Assessment of Emissions and Fuel-Use Changes Resulting from Modal Shifts in the Upper Mississippi River Basin

Martin E. Lipinski, *The University of Memphis*
David B. Clarke, *Clemson University*
Mark Burton, *Marshall University*

INTRODUCTION

Since the passage of the Intermodal Transportation Efficiency Act of 1991, there has been an increasing emphasis on the importance of providing an efficient system for freight movement. This legislation also recognized the importance of improving transportation by providing for the movement of commodities in a safe, cost-effective, environmentally sound, and fuel-efficient manner, by taking advantage of the "best" characteristics of modes or combination of modes. This requires an approach that acknowledges the complementary roles played by the private and public sectors and evaluates the impacts of transportation alternatives, which includes consideration of shifting commodities from one mode to another.

The U.S. Army Corps of Engineers districts are conducting a comprehensive investigation of the feasibility of navigation improvements on the Upper Mississippi River and the Illinois Waterway for the planning period 2000 to 2050. This six-year study, the *Upper Mississippi River-Illinois Waterway (UMR-IWW) Navigation Study,* involves personnel from three Army Corps of Engineers divisions and two Corps research laboratories (Construction Engineering, CERL, and Waterways Experiment Station, WES), as well as other federal agencies and five states. This study includes several major components, including commodity movement forecasts to the year 2050, cost analyses, environmental analyses, and evaluations of both large and small measures to enhance navigation.

Decisions made regarding navigation improvements or changes in operating policies on the waterways system affect the distribution of commodity flows among the competing modes—water, rail, and truck. Therefore, evaluations of navigation projects must include assessments of the impacts of modal shifts. The objectives of this study are to determine (1) fuel consumption, (2) emissions and (3) other environmental impacts such as road damage, maintenance and tire usage of commodity movements, primarily by waterway and by optional routings, when commodities shipments are diverted to alternative destinations or other modes.

COMMODITY FLOW DATABASE

In 1996, the Tennessee Valley Authority (TVA) conducted a comprehensive study of 1331 waterborne commodity movements that, in total or in part, were routed over the upper reaches of the Mississippi River navigation system in 1991. This study, *Transportation Rate Analysis: Upper Mississippi River Navigation Feasibility Study*, (*1*) estimated cost savings of 11 separate commodity groups for the movement of 137 million tons of cargo, when barge costs were compared with the next-best, all-land transportation alternatives. The commodity groups were

1. Corn;
2. Soybeans and meal;
3. Wheat;
4. Barley, oats, sorghum, hay;
5. Coal;
6. Petroleum products;
7. Chemicals;
8. Fertilizers;
9. Ores, scrap, and slag;
10. Stone, sand, cement; and
11. Processed products - including iron and steel products, foods, feeds, processed oils, etc.

The following information was recorded for each movement:

1. Corps-assigned shipment reference number,
2. Individual commodity description,
3. Commodity group description,
4. River origin,
5. River origin waterway mile,
6. Off-river origin (if applicable),
7. WCSC number,
8. Shipment tonnage,
9. River destination,
10. River destination waterway mile, and
11. Off-river destination (if applicable).

Basic transportation costs were included in the cost calculations for both the water and land routes. For the water routings, these included rail or truck rates to the nearest port, loading and unloading costs, transfer costs, and other incidental costs. The land routings also included the costs for all modes, and transfer and storage costs, where applicable. The report contains discussions of the methodology, assumptions, and all results. (1)

A major part of this work involved estimating the mileage by mode for each alternative routing for each of the origin-destination pairs included in the sample. For example, a typical water routing would include truck or rail mileage from the origin to the water port, mileage of the trip on the water, and truck or rail mileage from the destination port to the final destination. A land routing alternative may include both rail and truck mileage.

This initial work focused on one alternative—the all-land option. A subsequent investigation by TVA expanded the number of alternatives and evaluated other transportation options that may be viable. This follow-up study included the following options:

1. The Upper Mississippi River-Illinois Waterway (UMR-IWW) Alternative: This alternative assumes that the water routes are available for all origin-destination pairs and all commodities included in the sample.

2. The All-Land Alternative:
   This option assumes that all commodity movements between the origin-destination pairs in the sample are made using only rail or truck or a combination of the two.
3. The St. Louis Alternative:
   With this option, the Upper Mississippi River-Illinois Waterway is assumed to be closed, but goods can be transferred from rail or truck to barge at St. Louis for movement on other waterways.
4. The Gulf Alternative:
   This alternative assumes that international grain movements are shifted to the Gulf of Mexico in the Houston/Brownsville area or the Mobile, Alabama port via rail and truck without using the Upper Mississippi River-Illinois Waterway.
5. The Pacific Coast Alternative:
   This alternative assumes that international grain shipments are shifted from the Upper Mississippi River-Illinois Waterway to the Pacific Northwest via rail and truck to the Portland, Oregon, vicinity.
6. The Duluth/Great Lakes Alternative:
   Under this scenario, international grain shipments are shifted from the Upper Mississippi River-Illinois Waterway to the Great Lakes via rail and truck to the Duluth, Minnesota, vicinity.
7. The Domestic Alternative:
   This alternative assumes a modal shift from the Upper Mississippi River–Illinois Waterway to domestic destinations such as feedlots or ethanol plants.

For each of the alternatives listed above, all reasonable transportation options for each origin-destination were evaluated. In the cases of the Gulf Alternative, the Pacific Coast Alternative, the Duluth/Great Lakes Alternative, and the Domestic Alternative, only a limited number of grain movements were identified as being reasonable candidates for modal shifts, by nature of their origins and destinations. For the All-Land Alternative and St. Louis Alternative, some movements for each commodity group were identified as having a reasonable alternative path, but only if the origin-to-destination path was reasonable. For example, the St. Louis Alternative was not evaluated for movements with origins or destinations at or near St. Louis.

An additional alternative, identified as the Lowest-Transportation-Cost (LTC) Alternative, was defined for the comparison of fuel usage and emissions only. The LTC Alternative was not used in comparing infrastructure and tire cost savings. It was based on NED rates, with an adjustment made for lower ocean rates from the Pacific Northwest to Asia. Thus, the calculation of the fuel-cost differential (or the emissions-cost differential) is not between the UPR-IWW and the low-cost alternatives on the basis of fuel or emissions costs. It is the difference in fuel costs between the UMR-IWW Alternative and the alternative with the next lowest total transportation costs, as determined in the *Navigation Rate Analysis Study*. For example, if the UMR-IWW were not available to a shipper, the LTC Alternative would be the one of all remaining alternatives with the lowest total transportation costs. Thus, for some movements, the All-Land Alternative would be the LTC. For others, the St. Louis Alternative may be least costly. The Domestic and Great Lakes alternatives were not considered in selection of the LTC Alternative because terminal grain market prices were not available.

Some of the movements analyzed in the *Navigation Rate Analysis Study* are not included in this investigation. For example, movements 1088—1102—Sand—were excluded because there is no land alternative for moving dredge sand from midstream to the bank.

FUEL USAGE AND EMISSIONS MODELING

A number of studies have been completed comparing the fuel efficiency and environmental impacts of the primary freight modes. Previous investigations by the Congressional Budget Office, (2) S.E. Eastman, (3) and the Rand Corporation (4) found that waterway transportation was significantly more efficient than both rail and truck in energy consumption per ton-mile of commodity moved. Studies by the Environmental Protection Agency (5) and the Corps of Engineers (6) found that waterway transportation produces fewer emissions than competing modes. Two studies by the Minnesota Department of Transportation (7, 8) examined the impacts of shifting commodities to the waterways from other modes and found the costs associated with emissions, fuel, and tires were significantly less on the waterways.

The most recent and comprehensive study of fuel use and emissions was performed by the Tennessee Valley Authority, for commodity movements in the Missouri River Basin. (9) This investigation developed a new set of methodologies to calculate fuel consumption and the costs resulting from emissions. These will not be described here, but the reader is referred to the study for detailed descriptions of the procedures.

INPUTS TO UPPER MISSISSIPPI RIVER-ILLINOIS WATERWAY MODELING

The models developed in this investigation used the sample of commodity flows and routings and the fuel and emissions costs developed in the two studies cited above, conducted by the Tennessee Valley Authority. The sample of commodity origins and destinations was that used in the analysis of transportation rates on the Upper Mississippi River-Illinois Waterway. Fuel costs were calculated by multiplying the mileage, by mode, in each movement by the various alternatives—water, all-land, Gulf, etc.—by the fuel costs in per-ton-mile terms. For example, in the sample, movement 61 consists of 6,030 tons of corn moved from Beardstown, Illinois to Decatur, Alabama. If the corn were shipped via barge on the Upper Mississippi River-Illinois Waterway, the length of the move on truck to and from the water ports was determined to be 120 miles.

If that move were made on land only, the grain would be moved by rail on the Burlington-Northern system for 487 miles and on the Norfolk-Southern for 188 miles. The distance hauled by truck would be 85 miles. If the movement were made by land to St. Louis (the St. Louis Alternative), the corn would be shipped 178 miles by rail on the Burlington-Northern system, and the highway mileage would be 65 miles. For this shipment, the Gulf Alternative, Pacific Coast Alternative, and Duluth/Great Lakes Alternative do not apply. The Domestic Alternative—shipment to a domestic processing facility—would require a trip of 102 miles by truck. Given these mileages and fuel costs, the rail and truck fuel costs for transporting one ton of commodity were computed. It is to be noted that separate fuel costs were calculated for each railroad. The models for determining fuel costs were developed in the TVA study of the Missouri River Basin. The study of movements in this basin included models that took into account the conditions of each specific segment over which the shipments that were being analyzed moved. Factors considered included draft, tow size, current, etc., for each segment, i.e., Missouri, Lower Mississippi, Tennessee, etc. The fuel savings (or additional costs) for each alternative were calculated by taking the difference between the rail and highway fuel costs for the alternative being evaluated and the water alternative.

The same methodology was used to determine emission cost savings. For each mode, the emissions per ton-mile were calculated for the following categories: nitrogen oxides, carbon monoxide, volatile organic compounds, particulate matter, and sulfur dioxide. The Missouri River investigation describes the procedures for calculating the cost savings resulting from emission reduction in each of these categories. As with the fuel calculations, the reduction in emission costs resulting from modal shifts was found by multiplying the equivalent emission costs by mode for each alternative and computing the difference from the water alternative.

RESULTS—FUEL COST SAVINGS

Table 1 contains the results of the navigation-related fuel savings for each of the alternatives when compared with the base case—the Upper Mississippi River-Illinois Waterway Alternative. The shaded areas are those where a modal shift of a group of commodities resulted in a fuel savings. Table 2 contains a summary of the number of individual commodity movements that were compared to the UMR-IWW Alternative for each commodity group and for each alternative.

The LTC Alternative was selected by comparing fuel costs with the alternative that would be selected on the basis of total transportation costs. Thus, the calculation of fuel-cost differential is not between the UMR-IWW and the low-cost alternatives on the basis of fuel costs. It is the difference in fuel costs between the UMR-IWW Alternative and the alternative with the next lowest total transportation costs, as determined in the *Navigation Rate Analysis Study*. For example, if the UMR-IWW were not available to a shipper, the LTC Alternative would be the one of all remaining alternatives with the lowest total transportation costs. Thus, for some movements, the Land Alternative would be preferred. For others, the St. Louis Alternative may be the least costly.

DISCUSSION—FUEL COST SAVINGS

The summary in Table 1 shows that, for the sample analyzed in this study, shifting commodities from the UMR-IWW to the All-Land Alternative would result in over $13 million annually in additional fuel costs. This cost is based on assuming a fuel cost of $1 per gallon. Modal shifts to the other alternatives, i.e., LTC, St. Louis, Gulf, Pacific Coast, and Duluth/Great Lakes vary from $653,000 to $16 million each year.

Some explanations are in order for the cells in Table 1 that indicate that the UMR-IWW Alternative has higher fuel costs than the one it is being compared with. In the case of both the Domestic Alternative and the Duluth/Great Lakes Alternative, it is assumed, for these calculations, that a market exists for the commodity shipment. In actuality, these movements may not be cost-effective from a total transportation perspective, and the market may not be present. For example, a shipment of corn to a processing operation within the region is a domestic alternative. However, the costs of shipping the processed corn and the actual demand for this product were not considered in this evaluation.

The analysis indicated that the fuel costs of transporting chemicals would decrease with a mode shift for the UMR-IWW to other alternatives. It is believed that these results do not reflect the total costs of fuel due to the special handling requirements for chemical produces, i.e., heating pressurization, etc., and other factors such as shipment size that are not considered in the calculation of fuel costs for the other modes.

The comparison of the fuel costs for the modal shift from the UMR-IWW to the St. Louis Alternative indicates that several of the commodity groups in the sample showed fuel savings when transported via land to St. Louis for shipment to the final destinations. Again, the comparisons in this table reflect only fuel costs and not handling charges or other costs associated with the movement from the origin to the final destination.

RESULTS—EQUIVALENT EMISSION COST SAVINGS

The additional equivalent emission costs from modal shifts from the UMR-IWW Alternative to other alternatives for the sample of commodity movements are shown in Table 3. Shifts that resulted in cost savings are highlighted by shading. The same methodology was used to calculate the equivalent costs for the LTC Alternative. The choice of which alternative to identify as the LTC Alternative was based on selecting the one with the lowest total transportation costs, as determined in the *Navigation Rate Analysis Study.*

DISCUSSION—EQUIVALENT EMISSION COST SAVINGS

Modal shifts from the UMR-IWW to the alternative land routing would result in substantial additional costs associated with increased emissions. The estimated additional costs were calculated to exceed $32 million for the sample included in this study. Modal shifts to other alternatives, i.e., LTC, St. Louis, Gulf, Pacific Coast, and Duluth/Great Lakes, also showed an increase in costs associated with increased emissions.

The results in Table 3 show that shifts to the Domestic Alternative would result in savings in costs attributed to emissions. However, as mentioned in a previous section, these results are misleading, as they do not include all costs associated with this modal shift.

Market factors such as demand were not considered in constructing the alternative routings. The rationales for the fuel cost savings for chemical movements explained above are also applicable here for emission cost calculations.

COSTS ASSOCIATED WITH ROADWAY DAMAGE AND MAINTENANCE

A key factor to be considered when modal shifts result in increased truck transportation is the impact the additional truck traffic will have on the roadway infrastructure. The marginal impact of trucks on the roadways has been the subject of many studies and is controversial. The most recent cost-allocation study conducted by the Federal Highway Administration (10) determined costs for pavement damage, congestion, accidents, and noise for urban and rural Interstate facilities. The pavement costs estimated the marginal costs for 80-kip combination trucks on rural highways as $0.127 per vehicle mile. A Minnesota Department of Transportation study (11) estimated non-Interstate pavement damage from combination trucks at $0.177 per vehicle mile. The Minnesota study of the impacts of a modal shift used a value of $0.024 per vehicle mile for the pavement damage associated with truck travel that was not considered in the payment of road-user taxes.(8)

The *Navigation Rate Analysis Study* calculated the mileage by mode for each commodity movement in the sample, for each of the alternatives considered. The truck miles for each origin-destination pair in the sample were determined by finding the number of trucks needed to transport the commodity in the movement, and multiplying the number of trucks by the highway mileage by class—Interstate, local, and state—for each alternative. The number of trucks required was found by dividing the tonnage in each movement by the average payload per truck.

For this study, marginal costs resulting from increased truck traffic were assumed to be $0.177 for local and state (non-Interstate) highways and $0.127 for rural Interstate facilities. Table 4 summarizes the results of this analysis. This table shows that, in almost all instances, modal shifts from the UMR-IWW Alternative to other alternatives—All-Land, St. Louis, Gulf, etc.—will result in lowering costs associated with pavement damage. The reason is because of the longer truck hauls associated with shipments that use the river. For most origin-destination pairs, commodities will be carried by truck to a river port for the long and cost-effective portion of the trip to the final destination. If alternative paths are used, the highway distances are typically shorter to reach a nearby rail terminal.

COSTS ASSOCIATED WITH INCREASED TIRE USAGE

An additional cost item related to modal shifts is the cost of tires used when commodities are transported on highways. According to the American Trucking Association, the costs associated with increased travel average approximately $0.02 per mile for over-the-road, 80,000-lb tractor trailer operation. (12) This estimate is based on aggregating all costs associated with tires – new tires, retreads, tire disposal costs, etc.—for long-distance trips primarily made on high-type pavements. A previous comprehensive study done over 30 years ago segmented the costs and found them to be about $0.0125 per mile per truck. (11) Using these two cost figures and information obtained in conversations with tire company representatives, a tire cost of $0.03 per vehicle mile was selected for use in this study. This was a conservative figure that recognizes that costs may vary with payload, truck type, roadway type, and other variables.

Table 5 summarizes the findings of this analysis. This table shows that when goods are shifted from the UMR-IWW Alternative to most other alternatives, tire costs will increase because the number of highway miles driven will increase. As with pavement-damage costs, these results reflect the fact that commodities must be transported longer distances to reach the ports on the UMR-IWW than if they were moved to a rail terminal closer to the origin. These additional costs are not as significant as the cost savings resulting from less fuel consumption and the cost savings associated with the reduction in emissions.

APPLICATION OF MODELS TO TOTAL COMMODITY MOVEMENTS

The findings reported in this study were based on a sample of approximately 10 percent of all movements in 1991. The basic input data needed for each origin-to-destination movement via a defined alternative are (1) the tonnage moved, (2) the mileage on each mode for the specified alternative, and (3) the payload per truck for each highway movement. The models used to compute cost savings for fuel usage and emissions were developed for individual waterway segments in the Missouri River Basin Study. The equations for determining the costs associated with tire usage and pavement damage were developed from data provided by governmental studies and industry. Table 6 lists the cost equations used in this study.

To apply the models and calculate fuel, emissions, pavement-damage, and tire costs to a different sample or a larger population of O-D movements, the following procedures should be used:

1. Fuel Usage
   a. Determine the ton-miles for each individual commodity movement on each mode for each alternative evaluated.
   b. Divide the ton-miles by each mode by the ton-miles/gallon values in Table 6 to determine gallons of fuel used by each mode for a particular movement.
   c. Sum the gallons for all modes for each O-D movement.
   d. Multiply the gallons used by the cost per gallon.
   e. Sum the individual O-D movement fuel costs by each commodity group and by each alternative considered.
   f. Compare fuel costs between alternatives by commodity group.
2. Emissions
   a. Determine the ton-miles for each individual commodity movement on each mode for each alternative evaluated.
   b. Divide the ton-miles by each mode by the ton-miles/gallon values in Table 6 to determine gallons of fuel used by each mode for a particular movement.
   c. Multiply the gallons used by each mode in the movement by the equivalent emissions costs per gallon of fuel, as shown in Table 6.
   d. Sum the equivalent emissions costs by each mode for the individual O-D movement to determine the total emissions costs for the movement.
   e. Sum the individual O-D movement emissions costs by each commodity group and by each alternative considered.
   f. Compare emissions costs between alternatives by commodity group.
3. Tire Wear
   a. For each O-D movement that has a truck move associated with it, determine the number of trucks needed to carry the tonnage by dividing the total tonnage moved by the payload per truck.
   b. Multiply the number of trucks by the highway distance traveled to determine the vehicle miles of travel for each O-D movement.
   c. Multiply the vehicle-miles of travel by $0.03 (see Table 6).
   d. Sum the individual O-D movement tire costs by each commodity group and by each alternative considered.
   e. Compare tire-wear costs between alternatives by commodity group.
4. Pavement Damage
   a. For each O-D movement that has a truck move associated with it, determine the number of trucks needed to carry the tonnage by dividing the total tonnage moved by the payload per truck.

b. Determine the percentage breakdown of the individual truck movement between that which will be made on rural Interstate highways and that which will be made on other roadways (rural, local, state roads, etc.).

c. Multiply the roadway mileage by the percentages by the appropriate cost per vehicle mile (see Table 6) and by the number of trucks to determine the pavement-damage costs for each movement.

d. Sum these costs for each movement.

e. Sum the individual O-D movement pavement damage costs by each commodity group and by each alternative considered.

f. Compare pavement damage costs between alternatives by commodity group.

SUMMARY—TOTAL COST SAVINGS

A summary of all the costs considered in this study is presented in Table 7. The values in this table for the LTC Alternative include only the cost savings related to fuel and emissions. The LTC Alternative is the one selected over the UMR-IWW Alternative, based solely on the lowest transportation cost to the shipper. The data in this table show that costs associated with shipping commodities on alternatives to the UMR-IWW are significant, especially with respect to the costs for fuel and the costs associated with emissions. Shifts from the waterway to other modes will result in substantial additional costs to society.

The costs associated with higher fuel consumption and additional emissions for the All-Land Alternative—without any waterway transportation—were in excess of $46 million per year over the costs if waterway transportation were available. Even if waterway transportation were available south of St. Louis, the additional fuel and emission costs using rail and truck to St. Louis instead of the UMR-IWW were $4.6 million per year. The fuel and emission costs for the other alternatives—using surface transportation to the Gulf, Pacific Coast, or Great Lakes—were greater than the costs associated with goods movements on the waterway using the UMR-IWW. Some savings in costs were associated with reduced highway travel, but these savings were small in comparison to the extra fuel and emissions costs.

The cost savings reported for this study were based on the analysis of a sample of approximately 10 percent of the total annual tonnage on the Upper Mississippi River–Illinois Waterway and would be significantly higher if all shipments were included.

The results of this study are based only on a sample of 1,331 movements in one year. The cost savings of using the UMR-IWW versus the All-Land Alternative were computed to be in excess of $47 million. If all movements were considered, the cost savings would be several orders of magnitude higher.

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Table 1

Navigation-Related Fuel Savings –Upper Mississippi River – Illinois Waterway Alternative Versus Other Transportation Alternatives – By Commodity Groups

ALTERNATIVES

COMMODITY GROUP	LTC*	All Land	St. Louis	Gulf	Pacific	Lake	Domestic
CORN	$ 3,169,096	$ 7,615,532	$ 458,752	$ 6,558,520	$ 11,091,606	$ 415,990	$ (3,214,332)
SOY BEANS	$ 2,201,409	$ 3,643,054	$ 241,219	$ 1,887,416	$ 3,752,124	$ 323,042	$ (988,337)
WHEAT	$ 474,502	$ 672,880	$ (7,189)	$ 519,331	$ 1,054,181	$ 50,718	$ 534,990
BARLEY	$ 195,981	$ 415,640	$ (47,376)	$ 89,063	$ 563,119	$ (136,530)	
COAL	$ 63,399	$ 68,979	$ (1,148)				
PETROLEUM	$ 13,488	$ 106,724	$ (24,597)				
CHEMICAL	$ (353,045)	$ (396,455)	$ (197,893)				
FERTILIZER	$ 548,550	$ 721,437	$ (101,775)				
ORES	$ 146,265	$ 306,872	$ 16,842				
STONE	$ 88,036	$ 241,034	$ 13,735				
PROCESSED	$ 148,425	$ 262,454	$ 32,889				
ALL	$ 6,696,106	$ 13,658,152	$ 383,459	$ 9,054,330	$ 16,461,030	$ 653,220	$ (3,667,679)

Notes:

1. *LTC = Alternative with lowest transportation costs based on NED rate analysis
2. UMR-IWW = Upper Mississippi River – Illinois Waterway Alternative
3. See text for description of alternatives
4. Shaded areas represent excess costs, i.e., the alternative listed has lower fuel costs than the UMR-IWW
5. Values in the table are based on a sample of approximately 10 percent of all commodity movements

Table 2

Sample Sizes – Comparisons of Alternative Transportation Options with UMR - IWW Alternative – By Commodity Groups

ALTERNATIVES

COMMODITY GROUP	LTC*	Land	St. Louis	Gulf	Pacific	Lake	Domestic
CORN	73	73	49	17	16	16	54
SOY BEANS	64	64	40	13	13	13	51
WHEAT	75	75	39	22	21	21	60
BARLEY	36	36	22	14	14	14	
COAL	86	86	29				
PETROLEUM	196	196	59				
CHEMICAL	150	150	74				
FERTILIZER	140	140	57				
ORES	179	179	73				
STONE	118	118	41				
PROCESSED	113	113	61				
ALL	1,230	1,230	544	66	64	64	165

Notes:
*LTC = Alternative with lowest transportation costs based on NED rate analysis

This table lists the number of movements that are used in the calculation of equivalent cost differentials for fuel, emissions, etc. between the Upper Mississippi River – Illinois Waterway Alternative and te alternative in each column. For example, the cost differentials between the UMR-IWW Alternative and te Gulf Alternative for corn were determined on the basis of 17 origin-destination movements common to both alternatives.

Table 3

Equivalent Navigation Cost Savings For Emissions Reductions – Upper Mississippi River – Illinois Waterway Alternative Versus Other Transportation Alternatives - By Commodity Groups

Alternatives

COMMODITY GROUP	LTC*	Land	St. Louis	Gulf	Pacific	Lake	Domestic
CORN	$ 7,297,783	$ 15,864,105	$ 1,843,702	$ 1,326,842	$ 21,072,957	$ 3,036,945	$ (3,891,306)
SOY BEANS	$ 4,733,687	$ 7,528,422	$ 740,589	$ 380,151	$ 7,010,267	$ 1,124,284	$ (570,633)
WHEAT	$ 1,605,102	$ 2,063,547	$ 427,872	$ 1,287,097	$ 2,162,965	$ 260,981	$ (35,055)
BARLEY	$ 690,210	$ 1,123,519	$ 129,905	$ 376,388	$ 1,192,945	$ (13,966)	
COAL	$ 230,703	$ 243,815	$ 22,448				
PETROLEUM	$ 472,081	$ 770,390	$ 94,776				
CHEMICAL	$ (88,330)	$ 27,523	$ (138,689)				
FERTILIZER	$ 2,296,224	$ 2,756,256	$ 428,641				
ORES	$ 487,306	$ 788,838	$ 89,097				
STONE	$ 276,492	$ 575,691	$ 49,703				
PROCESSED	$ 386,638	$ 611,442	$ 123,045				
ALL	$ 18,387,896	$ 32,353,548	$ 3,811,089	$ 3,370,478	$ 31,439,134	$ 4,408,244	$ (4,496,994)

Notes:
1. *LTC = Alternative with lowest transportation costs based on NED rate analysis
2. UMR-IWW = Upper Mississippi River – Illinois Waterway Alternative
3. See text for description of alternatives
4. Shaded areas represent excess costs, i.e., the alternative listed has lower equivalent emissions costs than the UMR-IWW
5. Values in the table are based on a sample of approximately 10 percent of all commodity movements

Table 4

Pavement Damage Cost Savings – Upper Mississippi River – Illinois Waterway Alternative Versus Other Transportation Alternatives - By Commodity Groups

Alternatives

COMMODITY GROUP	Land	St. Louis	Gulf	Pacific	Lake	Domestic
CORN	$ (145,285)	$ (193,041)	$ (2,642)	$ (1,557)	$ (180,908)	$ 338,643
SOY BEANS	$ (11,872)	$ (32,680)	$ 31,670	$ 32,868	$ 24,436	$ (76,672)
WHEAT	$ (169,913)	$ (107,674)	$ (62,377)	$ (48,780)	$ (49,394)	$ (183,477)
BARLEY	$ (44,355)	$ (44,225)	$ (22,684)	$ (22,684)	$ (21,789)	
COAL	$ (6,584)	$ (2,859)				
PETROLEUM	$ (9,681)	$ (11,498)				
CHEMICAL	$ (3,965)	$ 31,559				
FERTILIZER	$ (234,137)	$ (111,324)				
ORES	$ (16,898)	$ (6,042)				
STONE	$ (17,620)	$ (915)				
PROCESSED	$ (6,400)	$ (5,957)				
ALL	$ (666,710)	$ (484,656)	$ (56,033)	$ (40,153)	$ (227,655)	$ 78,494

Notes:
1. UMR-IWW = Upper Mississippi River – Illinois Waterway Alternative
2. See text for description of alternatives
3. Shaded areas represent cost savings, i.e., the alternative listed has lower pavement damage costs than the UMR-IWW
4. Values in the table are based on a sample of approximately 10 percent of all commodity movements

Table 5

Tire Wear Cost Savings – Upper Mississippi River – Illinois Waterway Alternative Versus Other Transportation Alternatives - By Commodity Groups

Alternatives

COMMODITY GROUP	Land	St. Louis	Gulf	Pacific	Lake	Domestic
CORN	$ (28,198)	$ (34,681)	$ (513)	$ (309)	$ (33,960)	$ 70,758
SOY BEANS	$ (1,849)	$ (5,388)	$ 6,311	$ 6,572	$ 4,607	$ (14,192)
WHEAT	$ (33,616)	$ (21,483)	$ (12,175)	$ (9,640)	$ (9,756)	$ (35,640)
BARLEY	$ (8,830)	$ (8,750)	$ (4,519)	$ (4,519)	$ (4,350)	
COAL	$ (1,240)	$ (529)				
PETROLEUM	$ (1,920)	$ (2,254)				
CHEMICAL	$ (742)	$ 6,341				
FERTILIZER	$ (44,423)	$ (4,271)				
ORES	$ (3,210)	$ (1,146)				
STONE	$ (3,461)	$ (168)				
PROCESSED	$ (1,273)	$ (1,174)				
ALL	$ (128,761)	$ (73,503)	$ (10,897)	$ (7,896)	$ (43,459)	$ 20,926

Notes:
1. UMR-IWW = Upper Mississippi River – Illinois Waterway Alternative
2. See text for description of alternatives
3. Shaded areas represent cost savings, i.e., the alternative listed has lower tire wear costs than the UMR-IWW
4. Values in the table are based on a sample of approximately 10 percent of all commodity movements

Table 6
Values for Cost Calculation Equations

		WATER	RAIL	HIGHWAY
Fuel	ton-miles/gallon	591	255*	75
Emissions	(per gallon)			
	CO	0.159	0.2067	0.0954
	NOx	0.765	1.1322	0.4896
	PM	0.0835	0.0835	0.021
	SO_2	0.0589	0.1243	0.0153
	VOC	0.0935	0.1758	0.0299
Tires	(per Vehicle/Mile)			$0.03
Pavement Damage	(per Vehicle/Mile)			$0.127 - rural interstates 0.177 - rural local and other highways

*varies with railroad

Table 7

Total Cost Savings – Upper Mississippi River – Illinois Waterway Alternative Versus Other Transportation Alternatives - By Commodity Groups

ALTERNATIVES

COMMODITY GROUP	LTC*	Land	St. Louis	Gulf	Pacific	Lake	Domestic
CORN	$ 10,466,879	$ 23,306,154	$ 2,074,733	$ 7,882,207	$ 32,162,697	$ 3,238,068	$ (6,696,236)
SOY BEANS	$ 6,935,096	$ 11,157,755	$ 943,740	$ 2,305,547	$ 10,801,832	$ 1,476,369	$ (1,649,834)
WHEAT	$ 2,079,604	$ 2,532,898	$ 291,526	$ 1,731,876	$ 3,158,725	$ 252,549	$ 280,818
BARLEY	$ 886,191	$ 1,485,974	$ 29,554	$ 438,248	$ 1,728,861	$ (176,635)	
COAL	$ 294,102	$ 304,971	$ 17,912				
PETROLEUM	$ 485,569	$ 865,513	$ 56,426				
CHEMICAL	$ (441,375)	$ (373,639)	$ (298,682)				
FERTILIZER	$ 2,844,774	$ 3,199,133	$ 211,270				
ORES	$ 633,571	$ 1,075,602	$ 98,751				
STONE	$ 364,528	$ 795,644	$ 62,356				
PROCESSED	$ 535,063	$ 866,224	$ 148,803				
ALL	$ 25,084,002	$ 46,549,649	$ 4,605,701	$ 12,469,945	$ 47,932,421	$ 5,245,661	$ (8,222,240)

Notes:
1. *LTC = Alternative with lowest transportation costs based on NED rate analysis
2. UMR-IWW = Upper Mississippi River – Illinois Waterway Alternative
3. See text for description of alternatives
4. Shaded areas represent excess costs, i.e., the alternative listed has lower total costs than the UMR-IWW
5. Values in the table are based on a sample of approximately 10 percent of all commodity movements