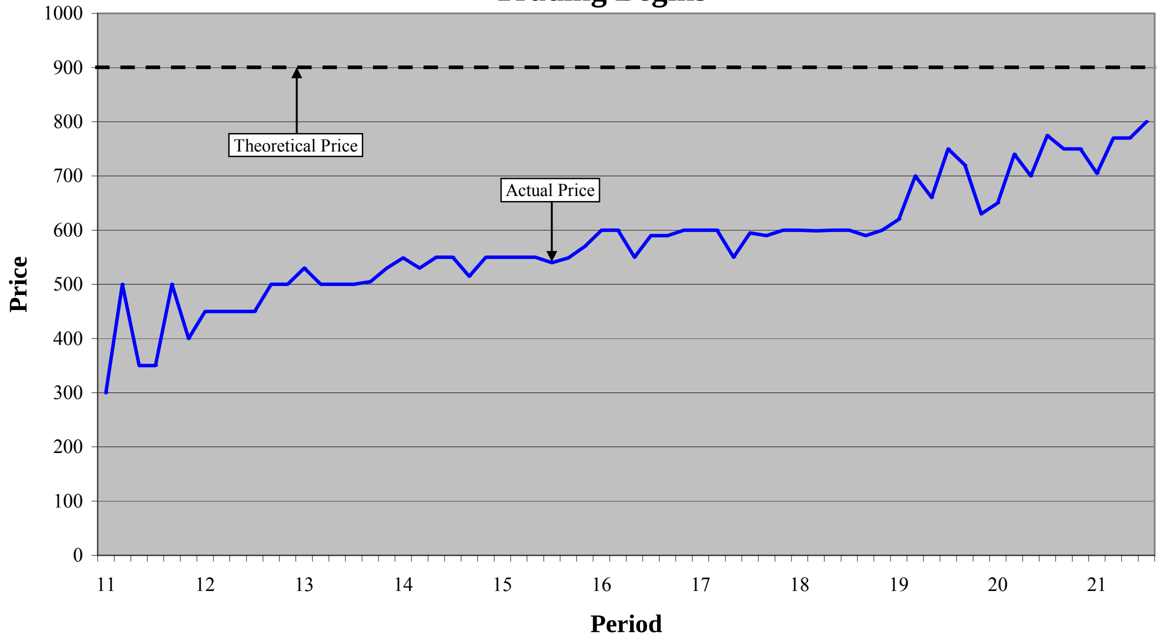
<u>RESULT 3.</u> Permit prices evolve toward those consistent with basic principles of economics.

The next three figures demonstrate that the mechanism through which the policy operates can be well understood in terms of basic economic principles. The operators acquire the priority permits before soliciting the types of contracts they ship. Thus, with a permit of priority one, an operator is guaranteed a faster passage and can more safely enter into higher value types of contracts. The potential value of the contracts creates value for the permits and thus becomes reflected in the permit prices. Only those whose shipping plans can benefit from the higher priority will pay the high price for a permit of priority one.

The laws of supply and demand tell us exactly what those prices should be. Relying on these laws, we can determine the equilibrium prices for each permit type and use these as predictions to compare with the results of the testbed.

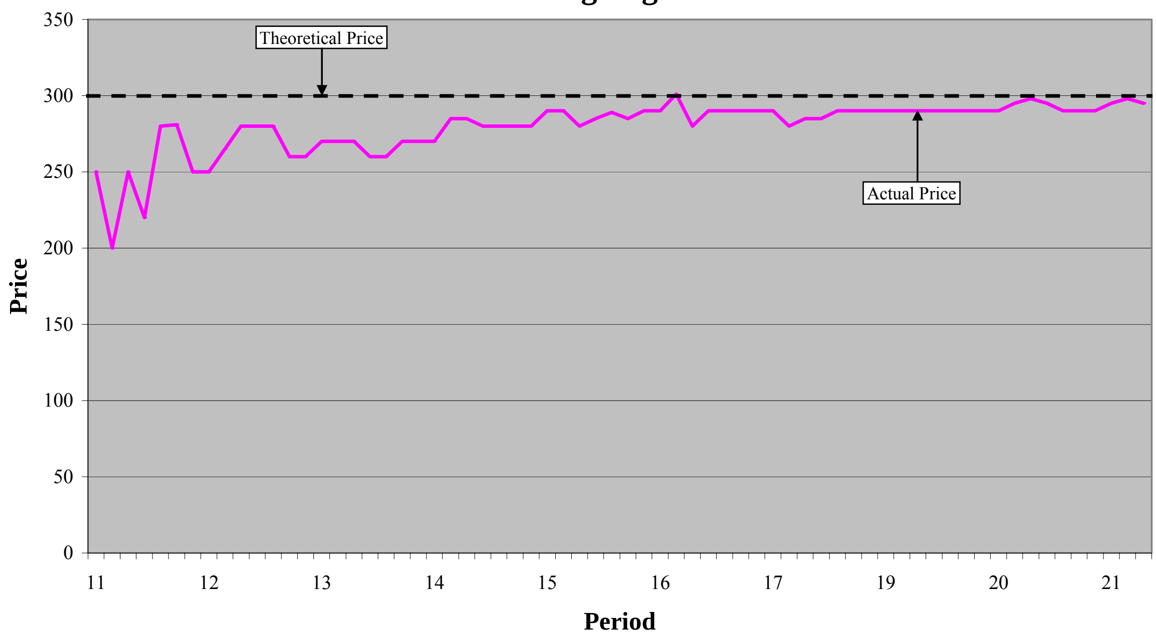
Figures 5, 6 and 7 contain the data on the price of each of the contract types over time. The prices converge over time toward the prices predicted by the laws of supply and demand. Specifically, the price of permits of priority one converges toward the predicted equilibrium price of 900. Similarly, the prices of permits of priorities two and three converge to their predicted prices. In the testbed, permits of priorities four and five traded at an insufficient volume to justify a figure; they command a price of zero, which is consistent with the basic principles.

Figure 5: Market for Priority 1 Permits After Priority Permit Trading Begins



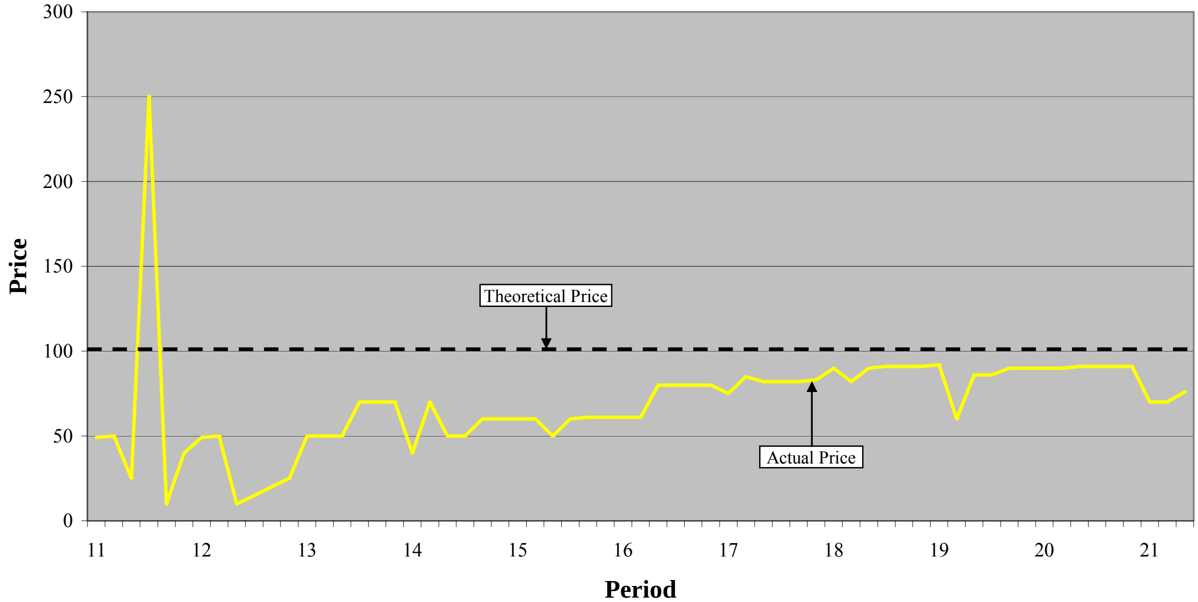
Source: Testbed Data.

Figure 6: Market for Priority 2 Permits After Priority Permit Trading Begins



Source: Testbed Data.

Figure 7: Market for Priority 3 Permits After Priority Permit Trading Begins



Source: Testbed Data.

In the figures the colors of the priority permit graphs reflect the colors of the types of contracts (A, B and C) that are moved under those priorities. This is done to help carry the intuition of what is otherwise a subtle economic transformation from the first come and first serve to the flows of contracts under the priority permit system.

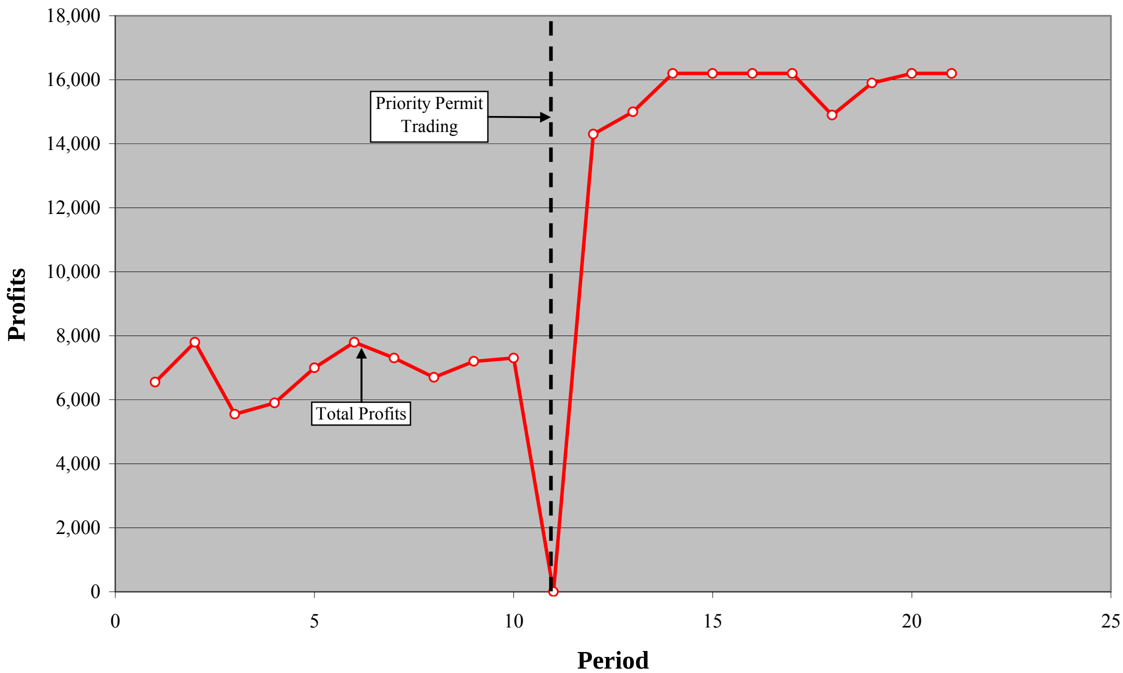
Another way to view the value created by the introduction of the priority permits is through system efficiency measures. The system is 100 percent efficient if system wealth is maximized. This is the standard cost-benefit measure applied to the testbed environment. As the next result demonstrates, the proposed policy accomplishes that goal. By measuring system efficiency under both the "first-come-first-served" system and under the system of priority permits we are able to measure the value created by the system of priority permits and see that this value creation is a direct result of economic efficiency enhancement.

RESULT 4. The priority permit system operates to maximize total profits of operators. The system operates at 100 percent efficiency from a cost-benefit measure. Both the "first-come-first-served" and the priority system are near the predictions of the models when applied to the two systems.

Figure 7 contains total system profits, the sum of all operators' profits for each period. The first 10 periods are profits under the "first-come-first-served" system and from period eleven on the system is operating under the priority system. The dashed line indicates the levels predicted by the basic model when the "first-come-first-served" system is in place (44 percent efficient) and the dotted line is the prediction when the priority system is in place (100 percent).

Two facts are apparent from Figure 8. First, the system performance is almost exactly as predicted by basic economic principles. Clearly, the models capture the essence of what is taking place in these complex interactions. Secondly, total profits increase dramatically with the introduction of the proposed policy. This increase in wealth comes from two sources of increased system efficiency: (1) the processing of the shipments at the lock reflects the relative time value of the cargo and (2) the increased value due to the reduction of uncertainty. The former reflects the decentralized, self organizing process of markets in which the cargo with the greatest time value is shipped with the highest priority. The shippers do this as a natural part of managing their affairs. With the latter, shippers are able to engage in contracts of a different sort that have a greater dependence on time value. Thus, the cargo shipped in general under the Priority Permit system has greater value due to the removal of the uncertainty. Under the first come first serve system the uncertainty forces shippers to compromise by choosing to engage in contracts that have less time sensitivity and less overall value.

Figure 8: Total Profits to All Shippers



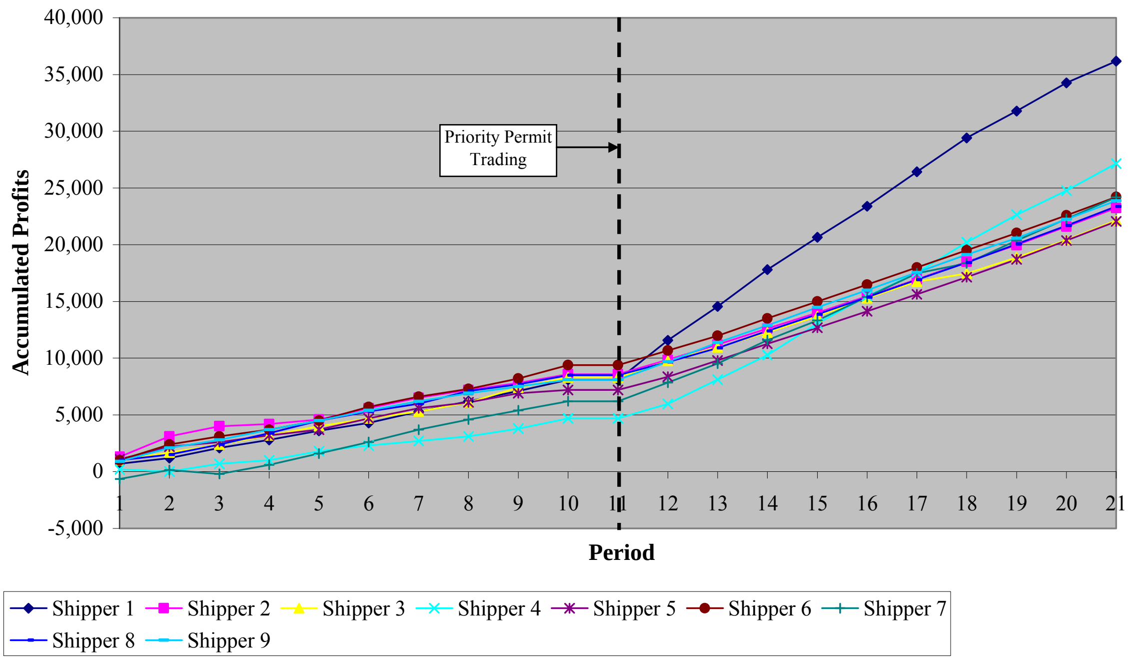
Source: Testbed Data.

The final result is with respect to the distribution of the benefits and answers the question: To whom does all of the increase in wealth accumulate? The answer to this question is closely tied to the manner in which the initial distribution of permits is made among the operators.

RESULT 5. The distribution of profit opportunities is distributed equitably among the existing shippers so that the wealth created by the introduction of the priority permit system is shared equitably among them.

Figure 9 contains the accumulated profits for each of the shippers over the time of the testbed. All increase and none decrease. Even with fairly balanced growth, we can see that one operator's profits grew somewhat faster, due to the aggressive purchase permits of priority one when their price was low relative to market value. This shipper recognized the potential and was an early catalyst in developing the most lucrative market. Since all shippers had a portfolio that included some of all priorities of permits, those who were not able to actively participate in the taking of higher valued contracts were able to profit nonetheless by the sale of their permits of priority one, two and three and then specialize in the lower priority cargo opportunities that were available to them.

Figure 9: Accumulated Profits by Individual Shippers After Priority Permit Trading Begins



Source: Testbed Data.

E. Illustration: Using priority permit prices to estimate the marginal value of increased lock capacity

Table 6

	Priority			
Measure Altered	**1st**	**2nd**	**3rd**	**4th**
	--------(value)--------			
(a)	**(b)**	**(c)**	**(d)**	**(e)**
Theory price	900	300	100	0
Cargo value	1000 (A)	400 (B)	200 (C)	100 (D)

An increase in lock capacity will increase commodity flow up to the resource constraint imposed by the number of boats. All boats are fully utilized in the test so an increase in lock capacity will not increase the total number of shipments but it will change the composition of shipments benefiting social welfare. The following changes will take place theoretically if the capacity is increased to let one more boat through the lock under first priority conditions.

One boat will stop shipping with a permit of priority two and instead use a permit with priority one. In so doing, it will stop making contracts of type B and begin making contracts of type A. The implied gain from this change is 500.

A second boat will stop shipping a C under priority three and acquire the second priority that has become free. This leads to a gain of 200. Subsequently, a third boat will move from the shipping of a D contract to a shipping of a C contract, creating a gain of 100. The remaining boats will continue to ship D contracts, leaving the gain unchanged.

The total gain therefore is 500+200+100, or 900. The value of increasing the lock size to accommodate one additional priority one permit equals 900, i.e. the price of the priority one certificate.

Likewise, suppose the lock capacity is increased to allow one more of all classes of priority to be used. The gain is one more priority one permit, creating a shift from a D contract to an A contract, leading to a gain of 900; additionally, there is one more priority two permit, creating a shift from a D contract to a B with a gain of 300, and one more priority three permit, leading to a shift from a D contract to a C contract, creating a gain of 100. Finally, all boats are used so there is no additional traffic of cargo D. The total gain is therefore 900+300+100, or 1300. The sum of prices is also 900+300+100, or 1300.

Thus, priority prices can be used to compute the implicit value of increasing the lock size. Of course if additional boats are free and if the increase in lock capacity means that three more D could be processed by the lock then that gain can be added to the benefit calculation.

V. FURTHER CONSIDERATIONS

The proposed policy does not increase lock capacity, nor can it change the peak load aspect of the system in the upper Mississippi. While the proposed policy does increase the economic value associated with river commerce by reducing the cost associated with congestion, it does not decrease the amount of river traffic or increase the number of possible lockages – although the number of actual lockages might increase. Some measure of congestion will likely remain in the system when demand is relatively high, but the delays associated with that congestion will be less costly. That is, the policy increases the value of the use of the river to all parties. Moreover, the market prices of the priority permits provide a measure of the value of avoiding those delays and, therefore, to reducing congestion.

The proposal is made using some terms of art from economics but no language here is intended to take account of the legal or regulatory definitions that might be part of the surrounding legislation and administration. The instructions used in the preliminary testing of the model were written so that a reader applying the ordinary meaning of the words would understand the economic setting and their role and incentives. Should this proposal be formally adopted, the implementation should include a legal review to avoid any unintended confusion. Of course, every effort has been taken by those involved to avoid any such confusion.

APPENDIX: THE NUMBER AND SIZE OF PRIORITY LEVELS

Optimum

Priority levels are designated as 1st, 2nd, 3rd, etc. and a priority level gives access to the position in a queue. That is, as the queue at a lock is formed if a boat is priority i and another boat is priority j with i<j the priority i is ahead of priority j in the queue.

Let I= {1, 2,...,n} we the levels of priority and let X_i be the number priority i permits available for use for an arbitrary and fixed time period to be considered for analysis. Let x_i be the number of priority i permits "in use".

Let

(1) $V^i(x_i, \sum_{j<i} x_j)$

be the private value of priority i boats. The value of priority boats decreases with the number of higher priority boats since the priority i boat must wait in the queue until all higher priority boats have moved through the lock. This relationship is the cost of congestion caused by delay, which is included in the valuation function.

Let the capacity of the lock be constrained by

(2) $\sum_{i \in I} X_i = C$

where C is the capacity of the lock, the total number of boats that can be moved through the lock during the time period under consideration.

The total social value of a pattern of lock use is given by the expression

(3) $V^1(x_1) + V^2(x_2, x_1) + V^3(x_3, x_1+x_2) +.. +V^k(x_k, \sum_{h<k}x_h) +...+ V^n(x_n, \sum_{h<n}x_h)$

for $x_i \leq X_i$.

The necessary conditions for optimum social welfare are found by maximizing (3) subject to the constraint imposed by (2).

Assume that all priority levels are used to the maximum. Then the conditions for the optimum number of permits in each priority level can be determined by finding the optimum of (3) subject to (2). These are:

$$(4) \quad \partial V^1/\partial X_1 + \partial V^2/\partial X_1 + \partial V^3/\partial X_1 +... + \partial V^n/\partial X_1 + \lambda = 0$$
$$\partial V^2/\partial X_2 + \partial V^3/\partial X_2 +... + \partial V^n/\partial X_2 + \lambda = 0$$
$$\partial V^3/\partial X_3 +... + \partial V^n/\partial X_3 + \lambda = 0$$
$$.........$$
$$\partial V^n/\partial X_n + \lambda = 0$$

The variable λ is associated with the constraint (2) so must be added to the set of equations (4) that describe the necessary conditions for the (interior) optimum.

The optimum has a clear interpretation. Consider the equations as

$$(5) \quad \partial V^i/\partial X_i = -\sum_{k>i} \partial V^k/\partial X_i + \partial V^n/\partial X_n$$

which says that the marginal private value of increasing the number of permits of priority i should be equal to the sum of the marginal cost imposed on all lower levels of priority traffic (all of which are negative) plus the opportunity cost of one less permit of the lowest priority traffic. The latter reflects the fact that if one more boat of higher priority is created the overall constraint of the lock requires that the lowest level of priority must be decreased by one unit and its marginal value (positive) is the opportunity cost of the unit. Of course, all marginal values are measured at the constrained optimum from which the change is considered.

An analysis of the difference between two "adjacent" priority levels will be useful. Consider priority level i and the immediately lower level of priority level i+1. Subtracting the marginal social value of level i+1 from the higher priority level i we get:

(6) $\partial V^i/\partial X_i - \partial V^{i+1}/\partial X_{i+1} = -[\sum_{k>i} \partial V^k/\partial X_i - \partial V^n/\partial X_n] + [\sum_{k>i} \partial V^k/\partial X_i - \partial V^n/\partial X_n]$

which is simply the value of the externality of i on the adjacent priority level, i+1:

(7) $\partial V^i/\partial X_i - \partial V^{i+1}/\partial X_{i+1} = -\partial V^{i+1}/\partial X_i$.

That is, the difference between the marginal private value of permit level i and the marginal private value of the lower priority level permit i+1 is the value of the externality imposed by the former on the latter.

Suppose the X_i have been set at some level other than the solution to (4) and (2). In that case, under suitable (convexity) conditions (7) can be used as a tool to adjust the levels and create new levels (levels that have been constrained to 0 permits).

<u>Equilibrium</u>

The analysis proceeds as if there is a system of marginal externality charges that will be reflected in permit prices. This tool will allow us to examine how permit prices interact in relation to the optimum.

For purposes of analysis we will assume that each agent operates with a variable number of boats and the marginal cost of a boat is reflected in the private value functions. This assumption allows us to explore essential properties of the competitive equilibrium. In particular, when deploying boats the agents will adjust until the marginal profit opportunities of the use of a priority permit is equal to the price of the permit. That is, for any agent r the marginal profit from operating any priority level i satisfies the equation:

(8) $\partial V^{ri}(x_{ri})/\partial x_{ri} = P_i$.

The generality of this property allows the analysis to proceed without regard to the individual agent specific notation. That is, for all i we have:

(9) $\partial V^i/\partial X_i = P_i$.

The relationship between equilibrium expressed by (7) and the optimal number of permits as expressed by (5) can be seen through the application of a connecting model of optimal externality taxes.

Policy

Combining (7) and (9) we have (recalling that the externality is negative):

(10) $\partial V^i/\partial X_i - \partial V^{i+1}/\partial X_{i+1} = P_i - P_{i+1} = -\partial V^{i+1}/\partial X_i$

This tells us that the difference in price between two adjacent priority levels *should* be equal to the marginal cost of the externality that the higher level imposes on the lower. That is a property of the optimum.

Within the context of the model, the implications for policy are straight forward. If the marginal cost of crowding of a priority level on the immediate lower level is less than the difference between the prices then the number of permits of the lower level priority can be reduced and the number of higher level priority permits increased by the same amount. Similarly, if the difference in prices is less than the external congestion cost then the number of the higher level priority permits should be reduced and the lower level increased.

The generalization to non adjacent priority levels is straight forward. From (4) we can extract the equation for two arbitrary levels of priority to get:

(11)
$\partial V^i/\partial X_i + \partial V^{i+1}/\partial X_i + .. \partial V^{i+k}/\partial X_i + \partial V^{i+k+1}/\partial X_i \ ... + \partial V^n/\partial X_1 + \lambda = 0$
$\partial V^{i+k}/\partial X_{i+k} + \partial V^{i+k+1}/\partial X_{i+k} + \partial V^{i+k+2}/\partial X_{i+k} + ... + \partial V^n/\partial X_{i+k} + \lambda = 0.$

Asking about the difference in marginal private values we get:

(12)
$\partial V^i/\partial X_i - \partial V^{i+k}/\partial X_{i+k} = -[\partial V^{i+1}/\partial X_i + .. \partial V^{i+k}/\partial X_i + \partial V^{i+k+1}/\partial X_i \ ... + \partial V^n/\partial X_1 + \lambda] + [\partial V^{i+k+1}/\partial X_{i+k} + \partial V^{i+k+2}/\partial X_{i+k} + ... + \partial V^n/\partial X_{i+k} + \lambda]$

Assume the marginal congestion cost on a lower level of priority is the same for all higher levels of priority. This assumption appears natural since all higher levels of priority must be cleared from the queue before the lower level has access to the lock. The lower level must wait the same regardless of the order in which the higher levels of priority are served. The assumption is

(13) $\partial V^k/\partial X_i = \partial V^k/\partial X_r = q_k$ for all $i,r < k$.

Substituting and collecting the terms of (12) we have:

(14) $\partial V^i/\partial X_i - \partial V^{i+k}/\partial X_{i+k} = -\sum_{i+1}^{i+k} q_r$.

Using (9) again we have:

(15) $P_i - P_{i+k} = - \sum_{i+1}^{i+k} q_r$.

An additional unit of level i permit is suggested by the model if the difference in the price of i and the price of the lowest level of priority is greater than the sum of the congestion cost imposed by an additional unit of i on all levels of priority less than i.

APPENDIX: LOCK AND VESSEL STOP AND SLOWDOWN CODES

Code	Description
A	A - Weather – fog
B	B - Weather – rain
C	C - Weather - sleet or hail
D	D - Weather - snow
E	E - Weather - wind
F	F - Weather - lightning
G	G - Surface - low water
H	H - Surface - ice on or around tow
I	I - Surface - river current or outdraft
J	J - Surface – flood
O	O - Surface - debris
N	N - Surface - operations (run-spill-divert water; flush seals-reserve, etc)
K	K - Tow - interference by other vessel(s)
L	L - Tow - tow malfunction or breakdown
M	M - Tow - tow staff occupied with other duties
P	P - Tow - tow accident or collision
Q	Q - Lock - debris in lock recess or lock chamber
U	U - Lock - ice on lock or lock equipment
R	R - Lock - lock hardware or equipment malfunction
S	S - Lock - lock staff occupied with other duties
T	T - Lock - maintaining lock or lock equipment
Y	Y - Lock - inspection or testing lock
AA	AA - Lock - accident or collision in lock
BB	BB - Lock - closed (unmanned shift)
EE	EE - Lock – repair lock or lock hardware
V	V - Other - tow detained by Corps or Coast Guard
W	W - Other - collision or accident (not tow or not in lock; see P, AA)
X	X - Other – bridge or other structure (railway or vehicular bridge)
CC	CC - Other - grounding
DD	DD - Other - environmental conditions (fish, animals, oil spills, hydrilla etc.)
FF	FF – Other – lock okay; unused for other reason (CG river closing etc)
Z	Z - Other (Remarks)
	- None

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- A model for forecasting international and domestic traffic flows and how they may be affected by project improvements.
- A regional traffic routing model that will identify the annual quantities of commodities coming from various origin points and the routes used to satisfy forecasted demand at each destination.
- A microscopic event model that will generate routes for individual shipments from commodity origin to destination in order to evaluate non-structural and reliability measures.

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