REVISED DRAFT REPORT

ANALYSIS OF THE ENERGY, SAFETY, AND TRAFFIC EFFECTS OF PROPOSED UPPER MISSISSIPPI RIVER-ILLINOIS WATERWAY SYSTEM NAVIGATION IMPROVEMENTS

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Analysis of the Energy, Safety, and Traffic Effects of Proposed Upper Mississippi River-Illinois Waterway System Navigation Improvements

Revised Draft Report

Prepared for the United States Army Corps of Engineers

by

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Report Summary

The Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study is a comprehensive analysis of potential navigation improvements to the Upper Mississippi River and Illinois Waterway. This component of the study examines the energy, safety, and traffic effects of 20 waterway traffic scenarios and navigation alternatives.

Alternatives and Cases Analyzed

The navigation alternatives represent potential improvements to the Upper Mississippi River and Illinois Waterway System, or navigational policies such as lock congestion fees. The alternatives are designated as 2, 4, 5, and 6. Under Alternative 2, congestion fees would be imposed upon commercial traffic by means of a lockage fee.[1] Under Alternative 4, moorings would be constructed at Locks 12, 14, 18, 20, 22, and 24 on the Mississippi River and at LaGrange on the Illinois Waterway. Under Alternative 5, moorings would be constructed at Locks 12, 14, 18, and 24 on the Mississippi River and at LaGrange on the Illinois Waterway. In addition, Locks 20-25 on the Upper Mississippi River would be extended to accommodate 1,200-foot tows. Under Alternative 6, moorings would be constructed at Locks 12, 14, 18 and 24 on the Mississippi River and new 1,200-foot locks would be constructed at Locks 20-25, as well as at Peoria and LaGrange on the Illinois Waterway. In addition, Locks 14-18 on the Mississippi River would be extended to 1,200 feet and switchboats would be located at Locks 11, 12, and 13.

The implementation of a navigation alternative would affect future waterway transportation conditions and costs. However, there is some uncertainty regarding the sensitivities of individual commodities to waterway transportation conditions and costs. These uncertainties are represented through the use of different economic model conditions. One condition reflects an inelastic state in which individual waterway movements are not sensitive to barge prices until they reach the level of an alternative mode (e.g., rail), at which level the shipments disappear from the waterway. This inelastic condition is represented by the Tow Cost Model (TCM). In comparison, the ESSENCE model is based on the assumption that individual waterway movements are sensitive to increases in barge prices before they reach the levels of rail rates. Thus, traffic will be diverted from the waterway over time, as barge rates increase relative to rail rates. Instead of a single elasticity value, upper- and lower-bound elasticities are specified with the ESSENCE model.

There is also uncertainty as to the level of overall waterway travel demand.
In total, five economic conditions are considered in this report. These economic conditions represent combinations of elasticity and waterway demand. The five economic conditions are as follows:

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[1] Currently, federal law does not allow for congestion fees. However, studies of the potential effects of such fees are not prohibited by law.

- Scenario 2 ESSENCE Lower Bound
- Scenario 3 ESSENCE Lower Bound
- Scenario 3 ESSENCE Upper Bound
- Scenario 3 TCM
- Scenario 5 ESSENCE Lower Bound

Four navigation alternatives are considered for each of these economic conditions.

Incremental Traffic

The incremental tons for each traffic scenario and navigation alternative were developed by USACE. Incremental tonnage is defined as the difference between the forecast tonnage for a traffic scenario/alternative and the forecast tonnage under the "without-project" scenario. Traffic forecasts were developed for 2025, 2035, and 2050. The key information source used in this study is a data set provided by the Corps, which contains forecasted waterway tons for the "with-project" and "without-project" scenarios for each alternative. The data set includes traffic forecasts for specific commodity movements among 7 states or regions – Illinois, Iowa, Minnesota, Missouri, Wisconsin, the Lower Mississippi Valley, and the remainder of the United States.[2] Agricultural commodities (primarily grain) comprise the greatest proportion of incremental tons for most traffic scenarios and alternatives.

Key Assumptions

Rail is the most feasible alternative to barge movements, given the commodities and distances involved. Because the traffic data are aggregated at the state level, an analysis of gathering or distribution movements by truck cannot be performed. The effects described in this report are based strictly on railroad and waterway comparisons. Many changes are likely to occur between now and 2025 that will affect farm-to-rail station and farm-to-river delivery distances. The growing concentration of traffic at shuttle-train facilities suggests that farm-to-rail trucking distances are likely to increase between now and 2025, as farmers take advantage of lower prices at shuttle elevators. When faced with rising congestion on the Upper Mississippi River and Illinois Waterway, some farmers may truck grain to St. Louis to access lower barge rates. If such long-haul trucking occurs in the without-project case, the impacts presented in this study may be understated.

For all commodities other than grain, the railroad mileage is assumed to be the same as the waterway mileage. In some instances, grain destinations may shift in the without-project case. Forty percent of the incremental grain is assumed to move to the Pacific Northwest and travel an average distance of 2,000 miles by rail. The remaining 60

[2] The *incremental traffic data set* used in the study can be obtained from the U.S. Army Corps of Engineers project managers, John P. Carr or Richard J. Manguno. Mr. Carr can be contacted at: John.P.Carr@mvr02.usace.army.mil. Mr. Manguno can be contacted at: Richard.J.Manguno@mvn02.usace.army.mil.

percent is assumed to move to the Gulf of Mexico and travel 1,000 miles by rail.

Fuel Efficiency Analysis

Barge fuel consumption factors were provided by Tennessee Valley Authority (TVA). During the 1999-2001 period, revenue ton-miles per gallon (RTMG) ranged from 276 to 326 on the Upper Mississippi River and from 229 to 301 on the Illinois River. According to TVA estimates, revenue ton-miles per gallon during the same period ranged from 583 to 642 on the lower-river segment from Cairo, Illinois to Baton Rouge, Louisiana. However, future upper-river fuel efficiencies are expected to be higher than historic values because of the effects of the proposed lock extensions and mooring cells. Upper-river fuel efficiencies in 2025, 2035, and 2050 have been forecast by TVA for each traffic scenario and alternative. These forecasts reflect reductions in queuing and delays at the locks identified for improvement in each of the navigation alternatives. The projected RTMG values for the five traffic scenarios range from 319 RTMG for Traffic Scenario 3, under the ESSENCE Upper-Bound conditions, to 368 RTMG under the conditions described earlier for the Tow Cost Model.

Railroad fuel efficiency has been increasing over time, from 332 RTMG in 1990 to 404 RTMG in 2002. The industry average reflects a wide range of traffic and operating conditions, including: (1) bulk trainload and unit-train operations, (2) mixed freight carload traffic, and (3) trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) traffic. TOFC and COFC traffic require the most gallons per revenue ton-mile because of lower net weight-to-tare weight ratios. Most of the incremental traffic consists of bulk commodities such as grain, coal, and petroleum products which can be moved efficiently in multi-car or trainload quantities. Most of this traffic would move long distances to the same or alternate markets in the without-project cases. Thus, it is expected that the average revenue ton-miles per gallon generated by this traffic would exceed the industry average.

In this study, railroad fuel consumption is predicted using a statistical model estimated from data reported to the Surface Transportation Board (STB). In the model, gallons of fuel consumed are related to carloads handled and gross ton-miles of cars and contents (GTMC). The explanatory activity variables in the model are: carloads handled in unit-train service, carloads handled in nonunit-train service, unit-train GTMC, and nonunit-train GTMC. Fixed network effects are accounted for through the inclusion of railroad indicator variables. The model explains 99.8 percent of the variation in railroad fuel consumption. T-tests show that the four activity variables are statistically significant, with p-values ranging from 0.010 to less than .0001. Several of the railroad indicator variables are statistically significant. The predictive capabilities of the model were tested by comparing predicted and actual results for 2001. The model is very accurate for the largest railroads.[3]

The model was used to predict revenue ton-miles per gallon for hypothetical movements,

[3] For example, the prediction error expressed as a percentage of actual gallons is less than 1 percent for UP and CSX, 1.7 percent for BNSF, and 3.9 percent for NS. Collectively, BNSF, CSX, NS, and UP accounted for 95 percent of all Class I railroad fuel use in 2001.

including TOFC and grain shipments. For TOFC shipments, the predicted values range from 50 RTMG at 100 miles to 385 RTMG at 2,000 miles. For grain shipments, the predicted values range from 135 RTMG at 100 miles to 695 RTMG at 2,000 miles. At distances of 1,000 miles, the model predicts 255 and 570 RTMG for TOFC and grain shipments, respectively. These forecasts are consistent with estimates from a Federal Railroad Administration study in which the predicted railroad fuel efficiencies ranged from 196 to 350 RTMG for TOFC trains and from 414 to 843 RTMG for mixed freight trains. Moreover, the results are consistent with a 1999 study by Gervais and Baumel in which RTMG estimates ranged from 513 to 802 for unit grain-train movements. Intuitively, the forecasts make sense in light of the reported 2002 railroad industry average of 404 RTMG, which reflects a mixture of COFC/TOFC and bulk-commodity shipments. Clearly, the revenue ton-miles per gallon generated by the incremental grain traffic would be greater than the industry average.

The weighted-average waterway trip distance for incremental grain traffic ranges from 1,300 to 1,500 miles for the five traffic scenarios, with a midrange estimate of 1,400 miles. The projected length of haul by rail is 1,400 miles, assuming that 60 percent of the grain traffic moves 1,000 miles to the Gulf and 40 percent moves 2,000 miles to the Pacific Northwest. The highest RTMG forecast for upper-river movements under any traffic scenario is 368. Thus, the highest possible weighted-average RTMG for a river movement to New Orleans is 558, when both upper- and lower-river values are considered. In comparison, the fuel model predicts railroad revenue ton-miles per gallon of 636 and 684 for nonunit and unit-train movements, respectively. Based on these estimates, it does not appear that the potential waterway investments would reduce annual transportation fuel consumption.

The emission of air pollutants is related to fuel consumption. EPA regulations limit the grams that can be emitted per gallon of fuel used by locomotive and marine diesel engines.[4] In 2025, it is likely that the emission rates of locomotive and towboat diesel engines will be similar and much lower than historical emission rates. Because the potential waterway investments would not affect fuel conservation appreciably, it is unlikely that these improvements would have a material effect on the emission of air pollutants.

Safety Analysis

Substantial increases in railroad train-miles are forecast for many of the without-project cases. Over time, incremental train-miles will result in additional highway grade-crossing, trespasser, and derailment accidents. Three types of accident-related costs are considered in this analysis: fatalities, injuries, and property damage to the carrier. Annual costs are estimated for the with-project and without-project scenarios. Typically, without-project accident costs are based on railroad accident factors, while with-project costs reflect waterway accident data. A two-step analysis process is followed for both modes: (1) estimate annual accidents, fatalities, and injuries for the incremental traffic,

[4] EPA regulations specify emission rates in grams per brake horsepower-hour. However, these rates can be converted to equivalent rates of grams per gallon.

and (2) multiply the annual events by the applicable unit cost per property damage, fatality, or injury.

Information from a 1998 University of Memphis study, conducted for USACE, is used to estimate waterway accident costs. The 1998 study quantified waterway accident damage costs and injury and death rates per ton-mile for the Upper Mississippi River and Illinois Waterway. These injury and death rates and property damage costs are used in this analysis. However, the property damage costs are indexed to 2002 levels.

Accident, injury, and fatality rates per million train-miles have been estimated for the primary Class I railroads serving the study region. These rates were derived from the Federal Railroad Administration's Office of Safety Analysis Web Site. Train accident, fatality, and injury rates were computed from *Summary of Accident/Incident Counts* and *Summary of Operational Data*. They represent weighted averages for the 2000-2002 time frame. Each rate is calculated and weighted on the basis of million train-miles. Railroad property damage costs per train accident were calculated from *Train Accidents by Type and Major Cause* and *Summary of Accident/Incident Counts*. Railroad accident statistics are dominated by rail-highway grade-crossing crashes and trespasser accidents. More than 90 percent of railroad accidents during the 2000-2002 period were the result of highway-rail crossing or trespasser accidents.

The unit costs used in this study are estimated by the National Safety Council (NSC) and represent the average costs of fatal and nonfatal unintentional injuries. For purposes of consistency, the same unit costs are applied to waterway and railroad injuries. NSC recommends the use of "comprehensive costs" for purposes of benefit-cost analysis. Comprehensive costs include economic costs plus a measure of the value of "lost quality of life." The economic components of motor-vehicle injury and fatality costs include wage and productivity losses, medical expenses, and administrative expenses. Wage and productivity losses include the value of wages, fringe benefits, household production, and travel delay. Comprehensive costs also include the "value of a person's natural desire to live longer or to protect the quality of one's life;" i.e., someone's willingness to pay for improved safety (NSC, 1999). When people's willingness to pay to avoid lost quality of life is considered, the estimated unit costs are $3.5 million per death and $44,000 for a non-incapacitating injury.

The projected changes in railroad fatality rates shown in this report should be viewed as average rates that would occur over a multi-year period based on the traffic forecast for a particular year. The predictions range from 1 additional fatality per year in several of the traffic scenarios to more than 10 additional fatalities in 2050 for Scenario 3 (ESSENCE Upper Bound) and Scenario 5.

Grade-Crossing Traffic Delay and Noise

Incremental railroad traffic would result in changes in traveler delay at railroad/highway crossings. A comprehensive analysis of grade-crossing delay is beyond the scope of this study. However, several illustrations are presented based on probable routings. In the first scenario, half of the grain traffic to the Gulf (or 30 percent of the incremental grain traffic) is assigned to UP lines that run through East St. Louis, Pine Bluff, AR, and

several other cities en route to New Orleans. In the second scenario, all of the grain traffic to the Gulf (or 60 percent of the incremental grain traffic) is assigned to UP lines.

The delay estimates are based on a methodology developed by the Section of Environmental Analysis (SEA) of the U.S. Surface Transportation Board. SEA typically prepares an independent environmental review for proposed railroad projects that would generate significant environmental impacts. The methods are the same ones used in the recent DM&E Powder River Basin Line Extension case. The following delay indicators are considered: blocked crossing time per train, average vehicular delay, number of vehicles delayed per day, and maximum vehicle queue.

Incremental railroad traffic may result in three types of noise: (1) locomotive (propulsive) noise, (2) train noise, and (3) horn noise. Noise is an important community impact that is considered by the STB in rail-line analyses. The noise illustrations presented in this report are based on a methodology developed by the Section of Environmental Analysis. A weighted-average Day-Night Sound Level (L_{dn}) is used to account for the differential effects of noises throughout the day. L_{dn} represents a weighted-average of cumulative average noise exposure during a 24-hour period. Noise events that occur between 10 p.m. and 7 a.m. are increased by 10 decibels to account for increased annoyance from loss of sleep.

Typically, an L_{dn} value of 65 dBA is used as a threshold indicator of noise impacts. Because noise levels depend upon the distance of a receptor from the track and the rate of attenuation, the distance from the track centerline to the 65 L_{dn} contour is estimated at each crossing based on noise emissions from existing daytime and nighttime trains. The incremental trains are then included in the total traffic and the distance to the 65 L_{dn} contour is recomputed. The additional housing units impacted consist of those units which lie outside of the 65 L_{dn} contour with existing train traffic, but which would lie within the 65 L_{dn} contour with the incremental train traffic.

Summary and Conclusions

Energy Impacts. The general conclusion of the Energy Efficiency Analysis is that there is no evidence to suggest that the potential waterway improvements would have a significant beneficial effect on annual fuel consumption. The emission of air pollutants is directly linked to fuel consumption. Therefore, it is unlikely that the potential waterway investments would have a significant beneficial effect on the emission of air pollutants.

Safety Impacts. The projected changes in accident costs are shown for Traffic Scenario 3 in Tables I, II, and III. As the tables show, the net change is very large for some alternatives: e.g., $39 million in year 2050 under Alternative 6, ESSENCE Upper Bound. Negative signs associated with Alternative 2 (which reflects lockage fees) indicate that additional traffic would move on the railway instead of the waterway in the with-project case, resulting in negative benefits or disbenefits.

Table I Accident Costs (Injuries and Fatalities) in Millions of Dollars Scenario 3 – Tow Cost Model (TCM)				
Year	**Alt 2**	**Alt 4**	**Alt 5**	**Alt 6**
2025	-9.8	2.1	2.7	2.5
2035	-9.9	7.2	11.4	12.0
2050	-11.6	7.3	13.3	16.4

Table II Accident Costs (Injuries and Fatalities) in Millions of Dollars Scenario 3 – ESSENCE Lower Bound				
Year	**Alt 2**	**Alt 4**	**Alt 5**	**Alt 6**
2025	-15.2	3.9	7.9	8.2
2035	-18.4	7.0	15.6	21.3
2050	-21.6	7.0	18.3	27.1

Table III Accident Costs (Injuries and Fatalities) in Millions of Dollars Scenario 3 – ESSENCE Upper Bound				
Year	**Alt 2**	**Alt 4**	**Alt 5**	**Alt 6**
2025	-18.0	5.3	13.3	13.8
2035	-20.8	7.7	21.1	32.8
2050	-22.8	7.7	23.4	38.5

Grade Crossing Traffic Delays and Noise Impacts. The grade-crossing delay and noise analysis procedures utilize the same database. Changes in noise levels are analyzed at the same crossings for selected cities using the same number of incremental trains. Tables IV-XII show the estimated crossing delay and noise impacts for Traffic Scenario 3, assuming that 30 percent of the incremental grain traffic moves via the Gulf route. The tables are illustrated with the following examples:

- Under Alternative 6 (TCM) in 2050, the projected change in housing units subject to railroad L_{dn} of 65 dBA or greater is 648 (Table VI). Approximately 1,244,000 fewer highway vehicles would encounter grade-crossing delays, totaling 38,000 hours per year.

- In 2050, under Alternative 6 (ESSENCE Lower Bound) the projected change in housing units subject to railroad L_{dn} of 65 dBA or greater is 1,016 (Table IX). Approximately 2,073,000 fewer highway vehicles would encounter grade-crossing delays, totaling 64,000 hours per year.
- Under Alternative 6 (ESSENCE Upper Bound) in 2050, the projected change in housing units subject to railroad L_{dn} of 65 dBA or greater is 1,193 (Table XII). Approximately 2,488,000 fewer highway vehicles would encounter grade-crossing delays, totaling 77,000 hours per year.

Negative signs associated with Alternative 2 (which reflects lockage fees) indicate that additional traffic would move on the railway instead of the waterway in the with-project case, resulting in negative benefits or disbenefits.

It must be emphasized that the impacts shown in Tables IV-XII reflect the analysis of crossings in major communities only, along one impacted route. If 60 percent of the incremental grain traffic moves via this route, the impacts will be greater than the estimates shown in Tables IV-XII. When gauging delay and noise impacts, it is important to recall that these are incremental values – i.e., they reflect only the estimated change in noise and delay levels. For example, the total number of housing units impacted by railroad noise levels under Alternative 6 (ESSENCE Upper Bound) in 2050 is much greater than the incremental value of 1,193.

Table IV Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
Tow Cost Model (TCM) – 2025

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-451	241	241	241
Additional Delay per Year in Hours	-25,630	12,815	12,815	12,815
Additional Vehicles Delayed per Year	-829,264	414,632	414,632	414,632

Table V Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
Tow Cost Model (TCM) – 2035

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-451	451	648	648
Additional Delay per Year in Hours	-25,630	25,630	38,445	38,445
Additional Vehicles Delayed per Year	-829,264	829,264	1,243,897	1,243,897

Table VI Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
Tow Cost Model (TCM) – 2050

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-648	241	648	648
Additional Delay per Year in Hours	-38,445	12,815	38,445	38,445
Additional Vehicles Delayed per Year	-1,243,897	414,632	1,243,897	1,243,897

Table VII Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
ESSENCE Lower Bound – 2025

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-451	241	451	451
Additional Delay per Year in Hours	-25,630	12,815	25,630	25,630
Additional Vehicles Delayed per Year	-829,264	414,632	829,264	828,264

Table VIII Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
ESSENCE Lower Bound – 2035

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-648	241	648	837
Additional Delay per Year in Hours	-38,445	12,815	38,445	51,260
Additional Vehicles Delayed per Year	-1,243,897	414,632	1,243,897	1,658,529

Table IX Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
ESSENCE Lower Bound – 2050

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-837	451	648	1,016
Additional Delay per Year in Hours	-51,260	25,630	38,445	64,075
Additional Vehicles Delayed per Year	-1,658,529	829,264	1,243,897	2,073,161

Table X Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
ESSENCE Upper Bound – 2025

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-648	241	451	451
Additional Delay per Year in Hours	-38,445	12,815	25,630	25,630
Additional Vehicles Delayed per Year	-1,243,897	414,632	829,264	829,264

Table X1 Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
ESSENCE Upper Bound – 2035

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-648	451	648	1,016
Additional Delay per Year in Hours	-38,445	25,630	38,445	64,075
Additional Vehicles Delayed per Year	-1,243,897	829,264	1,243,897	2,073,161

Table XII Crossing Noise and Delay Impacts
Scenario 3 With 30% of Incremental Grain Traffic
ESSENCE Upper Bound – 2050

Impact Measure	Alt 2	Alt 4	Alt 5	Alt 6
Additional Housing Units > 65 dDA	-837	451	837	1,193
Additional Delay per Year in Hours	-51,260	25,630	51,260	76,889
Additional Vehicles Delayed per Year	-1,658,529	829,264	1,658,529	2,487,793

Table of Contents

1. Introduction 1
   1.1 Navigation Efficiency Alternatives 1
   1.2 Cases Analyzed 2
   1.3 Traffic Forecasts and Alternate Destinations 2
      1.3.1 Commodity Composition 2
      1.3.2 Destinations and River Distances 3
      1.3.3 Alternate Destinations and Rail Distances 4
   1.4 Scope and Key Assumptions 5
      1.4.1 Assumptions Regarding Farm Truck Delivery Patterns and Distances 5
      1.4.2 Relationship of Impacts to Other Components of the UMR-IWW Study 6
2. Energy Efficiency Analysis 6
   2.1 Barge Energy Efficiency Factors 6
   2.2 Railroad Fuel Efficiency Factors 8
      2.2.1 Trends in Railroad Fuel Efficiency 9
      2.2.2 Review of Fuel Efficiency Studies 10
      2.2.3 Statistical Model of Railroad Fuel Consumption 13
   2.3 Potential Changes in Fuel Consumption 19
3. Safety Analysis 20
   3.1 Approach and Data Sources 20
      3.1.1 Waterway Accident Factors and Costs 20
      3.1.2 Railroad Accident Factors and Costs 21
      3.1.3 Assignment of Traffic to Railroads 23
      3.1.4 Estimates of Fatality and Injury Costs 24
   3.2 Results of Safety Analysis 26
      3.2.1 Summary of Incremental Traffic 26
      3.2.2 Projected Changes in Railroad Fatality Rates 27
      3.2.3 Projected Changes in Accident Costs 29
      3.2.4 Caveats Regarding Safety Analysis 30
4. Grade Crossing Traffic Delays 30
   4.1 Grade Crossing Data 31
      4.1.1 Development of Highway-Rail Crossing Data Files 32
      4.1.2 Identification of Union Pacific Route to the Gulf 32
   4.2 Analysis Methods 33
      4.2.1 Blocked Crossing Time per Train 33
      4.2.2 Average Vehicular Delay 34
      4.2.3 Number of Vehicles Delayed Per Day 34
      4.2.4 Maximum Vehicle Queue 35
      4.2.5 Emergency Vehicle Response 35
5. Noise Analysis Procedures 36
   5.1 Data and Analysis Methods 36
      5.1.1 Housing Database File 36
      5.1.2 Equivalent Sound Level of a Single-Noise Event 37

5.1.3 Locomotive Versus Freight Car Noise 38
5.1.4 Noise Attenuation with Distance 38
5.1.5 Nighttime Noise Levels 39
5.2 Specific Steps and Methods in Noise Analysis 39
5.2.1 Compute Locomotive SEL 39
5.2.2 Compute Freight Car SEL 39
5.2.3 Compute Total Train SEL 40
5.2.4 Compute Equivalent Day-Night Sound Level 40
5.2.5 Compute Distance to 65 dBA Contour Line 40
6. Results Of Crossing And Noise Analysis 41
6.1 Illustrative Impacts for 30 Percent of Incremental Grain Traffic 41
Appendix A. Forecasts of Incremental Tons – by Year, Commodity, Origin, and Destination 48
Appendix B. Percent of Incremental Tons of Grain Originated by State 63
Appendix C. Details of Railroad Fuel Model 68
Appendix D. Additional Housing Units Affected by Railroad Noise 70
Appendix E USACE and Independent Technical Reviews 78
TVA Independent Technical Review 85
Strong Points 86
Points of Concern 87
Factors Affecting Regional Transportation 88
Country elevators 88
Trucking 89
Rail 89
Contracting 90
Taxes 90
Barge Storage 90
Local Markets and Production 91
Elasticity 92
Magnitude of Rail Noise Impacts 92
General Conclusions 93
Tolliver's Response to TVA Independent Technical Review 97
Recommendations 97

List of Acronyms

AAR	American Association of Railroads
ATSF	Atchison, Topeka, & Sante Fe Railway
BN	Burlington Northern Railroad (antecedent name)
BNSF	Burlington Northern-Santa Fe Railway
CNW	Chicago & Northwestern Railway
CR	Consolidated Railway Corporation
COFC	Container-on-Flatcar
DM&E	Dakota, Minnesota & Eastern Railroad
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
GTMC	Gross Ton-Miles of Cars and Contents
GTW	Grand Trunk Western Railroad
IC	Illinois Central Railway
ICG	Illinois Central Gulf (antecedent name)
KCS	Kansas City Southern Railway
NS	Norfolk Southern Railway
NSC	National Safety Council
PNW	Pacific Northwest
RTMG	Revenue Ton-Miles per Gallon
SOO	Soo Line Railroad
SP	Southern Pacific Railroad
SEA	Section of Environmental Analysis
SEL	Single-Event Noise Level
STB	Surface Transportation Board
TVA	Tennessee Valley Authority
TCM	Tow Cost Model
TOFC	Trailer-on-Flatcar
TPS	Train Performance Simulator
UMR-IWW	Upper Mississippi River-Illinois Waterway
UP	Union Pacific Railroad
USACE	United States Army Corps of Engineers
USDOT	United States Department of Transportation

1. INTRODUCTION

The Upper Mississippi River-Illinois Waterway (UMR-IWW) System Navigation Study is a comprehensive analysis of potential navigation improvements on the Upper Mississippi River and Illinois Waterway. The study area includes 854 miles of the Upper Mississippi River between Minneapolis-St. Paul, MN and the mouth of the Ohio River, and 348 miles of the Illinois Waterway – which connects the Great Lakes with the Mississippi River. The Upper Mississippi River encompasses 29 locks and dams. An additional 8 locks and dams are located on the Illinois Waterway. Jurisdictionally, the study area includes parts of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

This study examines the energy, safety, and traffic effects of 20 waterway traffic scenarios and navigation alternatives. The navigation alternatives represent potential improvements to the Upper Mississippi River and Illinois Waterway System, or navigational policies such as lock congestion fees. The effects of four navigation alternatives are analyzed under five traffic scenarios.

1.1 Navigation Efficiency Alternatives

The navigation alternatives are designated as 2, 4, 5, and 6. The implementation of these alternatives would improve waterway traffic conditions by increasing the capacities of lock chambers, increasing the efficiency of barge approaches to locks, or improving queue conditions through navigational enhancements or congestion pricing.

Under Alternative 2, congestion fees would be imposed upon commercial traffic by means of a lockage fee. Theoretically, lockage fees would induce waterway users who benefit least from the system to reduce usage, thereby reducing delays for the remainder of the traffic. Under Alternative 4, moorings would be constructed at Locks 12, 14, 18, 20, 22, and 24 on the Mississippi River and at LaGrange on the Illinois Waterway.[5] In addition, switchboats would be stationed permanently at Locks 20-25.[6] Under Alternative 5, moorings would be constructed at Locks 12, 14, 18, and 24 on the Mississippi River and at LaGrange on the Illinois Waterway. In addition, Locks 20-25 on the Upper Mississippi River would be extended to accommodate 1,200-foot tows.[7] Under Alternative 6, moorings would be constructed at Locks 12, 14, 18 and 24 on the Mississippi River and new 1,200-foot locks would be constructed at Locks 20-25, as well as at Peoria and LaGrange on the Illinois Waterway. In addition, Locks 14-18 on the Mississippi River would be extended to 1,200 feet and switchboats would be located at Locks 11, 12, and 13. These alternatives are detailed in the July 2003 Status Report, available from the Navigation Study Web Site at: http://www2.mvr.usace.army.mil/umr-iwwsns/.

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[5] Moorings are tie-off facilities that allow the next tow in a queue to wait closer to the occupied lock, thus decreasing the average approach time at heavily used locks.
[6] Switchboats are hired vessels permanently stationed on the upstream and downstream sides of a lock to assist in the handling cuts during a double lockage.
[7] Alternative 5 would also include switchboats at various locations.

1.2 Cases Analyzed

There is some uncertainty regarding the sensitivities of individual commodities to waterway transportation conditions and costs. These uncertainties are represented through the use of different economic model conditions. One condition reflects an inelastic state in which individual waterway movements are not sensitive to barge prices until they reach the level of an alternative mode (e.g., rail), at which level the shipments disappear from the waterway. This inelastic condition is represented by the Tow Cost Model (TCM). In comparison, the ESSENCE model is based on the assumption that individual waterway movements are sensitive to increases in barge prices before they reach the levels of rail rates. Thus, traffic will be diverted from the waterway over time, as barge rates increase relative to rail rates. Instead of a single elasticity value, upper- and lower-bound elasticities are specified with the ESSENCE model. There is also uncertainty as to the level of overall waterway demand.

The various levels of traffic demand are referred to as traffic scenarios. The combinations of elasticity and waterway demand represent different economic conditions. In total, five economic conditions were considered for this report. Four navigation alternatives were considered for each of five economic conditions. Thus, 20 separate cases were analyzed.

1.3 Traffic Forecasts and Alternate Destinations

The incremental tons for each traffic scenario and navigation alternative were developed by the United States Army Corps of Engineers (USACE). Incremental tonnage is defined as the difference between the forecast tonnage for a traffic scenario/alternative and the forecast tonnage under the "without-project" scenario.

Traffic forecasts were developed for 2025, 2035, and 2050. These forecasts are the starting point for this analysis. The key information source is a data set provided by the Corps which contains forecasted waterway tons for the "with-project" and "without-project" scenarios for each alternative.[8] The data set includes incremental traffic forecasts for specific commodity movements among 7 states or regions — Illinois, Iowa, Minnesota, Missouri, Wisconsin, the Lower Mississippi Valley, and the remainder of the United States.

1.3.1 Commodity Composition

The incremental traffic is summarized in Appendix A by commodity, origin, and destination. This information is derived from the data set provided by USACE. Commodity Group 1 – Agriculture & Forestry Products – comprises the greatest proportion of incremental tons for most traffic scenarios and alternatives. The proportion ranges from a high of 99 percent in 2035, for Traffic Scenario 5 and Alternative 1, to a

[8] The *incremental traffic data set* used in the study can be obtained from the U.S. Army Corps of Engineers project manager, John P. Carr, upon request. Mr. Carr can be contacted at: John.P.Carr@mvr02.usace.army.mil.

low of 59 percent in 2050 under Alternative 4 of the Tow Cost Model. The weighted-average proportion (as a percent of incremental tons) is 85 percent across all traffic scenarios and alternatives (Table 1). Commodity Group 1 consists primarily of grain.

Table 1 Composition of Incremental Tons for all Traffic Scenarios and Alternatives

Commodity	Weighted Mean Percent of Incremental Tons
Agricultural & Forestry Products	84.7
Chemicals	6.5
Coal	3.3
Iron & Steel Products	0.6
Petrol. Refining Products	3.5
Stone, Clay, & Glass Products	1.6

Coal comprises 34 percent of the incremental tons under Alternative 4 of the Tow Cost Model (2050), but is zero or insignificant for many traffic scenarios and alternatives. Chemicals comprise as much as 13 percent of the incremental tons in 2035 under Alternative 4 of the Tow Cost Model, and 7 percent of total incremental tons. Petroleum refining products comprise from zero to 6 percent of incremental tons, with a weighted average of 3.5 percent.

1.3.2 Destinations and River Distances

Approximately 90 percent of the grain tonnage affected by the potential waterway improvements is destined for the Lower Mississippi River Valley, presumably for the Gulf of Mexico.[9] Average waterway distances for shipments to the Gulf are shown in Table 2. The average distance for grain shipments from Iowa is roughly equivalent to the river distance from Davenport to New Orleans, while the weighted-average distance for grain shipments from Illinois is roughly equivalent to the river distance from Beardstown to New Orleans.

Table 2 Average Waterway Distances for Shipments to the Lower Mississippi River Valley

Origin State	Commodity	
	Grain	Other
Illinois	1,156	825
Iowa	1,328	1,338
Minnesota	1,634	1,245
Missouri	853	691
Wisconsin	1,465	1,466

If the grain shipments are destined for Baton Rouge instead of New Orleans, then the weighted center-of-origin will lie farther to the North. For example, the average waterway distance for grain originated from Illinois is roughly equivalent to the river

[9] This value is computed from the tons in the without project case. The actual percent ranges from 87 to 91 percent across the traffic scenarios and alternatives.

distance from Hennepin to Baton Rouge. The average waterway distance for grain originated from Iowa is roughly equivalent to the river distance from Lock & Dam 10 (near Guttenberg) to Baton Rouge.

The waterway distances seem reasonable in light of grain production patterns. For example, the most intense area of corn production in Iowa extends from Davenport northwest through Mason City. Thus, the weighted center-of-origin for grain shipments from Iowa probably lies between Davenport and Guttenberg.

1.3.3 Alternate Destinations and Rail Distances

For all commodities other than grain, the railroad mileage is assumed to be the same as the waterway mileage. In some instances, grain destinations may shift in the without-project case. Forty percent of the incremental grain is assumed to move to the Pacific Northwest and travel an average distance of 2,000 miles by rail.[10] The remaining 60 percent is assumed to move to the Gulf of Mexico and travel 1,000 miles by rail.

Table 3 shows rail distances from key stations in the study region to New Orleans. An average rail distance of 1,000 miles seems reasonable in light of these distances. For most traffic scenarios and alternatives, in order for 60 percent of the grain to move to the Gulf, all of the incremental tons originated in Illinois and Missouri would have to move there, as well as significant quantities of grain originated from Iowa (Appendix B).[11] The movement of northern Iowa corn to the Gulf by rail would require some hauls of 1,200 miles or more.

Table 3 Rail Distances from Select Stations in the Study Region to New Orleans, LA

Origin City	Origin State	Railroad	Rail Miles
Beardstown	IL	BNSF	1,211
Peoria	IL	UP	980
Quincy	IL	BNSF	1,221
Clinton	IA	UP	1,093
Morrison	IL	UP	1,078
Cedar Rapids	IA	UP	1,172
Mason City	IA	UP	1,290
Davenport	IA	BNSF	1,346

[10]This representative distance was developed by USACE. As points of reference, 2,000 miles is the approximate rail distance from Dubuque, IA to Portland, OR via BNSF, and from Cedar Rapids, IA to Portland, OR via the UP. Some longer hauls from the study region to the Pacific Northwest are possible. For example, it is more than 2,200 rail miles from Peoria, IL to Portland, OR. However, some shorter hauls from the study region to the Pacific Northwest are possible. For example, it is approximately 1,800 miles from St. Paul, MN to Portland, OR via BNSF. Moreover, the length of haul may vary with the Pacific Coast destination. For example, the rail distance from Cedar Rapids, IA to Seattle, WA via the UP is approximately 2,200 miles. Given the variety of potential origins and destinations involved, 2,000 miles is a representative value for movements from the study region to the Pacific Northwest.

[11] Only 7 to 8 percent of the incremental grain is originated in Missouri.

Table 3 Rail Distances from Select Stations in the Study Region to New Orleans, LA			
Origin City	**Origin State**	**Railroad**	**Rail Miles**
La Crosse	WI	UP	1,373

1.4 Scope and Key Assumptions

The analysis focuses on changes in energy consumption, emission levels, safety, grade-crossing traffic delays, and noise as a result of changes in railroad and waterway traffic levels. Rail is the most feasible alternative to barge movements, given the commodities and distances involved. Any gathering or distribution movements by truck at origin or destination are excluded from the analysis.

There are several practical reasons for this approach. (1) The incremental tons of traffic provided by USACE are aggregated by state. At this level of aggregation, it is impossible to analyze potential changes in farm-to-delivery station movements. Such an analysis would require a very fine level of detail, almost at the individual farm level. (2) The incremental traffic forecasts are applicable to 2025 and beyond. Many changes are likely to occur between now and 2025 that will affect farm-to-rail and farm-to-river trucking distances. At present, farm-to-river distances may be greater than farm-to-rail distances in some areas. However, the growing concentration of traffic at shuttle-train facilities suggests that farm-to-rail trucking distances are likely to increase between now and 2025, as farmers take advantage of lower prices at shuttle elevators. (3) There is no sound analytical method for projecting farm-to-river and farm-to-railroad trucking distances in 2025, 2035, and 2050.

1.4.1 Assumptions Regarding Farm Truck Delivery Patterns and Distances

Given the uncertainty surrounding future grain deliveries, it is assumed that local farm trucking patterns and distances will not vary appreciably between the with-project and without-project cases in 2025, 2035, and 2050. In the with-project case, incremental grain traffic will be trucked from farms to elevators located on the Illinois and Upper Mississippi Rivers. In the without-project case, incremental grain will be trucked from farms to elevators located on rail lines. In some cases, rail lines parallel the river and grain elevators have both river and railroad access. For example, rail lines parallel the Illinois River from Joilet to south of Peoria. Grain delivered to river elevators in this region most likely would be trucked to the same elevator or to a nearby destination in the without-project case. In some areas, grain moves from inland to river elevators by local or regional railroads. The Iowa Interstate (IAIS) is one example. This local railroad delivers grain to ADM Growmark in Peoria, which functions as both a barge transfer facility and a terminal elevator. In these situations, local farm trucking patterns will not differ appreciably with or without waterway improvements.

Tennessee Valley Authority (TVA) suggests that some farmers, when faced with rising congestion and barge costs on the Upper Mississippi River and Illinois Waterway, may truck their grain to St. Louis for transfer to barge (Appendix). If such long-haul trucking occurs in the without-project case, the energy, environmental, and safety impacts estimated in this study may be understated. In general, if truck gathering and distribution

patterns vary appreciably across scenarios and alternatives, some impacts will not be accounted for in this study – in which case, the results should be interpreted accordingly.[12]

1.4.2 Relationship of Impacts to Other Components of the UMR-IWW Study

The objective of this study is to estimate energy, safety, and other impacts in dollars. Some of the cost impacts presented in this report may be included in other studies. For example, fuel costs are reflected in the transportation rates of carriers. Therefore, any change in energy cost presented in this report may not be additive to benefits computed elsewhere in the UMR-IWW System Navigation Study.

Since insurance costs are an explicit component of barge and rail costs, insured losses may be accounted for in transportation efficiency benefits. However, it is not readily apparent that all safety, pollution costs, and traffic interference costs are internalized or borne by the railroad. For example, highway grade-crossing accidents may result in lawsuits against state or local governments, as well as against the railroad. Moreover, highway grade-crossing traffic delays and noise impacts constitute externalities that are not reflected in barge or railroad rates.

2. ENERGY EFFICIENCY ANALYSIS

2.1 Barge Energy Efficiency Factors

Barge fuel consumption factors have been obtained from the Tennessee Valley Authority (TVA). Table 4 shows estimates of revenue ton-miles per gallon for the Mississippi River and Illinois Waterway for 1999-2001. During this period, revenue ton-miles per gallon (RTMG) ranged from 276 to 326 on the Upper Mississippi River and from 229 to 301 on the Illinois River. According to TVA estimates, revenue ton-miles per gallon during the same period ranged from 583 to 642 on the lower river segment from Cairo, Illinois to Baton Rouge, Louisiana (Table 4). These values, it should be noted, are applicable to all river traffic, not just the contested movements. In the with-project scenario, upper river fuel efficiencies are expected to be higher than historic values because of the effects of the proposed lock extensions and mooring cells.

[12] As noted earlier, the quantification of farm trucking impacts for each scenario and alternative would require a detailed geographic study of farm production, truck fleet characteristics, and elevator locational patterns and characteristics. Such an analysis is beyond the scope and time frame of this study. Moreover, its findings may be valid for a short duration only because of future elevator consolidation and the effects of shuttle-train facilities on farmer delivery patterns.

Table 4 Estimated Revenue Ton-Miles per Gallon for Mississippi River Segments			
River Segment	Revenue Ton-Miles per Gallon		
	1999	2000	2001
Minneapolis-to-Mouth of Missouri River	276	306	326
Illinois River	229	301	290
Mouth of Missouri River-to-Mouth of Ohio River	511	567	549
Mouth of Ohio River-to-Baton Rouge	614	583	642
Source: Tennessee Valley Authority			

Upper river fuel efficiencies in 2025, 2035, and 2050 have been forecast by TVA for each traffic scenario and alternative. These forecasts reflect reductions in queuing and delays at the locks identified for improvement in each of the navigation alternatives. The TVA forecasts represent weighted averages for the entire upper river system, assuming that all navigation improvements are implemented simultaneously.

Projected RTMG values for the five traffic scenarios are shown in Tables 5 through 9. These values range from 319 RTMG for Traffic Scenario 3, under the ESSENCE Upper Bound conditions, to 368 RTMG under the conditions described earlier for the Tow Cost Model.

Table 5 Projected Upper River Fuel Efficiency Values: Scenario 2 – ESSENCE Lower Bound			
Navigation Alternative	Revenue Ton-Miles per Gallon		
	2025	2035	2050
2	327	334	336
4	321	324	323
5	336	342	342
6	336	357	360

Table 6 Projected Upper River Fuel Efficiency Values: Scenario 3 – ESSENCE Lower Bound			
Navigation Alternative	Revenue Ton-Miles per Gallon		
	2025	2035	2050
2	333	339	342
4	324	322	320
5	339	344	339
6	344	363	363

Table 7 Projected Upper River Fuel Efficiency Values: Scenario 3 – ESSENCE Upper Bound			
	Revenue Ton-Miles per Gallon		
Navigation Alternative	2025	2035	2050
2	328	332	333
4	320	320	319
5	332	336	335
6	335	361	354

Table 8 Projected Upper River Fuel Efficiency Values: Scenario 3 – Tow Cost Model			
	Revenue Ton-Miles per Gallon		
Navigation Alternative	2025	2035	2050
2	341	343	342
4	331	319	317
5	348	347	337
6	349	360	368

Table 9 Projected Upper River Fuel Efficiency Values: Scenario 5 – ESSENCE Upper Bound			
	Revenue Ton-Miles per Gallon		
Navigation Alternative	2025	2035	2050
2	336	343	340
4	324	320	317
5	344	339	335
6	342	364	363

2.2 Railroad Fuel Efficiency Factors

Two approaches were considered for estimating railroad fuel consumptions factors: (1) train resistance equations and (2) statistical models. Train resistance equations can provide detailed estimates of fuel efficiencies for various routes and train consists. However, train resistance equations require detailed information about the grade and curvature of the route, as well as precise train weights and locomotive horsepower ratings.

Train resistance equations are useful for illustrative purposes. However, the traffic scenarios used in this study encompass many commodities, markets, and possible routes. As noted earlier, state originations and terminations are the finest level of traffic detail. Moreover, the traffic forecasts are based on likely distributions of markets for grain and other commodity movements well into the future. Without detailed traffic and route data, the best approach is a statistical analysis of railroad fuel consumption based on Class I railroad data.

2.2.1 Trends in Railroad Fuel Efficiency

As shown in Figure 1, railroad fuel efficiency has been increasing over time, from 332 RTMG in 1990 to 404 RTMG in 2002.[13] The industry average reflects a wide range of traffic and operating conditions, including: (1) bulk trainload and unit-train operations, (2) mixed freight carload traffic, and (3) trailer-on-flatcar (TOFC) and container-on-flatcar (COFC) traffic. TOFC and COFC traffic require more gallons per revenue ton-mile because of lower net weight-to-tare weight ratios. In comparison, bulk trainload and unit-train operations exhibit higher net-to-tare ratios. For example, the net-to-tare weight ratio is approximately 3.5 for a 286,000-pound covered hopper car loaded with 111 tons of grain. In general, fuel efficiency increases over distance as the fuel consumed in origin-destination switching and way train operations is spread over more revenue ton-miles.

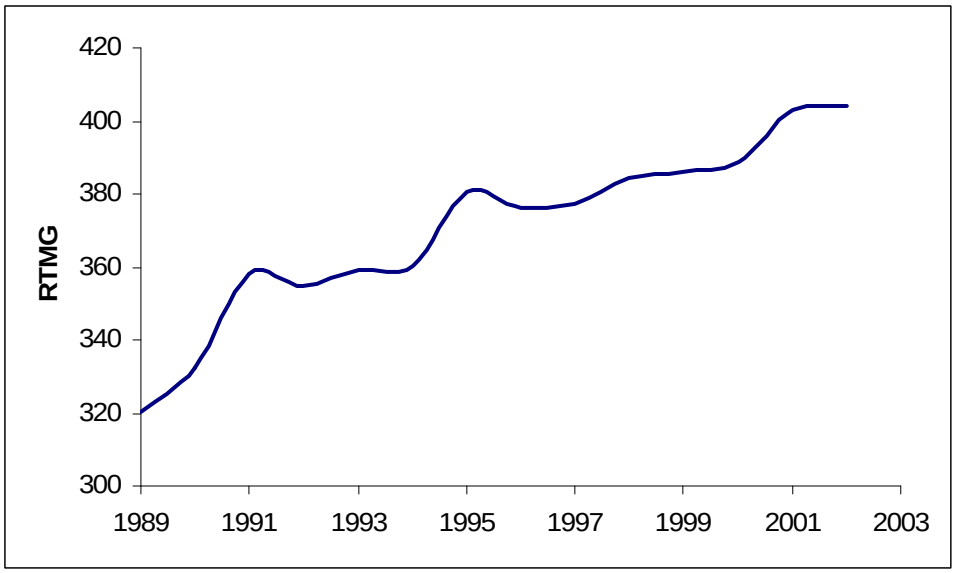

Figure 1 Railroad Revenue Ton-Miles per Gallon (Computed from R-1 Reports to the STB)

[13] The values shown in Figure 1 are computed from Class I Railroad Annual R-1 Reports to the Surface Transportation Board. Locomotive fuel consumed during the year is reported in Schedule 750 of the R-1 Report. Revenue ton-miles is computed from Schedule 755 – Railroad Operating Statistics – which contains many other railroad activity measures such as gross ton-miles and train-miles.

Most of the incremental traffic consists of bulk commodities such as grain, coal, and petroleum products, which can be moved efficiently in multi-car or trainload quantities. Most of this traffic would move long distances to the same or alternate markets in the without-project cases. Thus, it is expected that the average revenue ton-miles per gallon generated by this traffic would exceed the industry average.

2.2.2 Review of Fuel Efficiency Studies

A detailed review of railroad fuel efficiency studies is presented in an earlier report by Tolliver (2000), which can be viewed at: http://www2.mvr.usace.army.mil/umr-iwwsns/documents/aug2000-entirereport.pdf. In this report, the review is limited to studies that have estimated railroad fuel efficiency factors for bulk or mixed freight traffic.

2.2.2.1 Federal Railroad Administration Truck-Rail Fuel Efficiency Study

Perhaps the most comprehensive public domain analysis of railroad fuel efficiency occurred in 1991, sponsored by the Federal Railroad Administration. The consultant – Abacus Technology Corporation – used a train performance simulator (TPS) adapted for use by FRA in the 1970s. A TPS is a computer program that uses train resistance equations to simulate the performance of a train over various sections of track.

Altogether, 43 hypothetical rail movements were analyzed, including 32 Class I scenarios. The stated intent of the study was to compare rail and truck energy consumption for truck-competitive rail movements. Because of the orientation of the study, most of the railroad simulations featured mixed freight, TOFC, and automobile traffic.

The results of the simulations are shown in Table 10. The estimated fuel efficiencies range from 414 to 843 RTMG for mixed freight trains, and from 279 to 499 RTMG for mixed freight trains with autoracks. In comparison, the estimated fuel efficiencies range from 196 to 350 RTMG for TOFC trains. Comparatively, these results make sense given the higher tare weight-to-net weights ratios of TOFC trains.

Some caution should be exercised in drawing inferences from the FRA simulations. Their stated purpose was to compare the fuel economy of railroads and trucks for a limited set of commodities. The basis for comparison was the train movement, not the shipment. The fuel required for delivering empty cars to shippers and for terminal switching operations is not accounted for adequately in the analysis. Thirteen of the 32 Class I scenarios consisted of all loaded cars. Only 6 percent of the cars in these simulations were empties. Moreover, the results do not reflect the consolidation of cars at multiple stations, as is typically required for way train operations.

Table 10 Revenue Ton-Miles per Gallon for Class I Scenarios in FRA Study		
Train Type	Range in RTMG Estimates	
	Minimum Value	Maximum Value
Mixed Freight	414	843
Mixed Freight with Autos	279	499
Double-stack	243	350
TOFC	196	327
Solid Autos	206	206
Source: Federal Railroad Administration, *Rail Vs. Truck Fuel Efficiency*, 1991		

2.2.2.2 Unit Grain Train Fuel Consumption Study

A 1999 study by Gervais and Baumel used computer simulations provided by two Class I railroads for unit grain train movements from Boone, Iowa to New Orleans and Los Angeles. The hypothetical movements consisted of 100-car trains for two different car load factors: 100 and 110 tons. The 110-ton load factor corresponds to a 286,000-pound covered hopper car which has become commonplace in the transportation of grain. A 110-car movement from Sioux City to Tacoma, Washington was also evaluated. Each trip was simulated with three different types of locomotives. The high-end fuel efficiencies shown in Table 11 reflect the use of SD-60 and C40-8 locomotives, while the low-end estimates reflect the use of SD-40 locomotives.

Table 11 Simulated Fuel Efficiency of Unit Grain Trains Movements from Iowa				
Origins-Destinations	Simulations	Cars per Train	Load per Car	RTMG Range
Boone, IA to Los Angeles	6	100	100, 110	513-585
Boone, IA to New Orleans	6	100	100, 110	688-802
Sioux City to Tacoma	2	110	110	554-664
Source: Gervais and Baumel. *Fuel Consumptions for Shipping Grain Varies by Origin, Destination*. Feedstuffs, Vol. 71(36).				

2.2.2.3 Locomotive Tests

A report by Dunn and Eggleton (2002) provides data on the fuel consumption rates of locomotives and typical duty cycles. A duty cycle represents the percentage of time that a locomotive spends in each throttle setting during a typical hour. It varies considerably among road train service, local service, and yard and switching service. The duty cycles presented in this report are based on the fleet profile that existed in Canada in 2001 (Table 12). The U.S. Class I fleet is similar in composition.

Table 12 Road Locomotive Fleet of Canadian Class I Railroads as of 2001			
Unit	**Horsepower Rating**	**Number of Units**	**Gallons of Fuel Consumed per Hour**
SD-40	3,000	890	35
SD-50	3,600	64	40
SD-60	3,800	63	38
SD 70	3,000	7	34
SD 70	4,000	12	42
SD-75	4,300	240	40
SD 90	6,000	4	55
Dash 8	4,000	55	38
Dash 9	4,400	408	42
Source: Robert Dunn and Peter Eggleton. *Influence of Duty Cycles and Fleet Profile on Emissions from Locomotives in Canada*, June 2002.			

The SD-40 is a 3,000 HP unit widely used in the U.S. and Canada. A representative duty cycle for an SD-40 in road-train service is shown in Table 13. As Table 13 shows, the SD-40 spends only 17 percent of its time during a typical duty cycle in throttle setting 8. Nine percent of the time is spent in dynamic braking (DB) mode, where the locomotive's traction motors are used to generate resistance to forward motion. Another 46 percent of the time is spent in idle while the locomotive waits at side tracks, approaches to block signals, or yards while crews are exchanged.

Table 13 Fuel Consumption Rate for EMD SD-40 Locomotive in Typical Road Duty			
Throttle Notch	**HP Generated**	**Gallons/Hr**	**Time in Notch**
DB	.	18.7	9.0%
Low Idle	.	4.0	0.0%
Idle	18	6.0	46.0%
1	106	11.8	4.0%
2	351	21.8	4.0%
3	666	39.9	4.0%
4	992	55.2	4.0%
5	1,440	77.7	4.0%
6	1,934	101.3	4.0%
7	2,766	144.7	4.0%
8	3,267	170.5	17.0%
Source: Robert Dunn and Peter Eggleton. *Influence of Duty Cycles and Fleet Profile on Emissions from Locomotives in Canada*, June 2002.			

The important implication of Table 13 is that railroad fuel-use studies must consider the time that a locomotive spends idling during a typical duty cycle as a result of road and yard delays or delays at industry locations.

2.2.3 Statistical Model of Railroad Fuel Consumption

2.2.3.1 Panel Data Set

Class I railroads maintain separate accounts for recording locomotive fuel consumed during the year and report these values to the Surface Transportation Board (STB) in Schedule 750 of the R-1 Report. In addition to fuel consumption, Class I railroads report numerous operating and expense data in the same report. Of particular relevance to this study is Schedule 755 B *Railroad Operating Statistics* B which contains many railroad activity measures.

The data set for this study consists of Class I railroad observations for the years 1989 through 2001. It includes observations for the following railroads: Atchison, Topeka, & Sante Fe (ATSF), Burlington Northern (BN), Chicago & Northwestern (CNW), Conrail (CR), CSX, Grand Trunk Western (GTW), Illinois Central (IC), Kansas City Southern (KCS), Soo Line (SOO), Southern Pacific (SP), and Union Pacific (UP).

Because of mergers, the observations and railroads in the database vary across time. The Soo Line, GTW, and KCS did not merge during the period. However, CNW was acquired by UP in 1995. Moreover, UP merged with Southern Pacific in 1997. Burlington Northern merged with ATSF in 1996 to form BNSF. CSX and NS acquired parts of Conrail in 1999. Canadian National and ICG merged in 1998. However, the Illinois Central continued to file separate reports with the STB through 2001. Thus, as a practical matter, the CN-IC merger did not impact the data used in this study.

2.2.3.2 Statistical Methods

A widely-used statistical technique – least-squares regression – is used to model railroad fuel consumption. This technique mathematically fits a line through observed data points so as to minimize the sum of the squared deviations about the line. The SAS Autoreg procedure is used for this purpose.[14] Autoreg estimates the model's coefficients after adjusting for any serial correlation that may exist in the data set.[15] Detailed information is generated about the goodness of fit of the regression line and the statistical significance of explanatory variables.[16] Specifically, Autoreg computes a p-value associated with the

[14] SAS is a registered trademark of the SAS Institute.

[15] Serial correlation is encountered most often when using time series or pooled data. A major assumption of the linear regression model is that any value of the dependent variable is statistically independent of any other value of the dependent variable; i.e., the error terms of the model are statistically independent. Even when autocorrelation exists, the parameter estimates are unbiased. However, the standard errors of the estimates are biased.

[16] Usually, the parameters of a regression model are estimated from sample data. In this case, the 1989-2001 data set is viewed as a sample of all possible of Class I railroads. At one time, there were more than 100 Class I carriers in the United States. In any given year, a railroad must meet a revenue threshold in order to qualify as a Class I carrier. Viewing the data set as a sample allows the use of probability theory in the analysis of explanatory variables.

t-statistic.[17] In general, the smaller the p-value, the greater the level of evidence against the null hypothesis that the coefficient is not significantly different from zero. For example, a p-value of 0.01 means that the probability of obtaining a greater value of *t* is only 1 in 100 when the null hypothesis is true.

2.2.3.3 General Model of Railroad Fuel Consumption

Railroad fuel consumption is a function of activity over time. Some fuel is consumed each time a carload is originated, terminated, or interchanged with another railroad. When shipments are originated or terminated by a railroad, freight cars must be spotted and pulled at industry locations. In addition, cars must be spotted and pulled at agreed-upon locations when traffic is exchanged among railroads.

Fuel consumed in origin, destination, or interchange switching is primarily a function of carloads handled. The car weight and switching distance are secondary factors. Typically, a car switched in industry or interchange service travels 4 miles or less.[18] In comparison, fuel consumed in train operations is primarily related to the weights of the freight cars and the line-haul distance. A general model of railroad fuel consumption is shown in Equation 1.

(1) $FG = f(CH, GTMC, T)$

Where:

FG	=	Gallons of fuel consumed
CH	=	Carloads handled
$GTMC$	=	Gross ton-miles of cars and contents
T	=	Time

CH is derived from the total number of freight cars originated, terminated, received, or delivered.[19] A shipment that is originated and terminated by the same railroad represents one carload handled. Similarly, a shipment that is originated by one railroad and delivered to another railroad represents a carload handled. In fact, each carload that is handled results in 2 origin, destination, or interchange switches of a loaded car.

The gross ton-miles of cars and contents reflect the weights of trains and the distances traveled. GTMC includes revenue ton-miles, as well as the loaded and empty ton-miles of freight cars. The variable T (time) is expected to have a negative sign in the model, indicating that fuel efficiency is increasing over time as a result of newer, more efficient

[17] If there isn't a linear relationship between a response variable and an explanatory variable, the slope of the regression line should not be significantly different from zero. A t-statistic is used to test for this condition; it is computed as the parameter estimate divided by its standard error. If the standard error is large in relation to the parameter estimate, the t-value will be low. Because the t-statistic has a known probability distribution, it can be used to determine whether there is sufficient evidence to reject the null hypothesis that the coefficient is not significantly differ from zero. The p-value defines the probability of obtaining a greater absolute value of *t* when the null hypothesis is true.
[18] STB. *Uniform Railroad Costing System*. Worktable E.
[19] Carloads are received or delivered when railroads interchange traffic.

locomotives being added to the fleet, and other technological and operational changes that are not reflected in the activity variables.

2.2.3.4 Fixed Effects Model

Fuel efficiency may vary across railroads for many reasons other than differences in activity variables. Differences in terrain and network structure are potential sources of variation.[20] To account for fixed network effects, a vector of railroad indicator variables (RR) is included in the model, as shown in Equation 2. The indicator variables shift the intercept of the regression line, and in doing so represent each railroad's unique system factors (such as grade and climate).

$$(2) \quad FG = f(CH, GTMC, T, RR)$$

Each Class I railroad that existed during the 1989-2001 period is represented by an indicator variable – e.g., *IC*. An indicator variable can assume values of zero or one. For example, if the observation is for the IC Railroad, then the indicator variable *IC* equals 1. Otherwise, *IC* equals zero.

In addition to controlling for fixed network effects, railroad indicator variables can control for mergers, which redefine the railroad network. Statistically, mergers are handled through the use of additional indicator variables. For example, the UP system includes three railroads that appear in the database: UP, SP, and CNW. UP gained control of CNW in 1995 and merged with SP in 1997. Additional merger variables have been defined to control for these events. The variable *UPCNW* assumes a value of 1 in 1995, and each year thereafter, but is zero otherwise. Similarly, *UPSP* assumes a value of 1 in 1996, and each year thereafter, but is zero for earlier years. Other mergers are handled in a similar manner.

2.2.3.5 Train-Service Effects Model

The R-1 report contains activity levels for three classes of train service: way, through, and unit. Train class is important to fuel economy because locomotive capacity is more fully utilized by longer trains, even though the trailing tons are greater. Locomotives are not added continuously, but in discrete units. Thus, fuel consumption per ton-mile is expected to decrease with train size. Unit trains do not switch en route or require yard classification. Thus, a unit train is expected to be more fuel efficient than a through or way train, even when hauling the same tonnage.

[20] Of the Class I railroads, Soo Line, GTW, ICG, and KCS are essentially north-south railroads. They interchange much of their traffic with other Class I carriers. In contrast, UP and BNSF frequently traverse the Rocky Mountains when moving products to and from the Pacific Coast. Much of their traffic is local or single-line in nature. The three eastern railroads are distinct from the midcontinent and western carriers in terms of climate, terrain, and other network factors.

Train service is defined in Schedule 755 of the R-1 report, wherein the STB defines a way train as one operated "primarily to gather and distribute cars in road service and move them between way stations or way points." In comparison, through trains operate "between two or more major concentration or distribution points." A unit train is defined as:

> *... a specialized shuttle type service in equipment (railroad or privately owned), dedicated to such service, moving between origin and destination. The applicable contracts or tariffs generally require that a specific tonnage or quantity of carloads be tendered as a unit for shipment on one bill of lading or other shipping document in a solid train for movement between origin and destination.*

When viewed collectively, way and through train services constitute nonunit-train service. Usually, a way-train trip is related to a prior or subsequent through-train move. Clearly, a railroad may substitute unit-train for nonunit-train service, and vice-versa. Therefore, the fuel consumption model presented earlier can be modified to include train service-effects (Equation 3).

(3) $FG = f(CH_U, CH_N, GTMC_U, GTMC_N, T, RR)$

Where:

CH_U = Carloads handled in unit-train service
CH_N = Carloads handled in nonunit-train service
$GTMC_U$ = Gross ton-miles of cars and contents in unit-train service
$GTMC_N$ = Gross ton-miles of cars and contents in nonunit-train service

2.2.3.6 Results of Statistical Model

The train service/fixed effects model was estimated using 135 observations from 1989 through 2001. The complete results of the analysis are documented in Appendix C. The R-square of this model is 0.998, meaning that it explains 99.8 percent of the variation in railroad fuel consumption. Moreover, the model has a low coefficient of variation, which is a measure of the model's precision.[21]

The parameter estimates and key statistical indicators are summarized in Table 14. The parameter estimates for the activity variables can be interpreted as partial derivatives – e.g., the change in gallons of fuel consumed resulting from a per-unit change in an activity variable, while holding other effects constant. This is a plausible interpretation of the activity variables, even though they may be related. For example, it is possible to vary nonunit-train activities while holding unit-train activities constant, and vice-versa. Moreover, it is possible to vary the number of carloads handled without varying gross ton-miles. [22]

[21] The coefficient of variation is the model error taken as a percentage of the dependent variable mean. The value of 5.1 means that the error of the model is very small in relation to the mean.
[22] Many carloads do not receive line-haul service and thus accrue no gross ton-miles. A good example is an intraterminal or interterminal switch, in which the carload is originated and terminated within the switching limits of a port or major terminal. Similarly, carloads received in interchange service from another railroad

Table 14 Parameter Estimates and Statistical Tests for Railroad Fuel Consumption Model

Variable	Estimate	Standard Error	t-Value	Prob. > |t|
Intercept	16,669,567	6,659,595	2.50	0.014
Unit-Train Carloads Handled	26.96	10.30	2.62	0.010
Nonunit-Train Carloads Handled	31.92	8.25	3.87	0.000
Unit-Train GTMC (Thou.)	0.66	0.11	6.24	<.0001
Nonunit Train GTMC (Thou.)	0.69	0.09	7.55	<.0001
BNSF	16,958,882	18,692,623	0.91	0.366
ATSF	147,565,283	16,082,640	9.18	<.0001
BN	191,263,949	34,225,503	5.59	<.0001
UPSP	6,762,059	18,129,315	0.37	0.710
UPCNW	59,166,616	18,987,782	3.12	0.002
SP	161,151,486	17,316,752	9.31	<.0001
UP	176,150,646	30,769,742	5.72	<.0001
ICG	(7,351,903)	6,129,408	-1.2	0.233
CNW	(29,225,055)	11,846,844	-2.47	0.015
SOO	(8,185,949)	5,896,207	-1.39	0.168
CR	11,371,197	25,226,994	0.45	0.653
CSX	31,645,984	35,640,772	0.89	0.377
CSXCR	24,699,549	21,995,801	1.12	0.264
GTW	(7,404,724)	5,817,449	-1.27	0.206
NSCR	20,156,078	19,306,610	1.04	0.299
NS	33,684,251	28,054,466	1.2	0.232
T	(1,525,813)	597,365	-2.55	0.012

As expected, *T* has a negative sign showing that fuel consumption is decreasing over time, after controlling for activity levels. Several of the railroad indicator variables are statistically significant, suggesting that they are capturing much of the fixed network and mergers effects. When holding all else constant, the interpretation of the activity variables is as follows:

- Each unit-train carload handled results in 27 gallons of fuel consumed
- Each nonunit-train carload handled results in 32 gallons of fuel consumed
- Each thousand unit-train gross ton-miles results in .66 gallons of fuel consumed.
- Each thousand nonunit-train gross ton-miles results in .69 gallons of fuel consumed

In evaluating the parameter estimates, it must be recalled that the CH variables reflect 2 switches per loaded car, plus the related switching of empty cars. For bulk commodity shipments, an empty car must be spotted for each car that is loaded. The parameter estimates reflect the switching of both cars. The estimates also reflect fuel consumption associated with the repositioning of locomotives and the idling of locomotives, while

may be delivered to the consignee by a yard crew. Moreover, it is possible to vary gross ton-miles and hold carloads constant by increasing or decreasing the length of haul or the weight of the car.

waiting to switch. As a point of reference, an SD-40 locomotive may consume 22 to 55 gallons per hour during road switching operations when the locomotive is in throttle notches 2 through 4 (Table 13). Based on these fuel consumption rates, the parameter estimate of 32 gallons per nonunit-train carload handled represents less than an hour of locomotive time incurred in switching as many as 4 cars (2 loaded cars and 2 empty cars).

2.2.3.7 RTMG Predictions

Figure 2 shows predicted revenue ton-miles per gallon for a hypothetical grain shipment in a 263,000-pound covered hopper car and a COFC or TOFC shipment.[23] The example assumes one interchange switch and non-unit train service. The model predicts RTMG values ranging from 135 at 100 miles to 695 at 2,000 miles for the grain shipment.[24] For the COFC shipment, the model predicts RTMG values ranging from 50 at 100 miles to 385 at 2,000 miles.

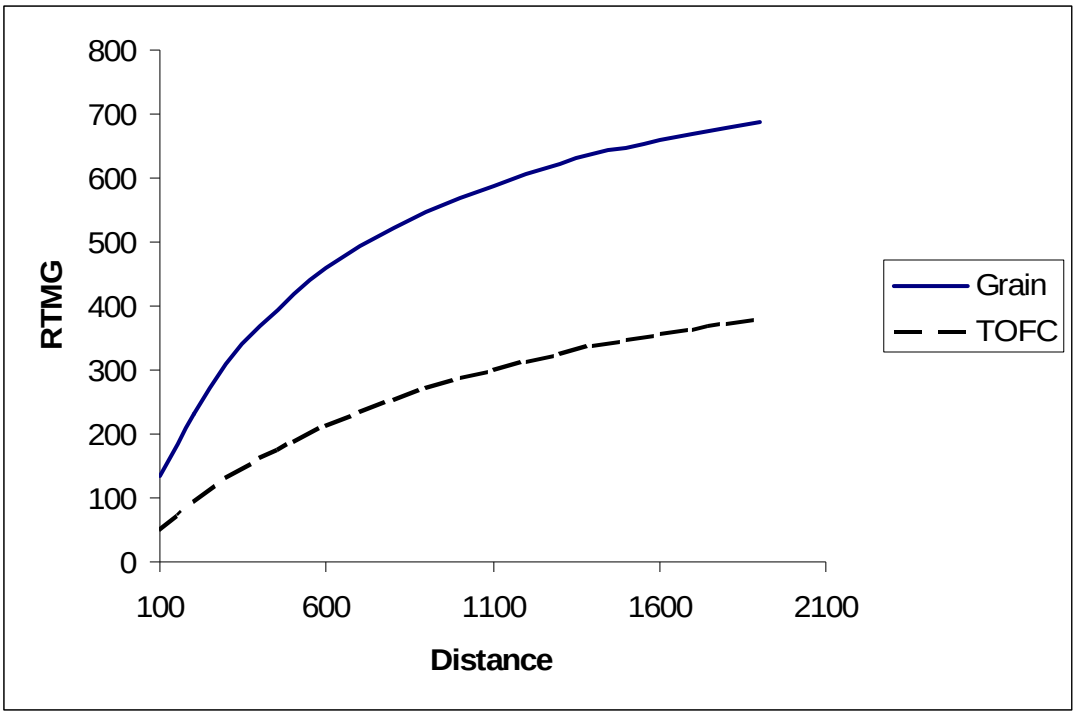

Figure 2. Predicted RTMG for Hypothetical Grain and TOFC Shipments

Logically, revenue ton-miles per gallon are relatively low for short trips where much of the energy is consumed in origin-destination switching and yard classification activities. However, revenue ton-miles per gallon are much greater for longer distances where much of the energy consumption is related to train operations.

[23] The grain example assumes a car tare weight of 31.5 tons and 100 net tons per car. The COFC example assumes a car tare weight of 30 tons, container tare weights of 10 tons total, and 30 net tons per car.
[24] The model predicts RTMG values ranging from 155 at 100 miles to 795 at 2,000 miles for a unit train grain shipment

2.3 Potential Changes in Fuel Consumption

The weighed-average waterway trip distance for incremental grain traffic ranges from 1,300 to 1,500 miles for the 5 traffic scenarios, with a midrange estimate of 1,400 miles. The projected length of haul by rail is 1,400 miles (i.e., 60 percent to the Gulf at 1,000 miles and 40 percent to the PNW at 2,000 miles). The highest RTMG forecast for upper river movements under any traffic scenario is 368 (Table 8). As shown in Table 15, the highest possible weighted-average RTMG for a river movement is 558. In comparison, the model predicts railroad revenue ton-miles per gallon of 636 and 684 for nonunit and unit-train movements, respectively.

Table 15 Waterway RTMG Estimates for Average Incremental Grain Movement

River Segment	River Miles	RTMG
Upper River	370	368
St. Louis to Cairo	180	549
Cairo to New Orleans	850	642
Total or Weighted Average	1,400	558

Admittedly, the rail estimates are derived from a statistical model and involve some uncertainty.[25] Nevertheless, these forecasts are consistent with the FRA estimates shown in Table 10 and the Gervais-Baumel estimates shown in Table 11. Moreover, the forecasts make sense in light of known data.

As noted earlier, the reported 2002 railroad industry average is 404 RTMG. This average reflects a mixture of TOFC/COFC shipments with relatively low fuel efficiency and bulk commodity shipments with higher fuel efficiency. The revenue ton-miles per gallon generated by the incremental grain traffic will be much greater than the industry average. Based on these inferences, the general conclusion of the analysis is that there is no evidence to suggest that the potential waterway investments would have a significant beneficial effect on annual fuel consumption.

The emission of air pollutants is related to fuel consumption. EPA regulations limit the grams that can be emitted per gallon of fuel used by locomotive and marine diesel engines. In 2025, it is likely that the emission rates of locomotive and towboat diesel engines will be similar, and much lower than historical emission rates. Most of the Category 2 marine diesel engines used in towboats are manufactured by General Motors Electromotive Division (EMD), Caterpillar, and General Electric. These companies also supply most of the locomotives used in the United States. In fact, most Category 2

[25] A final qualification must be made regarding the use of the fuel equation. It is assumed that fuel use increases linearly with railroad activity levels, as traffic is added to or removed from the railroad system, and that the removal or addition of traffic does not affect the network structurally. In other words, fixed network effects remain constant while traffic changes. Given the quantities of incremental traffic involved, this seems to be a reasonable assumption. However, substantial increases in railroad traffic levels may lead to network changes, such as the addition of track miles or the construction of new yards. Alternatively, substantial increases in traffic may introduce new or higher levels of congestion that are not reflected in the historic data.

marine engines are "essentially marinized locomotive two- and four-stroke engines" (EPA, 1999, p. 56). Thus, it is reasonable to assume that in 2025, the emission rates of diesel locomotives and Category 2 marine diesel engines will be comparable. Because the potential waterway investments would not affect fuel conservation appreciably, it is unlikely that the improvements would have a material effect on the emission of air pollutants.

3. Safety Analysis

Substantial increases in railroad train-miles are forecast for many of the without-project cases. Over time, incremental train-miles will result in additional highway grade-crossing, trespasser, and derailment accidents. In the with-project cases, these additional accidents and fatalities would not occur. Therefore, projected increases in accident costs are counted as benefits, because they can be avoided if the waterway improvements are made.

3.1 Approach and Data Sources

Three types of accident-related costs are considered in this analysis: fatalities, injuries, and property damage to the carrier. Annual costs are estimated for the with-project and without-project scenarios. Typically, without-project accident costs are based on railroad accident factors, while with-project costs reflect waterway accident data. A two-step analysis process is followed for both modes: (1) estimate annual accidents, fatalities and injuries for the incremental traffic and (2) multiply the annual events by the applicable unit cost per property damage, fatality or injury.

3.1.1 Waterway Accident Factors and Costs

Information from a 1998 University of Memphis study, conducted for USACE, is used to estimate waterway accident costs.[26] The University of Memphis study quantified waterway accident damage costs and injury and death rates per ton-mile for the Upper Mississippi and Illinois waterways. The injury and death rates per ton-mile were then applied to injury and death cost estimates to determine the annual fatality and injury costs. The injury and death unit costs were obtained from the National Safety Council publication, *Accident Facts - 2002.*

To obtain injury and death rates and accident damage costs per ton-mile, the University of Memphis study reviewed a 1996 study conducted by the Transportation Analysis and Research Center for the USACE.[27] The 1996 study compiled waterway accident rates on the Upper Mississippi and Illinois waterways. Injury, death, and damage rates were

[26]University of Memphis, Transportation Studies Institute. *Accidents and Hazardous Spills Analysis for Upper Mississippi River Basin*, Prepared for U.S. Army Corps of Engineers, Rock Island District, September 1998.

[27]Transportation Research and Analysis Center. *Upper Mississippi River - Illinois Waterway System Navigation - Accidents and Hazardous Spills Task, Final Report*, Prepared for the U.S. Army Corps of Engineers, Rock Island District August 1996.

computed from two different U.S. Coast Guard accident databases – the CASMAIN database and the MINMOD database. When reviewing these rates, the authors of the University of Memphis study found large discrepancies. The largest discrepancy was in injury rates, where one database showed an injury rate that was 2 percent of the injury rate shown in the other. The 1998 authors found that the discrepancy was the result of one database reporting minor injuries not resulting from accidents (e.g., sprained wrists from winding rope). Thus, for purposes of computing injury rates on the Upper Mississippi and Illinois waterway systems, the 1998 authors used the more conservative estimates, as they found that injury statistics of other modes did not include injuries not resulting from accidents. For purposes of computing death rates and damage costs per ton-mile, the authors used the higher rate from the two databases.

The injury and death rates used in the University of Memphis study are used in this analysis, as are the damage costs per ton-mile. However, the property damage costs have been indexed to 2002 levels. All three waterway accident factors are shown in Table 16.

Table 16 Waterway Injury Rates, Death Rates, and Accident Damage Costs per Ton-Mile

	Upper Mississippi River	Illinois Waterway
Injuries per Ton-Mile	0.00000000011	0.000000000023
Deaths per Ton-Mile	0.000000000052	0.000000000058
Damage Cost per Ton-Mile (2002 $)	$0.0002807	$0.000033

Source: University of Memphis, Transportation Studies Institute. *Accidents and Hazardous Spills Analysis for Upper Mississippi River Basin*, Prepared for U.S. Army Corps of Engineers, Rock Island District, September 1998. (Damage Costs placed in 2001 prices using the GDP implicit price deflator.)

In order to estimate the change in waterway accident costs on the Lower Mississippi River system, the University of Memphis study adjusted the accident rates on the Upper Mississippi River by a relative risk factor. The authors examined the ratio of Upper Mississippi River insurance costs to insurance costs on the rest of the waterway system to estimate the risk on the Upper Mississippi relative to the rest of the waterway system. They found that the insurance costs per ton-mile on major segments of the inland waterway network connecting to the Upper Mississippi were 73 percent of the insurance costs per ton-mile on the Upper Mississippi. Thus, they adjusted the injury, death, and damage rates shown in Table 16 by multiplying them by .73 in order to obtain estimates for the lower Mississippi River. The same relationship is assumed to hold true for this study.

3.1.2 Railroad Accident Factors and Costs

Exposure to accidents increases with railroad activity levels or train-miles. Accident damage may increase with the weight of the train. However, the probability of an accident is affected mostly by train speed, traffic control, frequency of grade crossings, and many operational and human factors.

As railroad train-miles increase, the frequencies of three types of accidents are affected: (1) highway grade-crossing accidents, (2) trespasser accidents (e.g., people crossing rail tracks at unauthorized locations or trying to obtain illegal rides on freight trains); and (3)

train derailments and other types of road train accidents. Moreover, worker injuries or fatalities for trainmen and other railroad occupations may increase with train activity. For these reasons, railroad accidents are forecast on the basis of million train-miles.

Table 17 shows accident, injury, and fatality rates per million train-miles for the primary Class I railroads serving the study region. These rates were derived from the Federal Railroad Administration's Office of Safety Analysis Web Site.[28] The train accident, fatality, and injury rates were computed from the *Summary of Accident/Incident Counts* and *Summary of Operational Data* tables. They represent weighted averages for the 2000-2002 time frame. Each rate is calculated and weighted on the basis of million train-miles.

Table 17 Average Railroad Accident, Injury, and Fatality Rates per Million Train-Miles: 2000-2002

Railroad	Train Accidents	Fatalities	Nonfatal Injuries
BNSF	3.55	0.88	8.66
CSX	3.67	1.16	9.89
IC	6.08	1.89	17.30
NS	2.64	1.33	7.35
UP	4.59	1.18	10.02

The FRA defines a train accident as an event involving on-track equipment that results in monetary damages to track and equipment in excess of $6,600 (in 1998 dollars). Damage to the cargo is not included in property damage cost, although the railroad may be subject to loss and damage claims. Moreover, the cost of clearing wrecks and environmental mitigation are not reflected in these estimates.

Railroad property damage costs per train accident are shown in Table 18 for 2002.[29] These costs were calculated from the *Train Accidents by Type and Major Cause* and the *Summary of Accident/Incident Counts* tables.

Table 18 2002 Railroad Property Damage Cost per Train Accident (Thousands of Dollars)

BNSF	$115
CSX	$81
IC	$103
NS	$56
UP	$111

[28] http://safetydata.fra.dot.gov/officeofsafety/.

[29] The costs shown in Table 18 have been adjusted to exclude property damage incurred during rail-highway grade crossing accidents. This is a relatively small proportion of property damage cost (e.g., 1 to 2 percent). It is excluded so that a consistent comparison can be made between railroad and waterway property damage cost, since the latter includes only costs related to barge operations. Moreover, it is unclear whether rail-highway grade crossing property damages include the highway vehicle, in which case, the costs may be reflected elsewhere.

Railroad accident statistics are dominated by rail-highway grade-crossing crashes and trespasser accidents. As shown in Table 19, a minimum of 89 percent of railroad accidents during the 2000-2002 period were the result of highway-rail crossing or trespasser accidents.

Table 19 Highway-Rail Grade Crossing and Trespasser Accidents as a Percent of Total Railroad Accidents

Railroad	2000	2001	2002
BSNF	94%	93%	89%
UP	96%	97%	97%
IC	100%	96%	100%
NS	97%	97%	96%
CSX	94%	99%	97%

Because railroad accident factors are expressed in train-miles, they reflect the average characteristics of freight trains. In applying these rates, it is important to determine whether the characteristics of the incremental traffic (such as average train weights) are substantially different from the attributes of the typical train. Substantial differences in train weights may invalidate the use of system averages.[30]

Table 20 shows the average weight of freight train cars and contents for the primary railroads serving the study region. The train weights for the BNSF, IC, and UP are in the range of 6,000 to 6,100 gross tons. As a point of reference, a 75-car train of 100-ton covered hopper cars results in an average train weight of 6,100 tons.

Table 20 Average Gross Trailing Tons of Freight Trains for Railroads Serving the Study Region: 2000-2002

BNSF	6,045
CSX	4,725
Illinois Central	6,089
Norfolk Southern	4,913
Union Pacific	6,036

The incremental traffic includes a wide range of commodities of different shipment sizes. Much of the corn traffic moves in 100- and 110-car trains. However, wheat moves primarily in 25-to 50-cars blocks.[31] Other commodities move primarily as single cars. Given this traffic mix, a train size of 6,000 tons should be representative of the incremental traffic.

[30] For example, train stopping distances may be greater for heavier trains.
[31] On the BNSF, the car block sizes are 26 and 52. The 52-car blocks are frequently referred to as unit trains.

3.1.3 Assignment of Traffic to Railroads

As shown earlier, accident rates may vary significantly among railroads. Regional and state commodity flows are the finest level of traffic data available for this study. In some cases, destinations are grouped into regions such as the Gulf Coast or Pacific Northwest. In analyzing safety impacts it is desirable to allocate the incremental traffic among railroads. The alternative is to use national statistics, which may not be reflective of the study region.

Many criteria could be used to make assignments including: (1) the density of rail lines in the originating state, (2) the proximity of rail lines to areas served by the river, (3) the density of rail lines in the destination region, (4) the proximity of rail lines to destinations served by the river, and (5) the directness or circuitousness of the route. In many cases, the most likely railroad to haul the incremental traffic is apparent from criteria 1 and 3. For example, 40 percent of the incremental grain traffic is destined for the Pacific Northwest (PNW). UP and BNSF are the only railroads with direct access to the PNW. However, the remaining 60 percent of the incremental grain moves to the Gulf of Mexico. UP, BNSF, NS, and Illinois Central have direct access to the Gulf.

Because the Illinois Central operates primarily in the Mississippi Valley, it may be the most representative railroad for analyzing movements to the Gulf. However, IC's lines are located on the eastern edge of the study region. Moreover, the IC's accident rates are much higher than the rates of other railroads. As shown in Table 19, the IC's accident rates are affected by a higher proportion of train operations in large metropolitan areas such as Chicago, Memphis, and New Orleans, and a resulting higher percentage of grade crossing and trespasser accidents. Most of the train-miles associated with the incremental traffic would occur in rural areas. Moreover, the UP's lines are closer to the Illinois Waterway than the IC's lines. Overall, BNSF and UP are the railroads most likely to move the incremental traffic to the PNW and Gulf.

Based on the foregoing rationale, the assignment of incremental traffic to railroads consists of assigning traffic to the BNSF and UP in a representative manner. Incremental traffic that originates or terminates in Minnesota or Missouri is assigned to the BNSF. As shown in Appendix A, these two states comprise as much as 90 percent of the incremental grain traffic in the Tow Cost Model. More typically, these two states comprise about 40 percent of the incremental traffic for other scenarios. The incremental traffic originating or terminating in Illinois, Iowa, and Wisconsin is allocated to the UP. Overall, these assignments result in approximately half of the incremental traffic being assigned to each railroad, when all traffic scenarios are considered.[32]

Railroad train-miles are estimated from revenue ton-miles using a train-mile-to-revenue ton-mile ratio. This ratio is specific to each railroad. It reflects the average empty-to-loaded mile percentage and assigns empty train-miles to loaded movements.

[32] Clearly, other railroads would originate or terminate some of the incremental traffic. However, the aggregation of the data at the state level does not facilitate a more precise assignment. This mostly affects traffic originated or terminated in Illinois, which could be handled any of 5 Class I railroads.

Some of the incremental traffic may be originated or terminated by a local or regional railroad that connects to or parallels the Mississippi River or Illinois Waterway. In addition to the IAIS mentioned earlier, railroads such as the DM&E and IMRL would probably handle some of the incremental traffic in the without-project cases. However, the hauls would be relatively short. Class II and Class III railroads do consistently report data to the STB or FRA that could be used in this study. Therefore, Class I railroad accident rates are used for all traffic, even though some of it may be originated or terminated by a local or regional railroad.

3.1.4 Estimates of Fatality and Injury Costs

The unit costs used in this study are estimated by the National Safety Council (NSC) and represent the average costs of fatal and nonfatal unintentional injuries. The NSC uses four categories to classify unintentional injuries: Motor Vehicle, Work, Home, and Public. The cost of a fatality should not vary greatly across the four categories.[33] However, injury costs may differ substantially among the classifications. Because "Motor Vehicle" is the only transportation-related category published by NSC, it is a logical selection for this study. Many railroad fatalities and injuries result from highway grade-crossing accidents. Thus, motor vehicle fatality and injury costs are the most relevant category for analyzing railroad accidents. For purposes of consistency, the same unit costs are applied to waterway injuries.

NSC recommends the use of "comprehensive costs" for purposes of benefit-cost analysis.[34] Comprehensive costs include economic costs plus a measure of the value of "lost quality of life." The economic components of motor-vehicle injury and fatality costs include wage and productivity losses, medical expenses, and administrative expenses. Wage and productivity losses include the value of wages, fringe benefits, household production, and travel delay. Medical expenses include ambulance and helicopter transport costs. Administrative expenses include the administrative cost of insurance, police, and legal costs.[35]

According to NSC, the economic cost components alone totaled $1,090,000 for each death and $39,900 for each motor vehicle injury in 2002. However, these estimates do not include the "value of a person's natural desire to live longer or to protect the quality of one's life;" i.e., someone's willingness to pay for improved safety. This value has been estimated through empirical studies of what people actually pay to reduce their safety and health risks. When people's willingness to pay to avoid lost quality of life is considered, the estimated unit costs become $3,470,000 per death and $44,200 for a non-incapacitating injury. According to NSC, these comprehensive costs can be interpreted

[33] For example, the estimated economic cost of a fatality in 1998 varied by less than 8 percent between the motor vehicle and work environments.

[34] This description of comprehensive costs is paraphrased from: *Injury Facts, 1999 Edition*, National Safety Council.

[35] The administrative cost of motor-vehicle insurance is estimated as the difference between premiums earned (adjusted to remove fire, theft, and casualty premiums) and pure losses incurred. Legal expenses include court costs, and plaintiffs and defendant's time and expenses.

as "the maximum amount society should spend to prevent a statistical death or injury."

In January 2002, the General Counsel of the U.S. Department of Transportation recommended using a value of life of $3 million for departmental studies.[36] The $3 million figure was derived by updating a 1993 estimate using the GDP implicit price deflator for the third quarter of 2001. In comparison, the NSC estimate represents 2002 data for the economic cost components.

Because the NSC values are more current, they are used in this analysis.[37] However, the fatality cost is rounded to the nearest half-million dollars (e.g., $3.5 million) and the non-incapacitating injury cost is rounded to $44 thousand to indicate that these values are estimates rather than precise numbers.

3.2 Results of Safety Analysis

3.2.1 Summary of Incremental Traffic

The total incremental tons for each traffic scenario and alternative are summarized in Tables 21-25. As noted earlier, lock congestion fees would be imposed under Alternative 2. This explains the negative signs associated with the incremental tons. With lockage fees, this traffic would move on the railway instead of the waterway in the "with-project" case. This result is the opposite of the traffic pattern expected under the other alternatives. Alternatives 4, 5, and 6 envision the expansion of lock capacities, the construction of new locks, and the addition of mooring cells. If these investments are made, the incremental traffic would move on the waterway instead of the railway. Therefore, the incremental tons have positive signs for these alternatives.

Generally, the incremental tons grow over time. However, the growth occurs at varying rates, depending on the traffic scenario and alternative. Moreover, the growth occurs at declining rates over time.

Table 21 Incremental Tons: Scenario 2 – ESSENCE Lower Bound

	Incremental Tons (Millions)		
Alternative	**2025**	**2035**	**2050**
2	-7.41	-10.07	-11.04
4	1.30	2.69	2.90
5	2.98	5.73	6.27
6	2.85	8.06	9.44

Table 22 Incremental Tons: Scenario 3 – ESSENCE Lower Bound

[36] U.S. Department of Transportation. Revised Departmental Guidance. *Treatment of Value of Life and Injuries in Preparing Economic Evaluation*. January, 2002.
[37] Moreover, it is important not to underestimate the value of a life.

Incremental Tons (Millions)			
Alternative	**2025**	**2035**	**2050**
2	-10.16	-13.00	-15.03
4	2.61	4.65	4.84
5	5.32	10.33	12.38
6	5.55	14.39	18.67

Table 23 Incremental Tons: Scenario 3 – ESSENCE Upper Bound			
Incremental Tons (Millions)			
Alternative	**2025**	**2035**	**2050**
2	-11.90	-13.71	-14.83
4	3.51	5.12	4.95
5	8.81	13.82	15.49
6	9.22	22.11	25.98

Table 24 Incremental Tons: Scenario 3 – TCM			
Incremental Tons (Millions)			
Alternative	**2025**	**2035**	**2050**
2	-9.23	-9.06	-9.12
4	1.10	5.15	6.35
5	1.99	8.52	11.29
6	1.84	9.54	14.32

Table 25 Incremental Tons: Scenario 5 – ESSENCE Lower Bound			
Incremental Tons (Millions)			
Alternative	**2025**	**2035**	**2050**
2	-11.35	-15.26	-14.48
4	3.99	5.48	5.62
5	8.00	13.74	14.29
6	7.43	21.06	23.59

3.2.2 Projected Changes in Railroad Fatality Rates

The projected changes in railroad fatality rates associated with the incremental traffic are shown in Tables 26-30. Logically, it is impossible for a proportion of a fatality to occur. However, there is some need for precision in these estimates. Therefore, the fatality rates should be viewed as average rates that would occur over a multi-year period, based on the traffic forecast for the particular year.[38]

[38] In this case, the need for precision requires a factional number of fatalities. The authors apologize for any perceived insensitivity as a result of this approach.

Table 26 Average Annual Change in Railroad Fatalities: Scenario 2 – ESSENCE Lower Bound			
Alternative	**2025**	**2035**	**2050**
2	-3.3	-4.4	-4.8
4	0.6	1.2	1.3
5	1.3	2.6	2.9
6	1.3	3.6	4.2

Table 27 Average Annual Change in Railroad Fatalities: Scenario 3 – ESSENCE Lower Bound			
Alternative	**2025**	**2035**	**2050**
2	-4.6	-5.6	-6.6
4	1.2	2.1	2.2
5	2.4	4.8	5.6
6	2.5	6.5	8.3

Table 28 Average Annual Change in Railroad Fatalities: Scenario 3 – ESSENCE Upper Bound			
Alternative	**2025**	**2035**	**2050**
2	-5.4	-6.3	-6.9
4	1.6	2.3	2.3
5	4.0	6.4	7.1
6	4.2	10.0	11.7

Table 29 Average Annual Change in Railroad Fatalities: Scenario 3 – TCM			
Alternative	**2025**	**2035**	**2050**
2	-3.0	-3.1	-3.6
4	0.6	2.2	2.3
5	0.9	3.5	4.1
6	0.8	3.7	5.1

Table 30 Average Annual Change in Railroad Fatalities: Scenario 5 – ESSENCE Lower Bound			
Alternative	**2025**	**2035**	**2050**
2	-5.0	-6.5	-6.2
4	1.8	2.4	2.5
5	3.7	6.1	6.5
6	3.5	9.3	10.4

The changes in fatalities associated with Alternative 2 are negative. These values may be interpreted as *disbenefits* resulting from the implementation of a waterway congestion fee, which would divert traffic from waterways to railroads. Under Alternative 2, railway traffic would increase in the with-project case. The congestion fee may create benefits for traffic that continues to use the waterway because of lower congestion levels. These benefits to waterway users—which were computed in an earlier phase of the study—would be valued positively. Thus, for Alternative 2, the net benefits would be the sum of the disbenefits shown in this report, and the benefits computed in other study components.

3.2.3 Projected Changes in Accident Costs

The predicted change in accident cost is shown for each traffic scenario and alternative in Tables 31-35. These tables summarize the annual **net** change in total accident cost resulting from each of the proposed alternatives. As the tables show, the net change is very large for some alternatives; e.g., $39 million under Alternative 6 for Scenario 3 – Upper Bound.

Table 31 Change in Accident Cost: Scenario 2 – ESSENCE Lower Bound			
	Millions of Dollars		
Alternative	**2025**	**2035**	**2050**
2	-10.9	-14.7	-16.0
4	1.9	4.0	4.3
5	4.4	8.5	9.6
6	4.3	11.8	13.8

Table 32 Change in Accident Cost: Scenario 3 – ESSENCE Lower Bound			
	Millions of Dollars		
Alternative	**2025**	**2035**	**2050**
2	-15.2	-18.4	-21.6
4	3.9	7.0	7.0
5	7.9	15.6	18.3
6	8.2	21.3	27.1

Table 33 Change in Accident Cost: Scenario 3 – ESSENCE Upper Bound			
	Millions of Dollars		
Alternative	**2025**	**2035**	**2050**
2	-18.0	-20.8	-22.8
4	5.3	7.7	7.7
5	13.3	21.1	23.4
6	13.8	32.8	38.5

Table 34 Change in Accident Cost: Scenario 3 – TCM			
	Millions of Dollars		
Alternative	**2025**	**2035**	**2050**
2	-9.8	-9.9	-11.6
4	2.1	7.2	7.3
5	2.7	11.4	13.3
6	2.5	12.0	16.4

Table 35 Change in Accident Cost: Scenario 5 – ESSENCE Lower Bound			
	Millions of Dollars		
Alternative	**2025**	**2035**	**2050**
2	-16.5	-21.4	-20.5
4	5.9	7.8	8.0
5	12.1	20.2	21.2
6	11.6	30.4	33.9

3.2.4 Caveats Regarding Safety Analysis

It should be noted that the estimation of accident costs is not an attempt to place blame or portray railroads as an unsafe mode. As shown in Table 19, the preponderance of rail-related fatalities and injuries result from highway-rail grade crossing collisions and from trespassers making illegal and ill-advised track crossings. Indeed, the railroads are blameless in many of these cases. Nevertheless, from a social-cost perspective, the injury or fatality is relevant, regardless of fault. It is nearly impossible for a barge to collide with an automobile. Moreover, the concept of trespassing is much different between rail and barge transportation. These differences are simply functions of the ways used and their proximity to pedestrians and drivers.

Many facets of accident-related costs are reflected in railroad and barge casualty and insurance costs, and thus may be reflected in part or in whole in the benefits estimated in earlier studies. Most likely, the costs of worker injuries are included in casualty and insurance costs and thus are accounted for already. However, the answer is not so clear for motor vehicle, trespasser, and other non-worker fatalities and injuries.

4. GRADE-CROSSING TRAFFIC DELAYS

Incremental railroad traffic will result in changes in traveler delay at railroad/highway crossings. A comprehensive analysis of grade crossing delay is beyond the scope of this study. Such an analysis would require the precise routing of all incremental traffic from origin to destination, so that incremental trains could be forecast at all crossings. However, several illustrations are presented in this report based on probable routings.

Two route scenarios are analyzed. In the first scenario, half of the grain traffic to the Gulf (or 30 percent of the incremental grain traffic) is assigned to UP lines that run through East St. Louis, Pine Bluff, AR, and several other cities en route to New Orleans.

In the second scenario, all of the grain traffic to the Gulf (or 60 percent of the incremental grain traffic) is assigned to UP lines.

4.1 Grade-Crossing Data

Grade crossing data have been compiled for each route from the Federal Railroad Administration's Highway-Rail Crossing Inventory. Both the crossing delay and noise analysis procedures utilize this database. The Crossing Inventory Files are located at FRA's Safety Analysis website, http://safetydata.fra.dot.gov/officeofsafety/.

The Crossing Inventory contains the following information for each crossing:

- Crossing Number
- City and State
- Railroad
- Branch name and railroad subdivision
- Type of grade crossing
- Number of through trains per day (stratified by daytime versus nighttime trains)
- Number of switching or local trains per day
- Maximum train speed
- Average annual daily traffic (AADT)
- Type of crossing highway and number of traffic lanes
- Percent trucks in the highway traffic stream

The key data elements are summarized in Table 36.

Table 36 Key Highway-Rail Crossing Inventory Data Elements

Data Item	Description
Crossing No.	6 numeric characters followed by 1 alphabetic character
State	2-character state code
County	4-character county code
Railroad Operating Company	
RR Division	Railroad Division Name
RR Subdivision	Railroad Subdivision
Branch or Line Name	Branch/Line Name
RR Milepost	Milepost reference of crossing
Type of Crossing	11-Pedestrian at grade 12-Pedestrian RR under 13-Pedestrian RR over 21-Private at grade 22-Private RR under 23-Private RR over 31-Public at grade 32-Public RR under 33-Public RR over)
Position of Crossing	1=At grade under 2=RR Under 3=RR over
Private Crossing Category	1=Farm 2=Residential 3=Recreational 4=Industrial 5=Commercial
Day Thru Train Movements	
Night Thru Train Movements	

Table 36 Key Highway-Rail Crossing Inventory Data Elements	
Data Item	**Description**
Night Switching Movements	
Maximum Timetable Speed	
No. of Traffic Lanes Crossing RR	
AADT	Annual Average Daily Traffic (AADT)
Percent Trucks:	Percent of Trucks in Traffic Stream of Crossing Highway

4.1.1 Development of Highway-Rail Crossing Data Files

For the delay analysis, crossings with less than 100 AADT were eliminated, as well as grade-separated crossings, private crossings, and crossings reporting a maximum speed of zero.[39] The day and night through-train movements represent the number of existing trains at the highway-rail crossing. The incremental trains were calculated from the incremental tons for each traffic scenario and apportioned to the crossing in relation to the existing ratio of day to night through trains. The noise analysis data file (discussed later) is nearly identical to the delay crossing file with the exception that public railroad over and under crossings are also used.[40]

4.1.2 Identification of Union Pacific Route to the Gulf

The current railroad traffic movements were identified using the U.S. Waybill sample. The Waybill data reported railroad traffic movements to the Gulf region which were identified as Union Pacific movements terminating in the New Orleans Business Economic Analysis Area (BEA). Additional analysis of zip codes identified Union Pacific traffic terminating in the southern region of the New Orleans metropolitan area. Conversations with a Union Pacific representative,[41] in conjunction with the waybill analysis and UP railroad maps, helped identify a route originating in the analysis region terminating in the New Orleans BEA. The route originates in Illinois and moves southward through Missouri, Arkansas and Louisiana through the following Union Pacific railroad subdivisions.

- Springfield
- Chester
- Jonesboro
- Pine Bluff
- McGehee
- Monroe
- Alexandria
- Livonia

[39] Highway-rail crossings reporting no main-line track were also eliminated from the data file.
[40] The highway-rail crossing data files developed for the Union Pacific analysis to the Gulf used the railroad subdivision, state and city identifiers in the crossings database. These fields contain geographic and railroad information allowing for the identification of a specific route and the accompanying route highway-rail crossings. All crossings on the identified route not meeting the specifications described earlier were eliminated from the route.
[41] Telephone conversation with John Bromley, Union Pacific, November 25, 2003.

- Avondale

Railroad timetables for these subdivisions are available at the Union Pacific website located at http://www.up.com/. Cities along the route include East St. Louis, IL, Pine Bluff, AR., and the southern New Orleans metropolitan area.

4.2 Analysis Methods

The illustrations are based on a methodology developed by the Section of Environmental Analysis (SEA) of the Surface Transportation Board. SEA typically prepares an independent environmental review for proposed railroad projects that would generate significant environmental impacts. The methods are the same ones used in the recent DM&E Powder River Basin Line Extension case.

Three of the most important factors that affect traveler delay are: (1) the number of trains per day, (2) the time it takes a train to pass through the highway/rail crossing, and (3) the number of highway vehicles that move through the crossing each day. Another important consideration is the time of day a crossing is blocked. If a crossing is blocked during rush hour, many more vehicles will delayed than if it is blocked during the off-peak period. The following impact indicators are considered in the analysis:

- Blocked crossing time per train
- Average vehicular delay
- Number of vehicles delayed per day
- Maximum vehicle queue
- Average delay for all vehicles

4.2.1 Blocked Crossing Time per Train

The time required for a train to pass through a grade crossing is called the "blocked crossing time." Intuitively, blocked crossing time is a function of train length and speed. In addition, blocked crossing time includes the elapsed time until the last vehicle has cleared the crossing.

In the DM&E case, STB used the following equation—derived from FRA's *Guidebook for Planning to Alleviate Urban Railroad Problems*—to estimate blocked crossing times.

$$(3) \quad TB = \frac{L}{88\ V} + 0.5$$

Where:

TB	=	The time during which a train blocks a grade crossing, in minutes
L	=	Length of the train in feet
V	=	Train speed, in miles per hour
88	=	Conversion factor from miles per hour to feet per minute
0.5	=	Additional delay until the last vehicle clears crossing (30 seconds)

4.2.2 Average Vehicular Delay

The "average vehicular delay" is the average time a driver has to wait at a highway/rail grade crossing when traffic is stopped to let a train pass. The arrival rate of vehicles at a blocked crossing is a key assumption in this calculation. In the DM&E case, STB assumed that vehicles would arrive at a blocked crossing in a uniformly distributed manner. Based on this assumption, SEA calculated the average delay using Equation 4 which is derived from FRA's *Guidebook for Planning to Alleviate Urban Railroad Problems.*[42]

(4) $TD = 0.5\,TB + .3$

Where:

TD = Average vehicular delay, in minutes
0.5 = Average delay factor per vehicle, assuming a uniform distribution of arrivals
0.3 = An allowance for queue dissipation, in minutes

Equation 4 assumes that the average vehicle will be delayed half the time it takes for the crossing to clear, plus an additional 20 seconds before the queue dissipates completely.

4.2.3 Number of Vehicles Delayed Per Day

The number of vehicles delayed per day represents the number of drivers in a 24-hour period stopped for trains at grade crossings. STB estimates the number of vehicles delayed per day from the following equation:

(5) $VD = ADT\left(\frac{N * TB}{1440}\right)$

Where:

VD = Number of vehicles delayed per day
TB = The time during which a train blocks a grade crossing, in minutes
N = Number of trains per day
ADT = Average daily traffic
1440 = Minutes per day

The term *(N*TB)/1440* is the proportion of time during a 24-hour period that the crossing is blocked by a train. If the arrival of trains and vehicles at the crossing are uniformly distributed, then *(N*TB)/1440* represents the probability that a vehicle will encounter an occupied crossing.

[42] Federal Railroad Administration, *Guidebook for Planning to Alleviate Urban Railroad Problems*, June 1972, DOT-FR-20037.

4.2.4 Maximum Vehicle Queue

The maximum vehicle queue is the longest queue expected at the grade crossing during a 24-hour period. Logically, the maximum queue should occur during the peak travel hours of the day. In the DM&E case, STB estimated the maximum vehicle queue from Equation 4, which assumes that 10 percent of ADT occurs during peak hours and 60 percent of vehicles move in the peak traffic direction.

$$(6) \quad Q = 0.1ADT\left[\frac{0.6}{60}\right]\left[\frac{TB}{\left(NL/2\right)}\right]$$

Where:

Q = Maximum vehicle queue in peak hour (number of vehicles)
0.1 = Factor to convert ADT to peak-hour traffic
0.6 = Factor to convert two-way traffic to peak direction traffic
60 = Factor to convert traffic volume per hour to traffic volume per minute
NL = Number of roadway lanes at grade crossing
2 = Factor to convert total roadway lanes to peak-direction lanes

4.2.5 Emergency Vehicle Response

If a crossing is blocked by a train, an emergency vehicle could be delayed. Several of the indicators presented earlier are useful measures of potential delay. The average delay per vehicle (TD) caused by a train moving through a grade crossing is an indicator of the average time an emergency vehicle might have to wait if a grade crossing is blocked. The blocked crossing time (TB) is an indicator of the risk of delay since it is an indirect measure of the probability that a grade crossing will be blocked when an emergency vehicle needs to cross. The total blocked crossing time is computed by multiplying the number of trains per day (N) times the blocked crossing time per train (TB).

Although this procedure provides an analysis of the increased risk of delay, it does not address the consequences of delay. Clearly, there is an opportunity cost to a driver delayed at a blocked crossing. However, the driver's lost time in no way compares to the potential loss of health or life resulting from the delay of an emergency vehicle.

The grade crossing delay and noise analysis procedures utilize the same database. Changes in noise levels are analyzed at the same crossings, using the same number of incremental trains. Therefore, the results are presented together, later in the report. Next, the noise analysis procedures are highlighted.

5. NOISE ANALYSIS PROCEDURES

Noise is an important community impact that is considered by the STB in rail-line analyses. Incremental railroad traffic may result in three main types of noise: (1) locomotive (propulsive) noise, (2) train noise, and (3) horn noise. Locomotive noise includes engine-related and exhaust noise. Train noise includes all other sounds emanating from a moving train, except horn noise. Contact noise (e.g., noise generated by steel wheels in contact with steel rails) is the primary source of train noise. Contact noise includes rolling (normal), curve, and impact noise. Contact noise is intensified in curves, where contact pressure between wheel flange and rail is greatest. Contact noise may fluctuate and peak during a train passage as a result of discontinuities or imperfections in the wheel or rail. Repetitive impact noises may result from car wheels traversing rail joints. In general, contact noise varies with train speed, condition of wheels and rails, and type of rail. Engine noise varies with the throttle setting, age, and type of locomotive.

The locomotives are the dominant source of noise as a train approaches a fixed wayside point. Horn noise occurs in the vicinity of highway-railroad grade crossings or in emergency situations when the train horn must be sounded. When the horn is sounded, it creates the maximum noise level of the event. When the locomotive horn is sounded as a train approaches a crossing, it almost always constitutes the maximum noise level of the event.

5.1 Data and Analysis Methods

Incremental traffic may increase both railroad yard and train noise levels. Yard noises are more continuous in nature, and resemble highway noises. Given the level of data aggregation, it is not possible to model changes in yard noise in this study. Moreover, it is unlikely that significant incremental impacts would occur. Therefore, the report focuses on train noise. In comparison to yard noises, train noise events are discrete and discontinuous. Some train noises—such as the locomotive horn—occur only briefly during an event. For these reasons, train noise impacts are analyzed as single-event noises.

Train noise regulations are based on sound levels at 100 feet from the centerline of the track. Sound-level meters at these locations are designed to average the sound intensity over 1 second intervals. These sound-level meters are equipped with weighting circuits that filter out very low and high frequencies in much the same way a human ear would function. These filtered measurements are referred to as A-weighted decibels (dBA).

5.1.1 Housing Database File

The noise analysis required the development of a database of housing information for selected cities along the Union Pacific route to the Gulf. The housing information was used to calculate the number of housing units affected by the increase in noise levels associated with the incremental trains resulting from the traffic scenarios. Housing data

were obtained from the U.S. Census Bureau American FactFinder's website at http://factfinder.census.gov/home/saff/main.html?_lang=en. The website provides 2000 census data. Table 37 details the city and housing data used in the analysis.

Table 37 Housing Density for Selected UP/Gulf Route Cities.

City	Number of Housing Units	Land Area in Square Miles	Housing Density (per sq. mile)
East St. Louis, Il.	12,899	14.06	917.43
Pine Bluff, Ar.	22,484	45.61	492.96
Westwego, La.	4,521	6.68	1,287.57
Marrero, La.	13,046	8.05	1,620.62
Harvey, La.	8,601	3.19	1,417.24

Westwego, Marrero, and Harvey are in the southern New Orleans metropolitan area and are summarized as 'New Orleans' in the analysis results. These cities were identified from the Waybill analysis and the highway-rail crossing inventory as having Union Pacific railroad traffic.

The cities listed in Table 37 are by no means the only ones that would be affected by railway noise. The noise analysis should be viewed as an illustration of potential impacts at grade crossings in these cities. A complete analysis would require the estimation of noise levels at all locations along railroad routes, not just the crossings. The detailed information necessary for such an analysis would require substantial development time and the cooperation of railroads and affected communities. The illustrations presented in this report are intended to describe the potential scope and magnitude of these impacts.

5.1.2 Equivalent Sound Level of a Single-Noise Event

The equivalent sound level (L_{eq}) of a train event is measured by estimating the cumulative noise intensity of the event and dividing by the time duration of the event. If the fluctuating noises during an event are replaced by a constant noise equal to $L_{eq}(T)$, and $L_{eq}(T)$ is multiplied by the time of the event (t), then the receiver (and the human ear) will be exposed to the same total noise energy.

This is the basis for the Single-Event Noise Level (SEL) which is used by the Surface Transportation Board for purposes of environmental analysis. It is a measure of the total sound energy of an event, taking into account its equivalent intensity per second and its time duration. SEL is computed as: $L_{eq} + 10Log_{10}(t)$, where L_{eq} is defined as 10 times the log of the definite integral of the A-weighted sound levels with respect to time (t), divided by time. Intuitively, SEL is the product of the equivalent sound level per second and the seconds required for a train to pass a fixed wayside point where the sound intensity level is being measured.[43]

[43] Because both terms of the equation are logarithmic, SEL is computed through logarithmic multiplication. The product of two logarithmic terms is derived through addition.

5.1.3 Locomotive Versus Freight Car Noise

The SEL of a passing freight train may be viewed as the sum of two distinct sound events: locomotive noise and freight car noise. Locomotive noise may include propulsive and horn noise. Freight car noise includes contact and non-contact sounds. The total SEL of a passing train is computed as:

$$(7) \quad SEL_{total} = 10\log_{10}\left[10^{SEL(loc)/10} + 10^{SEL(car)/10}\right]$$

Where SEL_{loc} represents the SEL of the locomotives, and SEL_{car} represents the SEL of the remainder of the train. The SEL_{total} is assumed to be measured at 100 feet from the centerline of the track, in which case it is denoted as SEL_{total} (100 feet). However, this noise is attenuated at a rate of 4.5 dBA with each doubling of distance from the source.

Intuitively, SEL is elevated by both train velocity and length. Rolling, curve, and impact noises increase with train speed. A longer train requires more time to pass a fixed wayside location at a constant speed. Thus, train length has a separate time-related effect on SEL. The STB has developed an equation for SEL_{car} that considers both effects:

$$(8) \quad SEL_{car}(100\,feet) = 48.5 + 18.2\log_{10} V + \log_{10} T$$

In this equation, V represents velocity in miles per hour while T represents the total train passage time in seconds. T can be approximated by the following equation, where X is the average train length in feet:

$$(9) \quad T = 0.68(X/V)$$

5.1.4 Noise Attenuation with Distance

After analyzing field data in the DM&E case, SEA concluded that SEL measured near the track decays at a rate of 4.5 dBA for each doubling of distance. This decay rate includes ground attenuation, as well as losses in sound intensity resulting from distance. This relationship is represented as:

$$(10) \quad L_2 = L_1 + 15\log_{10}\left(\frac{D_1}{D_2}\right)$$

Where:

D_1 = Reference distance from track centerline
D_2 = D_1 plus a distance increment
L_1 = SEL at D_1
L_2 = SEL at D_2

When the ratio D_1/D_2 equals .5, the log of the ratio equals minus .3, and the term $15Log_{10}(D_1/D_2)$ equals minus 4.5.[44]

5.1.5 Nighttime Noise Levels

Rail lines are operated on a 24-hour basis. Usually, some trains pass through communities at night. A weighted-average Day-Night Sound Level (L_{dn}) is used to account for the differential effects of noises throughout the day.

L_{dn} represents a weighted-average of a receiver's cumulative average noise exposure from all events during a 24-hour period. Noise events that occur between 10 p.m. and 7 a.m. are increased by 10 decibels to account for increased annoyance from loss of sleep. If L_d is denoted as L_{eq}(h) for daytime hours from 7 am to 10 pm and L_n denote L_{eq}(h) for nighttime hours from 10 pm to 7 am, then L_{dn} can be expressed mathematically as:

$$(11) \quad L_{dn} = 10\log_{10}\left\{\frac{1}{24}\left[15\left(10^{L_d/10}\right)+9\left(10^{(L_n+10)/10}\right)\right]\right\}$$

5.2 Specific Steps and Methods in Noise Analysis

5.2.1 Compute Locomotive SEL

This computation depends upon whether the train horn is sounded. Because horn noise usually starts ¼ mile before a grade crossing and continues until the locomotive is through the crossing, it constitutes the dominant sound of the noise event. On the basis of field tests, the STB has concluded that locomotive SEL (SEL_{loc}) is 112.5 dBA at 100 feet from the track centerline when the train horn is sounded. When the horn is not sounded, SEL_{loc} is computed from Equation 12.

$$(12) \quad SEL_{loc} = L_{eq} + 10\log_{10}(t)$$

Equation 12 is used for over- and under-crossings where the horn is not required to be sounded. For all at-grade crossings, the assumed SEL_{loc} is 112.5 dBA.

5.2.2 Compute Freight Car SEL

The train passage time (T) in seconds is computed using Equation 12.

$$(13) \quad T = 0.68(X/V)$$

The SEL of the freight cars is then computed using Equation 13.

$$(14) \quad SEL_{car}(100\,feet) = 48.5 + 18.2\log_{10}V + 10\log_{10}T$$

[44] This equation underestimates SEL decay rate in some instances because it does not account for rows of buildings near the track. Rows of buildings between the train and the receiver may act as acoustical shields and attenuate sound. However, the STB assumed no acoustical attenuation in the DM&E case.

5.2.3 Compute Total Train SEL

Total train SEL is computed using Equation 14.

$$(15) \qquad SEL_{total} = 10\log_{10}\left[10^{SEL(loc)/10} + 10^{SEL(cars)/10}\right]$$

5.2.4 Compute Equivalent Day-Night Sound Level

The Day-Night Sound Level is computed using Equation 16. However, the SEL is increased by 10 decibels for nighttime movements. As noted earlier, incremental trains are assumed to be distributed among day and nighttime hours in the same proportion as existing train traffic. Thus, the railroad-related L_{dn} shown in Equation 16 represents a weighted-average SEL for all train events during a 24-hour period (SEL_{mean}), where night-time SEL measurements are weighted by 10 dBA and N equals the number of train passages.[45]

$$(16) \qquad L_{dn}(100\,feet) = SEL_{mean}(100\,feet) + 10\log_{10} N - 49.4$$

5.2.5 Compute Distance to 65 dBA Contour Line

A key question is: When does the railway noise level exceed a threshold that would constitute a community impact? Many agencies have adopted an L_{dn} value of 65 dBA as a threshold above which "land is considered incompatible for schools, hospitals, and residential use."[46] The Department of Housing and Urban Development (HUD) in its environmental noise standards defines an L_{dn} of 65 as the beginning of a "normally unacceptable noise zone."[47] Similarly, Federal Aviation Administration (FAA) considers noise environments where the L_{dn} is greater than 65 dBA as "not compatible with residential land uses."[48]

Clearly, noise impacts depend upon the distance of a receptor from the track and the rate of attenuation. A useful technique developed by the STB is to identify the distance from the track centerline to the 65 L_{dn} contour and then analyze the receptors that fall inside these lines. This distance to the 65 L_{dn} contour is represented in Equation 17.[49]

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[45] It should be noted that both logarithmic multiplication and division are performed in Equation 15. The mean SEL per event is multiplied by the number of events. The resulting product is divided by the seconds in a 24-hour period. The constant term 49.4 is a simplification of 10 times the log of 86,400 seconds.

[46] U.S. Department of Housing and Urban Development, "Environmental Criteria and Standards", 24 Code of Federal Regulations Part 51, 12 July 1979; amended by 49 FR 880, 6 January 1984.

[47] U.S. Department of Housing and Urban Development, "Environmental Criteria and Standards", 24 Code of Federal Regulations Part 51, 12 July 1979; amended by 49 FR 880, 6 January 1984.

[48] U.S. Department of Housing and Urban Development, "Environmental Criteria and Standards", 24 Code of Federal Regulations Part 51, 12 July 1979; amended by 49 FR 880, 6 January 198

[49] Equation 16 is derived from Equation 9 by letting D_1 equal 100 and L_2 equal 65. Subtracting L_1 from both sides of the equation and dividing by 15 yields: $(65-L_1)/15 = \text{Log}(100/D_2) = \text{Log}(100) - \text{Log}(D_2)$. Multiplying both sides of the equation by minus 1 yields: $(L_1-65)/15 = \text{Log}(D_2) - \text{Log}(100) = \text{Log}(D_2/100)$. By the definition of a logarithm, this expression is equivalent to: $10^{(L_1-65)/15} = D_2/100$, or $D_2 = 100[10^{(L_1-65)/15}]$.

(17) $$D = 100\left[10^{(L_{dn}100\,ft-65)/15}\right]$$

In the noise impact analysis, the distance to the 65 L_{dn} contour was estimated at each crossing based on noise levels from existing daytime and nighttime trains. Then, the incremental trains were included and the distance to the 65 L_{dn} contour was recomputed. The additional housing units impacted are those units which lie outside of the 65 L_{dn} contour with existing train traffic, but which would lie within the 65 L_{dn} contour with the incremental train traffic.

6. RESULTS OF CROSSING AND NOISE ANALYSIS

In these illustrations, the annual incremental trains have been rounded to an integer value. An integer value is necessary for the calculations, because train length is an input to both the delay and noise equations. The train size is assumed to be the same as the UP system average in 2001 (82 cars). Freight cars may be of varying lengths. A simplifying assumption is made that the incremental trains would be composed primarily of hopper and gondola cars, each with an approximate length of 58 feet from coupler to coupler. Three locomotives are assigned to each train. With the locomotives included, the approximate train length is 5,100 feet.

It must be recognized that this length represents a hypothetical system-average UP train, and is not based on observed data. Moreover, the annual trains are converted to an average daily value and allocated between day and nighttime hours. With the uncertainty involved in these assumptions, the estimates should be viewed as illustrations of potential impacts and the maximum impacts likely to occur at these crossings. Moreover, the noise analysis includes only the area within one-quarter mile of the approach to a crossing. This is the expected distance duration of the locomotive horn sound. In actuality, noise impacts would occur along the entire route. However, the change in noise levels is very dependent upon the existing train traffic at each location, as well as the number of incremental trains. Therefore, an analysis of noise impacts between crossings is not attempted.

6.1 Illustrative Impacts for 30 Percent of Incremental Grain Traffic

Table 38-52 list the estimated crossing delay and noise impacts, assuming that 30 percent of the incremental grain traffic moves via the Gulf route. Alternatives with the same number of incremental trains show the same impacts. As noted earlier, the rounding of trains introduces a significant approximation error for small numbers of incremental trains.

An example is used to illustrate the interpretation of the tables. Under Alternative 6 (TCM) in 2050, the projected change in housing units subject to railroad L_{dn} of 65 dBA or greater is 648 (Table 43). Approximately 1,244,000 fewer highway vehicles would

encounter grade-crossing delays in the with-project case, totaling 38,000 hours per year. In 2050, under Alternative 6 (Scenario 3 – ESSENCE Lower Bound) the projected change in housing units subject to railroad L_{dn} of 65 dBA or greater is 1,016 (Table 46). Approximately 2,073,000 fewer highway vehicles would encounter-grade crossing delays, totaling 64,000 hours per year. Under Alternative 6 (Scenario 3 – ESSENCE Upper Bound) in 2050, the projected change in housing units subject to railroad L_{dn} of 65 dBA or greater is 1,193 (Table 49). Approximately 2,488,000 fewer highway vehicles would encounter grade-crossing delays, totaling 77,000 hours per year. Negative signs associated with Alternative 2 (which reflects lockage fees) indicate that additional traffic would move on the railway instead of the waterway in the with-project case, resulting in negative benefits or disbenefits.

Table 38 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 2 – ESSENCE Lower Bound: 2025

Alternative	Additional Housing Units Greater Than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-451	-2	-25,630	-829,264
4	241	1	12,815	414,632
5	241	1	12,815	414,632
6	241	1	12,815	414,632

Table 39 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 2 – ESSENCE Lower Bound: 2035

Alternative	Additional Housing Units Greater Than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-648	-3	-38,445	-1,243,897
4	241	1	12,815	414,632
5	451	2	25,630	829,264
6	451	2	25,630	829,264

Table 40 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 2 – ESSENCE Lower Bound: 2050

Alternative	Additional Housing Units Greater Than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-648	-3	-38,445	-1,243,897
4	241	1	12,815	414,632
5	451	2	25,630	829,264
6	648	3	38,445	1,243,897

Table 41 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – TCM: 2025

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-451	-2	-25,630	-829,264
4	241	1	12,815	414,632
5	241	1	12,815	414,632
6	241	1	12,815	414,632

Table 42 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – TCM: 2035

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-451	-2	-25,630	-829,264
4	451	2	25,630	829,264
5	648	3	38,445	1,243,897
6	648	3	38,445	1,243,897

Table 43 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – TCM: 2050

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-648	-3	-38,445	-1,243,897
4	241	1	12,815	414,632
5	648	3	38,445	1,243,897
6	648	3	38,445	1,243,897

Table 44 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – ESSENCE Lower Bound: 2025

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-451	-2	-25,630	-829,264
4	241	1	12,815	414,632
5	451	2	25,630	829,264
6	451	2	25,630	829,264

Table 45 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – ESSENCE Lower Bound: 2035

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-648	-3	-38,445	-1,243,897
4	241	1	12,815	414,632
5	648	3	38,445	1,243,897
6	837	4	51,260	1,658,529

Table 46 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – ESSENCE Lower Bound: 2050

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-837	-4	-51,260	-1,658,529
4	451	2	25,630	829,264
5	648	3	38,445	1,243,897
6	1,016	5	64,075	2,073,161

Table 47 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – ESSENCE Upper Bound: 2025

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-648	-3	-38,445	-1,243,897
4	241	1	12,815	414,632
5	451	2	25,630	829,264
6	451	2	25,630	829,264

Table 48 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – ESSENCE Upper Bound: 2035

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	- 648	-3	-38,445	-1,243,897
4	451	2	25,630	829,264
5	648	3	38,445	1,243,897
6	1,016	5	64,075	2,073,161

Table 49 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 3 – ESSENCE Upper Bound: 2050

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-837	-4	-51,260	-1,658,529
4	451	2	25,630	829,264
5	837	4	51,260	1,658,529
6	1,193	6	76,889	2,487,793

Table 50 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 5 – ESSENCE Lower Bound: 2025

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-648	-3	-38,445	-1,243,897
4	241	1	12,815	414,632
5	451	2	25,630	829,264
6	451	2	25,630	829,264

Table 51 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 5 – ESSENCE Lower Bound: 2035

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-837	-4	-51,260	-1,658,529
4	451	2	25,630	829,264
5	648	3	38,445	1,243,897
6	1,016	5	64,075	2,073,161

Table 52 Crossing Noise and Delay Impacts With 30 Percent of Incremental Grain Traffic: Scenario 5 – ESSENCE Lower Bound: 2050

Alternative	Additional Housing Units Greater than 65 DBA	Trains per Day	Delay per Year in hours	Vehicles Delayed per Year
2	-837	-4	-51,260	-1,658,529
4	451	2	25,630	829,264
5	837	4	51,260	1,658,529
6	1,193	6	76,889	2,487,793

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Appendix A. Forecasts of Incremental Tons – by Year, Commodity, Origin, and Destination

Table A.1 Incremental Tons: By Commodity Group
Traffic Scenario 2 – ESSENCE Lower Bound: 2025

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-6,514,305	1,143,962	2,639,099	2,727,882
Coal Mining	-14,571	1,886	2,442	638
Chemicals	-356,631	66,377	154,387	-23,267
Petrol Ref	-451,859	62,856	138,135	99,231
SC&G Prod	-27,462	18,383	40,848	37,567
Iron & Steel	-40,423	4,159	8,838	6,442
Total	-7,405,251	1,297,623	2,983,749	2,848,493

Table A.2 Incremental Tons: By Origin Region
Traffic Scenario 2 – ESSENCE Lower Bound: 2025

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-2,967,979	320,377	751,660	644,309
Iowa	-1,649,802	396,956	928,179	1,010,812
Minnesota	-1,787,232	373,469	852,952	903,140
Missouri	-493,029	94,425	195,490	208,000
Wisconsin	-119,434	28,866	67,699	72,020
Lower Miss.	-327,089	62,093	137,259	-32,466
Other U.S.	-60,686	21,437	50,510	42,678
Total	-7,405,251	1,297,623	2,983,749	2,848,493

Table A.3 Incremental Tons: By Destination Region
Traffic Scenario 2 – ESSENCE Lower Bound: 2025

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-648,664	69,573	161,582	-42,914
Iowa	-25,121	21,284	46,053	45,938
Minnesota	-21,105	26,391	58,848	60,254
Missouri	-263,874	37,004	76,312	78,536
Wisconsin	-4,970	13,016	20,807	21,517
Lower Miss.	-6,391,867	1,121,870	2,598,274	2,669,619
Other U.S.	-49,650	8,485	21,873	15,543
Total	-7,405,251	1,297,623	2,983,749	2,848,493

Table A.4 Incremental Tons: By Commodity Group
Traffic Scenario 2 – ESSENCE Lower Bound: 2035

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-9,248,311	2,437,875	5,097,585	6,836,442
Coal Mining	-105,261	190	9,617	12,794
Chemicals	-230,633	152,513	308,275	640,849
Petrol Ref	-420,714	76,203	232,453	401,166
SC&G Prod	-12,428	22,801	65,070	138,567
Iron & Steel	-52,232	4,977	13,703	25,698
Total	-10,069,579	2,694,559	5,726,703	8,055,516

Table A.5 Incremental Tons: By Origin Region
Traffic Scenario 2 – ESSENCE Lower Bound: 2035

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-4,333,084	629,951	1,375,052	2,106,106
Iowa	-1,664,089	781,149	1,691,617	2,207,412
Minnesota	-3,016,836	850,371	1,779,014	2,421,477
Missouri	-644,559	207,237	399,187	427,417
Wisconsin	-151,361	59,487	130,113	183,676
Lower Miss.	-207,818	120,619	256,833	562,700
Other U.S.	-51,832	45,745	94,887	146,728
Total	-10,069,579	2,694,559	5,726,703	8,055,516

Table A.6 Incremental Tons: By Destination Region
Traffic Scenario 2 – ESSENCE Lower Bound: 2035

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-576,424	106,897	300,232	687,462
Iowa	6,555	35,894	81,052	141,057
Minnesota	6,274	61,594	122,501	168,851
Missouri	-259,763	88,667	162,110	180,532
Wisconsin	-399	9,814	29,388	39,554
Lower Miss.	-9,186,105	2,378,679	4,998,779	6,773,908
Other U.S.	-59,717	13,014	32,641	64,152
Total	-10,069,579	2,694,559	5,726,703	8,055,516

Table A.7 Incremental Tons: By Commodity Group
Traffic Scenario 2 – ESSENCE Lower Bound: 2050

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-9,973,033	2,556,009	5,669,633	7,819,621
Coal Mining	-123,591	319	10,694	15,352
Chemicals	-411,793	205,398	433,919	896,593
Petrol Ref	-441,067	113,491	275,183	506,361
SC&G Prod	-13,591	17,872	-133,773	169,230
Iron & Steel	-75,730	6,012	17,274	36,075
Total	-11,038,805	2,899,101	6,272,930	9,443,232

Table A.8 Incremental Tons: By Origin Region
Traffic Scenario 2 – ESSENCE Lower Bound: 2050

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-4,988,194	702,935	1,398,809	2,585,683
Iowa	-1,471,417	806,289	1,859,511	2,476,073
Minnesota	-3,349,696	859,264	1,873,340	2,648,387
Missouri	-664,393	242,789	521,473	559,543
Wisconsin	-137,065	61,112	137,878	201,899
Lower Miss.	-361,979	180,635	369,600	785,668
Other U.S.	-66,061	46,077	112,319	185,979
Total	-11,038,805	2,899,101	6,272,930	9,443,232

Table A.9 Incremental Tons: By Destination Region
Traffic Scenario 2 – ESSENCE Lower Bound: 2050

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-776,599	131,605	374,817	907,768
Iowa	39,993	58,836	-92,086	186,106
Minnesota	33,248	77,258	160,712	226,683
Missouri	-333,388	129,483	246,434	272,373
Wisconsin	1,537	10,705	30,366	42,869
Lower Miss.	-9,919,572	2,475,462	5,510,830	7,714,941
Other U.S.	-84,024	15,752	41,857	92,492
Total	-11,038,805	2,899,101	6,272,930	9,443,232

Table A.10 Incremental Tons: By Commodity Group
Traffic Scenario 3 – ESSENCE Lower Bound: 2025

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-9,379,777	2,347,988	4,758,140	5,060,199
Coal Mining	-95,147	5,123	7,535	8,632
Chemicals	-196,457	123,147	250,652	214,392
Petrol Ref	-429,095	108,011	232,942	178,813
SC&G Prod	-16,130	25,698	58,165	79,021
Iron & Steel	-47,659	4,577	12,540	9,212
Total	-10,164,265	2,614,544	5,319,974	5,550,269

Table A.11 Incremental Tons: By Origin Region
Traffic Scenario 3 – ESSENCE Lower Bound: 2025

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-4,444,496	613,322	1,311,492	1,178,066
Iowa	-2,425,331	821,588	1,686,744	1,875,917
Minnesota	-2,324,497	789,894	1,552,304	1,739,601
Missouri	-598,287	198,095	359,747	376,389
Wisconsin	-137,002	55,010	114,942	130,089
Lower Miss.	-185,174	97,491	214,231	172,023
Other U.S.	-49,478	39,144	80,514	78,184
Total	-10,164,265	2,614,544	5,319,974	5,550,269

Table A.12 Incremental Tons: By Destination Region
Traffic Scenario 3 – ESSENCE Lower Bound: 2025

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-527,596	136,824	282,775	209,370
Iowa	-3,635	34,682	68,840	91,566
Minnesota	2,882	49,035	96,419	103,406
Missouri	-248,821	74,526	132,042	134,087
Wisconsin	-716	8,789	26,648	29,331
Lower Miss.	-9,329,865	2,298,726	4,683,542	4,959,508
Other U.S.	-56,514	11,962	29,708	23,001
Total	-10,164,265	2,614,544	5,319,974	5,550,269

Table A.13 Incremental Tons: By Commodity Group
Traffic Scenario 3 – ESSENCE Lower Bound: 2035

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-12,357,750	4,187,757	9,487,815	12,571,375
Coal Mining	-105,614	-1,166	7,494	12,059
Chemicals	-79,626	370,064	641,957	1,057,081
Petrol Ref	-388,012	99,052	302,863	559,573
SC&G Prod	-12,146	-11,652	-129,691	151,628
Iron & Steel	-59,530	6,055	16,560	35,107
Total	-13,002,678	4,650,110	10,326,998	14,386,823

Table A.14 Incremental Tons: By Origin Region
Traffic Scenario 3 – ESSENCE Lower Bound: 2035

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-5,247,886	977,108	2,147,880	3,512,917
Iowa	-1,591,054	1,653,475	3,462,967	4,382,513
Minnesota	-5,166,231	1,330,662	3,198,147	4,384,354
Missouri	-709,645	271,057	653,507	684,278
Wisconsin	-162,082	83,767	205,993	301,502
Lower Miss.	-83,334	304,977	543,191	930,847
Other U.S.	-42,446	29,064	115,313	190,412
Total	-13,002,678	4,650,110	10,326,998	14,386,823

Table A.15 Incremental Tons: By Destination Region
Traffic Scenario 3 – ESSENCE Lower Bound: 2035

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-552,723	197,304	462,232	961,729
Iowa	117,464	120,388	14,927	274,104
Minnesota	51,743	37,643	163,654	236,216
Missouri	-287,702	129,637	268,357	291,394
Wisconsin	11,993	15,486	32,157	55,151
Lower Miss.	-12,280,988	4,132,172	9,340,535	12,476,942
Other U.S.	-62,465	17,480	45,136	91,287
Total	-13,002,678	4,650,110	10,326,998	14,386,823

Table A.16 Incremental Tons: By Commodity Group
Traffic Scenario 3 – ESSENCE Lower Bound: 2050

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-14,509,506	4,260,086	11,105,762	15,985,343
Coal Mining	-119,984	1,404	-6,979	18,120
Chemicals	-21,098	552,320	978,195	1,618,095
Petrol Ref	-335,607	186,773	389,154	770,479
SC&G Prod	46,145	-169,614	-103,549	226,483
Iron & Steel	-86,048	5,653	19,049	48,623
Total	-15,026,098	4,836,622	12,381,632	18,667,143

Table A.17 Incremental Tons: By Origin Region
Traffic Scenario 3 – ESSENCE Lower Bound: 2050

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-6,489,787	1,022,299	2,739,355	4,763,495
Iowa	-1,523,646	1,038,043	3,633,141	5,049,364
Minnesota	-5,945,612	1,854,948	3,989,150	5,951,532
Missouri	-788,229	338,700	869,832	909,567
Wisconsin	-173,140	81,970	221,618	372,602
Lower Miss.	-27,579	468,095	838,103	1,407,665
Other U.S.	-78,105	32,567	90,433	212,918
Total	-15,026,098	4,836,622	12,381,632	18,667,143

Table A.18 Incremental Tons: By Destination Region
Traffic Scenario 3 – ESSENCE Lower Bound: 2050

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-859,056	180,194	506,767	1,258,379
Iowa	263,389	-8,918	130,342	436,616
Minnesota	105,397	78,360	183,523	312,590
Missouri	-43,022	389,968	599,116	633,515
Wisconsin	16,279	11,062	32,333	61,197
Lower Miss.	-14,423,055	4,166,431	10,873,084	15,830,982
Other U.S.	-86,030	19,525	56,467	133,864
Total	-15,026,098	4,836,622	12,381,632	18,667,143

Table A.19 Incremental Tons: By Commodity Group
Traffic Scenario 3 – ESSENCE Upper Bound: 2025

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-10,801,821	3,147,532	7,691,058	8,427,144
Coal Mining	-20,077	2,378	2,695	2,851
Chemicals	-354,871	200,449	659,096	424,685
Petrol Ref	-613,027	142,413	394,516	251,438
SC&G Prod	-7,731	7,074	36,683	98,954
Iron & Steel	-104,142	10,393	26,969	17,415
Total	-11,901,669	3,510,239	8,811,017	9,222,487

Table A.20 Incremental Tons: By Origin Region
Traffic Scenario 3 – ESSENCE Upper Bound: 2025

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-5,654,908	923,189	2,353,358	2,069,646
Iowa	-2,469,959	1,102,937	2,743,760	3,205,117
Minnesota	-2,367,805	891,922	2,153,754	2,546,352
Missouri	-827,652	318,903	707,425	768,630
Wisconsin	-169,124	69,075	171,324	203,783
Lower Miss.	-331,713	170,640	573,844	332,239
Other U.S.	-80,508	33,573	107,552	96,720
Total	-11,901,669	3,510,239	8,811,017	9,222,487

Table A.21 Incremental Tons: By Destination Region
Traffic Scenario 3 – ESSENCE Upper Bound: 2025

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-839,838	187,998	652,943	312,975
Iowa	15,636	48,807	116,205	184,775
Minnesota	10,643	41,894	116,059	133,274
Missouri	-297,001	123,708	284,444	301,385
Wisconsin	1,385	17,251	38,214	45,351
Lower Miss.	-10,684,568	3,067,412	7,539,704	8,203,470
Other U.S.	-107,926	23,169	63,448	41,257
Total	-11,901,669	3,510,239	8,811,017	9,222,487

Table A.22 Incremental Tons: By Commodity Group
Traffic Scenario 3 – ESSENCE Upper Bound: 2035

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-12,650,791	4,696,294	12,687,724	18,978,127
Coal Mining	-24,732	161	7,341	14,596
Chemicals	-333,481	292,490	807,515	1,711,120
Petrol Ref	-571,706	126,589	436,272	1,101,288
SC&G Prod	-3,414	-9,613	-152,270	217,496
Iron & Steel	-122,720	12,410	37,067	85,710
Total	-13,706,844	5,118,331	13,823,649	22,108,337

Table A.23 Incremental Tons: By Origin Region
Traffic Scenario 3 – ESSENCE Upper Bound: 2035

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-6,791,526	1,318,423	3,507,927	6,447,396
Iowa	-2,685,800	1,589,077	4,428,244	6,310,149
Minnesota	-2,720,730	1,438,855	3,680,978	5,890,936
Missouri	-933,856	401,437	1,154,575	1,237,293
Wisconsin	-183,974	103,622	278,775	462,512
Lower Miss.	-306,326	238,777	671,480	1,493,957
Other U.S.	-84,632	28,140	101,670	266,094
Total	-13,706,844	5,118,331	13,823,649	22,108,337

Table A.24 Incremental Tons: By Destination Region
Traffic Scenario 3 – ESSENCE Upper Bound: 2035

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-910,478	208,683	672,882	1,767,583
Iowa	58,942	67,563	27,792	363,020
Minnesota	37,878	50,338	144,727	301,374
Missouri	-266,461	149,857	443,587	509,027
Wisconsin	6,572	12,876	43,559	79,594
Lower Miss.	-12,516,900	4,602,590	12,407,133	18,879,085
Other U.S.	-116,397	26,424	83,969	208,654
Total	-13,706,844	5,118,331	13,823,649	22,108,337

Table A.25 Incremental Tons: By Commodity Group
Traffic Scenario 3 – ESSENCE Upper Bound: 2050

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-13,665,199	4,692,060	14,156,511	22,107,620
Coal Mining	-114,476	178	7,211	20,667
Chemicals	-397,364	314,283	973,742	2,289,915
Petrol Ref	-528,023	117,790	413,755	1,205,809
SC&G Prod	24,942	-189,234	-100,854	244,805
Iron & Steel	-154,517	12,274	41,839	111,892
Total	-14,834,637	4,947,351	15,492,204	25,980,708

Table A.26 Incremental Tons: By Origin Region
Traffic Scenario 3 – ESSENCE Upper Bound: 2050

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-7,933,963	1,155,905	4,002,974	7,885,557
Iowa	-2,573,100	1,562,161	4,814,036	7,077,302
Minnesota	-2,742,041	1,364,117	4,029,388	6,716,318
Missouri	-956,391	486,538	1,463,022	1,556,806
Wisconsin	-182,161	95,137	299,725	521,747
Lower Miss.	-347,143	261,110	796,311	1,960,042
Other U.S.	-99,838	22,383	86,748	262,936
Total	-14,834,637	4,947,351	15,492,204	25,980,708

Table A.27 Incremental Tons: By Destination Region
Traffic Scenario 3 – ESSENCE Upper Bound: 2050

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-1,008,359	223,039	829,190	2,299,669
Iowa	109,919	-100,734	87,099	443,237
Minnesota	56,999	48,615	148,743	316,351
Missouri	-231,892	192,807	578,429	655,461
Wisconsin	8,718	10,560	35,821	79,320
Lower Miss.	-13,634,374	4,547,425	13,718,975	21,905,970
Other U.S.	-135,648	25,639	93,947	280,700
Total	-14,834,637	4,947,351	15,492,204	25,980,708

Table A.28 Incremental Tons: By Commodity Group
Traffic Scenario 3 – TCM: 2025

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-6,015,000	1,172,000	1,245,000	1,229,000
Coal Mining	-2,696,640	-395,000	167,000	164,000
Chemicals	-269,000	5,000	146,000	16,000
Petrol Ref	-142,000	108,000	117,000	117,000
SC&G Prod	-106,000	0	72,000	72,000
Iron & Steel	0	213,000	239,000	238,000
Total	-9,228,640	1,103,000	1,986,000	1,836,000

Table A.29 Incremental Tons: By Origin Region
Traffic Scenario 3 – TCM: 2025

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-3,761,920	17,000	21,000	21,000
Iowa	-68,040	30,000	546,000	547,000
Minnesota	-4,774,000	767,000	828,000	828,000
Missouri	-78,680	0	3,000	2,000
Lower Miss.	-382,000	268,000	555,000	408,000
Other U.S.	-164,000	21,000	33,000	30,000
Total	-9,228,640	1,103,000	1,986,000	1,836,000

Table A.30 Incremental Tons: By Destination Region
Traffic Scenario 3 – TCM: 2025

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-176,200	-322,530	290,470	139,470
Iowa	-1,525,400	53,530	54,530	54,530
Minnesota	-260,000	32,000	131,000	131,000
Missouri	-235,000	2,000	77,000	77,000
Wisconsin	-973,040	182,000	221,000	221,000
Lower Miss.	-6,059,000	1,156,000	1,211,000	1,211,000
Other U.S.	0	0	1,000	2,000
Total	-9,228,640	1,103,000	1,986,000	1,836,000

Table A.31 Incremental Tons: By Commodity Group
Traffic Scenario 3 – TCM: 2035

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-6,485,000	4,356,000	6,818,000	6,842,000
Coal Mining	-2,108,610	283,000	414,000	995,000
Chemicals	-330,000	695,000	870,000	1,014,000
Petrol Ref	0	14,000	278,000	287,000
SC&G Prod	-133,000	-196,000	-118,000	80,000
Iron & Steel	0	0	253,000	320,000
Total	-9,056,610	5,152,000	8,515,000	9,538,000

Table A.32 Incremental Tons: By Origin Region
Traffic Scenario 3 – TCM: 2035

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-2,518,700	1,233,200	1,425,520	1,633,520
Iowa	468,000	86,710	656,710	1,138,710
Minnesota	-5,786,000	3,094,000	5,115,000	5,131,000
Missouri	-74,910	39,090	43,770	44,770
Wisconsin	-536,000	0	0	1,000
Lower Miss.	-442,000	685,000	1,188,000	1,486,000
Other U.S.	-167,000	14,000	86,000	103,000
Total	-9,056,610	5,152,000	8,515,000	9,538,000

Table A.33 Incremental Tons: By Destination Region
Traffic Scenario 3 – TCM: 2035

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	241,000	26,000	214,960	897,960
Iowa	-1,620,400	-201,000	-110,960	101,040
Minnesota	-253,000	673,000	852,000	957,000
Missouri	-126,000	14,000	254,000	259,000
Wisconsin	-790,210	283,000	516,000	525,000
Lower Miss.	-6,508,000	4,357,000	6,789,000	6,795,000
Other U.S.	0	0	0	3,000
Total	-9,056,610	5,152,000	8,515,000	9,538,000

Table A.34 Incremental Tons: By Commodity Group
Traffic Scenario 3 – TCM: 2050

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-7,932,000	3,747,000	7,322,000	8,736,000
Coal Mining	-4,000	2,305,760	2,684,090	3,458,090
Chemicals	-949,000	464,000	1,192,000	1,379,000
Petrol Ref	0	13,000	181,000	280,000
SC&G Prod	-153,000	-220,000	-218,000	88,000
Iron & Steel	-77,840	38,000	133,000	381,000
Total	-9,115,840	6,347,760	11,294,090	14,322,090

Table A.35 Incremental Tons: By Origin Region
Traffic Scenario 3 – TCM: 2050

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-866,480	3,434,980	3,959,820	4,198,140
Iowa	526,000	85,570	150,570	1,166,570
Minnesota	-5,870,000	1,840,000	5,315,000	6,415,000
Missouri	-1,615,360	73,210	76,700	82,380
Wisconsin	-81,000	474,000	474,000	475,000
Lower Miss.	-1,017,000	425,000	1,267,000	1,867,000
Other U.S.	-192,000	15,000	51,000	118,000
Total	-9,115,840	6,347,760	11,294,090	14,322,090

Table A.36 Incremental Tons: By Destination Region
Traffic Scenario 3 – TCM: 2050

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-950,080	226,900	293,860	1,170,860
Iowa	-481,630	1,344,220	1,430,460	1,680,460
Minnesota	-328,000	33,000	775,000	933,000
Missouri	-273,560	136,000	279,000	383,000
Wisconsin	-28,650	848,640	1,184,770	1,453,770
Lower Miss.	-7,019,000	3,757,000	7,329,000	8,696,000
Other U.S.	-34,920	2,000	2,000	5,000
Total	-9,115,840	6,347,760	11,294,090	14,322,090

Table A.37 Incremental Tons: By Commodity Group
Traffic Scenario 5 – ESSENCE Lower Bound: 2025

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-10,704,869	3,648,124	7,436,079	7,218,973
Coal Mining	-94,932	-1,340	7,260	6,571
Chemicals	-139,516	184,642	353,109	303,293
Petrol Ref	-368,285	120,571	289,541	221,902
SC&G Prod	3,065	29,911	-96,931	-333,540
Iron & Steel	-46,992	5,193	14,145	10,023
Total	-11,351,529	3,987,101	8,003,203	7,427,222

Table A.38 Incremental Tons: By Origin Region
Traffic Scenario 5 – ESSENCE Lower Bound: 2025

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-4,648,419	870,527	1,712,840	1,246,660
Iowa	-2,092,933	1,195,939	2,527,036	2,550,948
Minnesota	-3,693,877	1,331,679	2,613,707	2,533,826
Missouri	-616,112	292,425	555,214	569,338
Wisconsin	-147,191	78,423	172,783	166,803
Lower Miss.	-121,702	163,671	311,885	260,961
Other U.S.	-31,295	54,437	109,738	98,686
Total	-11,351,529	3,987,101	8,003,203	7,427,222

Table A.39 Incremental Tons: By Destination Region
Traffic Scenario 5 – ESSENCE Lower Bound: 2025

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-505,864	127,905	332,473	121,504
Iowa	39,142	62,017	-58,627	-164,801
Minnesota	46,292	84,128	151,312	144,241
Missouri	-219,477	114,625	201,777	202,052
Wisconsin	4,716	10,899	31,709	30,288
Lower Miss.	-10,663,286	3,572,901	7,309,391	7,069,158
Other U.S.	-53,052	14,626	35,168	24,780
Total	-11,351,529	3,987,101	8,003,203	7,427,222

Table A.40 Incremental Tons: By Commodity Group
Traffic Scenario 5 – ESSENCE Lower Bound: 2035

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-15,216,744	4,967,802	12,578,878	18,685,272
Coal Mining	-102,033	995	-8,024	-54,221
Chemicals	244,148	502,802	938,639	1,466,441
Petrol Ref	-138,983	201,609	393,346	768,266
SC&G Prod	-1,635	-193,646	-176,506	157,442
Iron & Steel	-44,779	4,968	16,306	40,966
Total	-15,260,026	5,484,530	13,742,639	21,064,166

Table A.41 Incremental Tons: By Origin Region
Traffic Scenario 5 – ESSENCE Lower Bound: 2035

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-4,642,924	981,989	2,831,020	4,800,625
Iowa	-2,177,428	1,024,897	3,849,600	5,566,468
Minnesota	-7,170,879	2,627,501	5,070,581	7,871,953
Missouri	-939,683	307,160	853,739	886,922
Wisconsin	-524,868	82,706	237,697	442,584
Lower Miss.	224,863	426,211	816,174	1,292,326
Other U.S.	-29,107	34,066	83,828	203,288
Total	-15,260,026	5,484,530	13,742,639	21,064,166

Table A.42 Incremental Tons: By Destination Region
Traffic Scenario 5 – ESSENCE Lower Bound: 2035

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-484,321	144,278	422,267	1,068,715
Iowa	198,578	-63,326	76,175	379,158
Minnesota	160,066	123,532	219,179	361,500
Missouri	-72,102	341,100	524,625	557,839
Wisconsin	19,965	9,635	30,435	-3,802
Lower Miss.	-15,045,431	4,910,610	12,418,372	18,589,216
Other U.S.	-36,781	18,701	51,586	111,540
Total	-15,260,026	5,484,530	13,742,639	21,064,166

Table A.43 Incremental Tons: By Commodity Group
Traffic Scenario 5 – ESSENCE Lower Bound: 2050

Commodity	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Agriculture	-14,385,973	4,859,971	13,082,217	20,560,632
Coal Mining	-119,006	-7,900	-7,976	-57,693
Chemicals	344,475	774,112	1,283,375	2,039,445
Petrol Ref	-271,992	177,808	364,993	802,236
SC&G Prod	25,482	-186,569	-452,091	194,014
Iron & Steel	-76,320	4,579	18,141	51,589
Total	-14,483,334	5,622,001	14,288,659	23,590,223

Table A.44 Incremental Tons: By Origin Region
Traffic Scenario 5 – ESSENCE Lower Bound: 2050

Origin	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-6,164,059	951,572	2,666,526	5,471,122
Iowa	-1,373,217	862,972	3,626,067	5,751,883
Minnesota	-6,234,033	2,698,267	5,622,230	8,913,659
Missouri	-773,121	321,359	946,597	980,310
Wisconsin	-183,194	68,296	225,773	470,521
Lower Miss.	317,803	686,713	1,134,035	1,787,311
Other U.S.	-73,513	32,822	67,431	215,417
Total	-14,483,334	5,622,001	14,288,659	23,590,223

Table A.45 Incremental Tons: By Destination Region
Traffic Scenario 5 – ESSENCE Lower Bound: 2050

Destination	Alt. 2	Alt. 4	Alt. 5	Alt. 6
Illinois	-769,042	148,904	294,944	1,273,235
Iowa	238,027	-68,830	-32,839	432,978
Minnesota	422,721	344,862	434,586	629,481
Missouri	-36,279	373,430	603,258	639,797
Wisconsin	20,982	8,945	28,681	-9,507
Lower Miss.	-14,295,504	4,793,571	12,897,215	20,477,366
Other U.S.	-64,239	21,119	62,814	146,873
Total	-14,483,334	5,622,001	14,288,659	23,590,223

Appendix B. Percent of Incremental Tons of Grain Originated by State

Table B.1
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 2 – ESSENCE Lower Bound: 2025

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	39.0	25.4	25.7	22.8
Iowa	25.2	33.7	34.3	36.1
Minnesota	26.5	30.2	30.1	30.9
Missouri	7.4	8.1	7.3	7.5
Wisconsin	1.8	2.5	2.5	2.6
Other U.S.	0.1	0.0	0.0	0.0

Table B.2
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 2 – ESSENCE Lower Bound: 2035

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	40.8	24.5	25.0	26.7
Iowa	18.0	31.1	32.3	31.3
Minnesota	32.6	33.6	32.5	33.1
Missouri	6.8	8.3	7.7	6.1
Wisconsin	1.6	2.4	2.5	2.7
Other U.S.	0.1	0.0	0.0	0.0

Table B.3
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 2 – ESSENCE Lower Bound: 2050

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	43.5	25.2	25.7	27.9
Iowa	14.9	30.5	31.8	30.6
Minnesota	33.6	32.5	31.0	31.8
Missouri	6.6	9.4	9.1	7.1
Wisconsin	1.4	2.4	2.4	2.6
Other U.S.	0.1	0.0	0.0	0.0

Table B.4
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – ESSENCE Lower Bound: 2025

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	41.6	24.4	25.3	22.0
Iowa	25.9	34.3	34.7	36.3
Minnesota	24.7	30.7	30.2	31.9
Missouri	6.3	8.2	7.4	7.3
Wisconsin	1.5	2.3	2.4	2.6
Other U.S.	0.1	0.0	0.0	0.0

Table B.5
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – ESSENCE Lower Bound: 2035

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	37.9	21.9	22.9	24.8
Iowa	13.1	38.7	35.8	34.1
Minnesota	42.0	31.0	32.4	33.3
Missouri	5.6	6.4	6.8	5.4
Wisconsin	1.3	2.0	2.2	2.4
Other U.S.	0.1	0.0	0.0	0.0

Table B.6
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – ESSENCE Lower Bound: 2050

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	41.3	23.9	23.0	25.3
Iowa	10.9	23.4	31.9	30.7
Minnesota	41.2	42.9	35.3	36.0
Missouri	5.3	7.9	7.8	5.6
Wisconsin	1.2	1.9	2.0	2.3
Other U.S.	0.1	0.0	0.0	0.0

Table B.7
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – ESSENCE Upper Bound: 2025

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	46.1	27.0	27.6	23.2
Iowa	22.9	34.2	34.8	37.1
Minnesota	21.8	26.6	26.3	28.3
Missouri	7.5	10.0	9.1	9.0
Wisconsin	1.6	2.2	2.2	2.4
Other U.S.	0.1	0.0	0.0	0.0

Table B.8
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – ESSENCE Upper Bound: 2035

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	48.2	26.6	26.9	29.2
Iowa	21.4	33.1	34.1	32.4
Minnesota	21.6	29.7	27.8	29.5
Missouri	7.2	8.4	9.0	6.4
Wisconsin	1.5	2.2	2.2	2.4
Other U.S.	0.1	0.0	0.0	0.0

Table B.9
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – ESSENCE Upper Bound: 2050

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	52.4	26.7	26.8	30.4
Iowa	19.1	32.6	33.3	31.1
Minnesota	20.2	28.4	27.6	29.1
Missouri	6.9	10.2	10.2	6.9
Wisconsin	1.3	2.0	2.1	2.3
Other U.S.	0.1	0.0	0.0	0.1

Table B.10
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – TCM: 2025

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	18.5	0.1	0.2	0.2
Iowa	1.1	40.4	38.0	38.5
Minnesota	79.4	59.3	60.2	61.0
Missouri	1.0	0.0	0.1	0.0
Lower Miss.	0.0	0.3	1.4	0.2

Table B.11
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – TCM: 2035

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	1.6	26.1	17.0	16.9
Iowa	0.1	2.0	8.5	8.5
Minnesota	89.1	71.0	74.0	73.8
Missouri	0.9	0.8	0.5	0.5
Wisconsin	8.3	0.0	0.0	0.0
Lower Miss.	0.0	0.0	0.1	0.3

Table B.12
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 3 – TCM: 2050

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	6.3	35.6	18.4	15.5
Iowa	0.0	2.3	2.0	6.2
Minnesota	73.1	48.0	72.3	72.0
Missouri	19.5	1.6	0.8	0.7
Wisconsin	1.0	12.6	6.5	5.4
Lower Miss.	0.0	0.0	0.0	0.2
Other U.S.	0.1	0.0	0.0	0.0

Table B.13
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 5 – ESSENCE Lower Bound: 2025

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	38.6	22.3	23.6	21.8
Iowa	19.7	32.1	33.3	34.7
Minnesota	34.6	35.5	33.4	33.4
Missouri	5.7	7.9	7.4	7.8
Wisconsin	1.4	2.1	2.3	2.3
Other U.S.	0.1	0.0	0.0	0.0

Table B.14
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 5 – ESSENCE Lower Bound: 2035

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	28.5	19.9	21.6	22.5
Iowa	14.6	19.9	30.0	29.1
Minnesota	47.3	52.4	39.8	41.3
Missouri	6.1	6.1	6.7	4.7
Wisconsin	3.5	1.7	1.9	2.4
Other U.S.	0.1	0.0	0.0	0.0

Table B.15
Percent of Incremental Tons of Grain Originated by State
Traffic Scenario 5 – ESSENCE Lower Bound: 2050

Origin	Percent of Tons Alt. 2	Percent of Tons Alt. 4	Percent of Tons Alt. 5	Percent of Tons Alt. 6
Illinois	39.6	19.8	21.3	23.1
Iowa	10.1	16.8	27.2	27.2
Minnesota	43.6	55.4	42.6	42.7
Missouri	5.3	6.5	7.2	4.7
Wisconsin	1.3	1.4	1.7	2.3
Other U.S.	0.1	0.0	0.0	0.0

Appendix C. Details of Railroad Fuel Model

One way of assessing the predictive capabilities of a model is to compare its predicted values to observed values. The fuel model has a low coefficient of variation (5.1), meaning that it could be a good predictor of fuel use. Table C.1 shows a comparison between actual and predicted gallons of fuel consumed for 2001.

Table C.1 Prediction Error of Fuel Model for 2001

Railroad	Actual Gallons	Predicted Gallons	Difference (in Gallons)	Percent Difference
BNSF	1,177,144,447	1,197,664,724	20,520,277	1.7
CSX	580,383,998	584,618,748	4,234,750	0.7
GTW	22,522,767	21,743,679	-779,088	-3.5
ICG	58,934,384	52,361,225	-6,573,159	-11.2
KCS	57,633,711	49,093,932	-8,539,779	-14.8
NS	477,644,140	496,181,166	18,537,026	3.9
SOO	49,674,000	42,535,139	-7,138,861	-14.4
UP	1,286,544,322	1,292,399,584	5,855,262	0.5

In percentage terms, the model is very accurate for the largest railroads. For example, the prediction error expressed as a percentage of actual gallons is less than 1 percent for UP and CSX, 1.7 percent for BNSF, and 3.9 percent for NS. Collectively, BNSF, CSX, NS, and UP accounted for 95 percent of all Class I railroad fuel use in 2001. On a percentage basis, the prediction errors are greatest for Soo Line, Kansas City Southern, and ICG. Collectively, these railroads accounted for less than 5 percent of Class I railroad fuel consumption in 2001. Overall, the model appears to be a good predictor of railroad fuel use.

The model used the SAS AUTOREG procedure. The detailed results are listed below.

The AUTOREG Procedure
Yule-Walker Estimates

SSE	2.44136E16	DFE	111
MSE	2.19942E14	Root MSE	14830441
SBC	4933.25639	AIC	4863.5298
Regress R-Square	0.9982	Total R-Square	0.9983
Durbin-Watson	2.0556	Pr < DW	0.1671
Pr > DW	0.8329		

Variable	DF	Estimate	Standard Error	t Value	Approx Pr > |t|
Intercept	1	16669567	6659595	2.50	0.0138
Unit_Train_CH	1	26.9591	10.2978	2.62	0.0101
Nonunit_Train_CH	1	31.9201	8.2506	3.87	0.0002
Unit_Train_GTMC	1	0.6606	0.1058	6.24	<.0001
Nonunit_Train_GTMC	1	0.6856	0.0908	7.55	<.0001
atsf	1	147565283	16082640	9.18	<.0001
bn	1	191263949	34225503	5.59	<.0001
bnsf	1	16958882	18692623	0.91	0.3662
up	1	176150646	30769742	5.72	<.0001
sp	1	161151486	17316752	9.31	<.0001
upsp	1	6762059	18129315	0.37	0.7099
cnw	1	-29225055	11846844	-2.47	0.0152
upcnw	1	59166616	18987782	3.12	0.0023
icg	1	-7351903	6129408	-1.20	0.2329
gtw	1	-7404724	5817449	-1.27	0.2057
soo	1	-8185949	5896207	-1.39	0.1678
cr	1	11371197	25226994	0.45	0.6530
csx	1	31645984	35640772	0.89	0.3765
csxcr	1	24699549	21995801	1.12	0.2639
nscr	1	20156078	19306610	1.04	0.2988
ns	1	33684251	28054466	1.20	0.2324
t	1	-1525813	597365	-2.55	0.0120

Appendix D. Additional Housing Units Affected by Railroad Noise

The following tables detail the additional housing units affected by the railroad noise associated with the incremental trains under each project Traffic Scenario. Each table shows the additional number of housing units impacted by railroad noise in excess of 65 dBA due to the incremental train traffic. The additional housing units affected by the 30 percent incremental train traffic is shown in Tables D.1-D.15 while the 60 percent incremental train traffic noise impacts to housing units are shown in Tables D.16-D.30.

Table D.1
Additional Housing Units in S. New Orleans Affected by Railroad Noise at 30% Incremental Traffic: Scenario 2 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-385	-555	-555
4	206	206	206
5	206	385	385
6	206	385	555

Table D.2
Additional Housing Units in S. New Orleans Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-385	-555	-717
4	206	206	385
5	385	555	555
6	385	717	867

Table D.3
Additional Housing Units in S. New Orleans Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – ESSENCE Upper Bound

Alternative	2025	2035	2050
2	-555	-555	-717
4	206	385	385
5	385	555	717
6	385	867	1,016

Table D.4
Additional Housing Units in S. New Orleans Affected by Railroad Noise at 30% Incremental Traffic: Scenario 5 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-555	-717	-717
4	206	385	206
5	385	555	717
6	385	867	1,016

Table D.5
Additional Housing Units in S. New Orleans Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – Tow Cost Model

Alternative	2025	2035	2050
2	-385	-385	-555
4	206	385	206
5	206	555	555
6	206	555	555

Table D.6
Additional Housing Units in East St. Louis Affected by Railroad Noise at 30% Incremental Traffic: Scenario 2 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-30	-42	-42
4	16	16	16
5	16	30	30
6	16	30	42

Table D.7
Additional Housing Units in East St. Louis Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-30	-42	-56
4	16	16	30
5	30	42	42
6	30	56	68

Table D.8
Additional Housing Units in East St. Louis Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – ESSENCE Upper Bound

Alternative	2025	2035	2050
2	-42	-42	-56
4	16	30	30
5	30	42	56
6	30	68	80

Table D.9
Additional Housing Units in East St. Louis Affected by Railroad Noise at 30% Incremental Traffic: Scenario 5 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-42	-56	-56
4	16	30	30
5	30	42	56
6	30	68	80

Table D.10
Additional Housing Units in East St. Louis Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – Tow Cost Model

Alternative	2025	2035	2050
2	-30	-30	-42
4	16	30	16
5	16	42	42
6	16	42	42

Table D.11
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 30% Incremental Traffic: Scenario 2 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-36	-51	-51
4	19	19	19
5	19	36	36
6	19	36	51

Table D.12
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-36	-51	-64
4	19	19	36
5	36	51	51
6	36	64	81

Table D.13
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – ESSENCE Upper Bound

Alternative	2025	2035	2050
2	-51	-51	-64
4	19	36	36
5	36	51	64
6	36	81	97

Table D.14
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 30% Incremental Traffic: Scenario 5 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-51	-64	-64
4	19	36	36
5	36	51	64
6	36	81	97

Table D.15
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 30% Incremental Traffic: Scenario 3 – Tow Cost Model

Alternative	2025	2035	2050
2	-36	-36	-51
4	19	36	19
5	19	51	51
6	19	51	51

Table D.16
Additional Housing Units in New Orleans Affected by Railroad Noise at 60% Incremental Traffic: Scenario 2 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-555	-717	-867
4	206	206	385
5	385	555	555
6	385	555	717

Table D.17
Additional Housing Units in New Orleans Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-717	-867	-1,016
4	206	385	385
5	385	717	867
6	385	1,016	1,154

Table D.18
Additional Housing Units in New Orleans Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – ESSENCE Upper Bound

Alternative	2025	2035	2050
2	-867	-867	-1,016
4	385	385	385
5	717	867	1,016
6	717	1,300	1,559

Table D.19
Additional Housing Units in New Orleans Affected by Railroad Noise at 60% Incremental Traffic: Scenario 5 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-867	-1,016	-1,016
4	385	555	555
5	555	1,016	1,016
6	555	1,300	1,428

Table D.20
Additional Housing Units in New Orleans Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – TCM

Alternative	2025	2035	2050
2	-555	-555	-717
4	206	385	385
5	206	717	717
6	206	717	867

Table D.21
Additional Housing Units in St. Louis Affected by Railroad Noise at 60% Incremental Traffic: Scenario 2 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-42	-56	-68
4	16	16	30
5	30	42	42
6	30	42	56

Table D.22
Additional Housing Units in St. Louis Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-56	-68	-80
4	16	30	30
5	30	56	68
6	30	80	92

Table D.23
Additional Housing Units in St. Louis Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – ESSENCE Upper Bound

Alternative	2025	2035	2050
2	-68	-68	-80
4	30	30	30
5	56	68	80
6	56	102	124

Table D.24 Additional Housing Units in St. Louis Affected by Railroad Noise at 60% Incremental Traffic: Scenario 5 – ESSENCE Lower Bound			
Alternative	**2025**	**2035**	**2050**
2	-68	-80	-80
4	30	42	42
5	42	80	80
6	42	102	114

Table D.25 Additional Housing Units in St. Louis Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – TCM			
Alternative	**2025**	**2035**	**2050**
2	-42	-42	-56
4	16	30	30
5	16	56	56
6	16	56	68

Table D.26 Additional Housing Units in Pine Bluff Affected by Railroad Noise at 60% Incremental Traffic: Scenario 2 – ESSENCE Lower Bound			
Alternative	**2025**	**2035**	**2050**
2	-51	-64	-81
4	19	19	36
5	36	51	51
6	36	51	64

Table D.27 Additional Housing Units in Pine Bluff Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – ESSENCE Lower Bound			
Alternative	**2025**	**2035**	**2050**
2	-64	-81	-97
4	19	36	36
5	36	64	81
6	36	97	110

Table D.28
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – ESSENCE Upper Bound

Alternative	2025	2035	2050
2	-81	-81	-97
4	36	36	36
5	64	81	97
6	64	122	151

Table D.29
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 60% Incremental Traffic: Scenario 5 – ESSENCE Lower Bound

Alternative	2025	2035	2050
2	-81	-97	-97
4	36	51	51
5	51	97	97
6	51	122	138

Table D.30
Additional Housing Units in Pine Bluff Affected by Railroad Noise at 60% Incremental Traffic: Scenario 3 – TCM

Alternative	2025	2035	2050
2	-51	-51	-64
4	19	36	36
5	19	64	64
6	19	64	81

Appendix E USACE and Independent Technical Reviews

The Tennessee Valley Authority was asked to conduct an independent technical review of this report. The review — conducted by Dr. Larry G. Bray, Mr. Chrisman A. Dager, and Ms. Charlotte A. Leibrock — is shown in the appendix, along with three technical reviews conducted by USACE personnel. My responses to the USACE reviews are shown in the review forms. My responses to the TVA independent technical review are provided afterwards.

Project Review Comments	**Type:** ITR Concept: Final: Other: Draft	**Page** 1 **of** 1 **Date:** 12/3
Project: Denver Tolliver draft report Dec 5, **Location:**	**Reviewer:** Name: **Jack Carr** Organization: **CE-MVR- PMA**	

General Response: Many of the typographical issues were the result of a poor file conversion process from Word to Adobe, which has been corrected with a newer version of the software.

Comment Number	Drawing/ Number	Page/ Space	COMMENT	ACTION
1.		i	Suggest attached write-up and tables be included in executive summary or up front in the report.	
2.		Pg 2	Section 1.2 is confusing to me. Suggest re-write of the references to scenarios being derived from models.	Section has been re-written
3.		Pg5	Section 1.4.1 typo: functions.	Corrected
4.		Pg6	Section 2.1 typo: efficiencies	Corrected
5.		Pg7-8	Tables 5-9 and all analyses that follow. Suggest that TCM and Essence Upper Bound Values be presented for all Scenario 2 Analyses that follow in this report.	Changed
			Also suggest that TCM and Essence Lower Bound Values be presented for all Scenario 5. Analyses that follow in this report.	
6.		Pg20	Para 2 Refer to accident databases as Coast Guard Accident Databases.	Corrected
7.		Pg19-Pg82	Emphasize that the change in accident costs, crossing noise and delay impacts are benefits: specifically accident costs avoided; fewer housing units impacted by noise of	Done
			A certain level; fewer vehicles delayed, and delay time avoided. These benefits are Attributed to specific alternatives, under the various assumptions.	
8.		Pg35	Section 5: Is Lmax used in any of equations presented? Show where it is used.	L_{max} is not used. It has been deleted from the sentence.
9.		Pg41	Section 6.1 Para 2 reference 214 housing units, tables show 241 housing units. Same page, text uses Ldn, following tables show DBA, suggest using one or the other.	Corrected. References changed to: railroad Ldn of 65 dBA
10.		Pg42	Tables 38-40; which model and elasticity assumptions are used here.	ESSENCE Lower and Upper Bound References Added
11.		Pg46	Tables50-52; which model and elasticity assumptions are used here.	Same response
12.		Pg47-Pg48	Tables53-55; which model and elasticity assumptions are used here.	Same response
13.		Pg51-52	Tables65-67; which model and elasticity assumptions are used here.	Same response
14.		Pg53-Pg82	Correct Appendices to reflect above comments.	

CEMVR FORM 44-E, 01 APR 98 (Revised)

Project Review Comments	**Type:** Draft Report Concept: Final: Other:	**Page** 1 **of** 1 **Date:** 1/14/04
Project: UMR-IWW System Navigation Study Report **Location:** Note: page numbers refer to page numbers of printed out copy	**Reviewer:** Name: **Josh Cackley** Organization: **US Army Corps of Engineers,**	

General Response: Many of the typographical issues were the result of a poor file conversion process from Word to Adobe, which has been corrected with a newer version of the software.

Comment Number	Drawing/ Numb	Page/ Space	COMMENT	ACTION
1		3	Under 1.3.2, the paragraph following table 2, Baton Rogue should be spelled Baton Rouge.	Change spelling
2		5	In the second paragraph under 1.4.1, in the third sentence the word "functions" appears to have a space between the o and the n.	Check for space
3		6	In the first paragraph under 1.4.2, in the second sentence there appears to be a space in the word "studies" between the d and i.	Check for space
4		6	In the first paragraph under 2.1, in the third sentence there appears to be a space in the word "revenue." Also Baton Rogue should be spelled Baton	Check for space and change spelling
5		8	In the first paragraph under 2.2, the last word in the second sentence "consists." I do not know what you mean by that word.	Explain or consider revising
6		10	In the third paragraph under 2.2.2.1, should the word "autoracks" be "autotracks"? I was just wondering	Review
7		11	In the paragraph above Table 11, it reads "A 110-car movement from Sioux City to Tacoma, Washington also was evaluated." Consider making it "was	Consider revision
8		13	Under 2.2.3.2, should dataset be one word or two?	Review
9		21	Under 3.1.2 in the paragraph following Table 17, in the second sentence the word "Damage" appears to have an extra space between the a and g.	Check for space
10		23	In the third paragraph under 3.1.3, the second to last sentence, check for a space between the words "Waterway than"	Check for space
11		28	In the paragraph under 3.2.3, the word "tables" appears to have a space between the e and s, both times the word appears in the paragraph	Check for space
12		29	In the first paragraph under 3.2.4, should the word "pedestrian" in the last sentence be plural?	Review (Changed)
13		32	Under 4.1.2, should "waybill" in the second sentence be capitalized?	Review (Changed)
14		33	Under 4.2.2, the word "calculation" in the second paragraph appears to have a space between the c and u.	Check for space
15		35	Under 5. it says "…(2) train (consist) noise…" but then later describes contact noise. Should the word "consist" be replaced with "contact"?	Review (Changed)
16		36	In the paragraph following Table 37 under 5.1.1, should "waybill" be capitalized?	Review (Changed)
17		38	In the first paragraph under 5.2.1, the third sentence reads "On the basis on field tests…" should it read "On the basis of field tests…"?	Consider revision (Changed)
18		41	In the second paragraph under 6.1, subscript the "dn" located in the Ldn so it reads L_{dn} and not Ldn.	Subscript text (Changed)
19		47	In the second paragraph under 6.2, subscript the "dn" located in the Ldn so it reads L_{dn} and not Ldn.	Subscript text (Changed)
20		65	In table A.38, unbold the row with "Origin, Alt. 2, Alt. 4, Alt. 5 and Alt. 6"	Unbold text (Changed)

Project Review Comments	**Type:** Concept: Final: Other: Draft	**Page** 1 **of** 3 **Date:** 2003/12/08
Project Analysis of the Energy, Safety, and Traffic Effects of Proposed UMR-IWW System… **Location:** UMR-IWW	**Reviewer:** Name: Sandra Brewer Organization: PM-A	

Comment Number	Drawing/ Number	Page/ Space	COMMENT	ACTION
1			Add Table of Acronyms Add References Section	Done
2		i	The Alternatives Section: Discussion of Alternative 2. Should be comment that current federal law prohibits fee-for-waterway but that this prohibition does not prevent evaluation of fee-for-use mechanism	Sentence added on Page i: Current federal law does not allow such fees.
3		i	Incremental Traffic Section: "…[t]he key information source is a data package provided by the Corps…." This data should be referenced in order to facilitate stakeholders' ability to view	Footnote added on Page i: The *incremental traffic data set* used in the study can be obtained from the U.S. Army Corps of Engineers project managers, John P. Carr or Richard J. Manguno
4		iii	Railroad Fuel Consumption Model: Line 12 "Many of the railroad indicator variables are also statistically significant." Only 38% of the railroad indicator variables were statistically significant. Replace "[many] of the … to [some] or [several] in order not to mislead the reader.	Sentence changed to: Several of the railroad indicator variables are also statistically significant.
5		iv	"The emission of air pollutants is directly linked to fuel consumption. Therefore, it is unlikely that the potential waterway investments would have a significant beneficial effect on air pollutants." First sentence is misleading. Fuel type is also a critical consideration to air pollution, *e.g,* fuels rich in sulfur or nitrogen compounds produce more air quality problems. Secondly, amount of fuel burned also affects air quality. The EPA, Emissions Control Lab reports that a tow moving one ton of cargo, 1,000 miles produces 1/5 the hydrocarbons, and less than 1/3 of carbon monoxide and nitrous oxide emissions of a train under the same situation.	Modified sentences read: The emission of air pollutants is related to fuel consumption. EPA regulations limit the grams that can be emitted per gallon of fuel used by locomotive and marine diesel engines. In 2025, it is likely that the emission rates of locomotive and towboat diesel engines will be similar, and much lower than historical emission rates. Because the potential waterway investments would not affect fuel conservation appreciably, it is unlikely that the improvements would have a material effect on the emission of air pollutants.

Project Review Comments	**Type:** Concept: Final: Other: Draft	**Page** 1 **of** 3 **Date:** 2003/12/08
Project Analysis of the Energy, Safety, and Traffic Effects of Proposed UMR-IWW System… **Location:** UMR-IWW	**Reviewer:** Name: Sandra Brewer Organization: PM-A	

Comment Number	Drawing/ Number	Page/ Space	COMMENT	ACTION
6		2	Commodity Composition section It is not clear how the grain proportion ranges from a high of 94% in 2035 under Traffic Scenario 5 to the low under Alternative 4 of the Tow Cost Model in 2050. The percentages are wrong if based on the numbers in the Appendix A. If the percentages are based on the data package provided by the Corps, this needs to be referenced. The footnote is unacceptable (See Comment 3)	Section is revised as follows: This information is derived from the data set provided by USACE. Commodity Group 1 – Agriculture & Forestry Products – comprises the greatest proportion of incremental tons for most traffic scenarios and alternatives. The proportion ranges from a high of 99 percent in 2035, for Traffic Scenario 5 and Alternative 1, to a low of 59 percent in 2050 under Alternative 4 of the Tow Cost Model.
7		12	"The important implication of Table 13 is that railroad…." This important implication should be stated in the Executive Summary – Railroad Fuel Efficiency Trends	Done
8	Fig 14	16	Variable IC Should be ICG	Done
9		19	Bottom of first full paragraph See comment 5	See comment 5 for revision

Project Review Comments	**Type:** Concept: Final: Other: Draft	**Page** 1 **of** 3 **Date:** 2003/12/08
Project Analysis of the Energy, Safety, and Traffic Effects of Proposed UMR-IWW System… **Location:** UMR-IWW	**Reviewer:** Name: Sandra Brewer Organization: PM-A	

Comment Number	Drawing/ Number	Page/ Space	COMMENT	ACTION
10	Tables 26-30	27-28	Negative values for Alternative 2 in Tables showing Average Change in Railroad Fatalities The negative numbers are counter-intuitive. Alternative 2 uses congestion fees for water transport; thus possibly increasing the use of rails. Increased use of railroads could lead to increased fatalities. It is unclear why increased fatalities is represented by a negative sign. Intuitively, increased fatalities is a positive number. An explanation is needed in the document.	The following paragraph has been added: The changes in fatalities associated with Alternative 2 are negative. These values may be interpreted as *disbenefits* resulting from the implementation of a waterway congestion fee, which would divert traffic from waterways to railroads. Under Alternative 2, railway traffic would increase in the with-project case. The congestion fee may create benefits for traffic that continues to use the waterway because of lower congestion levels. These benefits to waterway users—which were computed in an earlier phase of the study—would be valued positively. Thus, for Alternative 2, the net benefits would be the sum of the disbenefits shown in this report, and the benefits computed in other study.
11	Tables 31-35	28-29	Negative values for Alternative 2 in Tables showing Change in Accident Cost Same comment as 10. It is not intuitive that a negative number indicates accident costs are increasing as would be expected with increasing use of rails.	Same response as above.
12		32	Three of the most important factors that affect traveler delay….” Add time of crossing. A train crossing during rush hour has a higher vehicular delay than the same train crossing the same area during late evening.	The following sentences have been added: Another important consideration is the time of day a crossing is blocked. If a crossing is blocked during rush hour, many more vehicles will delayed than if it is blocked during the off-peak period.

Project Review Comments	**Type:** Concept: Final: Other: Draft	**Page** 1 **of** 3 **Date:** 2003/12/08
Project Analysis of the Energy, Safety, and Traffic Effects of Proposed UMR-IWW System… **Location:** UMR-IWW	**Reviewer:** Name: Sandra Brewer Organization: PM-A	

Comment Number	Drawing/ Number	Page/ Space	COMMENT	ACTION
13		41	Last full paragraph on page. Clarify how the additional 214 housing units are determined. Based on Table 38, one train adds 241 housing units, thus two trains should be 482 additional housing units for Alternative 2. Instead 451 is listed. 451 minus 241 is 210.	The paragraph has been rewritten as follows: An example is used to illustrate the interpretation of the tables. As shown in Table 38, one incremental train per day would result for Alternatives 4-6, assuming that 30 percent of the incremental grain traffic follows this route. For these alternatives, an additional 241 housing units would be subjected to railroad noise levels of 65 L_{dn} or greater under Traffic Scenario 2 in 2025. An additional 415,000 highway vehicles would encounter grade crossing delays totaling 13,000 hours per year. In 2050 under Traffic Scenario 2, an additional 648 housing units would be subjected to railroad noise levels of 65 L_{dn} or greater under Alternative 2, as a result of an additional 3 trains per day. An additional 1.24 million highway vehicles would encounter grade crossing delays of an additional 38,000 hours per year.
14			Throughout document Check for extra spaces within a word; consistent use of acronyms.	The spaces within words were the result of a poor conversion from Word to Adobe format.

A Review of

Dr. Denver Tolliver's

Analysis of the Energy, Safety, and Traffic Effects of Proposed Upper Mississippi River-Illinois Waterway System Navigation Improvements

February 17, 2004

Larry G. Bray, Ph.D.
Chrisman A. Dager
Charlotte Ann Leibrock

Dr. Denver Tolliver was asked by the Rock Island District of the U. S. Army Corps of Engineers to investigate the energy, safety, and traffic effects of 20 waterway traffic scenarios and navigation alternatives. The Tennessee Valley Authority (TVA) was asked to do an independent technical review (ITR) of Dr. Tolliver's report. In summary, the reviewers feel that a reasonably defensible assessment of energy, safety, and traffic effects was prepared for the various "with" and "without" project conditions based on the paradigm he builds. But with the "devil" being in the details, the reviewers do have some questions and comments about methodology and assumptions used in the study, especially as they relate to suspected impacts on study conclusions.

Strong Points

Dr. Tolliver does an excellent job reviewing modal energy efficiency. The interested reader can be referred to this document for the best summary we have seen. Efficiency data are synthesized from a variety of sources to produce an excellent summary of detailed modal efficiency. Additionally, little research has been done in the area of railroad noise pollution, and Dr. Tolliver develops a methodology to examine this issue. The paper is well written, easy to read, and provides an easily understood general framework of analysis. This is an excellent paper for those who have not studied in the area and, if summary tables could be prepared from the detailed data, an excellent guide could be developed for the USACE generally and groups that promote water transportation such as the National Waterways Council or Waterway Works.

The energy efficiency analysis methodology is particularly well done. The review of the literature brings together TVA work on water transportation and the rail studies by Federal Railroad Administration, Gervais and Baumel, and Dunn and Eggleton. The regression analysis of railroad fuel consumption is enlightening. Through a vigorous statistical linear regression analysis, a model is developed that produces data supporting the conclusion that waterway investment does **not** have a significant effect on fuel consumption (page 19).

The safety material is logical and well presented. Given the assumptions, the results are reasonable.

Points of Concern

The draft report very carefully lays out the assumptions upon which the analysis is based, and within the confines of these assumptions the reviewer most likely would reach the same conclusions as did Dr. Tolliver. In fact the report generally follows the rate study TVA completed for the USACE in 1996.

The concern is that the 1996 study estimates transportation rates based on early 1990s regional transportation patterns that have changed drastically. TVA was asked to re-examine the transportation rates in 2002 and noticed the change in the field interviews. The USACE was also notified of these changes in the National Academy of Sciences review in 2001. While the National Economic Development (NED) benefits of the river transportation changed by about 10% by 2002, changes in the regional distribution of traffic were dramatic. By keying his study to the 1991 transportation pattern, Tolliver assumes these impacts away and dates the impacts to what one might have found in 1991. Selected passages on page five amplify this concern:

> "Rail is the only feasible alternative to barge movements, given the commodities and distances involved. Any gathering or distribution movements by truck at origin or destination are excluded from the analysis."

> "The implication is that truck traffic patterns will not vary appreciably between the with-and without project cases. The rationale for this assumption is based on existing grain delivery practices and changes in railroad transportation that may increase farm-to rail-line hauling distances in future years."

> "In the with-project case, incremental grain traffic will be trucked from farms to elevators located on the Illinois and Upper Mississippi Rivers. In the without-project case, incremental grain will be trucked from farms to elevators located on rail lines."

> "A long-term trend of consolidation in the grain elevator industry has reduced the number of elevators located on rail lines and increased the trip distances from farms to rail stations. This trend is expected to continue in the future as shuttle elevators become larger and rail branch lines are abandoned."

It is unfortunate, but Dr. Tolliver is caught between the economics of the region that existed until the mid-1990s and the current manner in which mid-western farmers now operate. This reflects a decision made by the USACE to base their study on the mid-1990s rate study and not use the current rate update. While the NED effects changed minimally during the period (1996-2002), the transportation impacts were dramatic.

In reality, grain growers in the flood plain are principally locked into shipping to export or to final consumption by barge. Local country elevators have lost their rail service for single and multiple car service, and farmers have limited local demand opportunities to market grain. Grain growers have developed their own trucking companies to move their grain, and these farmers are willing to truck up to 50 miles without a backhaul to river terminal elevators. These factors are discussed below, and these factors are built into the paradigm upon which TVA's second NED rate update is based. In the parlance of the ongoing debate concerning the economics of grain transportation, TVA conducted field interviews in the 2002 rate update that points toward "inelasticity" of barge transportation with respect to rates.

Factors Affecting Regional Transportation

Country elevators

Prior to 1993 (the year of the great flood on the Mississippi River and tributaries), grain moved to market first by local farm truck through the country elevators which were rail served. Gervais and Baumel found that 70% of corn and soybeans moved to country elevators in 1994-1995. Country elevators are currently not the focus of grain collection as they once were. Now, on farm storage is becoming the predominant manner in which farmers operate, and it is more significant on the Illinois side of the Upper Mississippi

River than west of the River. During the field interviews, farmers reported that the sum of on farm storage exceeded river terminal elevator storage in the region.

Trucking

Farmers now truck to their customers in tractor semi trailers. Farm trucking enterprises haul grain to river terminals, unit train rail collection points, and to local markets. Gervais and Baumel found that the average trucking distance to the elevators was 37 miles. TVA was told that farmers will now truck to a distance of 100 miles with a backhaul and to a 50 mile maximum without a backhaul.

Rail

Railroads are not generally providing single and multiple-car service, but the railroads are concentrating their assets in unit train service. Passage of the 1980 Rail Staggers Act gave railroads the option of pricing service to unproductive activities, such as single and multiple car service, and to captive shippers at high rates. Another factor is the weight of the new generation of locomotives and the size of C6X covered hopper cars. This equipment is too heavy to move across the branch and short line tracks and bridges that were used to service Midwestern farmers. Anecdotal information would suggest that railroads are promoting service to ethanol plants in order to gain the higher revenue outbound tank car service.

The findings from interviews of Midwestern farmers are validated from information contained in the Surface Transportation Board's 2002 Waybill Data. Shown in Table 1 for national service, only 3.7 percent of corn moves in single or two car service. Thirty percent moves in service of up to 39 cars. Soybeans are served by the railroads in about the same manner: 2.3 percent in one or two car service and 32 percent in service of up to 39 cars.

Table 1: USA Grain Shipping By Service Type-Million Tons

	Corn	Soybeans	Wheat except Durum	Durum Wheat
Single Car- 1or 2 cars	2.700	0.489	2.337	0.749
Multi-Car-3 to 39 cars	22.224	6.729	18.626	1.761
Unit Train-40 or more cars	48.392	13.443	16.591	0.359
Total	73.317	20.661	16.591	2.870

Contracting

About 50% of the current corn and soybean crop is sold prior to harvest. It ranges from a low of 20% to a high of 80% on some farms. The penetration of contract grain sales has grown in the last decade with the growth of on farm storage. The grain is sold prior to being transported from the farm to the river elevators, and thus the grain might not have the option to move out of the region by rail transportation.

Taxes

Farmers are becoming much better businessmen. The timing of grain sales often reflects the need to defer income into another tax year.

Barge Storage

Barges are loaded to 12 feet on the upper Mississippi River for storage and as a conduit for the economical export of grains in midstream transfer. For that part of the barge storage inventory not sold to export, it is sold at a discount to tributary grain users as input into wet corn milling, ethanol production, animal feed, soybean oil and meal production, and bread production. About ten percent of the grain stored for export is

consumed in the grain-using industry located on navigable streams. On the Tennessee River, barges loaded to 12 feet can be accommodated for much of the year, excluding the winter season when the barges are light loaded and sold to shippers at a discount or are fleeted at Paducah, KY and lightered there. To compensate for the extra cost, the grain is purchased at a discount.

Local Markets and Production

Livestock farming in the flood plain has declined (some say virtually disappeared) due to zoning restrictions resulting from the 1993 flood. Two hundred and thirty thousand cattle and calves resided in the Illinois counties adjacent to the Mississippi River in 2002. If all were grown and fed only corn, these animals would account for only 800,000 tons of production[1]. However, some of these animals are calves and the grown animals are pastured or are fed milling by-products and animal waste[2]. Thus actual corn consumption is much lower than 800 tons. Additionally, contaminated grain or grain of too low a grade to be exported is sometimes rejected at New Orleans and returned to the shipper. This grain could be available for local animal consumption.

The land in the flood plain of the mid-western rivers is very fertile and supports a major grain production area. Table 1 summarizes corn and soybean production in the counties bordering the Mississippi River and Illinois Waterway in 2002 and those counties abutting the riverside counties. Over half the corn and soybeans in this production area is grown in Illinois. Production is then concentrated in Iowa, leaving Minnesota, Missouri and Wisconsin to produce 11.8 million tons of grain and 3.6 million tons of soybeans. By far, the major producer of grain in the region is Illinois.

[1] To make a profit, a country elevator must handle about three million tons of grain per year.
[2] The market penetration is unknown, but chicken litter can be fed to cattle directly or after sun drying and ensiling with grain meal or grasses. This animal feed (67% chicken litter) is much cheaper than grain.

Table 2: 2002 Agricultural Production in Counties Located on the River and One County Removed from the River (Millions of Tons)

State	Corn Million Tons	Soybeans Million tons
Illinois	26.5	7.7
Iowa	10.2	2.1
Minnesota	4.8	1.0
Missouri	3.2	2.0
Wisconsin	3.8	0.6
	48.5	13.4

Figures 1-3 (located at the end of the document) map the locations of corn and soybean processing plants located in Illinois, Iowa, and Missouri. Note that Illinois, the predominant production area close to the river has access to one corn processing plant in this two county zone along the river: the Schuyler County Two Rivers Plant. There is also one soybean processing plant in Adams County. Iowa has three corn plants located on the river and two plants located one county removed from the river. Another corn processing plant and a soybean processing plant is located three counties from the river in Linn County. Elsewhere in Iowa there are 17 corn processing plants and 7 soybean processing plants located well outside a reasonable trucking distance from the river farmers. The only grain processing plants in Missouri located near the river are the four corn plants and two soybean plants in St. Louis.

Elasticity

Certain niche products are very sensitive to shifts in freight rates. These include commodities that must be shipped in containers such as non-genetically altered grain, grain grown organically and certified seed grains.

Magnitude of Rail Noise Impacts

Regarding train and horn noise, it is hard to believe that one additional train diverted per day would impact only 451 additional homes in alternative 2 and 241 homes in alternative 6. This is a though thing to try and predict. At my home, for example, a

ridge deflects horn noise for miles. You would pick up, just in my neighborhood, 400 homes where horn noise rattles you windows in the middle of the night. Just for information, according to our consultants, horn noise varies as to whether the engineer has been involved in an event where someone died. Those who have produce louder and more frequent horn noise than those who have not.

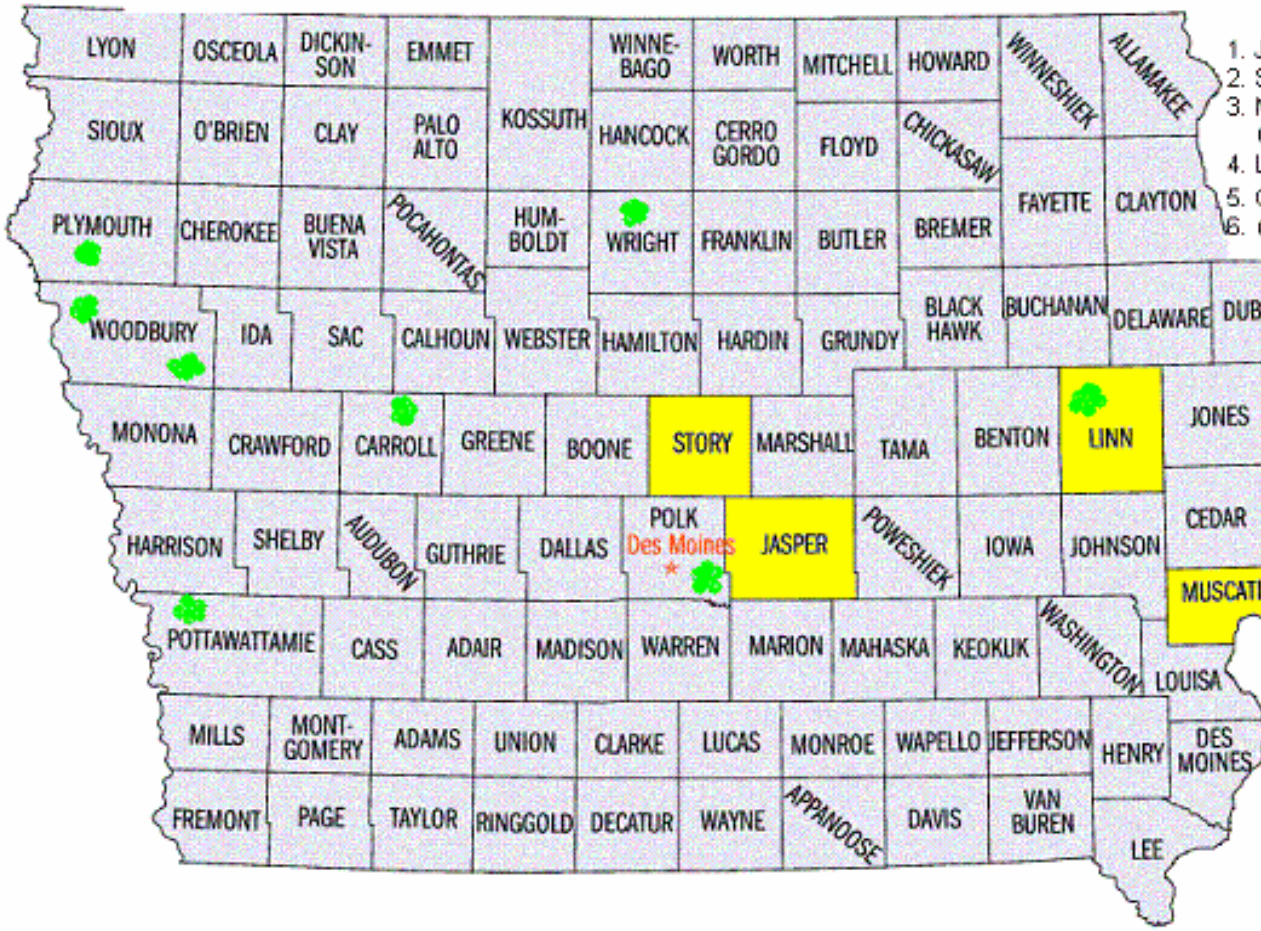
General Conclusions

Given the temporal and financial resources available, Dr. Tolliver has prepared a thorough and reasonably defensible assessment of the fuel, emission, and pollution abatement differentials that might be predicted under the various "with" and "without project" conditions consistent with TVA's 1996 rate study. In a re-look at transportation rates in 2002, TVA found that rates had changed by about 10 percent, but that regional transportation had changed dramatically. Dr. Tolliver did an excellent job assessing energy, safety, and noise impacts relating to a transportation environment that has changed to the extent that his study conclusions are really only valid for the paradigm laid out for him by the USACE. It might be true that the NED set of transportation rates changed so little that the USACE managers were comfortable using the old set of rates. But the transportation patterns behind the rates changed so drastically that the current data would have probably yielded different conclusions. The NED macro results mask the micro regional transportation conditions.

Recommendations

If the resources become available, it would be interesting to examine the impact of all of the truck traffic that will emanate from the without project condition. TVA was told that grain will be trucked around congestion and outages, thus staying on the river at points further down the river. If you are arguing that there will be no difference in fuel consumption in the with-out without conditions, there will less pressure to build new locks. On the other hand, if the alternative is to have trucks pouring into St. Louis, then fuel consumption and associated externalities will increase along with other environmental problems.

IOWA CORN & SOYBEAN PROCESSORS



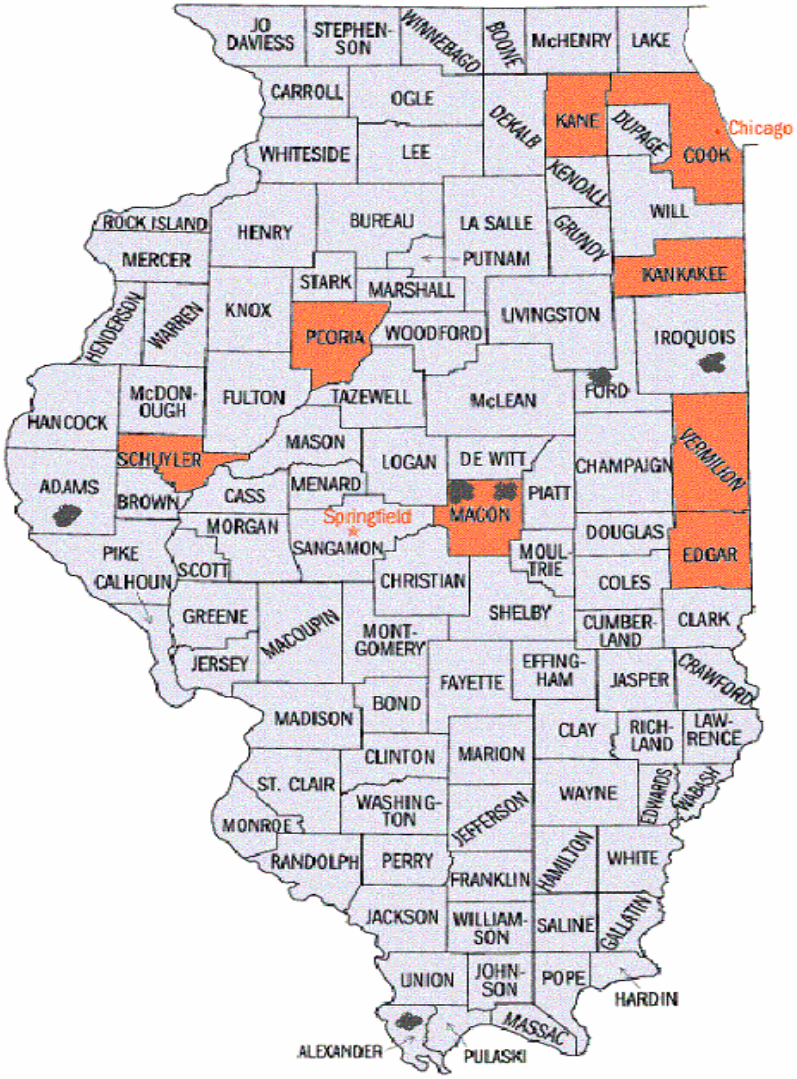
CORN

1. JASPER-SULLY CO-OP-102
2. STORY-TODD&SARGENT-100
3. MUSCATINE-GRAIN PROCESSING CORP-800
4. LINN-PENFORD PRODUCTS-300
5. CLINTON-ADM
6. CEDAR RAPIDS-ADM
7. MAHASKA-CARGILL
8. IOWA-SUNRISE ENERGY
9. GREENE-TALL CORN
10. SIOUX-SIOUXLAND ENERGY
11. QUAD-CORN PROCCESSORS
12. CHEROKEE-LITTLE SIOUX PROCESSORS
13. KOSSUTH-MIDWEST GRAIN PROCESSORS

SOYBEAN

1. POTTAWATTAM-BUNGE-125
2. LINN-CARGILL-100
3. WOODBURY-AG PROCESSING-100
4. POLK-ADM-100
5. WRIGHT-AG PROCESSING-75
6. CARROLL-WEST CENTRAL COOPERATIVE-75
7. WOODBURY-CARGILL-70

ILLINOIS CORN AND SOYBEAN PROCESSING PLANTS



CORN

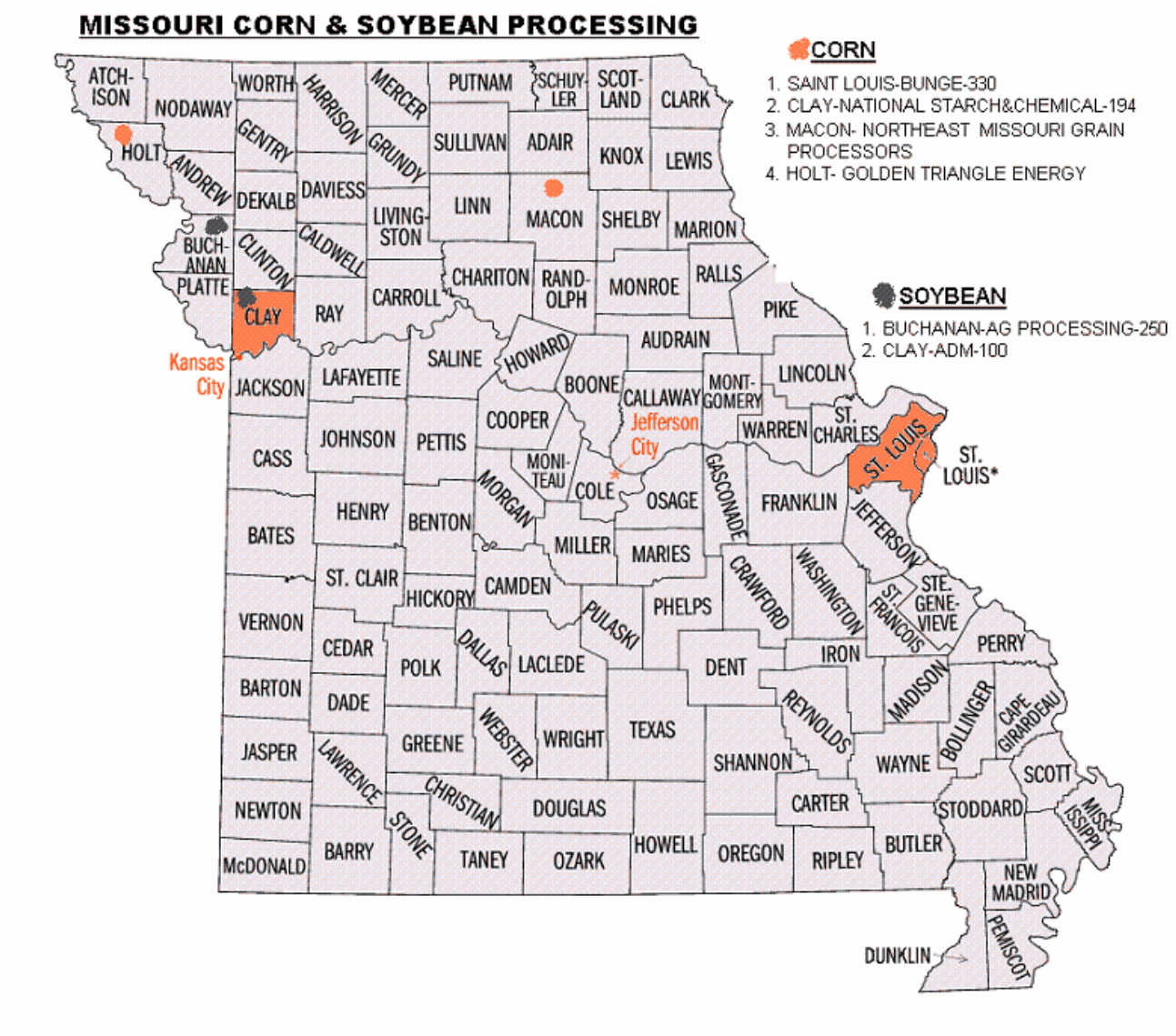
1. MACON-ADM-1000
2. MACON-ADM-280
3. COOK-CORN PRODUCTS INTERNATIONAL-850
4. VERMILLION-BUNGE MILLING-350
5. PEORIA-ADM-200
6. SCHUYLER-TWO RIVERS-200
7. EDGAR-ILLINOIS CEREAL MILLS-175
8. KANKAKEE-J R MILLING-130
9. KANE-HINTZSCHE FEED & GRAIN-70
10. MACON-AE STALEY

SOYBEAN

1. MACON-ADM-400
2. MACON-ADM-400
3. ADAMS-ADM-250
4. FORD-CENTRAL SOYA CO.-140
5. IROQUOIS-INCOBRASA INDUSTRIES-100
6. ALEXANDER-BUNGE-100

CORN

SOYBEAN


MISSOURI CORN & SOYBEAN PROCESSING
CORN
1. SAINT LOUIS-BUNGE-330
2. CLAY-NATIONAL STARCH&CHEMICAL-194
3. MACON- NORTHEAST MISSOURI GRAIN PROCESSORS
4. HOLT- GOLDEN TRIANGLE ENERGY
SOYBEAN
1. BUCHANAN-AG PROCESSING-250
2. CLAY-ADM-100
ATCH-ISON
NODAWAY
WORTH
HARRISON
MERCER
PUTNAM
SCHUY-LER
SCOT-LAND
CLARK
HOLT
GENTRY
GRUNDY
SULLIVAN
ADAIR
KNOX
LEWIS
ANDREW
DEKALB
DAVIESS
LIVING-STON
LINN
MACON
SHELBY
MARION
BUCH-ANAN
CLINTON
CALDWELL
PLATTE
CLAY
RAY
CARROLL
CHARITON
RAND-OLPH
MONROE
RALLS
PIKE
Kansas City
JACKSON
LAFAYETTE
SALINE
HOWARD
BOONE
AUDRAIN
CALLAWAY
MONT-GOMERY
LINCOLN
Jefferson City
WARREN
ST. CHARLES
ST. LOUIS
ST. LOUIS*
CASS
JOHNSON
PETTIS
COOPER
MONI-TEAU
COLE
OSAGE
GASCONADE
FRANKLIN
JEFFERSON
BATES
HENRY
BENTON
MORGAN
MILLER
MARIES
CRAWFORD
WASHINGTON
ST. CLAIR
HICKORY
CAMDEN
PULASKI
PHELPS
ST. FRANCOIS
STE. GENE-VIEVE
VERNON
CEDAR
POLK
DALLAS
LACLEDE
DENT
IRON
PERRY
BARTON
DADE
REYNOLDS
MADISON
BOLLINGER
CAPE GIRARDEAU
JASPER
LAWRENCE
GREENE
WEBSTER
WRIGHT
TEXAS
SHANNON
WAYNE
SCOTT
NEWTON
CHRISTIAN
DOUGLAS
CARTER
STODDARD
MISSISSIPPI
McDONALD
BARRY
STONE
TANEY
OZARK
HOWELL
OREGON
RIPLEY
BUTLER
NEW MADRID
PEMISCOT
DUNKLIN

Tolliver's Response to the TVA Independent Technical Review

The reviewers express concern that my report generally follows the rate study that TVA completed for USACE in 1996. In the 1996 study, rates were estimated on the basis of regional transportation patterns that existed during the early 1990s — patterns that have since changed dramatically. Because my report uses incremental traffic forecasts developed by USACE on the basis of this study, the reviewers fear that it does not reflect important changes that have occurred in the region.

Indeed, this is a legitimate concern. However, it is important for the energy, environmental, and safety impacts to be consistent with other components of the study. Thus, it is desirable to use the same traffic assumptions throughout the Upper Mississippi River-Illinois Waterway System Navigation Study. Otherwise, the safety and environmental impacts presented in this report would be based on different assumptions than other estimates. While I agree with the reviewers' concerns, their comments are more appropriately directed to the overall study.

The reviewers correctly point out that truck gathering and distribution movements are not reflected in the rail-barge comparisons presented in this report. There are several practical reasons for this omission. (1) The incremental tons of traffic provided by USACE for this study are aggregated by origin state. At this level of aggregation, it is impossible to analyze potential changes in farm-to-delivery point movements. (2) Such an analysis would require a very fine level of data detail, almost at the individual farm level. (3) The incremental traffic in this study represents forecasts to 2025 and beyond. Many changes are likely to occur between now and 2025, which will affect farm-to-rail and farm-to-river trucking distances. Even if current farmer delivery patterns could be identified precisely, they would almost certainly change between now and 2025. For example, the growing concentration of traffic at shuttle-train facilities means that farm-to-rail station trip distances are likely to increase over time as farmers take advantage of lower prices at shuttle elevators. Unfortunately, there is no analytical basis for forecasting these movement patterns in 2025, 2035, or 2050.

A major concern raised by the reviewers is the possibility of direct truck movements from farms to St. Louis in farmer-owned or leased semi-trailers. They correctly note that "if the alternative is to have trucks pouring into St. Louis, then fuel consumption and associated externalities will increase along with other environmental problems." If farmers in Iowa, Illinois, or Missouri truck directly to St. Louis in the without-project case, then the energy, environmental, and safety impacts estimated in this study will be seriously understated. USACE may wish to investigate this scenario, even if only through a case study.

Recommendations

Philosophically, I agree with the TVA reviewers. Practically, I believe it is important to use consistent demand and traffic assumptions throughout the Upper Mississippi River-Illinois Waterway System Navigation Study. I concur with the suggestion that an

analysis of long-haul trucking from farms to St. Louis should be considered, perhaps on a case-study basis. However, this would require a new traffic study in sufficient detail so that the likely flows into St. Louis could be predicted and separated from the long-haul railroad movements. This type of analysis is not possible using state-level traffic data. Such a study would require the development of a highway network and detailed analytical models. However, the effort may be worthwhile. In conclusion, I recommend that future studies:

- Provide a sufficient level of detail so that the effects of truck gathering and distribution movements can be analyzed
- Develop detailed origin-destination and route information so that grade-crossing delay and noise impacts can be fully analyzed
- Include estimates of the costs of noise mitigation or the impacts of railroad noise on property values
- Include estimates of the potential mitigating effects of grade separations and the costs of these separations