Transportation Impacts of Increased Ethanol Production: A Kansas Case Study

by Michael W. Babcock

The rapid expansion of the biofuel industry has driven the Kansas agricultural market into a new era. Nationally, fuel alcohol production has increased from 1,630 million gallons in 2000 to 9,239 million gallons in 2008, a 467% increase. This national trend has occurred in Kansas as well. As of December 2009 there are 10 operational ethanol plants in Kansas with a combined annual production capacity of 438 million gallons.

The growth of ethanol production in Kansas has affected the Kansas corn and sorghum markets in unknown ways. Historically, the principal market destination of Kansas corn was Kansas, Oklahoma, and Texas livestock feedlots with motor carriers accounting for all these shipments. The purpose of this research is to measure the transportation impact of Kansas ethanol production on the transportation of Kansas corn and sorghum. The specific objectives are: Objective A – Investigate the transportation impact of Kansas ethanol production on Kansas transportation from the point of view of the Kansas ethanol production industry, the grain elevator industry, and the Kansas railroad industry. Objective B – Investigate the impact of incremental truck traffic on road conditions in the vicinity of ethanol plants.

Anticipated results include the inbound and outbound shipments to and from Kansas ethanol plants by mode and origin/destination. This information is likely to indicate that Kansas ethanol production has altered the traditional corn and sorghum logistics system.

INTRODUCTION

The rapid expansion of the U.S. biofuel industry has driven the Kansas agricultural transportation market into a new era. Nationally, fuel alcohol production rose from 1,630 million gallons in 2000 to 9,239 million in 2008, a 467% increase (Renewable Fuels Association 2008). The number of ethanol production plants increased from 54 in January 2000 to 170 in January 2008, a 215% increase.

Many factors have contributed to the growth of the U.S. ethanol industry. Energy security and energy independence from unstable foreign countries has increased U.S. ethanol output. Global warming caused in part by combustion of fossil fuels, has encouraged consumption of ethanol. Rural economic development related to corn and ethanol production has contributed to biofuel expansion. Federal energy policies have also played a role. The Energy Policy Act of 2005 includes the Renewable Fuel Standard Program (RFS), which mandates the minimum amount of renewable fuels to be blended into gasoline. The RFS doubles the use of ethanol by 2012. The Energy Independence and Security Act of 2007 further expands the RFS by requiring that 36 billion gallons of renewable fuels be blended into gasoline and diesel by 2022. The record high prices of oil in the first half of 2008 contributed to ethanol production growth. However, the substantial decline in oil prices, which began in the Fall of 2008, has contributed to a slowdown in ethanol demand.

These national trends have occurred in Kansas as well. At the end of 2009, there were 10 operational ethanol plants in Kansas with a combined annual capacity of 438 million gallons (Kansas Corn Commission, Kansas Corn Growers Association, and Kansas Grain Sorghum Producers Association 2009). Of the 438 million gallons of capacity, 81% became operational between 2004 and 2008 (Kansas Corn Commission, Kansas Corn Growers Association, and Kansas Grain Sorghum Producers Association 2009).

The growth of ethanol production in Kansas has affected the Kansas corn and sorghum markets in unknown ways with resulting implications for Kansas agricultural transportation. Traditionally

(late 1970s to 2000), Kansas corn was delivered by motor carrier at harvest to the nearest country grain elevators. Prior to the expansion of ethanol production in Kansas, the primary destination corn markets of Kansas country elevators were Kansas, Oklahoma, and Texas livestock feedlots with motor carriers accounting for all of these shipments (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002). In Kansas, most of these corn shipments went to the western one-third of the state, which accounts for 77% of the feedlots in Kansas (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002). Some corn was shipped from country elevators by truck to alcohol plants in Kansas and Nebraska. About 15-20% of the Kansas corn was shipped from country elevators by truck to large terminal elevators in Hutchinson, Wichita, Salina, Topeka, and Kansas City, Kansas and then subsequently shipped by railroad to Texas Gulf of Mexico ports for export or to livestock feed locations in other states (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002).

While a large number of studies have been written on the economics of ethanol, very few studies have examined the impacts of increased ethanol production on regional agricultural transportation markets. The main objective and motivation of this paper is to contribute to this small but growing literature and in the process to indicate a useful methodology that can be used by researchers in other states. The specific objectives of the paper are:

- Investigate the transportation impact of Kansas ethanol production from the point of view of the Kansas ethanol production industry, the grain elevator industry, and the railroads serving Kansas.
- Investigate the impact of incremental truck traffic on state and county road conditions in the vicinity of Kansas ethanol plants.

U.S. AND KANSAS ETHANOL PRODUCTION AND CONSUMPTION

As of the end of 2009, there were 10 ethanol plants operating in Kansas (Table 1). Most of the plants are located in the western half of Kansas with East Kansas Agri-Energy being the lone exception. The plants vary widely in production capacity with Arkalon Energy, LLC, the largest (110 million gallons per year) and NESIKA Energy, LLC, the smallest (10 million gallons annually). The total production capacity of the Kansas ethanol plants is 438 million gallons per year, and they collectively use 156.2 million bushels of grain annually. Four of the plants are served by the Union Pacific Railroad and one by the Burlington Northern Santa Fe (BNSF) Railway. The Kansas and Oklahoma Railroad serves two plants and the Kyle Railroad, one. Two plants are not located on a railroad, but one of those will be served by the Kyle Railroad by the end of 2010.

The U.S. demand for ethanol is concentrated in high population density states where most of the people and vehicles are located. Table 2 contains the top dozen ethanol consumption states, which account for 65.3% of the total U.S. ethanol consumption. The top two states are California (14.49%) and Texas (9.46%), which together consume 24% of the U.S. total. Illinois accounts for 6% and a group of Midwestern states (Ohio, Michigan, and Minnesota) collectively account for 12% of total consumption. Five eastern states (New Jersey, New York, Massachusetts, Virginia, and Maryland) together account for 20.5% of total U.S. ethanol consumption.

Most of the U.S. ethanol production is concentrated in less than 10 Midwestern states (Tables 3 and 4). Table 3 displays the annual production capacity of the top eight states, which collectively account for 81.8% of the total U.S. ethanol production capacity. Iowa is the leading ethanol production capacity state, accounting for 27.7% of the national total. Illinois has 11.9% of the U.S. total, so these two states together account for more than one-third of national capacity.

Table 4 contains the number of operating ethanol plants in the top nine states, which collectively account for 81.2% of the U.S. total. Iowa is the leading state with 21.5% of the U.S. plants. Other leading ethanol producing states are Nebraska (13.1%), Minnesota (11.5%), South Dakota (7.9%), and Illinois (7.3%).

Table 1: Kansas Ethanol Plants (Production Capacity in Millions of Gallons Per Year)

Production Plant	Location	Production Capacity	Starting Date	Bushels of Grain Used	Originating Railroad
Abenoga Bioenergy Corp	Colwich	25	1982	8.9 million	Kansas & Oklahoma
Arkalon Energy, LLC	Hayne (near Liberal)	110	2007	39 million	Union Pacific
Bonanza Energy, LLC	Garden City	55	2007	19.6 million	Burlington Northern Santa Fe
East Kansas Agri-Energy	Garnett	40	2005	12.5 million	Union Pacific
Kansas Ethanol, LLC	Lyons	55	2008	19.6 million	Kansas & Oklahoma
Prairie Horizon Agri-Energy	Phillipsburg	40	2006	14.3 million	Kyle Railroad
Reeve Agri Energy	Garden City	13	1982	5.4 million	None
Western Plains Energy	Campus (near Oakley)	45	2004	16.1 million	Union Pacific
White Energy	Russell	45	2001	17.2 million	Union Pacific
NESIKA Energy, LLC	Scandia	10	2008	3.6 million	None
Total Capacity and Grain Used		438		156.2 million	

Source: (Location, Production Capacity, and Bushels of Grain Used) *Kansas Ethanol Production*, Kansas Corn Commission, Kansas Corn Growers Association, and Kansas Grain Sorghum Producers Association (http://www.ksgrains.com/ethanol, accessed February 2009).

Table 2: Top Dozen Ethanol Consumption States, 2007

Rank	State	Thousands of Gallons	Percent of Total U.S. Consumption
1	California	978,516	14.49
2	Texas	638,526	9.46
3	Illinois	405,258	6.00
4	New Jersey	387,114	5.73
5	New York	341,244	4.65
6	Ohio	305,382	4.52
7	Michigan	270,564	4.01
8	Massachusetts	253,218	3.75
9	Minnesota	236,418	3.50
10	Virginia	224,700	3.33
11	Maryland	204,498	3.03
12	Arizona	192,564	2.86

Source: U.S. Department of Energy, Energy Information Administration, State Energy Data System, *State Energy Consumption Estimates, 1960-2007*, Table 11 (www.eia.doe.gov/emeu/states/_seds.html).

Table 3: Annual Production Capacity, March 2009 (Millions of Gallons Per Year)

State	Capacity	Percent of U.S. Total
Iowa	2,866	27.67%
Illinois	1,233	11.90%
Nebraska	1,001	9.66%
South Dakota	906	8.75%
Minnesota	837.6	8.09%
Indiana	697	6.72%
Wisconsin	498	4.81%
Kansas	438	4.23%
Total Top 8 States	8,476.6	81.83%
U.S. Total Capacity	10,358.0	

Source: Renewable Fuels Association. *Biorefinery Locations* (http://www.ethanolrfa.org) Accessed November 27, 2009.

Table 4: Major Ethanol Production States, 2009

State	Number of Operating Plants	Percent of U.S. Total
Iowa	41	21.5%
Nebraska	25	13.1%
Minnesota	22	11.5%
South Dakota	15	7.9%
Illinois	14	7.3%
Indiana	12	6.3%
Kansas	10	5.2%
Wisconsin	9	4.7%
Ohio	7	3.7%
Total	155	
Grand Total	191	
% Top 9 States	81.2%	

Source: Renewable Fuels Association. *Biorefinery Locations* (http://www.ethanolrfa.org) Accessed November 27, 2009.

LITERATURE REVIEW

To date, relatively few studies have investigated the transportation implications of increased ethanol production. One of these studies (Yu and Hart 2008) analyzed transportation flow patterns of crops and biofuels in Iowa. The authors accomplish this goal by surveying grain marketers, grain handlers, corn/ethanol processors, and biodiesel producers concerning their grain, biofuels, and biofuels co-product transport flows in the 2006-2007 marketing year. They found that corn shipments to livestock feeding locations have declined due to increased ethanol production, although livestock feeding

is still the primary end user of Iowa corn. According to their surveys the biggest transportation infrastructure problems were unimproved gravel roads, while the biggest marketing problem was transportation costs.

Denicoff (2007) examines the changes in corn-based ethanol transportation requirements and grain transportation caused by growth in the ethanol industry. This was accomplished by analyzing surveys conducted by USDA personnel. Denicoff found that corn is being used less as livestock feed or export and more for ethanol production. The author found that in 2005, 60% of the ethanol was shipped by rail, 30% by trucks, and 10% by barge. She said that railroads were affected by increased ethanol production through a decrease in grain shipments and an increase in ethanol tonnage. Barge shipments decreased due to a decrease in corn exports.

Wu and Markham (2008) suggest strategies to ensure ethanol growth in Minnesota is not limited by logistical problems. The authors accomplish this by evaluating Minnesota Department of Agriculture surveys of ethanol plant managers. Some of the issues that concerned ethanol plant managers included the following:

- Railroad turnaround time
- Poor condition of rail track
- Lack of funds to improve rail track
- Costly and unreliable transportation
- Transportation capacity for transporting ethanol and DDG (dried distillers grain)
- Railroad reluctance to accept public funding

Wu and Markham's strategy for addressing these issues consist of an educational program to acquaint stakeholders with potential logistics problems and the negative consequences if nothing is done about them. They also identify public-private partnerships as the key to adequate investment in railroad infrastructure. The authors note policy support can aid railroads serving Minnesota in finding investment funds.

Khachatryan et al. (2009) explore the economic feasibility of cellulosic ethanol production in Washington State by presenting the availability, transportation, and collection costs of crop residue. The authors use farm gate costs, transportation costs, physical availability of feedstock, and geographical distribution of feedstock to obtain crop residue supply curves. From analyzing these curves the authors conclude that transportation costs have a considerable influence on the delivered cost of feedstock. However, the magnitude of this influence depends on the capacities of the processing plants and the haul distance to them. The authors perform a sensitivity analysis and find that small capacity processing plants, relative to plants with large capacity, have delivered feedstock costs that are less sensitive to higher diesel fuel prices.

Thompson and Meyer (2009) simulate consumer demand for ethanol together with ethanol transportation costs with respect to benchmark oil and ethanol prices. The authors find a nonlinear relationship between benchmark prices and ethanol transportation costs. The relationship depends on how widely ethanol is used within a state and how close ethanol prices are to the price of corresponding types of energy. For states with widespread use of ethanol, the authors found that the amount of ethanol shipped to that state is insensitive to fuel prices, but an increase in transportation prices will increase transportation expenditures. In contrast, Thompson and Meyer (2009) found that states where ethanol is less widely used as a fuel additive have a more price sensitive (elastic) demand for ethanol. The sensitivity increases if fuels with different levels of additives are priced the same in local markets. The authors note that the difference in energy values between ethanol and the fuel it is replacing will cause an increase in each state's transportation costs since a larger volume of gasoline with an ethanol additive will be required to generate the same energy output as gasoline with a MTBE additive.

METHODOLOGY AND DATA

Objective A was accomplished through personal interviews with managers of Kansas ethanol production plants, managers of Kansas grain companies, and personnel of the railroads serving Kansas ethanol plants. (Questionnaire in the Appendix. Questionnaires for other respondents available on request.) In addition to the interviews, managers of ethanol plants were asked to complete a detailed questionnaire containing the following sections:

a. Production and Capacity
b Inbound Transportation
c. Outbound Transportation
d. Carrier Choice Decision Factors
e. Kansas Transportation Infrastructure Quality
f. The Future

Seven of the 10 representatives of the ethanol plants answered all the questions on the questionnaire and the other three partially completed it.

The Kansas grain elevator industry supplies the corn and sorghum to the ethanol production plants. The author (and research assistants) interviewed 21 managers of Kansas grain companies that collectively account for 227 elevators and 200 million bushels of storage capacity. The managers also completed a questionnaire with the following sections:

a. Grain Receipts
b. Outbound Transportation
c. Carrier Choice Selection Factors
d. Summary (how have your markets for corn and sorghum changed as a result of increased ethanol production in Kansas?)

Representatives of the ethanol firms identified their grain suppliers, which resulted in the 21 grain company sample. Representatives of all 21 grain companies answered all the questions on the questionnaire.

Personnel of the railroads serving Kansas ethanol plants were interviewed by members of the research team. These railroads included the Union Pacific and the Burlington Northern Santa Fe, and two short line railroads – the Kansas and Oklahoma and the Kyle Railroad. Representatives of three of the four railroads answered all the questions on the questionnaire and the other one partially completed it. The questionnaire covers the following topics:

a. General Questions
b. Corn Shipments to Kansas Ethanol Plants
c. Outbound Ethanol Shipments from Kansas
d. Outbound DDG (dry distillers grain) Shipments from Kansas Ethanol Plants
e. Summary (expected ethanol car loadings in the next five years)

Objective B was accomplished by interviewing the county engineer or county road supervisor of counties that have ethanol plants. The county representatives also completed a questionnaire containing the following areas.

a. Current Condition of the County Roads
b. Revenue and Expenses
c. Impact of Ethanol Plant on County Roads

Representatives of all eight counties that have ethanol plants completed the questionnaire.

Secondary data sources include *Kansas Ethanol Production* (http://www.ksgrains.com/ethanol), the source for location, production capacity, and bushels of grain used in Kansas ethanol plants. State consumption of ethanol was obtained from Energy Information System, State Energy Data System (www.eia.doe.gov/emeu/states). State production capacity and number of ethanol plants was from Renewable Fuels Association (http://www.ethanolrfa.org).

TRANSPORTATION OF KANSAS ETHANOL PLANTS

The growth of ethanol production in Kansas has provided an additional market for Kansas corn and sorghum, and the transportation impacts of this new market are the subject of this section of the paper.

Inbound Transportation

The Kansas ethanol plants processed 156.2 million bushels of corn and sorghum in 2008, which was 22.3% of the combined Kansas production of corn and sorghum. Since the great majority of the inbound grain shipments are short distance hauls, motor carriers dominate the inbound shipments, accounting for 91% of the total. Nearly all the inbound motor carrier shipments (97.5%) were delivered in five axle semi-tractor trailer trucks. In a typical five day business week, the 10 Kansas ethanol plants unloaded 3,358 truckloads, or 672 per day. Since each truck hauls about 893 bushels, about 600,000 bushels are processed each day. The great majority of the shipments (82%) originate at grain elevators, with the other 18% delivered by farmers.

Most corn and sorghum shipments originate in the local area of the ethanol plants, with 91% originating within 100 miles of the plant. The remaining 9% are rail shipments predominantly from Iowa. Since the Kansas ethanol plants rely on the local area for corn and sorghum supply, the great majority (87%) of the truck shipments originate in Kansas.

Outbound Transportation

The outbound transportation of Kansas ethanol plants includes shipments of ethanol and co-products (DDG and WDG). Shipments occur by both rail and truck; however, rail is the dominant mode for outbound shipment of ethanol, accounting for 60% of the volume of shipments. Five plants shipped ethanol by rail to population centers in California, and four plants shipped ethanol to Texas by rail. Other rail shipment destinations include population centers in Illinois, New Mexico, Arizona, New York, and Washington. In general, rail was the preferred mode for long distance ethanol shipments.

Population centers in the states bordering Kansas were the principal destination markets for truck shipments of ethanol. Four Kansas plants shipped ethanol by truck to Colorado (primarily Denver) while six plants had truck shipments to Oklahoma (primarily Oklahoma City). Five ethanol plants shipped by truck to a wide variety of Kansas locations, including refineries, fuel blending locations, and retail outlets. Three plants had shipments to Texas population centers, including Dallas-Fort Worth, Houston, and Amarillo. In general, motor carrier was the preferred mode for relatively short distance ethanol shipments.

Most of the transportation of DDG (dry distillers grain) and WDG (west distillers grain) is handled by motor carrier. DDG and WDG are high protein livestock feed ingredients, and are both shipped relatively short distances by truck to livestock feeding locations. Kansas feedlots (mainly cattle and hogs) were named by all 10 ethanol plants as a primary market for DDG and WDG.

IMPACT OF ETHANOL PRODUCTION ON KANSAS GRAIN COMPANY TRANSPORTATION

This section of the paper documents how the Kansas grain industry's markets for corn and sorghum have changed as a result of Kansas ethanol production, and what have been the associated transportation impacts. To do this, a sample was selected of 21 Kansas grain companies that operate 227 grain elevators with a total storage capacity of 200 million bushels. These companies collectively had 2007 corn receipts of 106.2 million bushels and 83.5 million bushels of sorghum (also referred to as milo). The corn receipts amount to 20.9% of total Kansas 2007 corn production. The corresponding percentage for sorghum was 39.9%.

Outbound Shipments to Kansas Ethanol Plants

The 21 Kansas grain companies delivered 22.5 million bushels of corn to Kansas ethanol plants in 2007, all of which were delivered by motor carriers. Thus, 21.2% of the total corn receipts of the sample grain companies were delivered to Kansas ethanol plants [(22.5/106.2)*100=21.2%]. There were no corn shipments from the 21 companies to ethanol plants outside the state of Kansas.

In 2007, the sample grain companies shipped 22.1 million bushels of sorghum to Kansas ethanol plants, all of which were delivered by motor carrier. Thus, the Kansas grain companies shipped 26.5% of their total sorghum receipts to the 10 Kansas ethanol plants [(22.1/83.5)*100=26.5%].

It is interesting to note that the total percentage of Kansas corn plus sorghum production absorbed by Kansas ethanol plants in the 2007-2008 period (22.1%) is nearly identical to the corresponding percentage of the sample grain companies (23.5%). Also, the 44.6 million bushels of corn plus sorghum represents 28.6% of the 156.2 million bushels of corn and sorghum absorbed by Kansas ethanol plants.

Outbound Shipments to Other (Non-Ethanol) Markets

In 2007, the 21 Kansas grain companies shipped 77.6 million bushels of corn to markets other than Kansas ethanol plants. Hereafter referred to as non-ethanol plant locations. Nearly all (76.4 million bushels) of these corn shipments were by motor carriers, with only 1.2 million bushels shipped by rail. Most of the truck corn shipments were to Kansas livestock feedlots and feed mills. Much smaller truck shipments went to Kansas terminal elevator locations (primarily Kansas City and Topeka), Kansas pet food manufacturing plants, and poultry feeding locations in Arkansas and Missouri.

Only 4 of the 21 sample grain companies shipped corn by rail to non-ethanol plant locations. Rail shipment destinations included livestock feeding locations in California, Arizona, New Mexico, Oklahoma, and Texas. Other rail corn shipments were to Texas Gulf of Mexico export ports, Wichita and Hutchinson, Kansas, terminal elevators, and poultry feeding locations in Arkansas and Missouri.

The 21 grain companies shipped 56.8 million bushels of sorghum to non-ethanol plant locations. Unlike corn, a large percentage of outbound sorghum shipments were by rail. The rail shipments were classified in two categories: rail and truck rail. The rail category is shipments from one of the country elevators of the grain company sample. The truck-rail category involves a short haul truck movement from a country elevator location to a shuttle (train loader) train location, from which the sorghum is subsequently shipped by rail to final destination. Of the 56.8 million bushels of sorghum shipped by the 21 grain companies, 30 million (53%) bushels were shipped by truck, 3.8 million (7%) by rail, and 22.9 million (40%) by truck rail. Thus, the total sorghum shipments by rail and truck were about equal (53% vs. 47%).

The principal destination markets for the truck shipments of sorghum were Kansas livestock feed yards and feed mills. Much smaller shipments went to Oklahoma feedlots, Kansas pet food companies, Hutchinson, Kansas terminal elevators, and poultry feeding locations in Arkansas and Missouri.

Texas Gulf of Mexico export ports were the only sorghum destination market for rail shipments from the country elevator locations of the sample grain companies. Nine of the 21 grain companies had truck-rail sorghum shipments to Kansas shuttle train locations with subsequent rail shipment to Gulf ports for export.

Grain Company Shipments by Crop, Market Destination, and Mode of Transportation

The results of the previous discussion are summarized in Tables 5 and 6. The data in Table 5 indicate that 21.2% of the corn receipts of the 21 companies went to Kansas ethanol plants and 73.1% was shipped to non-ethanol plant locations, together accounting for 94.3% of the total corn receipts of

the sample grain companies. The remaining 5.7% of the corn receipts were likely used by farmers to feed their livestock.

Table 5 data reveal 26.5% of the 21 grain company sorghum receipts were shipped to Kansas ethanol plants, with 68% going to non-ethanol plant locations.

Table 5: 2007 Shipments of Sample Grain Companies by Crop and Market Destination

Market Destination	Corn Bushels (Millions)	Percent of Total Receipts
Ethanol Plants	22.5	21.2%
Non-Ethanol Plant Locations	77.6	73.1%
Total	100.1	94.3%
Market Destination	**Sorghum Bushels (Millions)**	**Percent of Total Receipts**
Ethanol Plants	22.1	26.5%
Non-Ethanol Plant Locations	56.8	68.0%
Total	78.9	94.5%

Table 6 data indicate that motor carriers shipped 100% of the corn going to Kansas ethanol plants and nearly all of the corn shipments to non-ethanol plant locations. Motor carriers accounted for all the sorghum shipments to Kansas ethanol plants, but only 53% of the sorghum shipments to non-ethanol plant locations.

In general, the emergence of ethanol plants as a new market for Kansas corn and sorghum hasn't changed the mode of transportation since all shipments to ethanol plants are by truck, as were the shipments to livestock feedlots before the emergence of ethanol as an additional market. However, the market destinations have changed significantly with a higher percentage of the corn and sorghum shipped to ethanol plants and a corresponding reduction in the percentage shipped to non-ethanol plant markets.

Table 6: 2007 Shipments of Sample Grain Companies by Crop, Market Destination, and Mode of Transport

Corn			
Market Destination	**Truck (millions of bushels)**	**Rail (millions of bushels)**	**Truck (percent of total)**
Ethanol Plants	22.5	0.0	100.0%
Non-Ethanol Plant Locations	76.4	1.2	98.5%
Total	98.9	1.2	98.8%
Sorghum			
Market Destination	**Truck (millions of bushels)**	**Rail* (millions of bushels)**	**Truck (percent of total)**
Ethanol Plants	22.1	0.0	100.0%
Non-Ethanol Plant Locations	30	26.8	52.8%
Total	52.1	26.8	66.0%

*Includes Rail Only and Truck-Rail

Destinations and Transport Modes of Non-Ethanol Plant Markets Before and After Expansion of Ethanol Production

From the late 1970s up to year 2000, when the number of ethanol plants in Kansas began to increase, the primary destination corn markets of Kansas grain companies were Kansas, Oklahoma, and Texas livestock feedlots with motor carriers accounting for all of these shipments (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002). Small amounts of corn were shipped from Kansas grain elevators by truck to alcohol plants in Kansas and Nebraska. About 15-20% of Kansas corn was shipped by truck from country elevators to large terminal grain elevators and then subsequently shipped by railroad to Texas Gulf of Mexico ports for export or to livestock feed locations in other states (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002). Small amounts of corn were shipped by truck from southeast Kansas to poultry feeding locations in Missouri and Arkansas.

After ethanol production increased in Kansas, the non-ethanol plant destination markets and associated transport modes for Kansas corn remained essentially the same. As before, in 2007, the primary market for non-ethanol plant corn was livestock feedlots (mostly in Kansas) with nearly all the shipments (98.5%) moving by truck. Truck shipments of corn to Kansas terminal elevators and shuttle train loading stations remained about the same magnitude as the pre-2000 period. Relatively small amounts of corn were shipped by truck from southeast Kansas to poultry feeding locations in Missouri and Arkansas. As was the case prior to 2000, a relatively small amount of Kansas corn was shipped by rail in 2007 to livestock feeding locations in other states and to Texas Gulf ports for export.

The primary market destinations of sorghum in the period before the expansion of ethanol production in Kansas were livestock feed lots and Texas Gulf ports. Motor carriers accounted for nearly all the shipments of sorghum to livestock feedlots, while railroads handled all the sorghum shipments to the Texas Gulf ports for export (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002). Some rail shipments went directly to Mexico. The modal split varied from year to year depending on market conditions with railroads obtaining 40-60% of the total shipments (Kansas State Board of Agriculture 1980; Kansas Department of Agriculture 2002).

The market destinations and modal split for sorghum shipped to non-ethanol plant destinations in 2007 was essentially the same as in the pre-2000 period. Motor carriers accounted for all the shipments to feedlots, while the sole destination for rail shipments was Texas Gulf ports. Motor carriers accounted for 53% of the total sorghum shipments to non-ethanol plant markets with railroads handling 47%.

Total transportation of corn has likely increased given the increase in Kansas corn production. Average annual Kansas production of corn in the 1990-2003 period was 314.5 million bushels (U.S.D.A. (NASS) and Kansas Department of Agriculture, various years). In the 2004-2009 period, when most of the Kansas ethanol plants began operations, average annual corn production was 472.6 million bushels, a 50% increase (U.S.D.A. (NASS) and Kansas Department of Agriculture, various years). Average annual Kansas sorghum production in the 1990-2003 period was 215.9 million bushels, falling to 201.5 million bushels in the 2004-2009 period, a 6.7% decrease (U.S.D.A. [NASS]; Kansas Department of Agriculture, various years). It isn't possible to document the trend in modal split in the post-2000 period since no statewide studies of Kansas grain movements have been conducted since 2000.

KANSAS ETHANOL PLANTS AND RAILROAD TRANSPORTATION

Rail transportation is important to Kansas ethanol plants. In some cases corn was delivered to these firms by rail and railroads supply outbound transportation of ethanol and distillers grain. The Kansas ethanol plants are served by two Class I railroads, which are Union Pacific (1,566 mainline track miles in Kansas) and Burlington Northern Santa Fe (1,237 mainline miles). Four Kansas ethanol

plants are served by the Union Pacific. The Burlington Northern Santa Fe serves one. Some Kansas ethanol plants are served by short line railroads. The Kansas and Oklahoma Railroad has 840 track miles in Kansas and serves two ethanol plants. The other short line serving a Kansas ethanol plant is the Kyle Railroad, which has 425 track miles in Kansas.

Railroad Corn Shipments to Ethanol Plants

In 2008, Class I railroads delivered 2,470 carloads of corn to Kansas ethanol plants. The typical shipment size was a 100-car unit train. Iowa was the origination state for 96% of the corn shipments with Minnesota accounting for the other 4%. One of the short lines delivered 14 carloads of sorghum to a Kansas ethanol plant.

Railroad Shipments of Ethanol and Distillers Grain

Railroads play a much larger role in the outbound shipments from Kansas ethanol plants than the inbound shipments of feedstock. In 2008, the two Class I railroads shipped a combined total of 8,200 cars of ethanol from Kansas ethanol plants. The two short line railroads shipped a combined total of 1,028 cars of ethanol which they subsequently interlined to one of the Class I railroads for shipment to the final destination. Thus, the 1,028 cars are part (12.5%) of the 8,200 cars shipped by Class I railroads.

Table 7 displays data on 2008 Class I railroad shipments from Kansas ethanol plants by destination market. The West region (California, Oregon, and Washington) and the South region (Texas, Oklahoma, and Louisiana) accounted for the largest percentage of ethanol shipments with 30.8% and 29.5%, respectively. The East of the Mississippi River region and the state of Arizona accounted for 19.1% and 16.1% of the total ethanol rail shipments from Kansas.

Railroad shipments of distillers grain are relatively minor since most of it is shipped by truck to Kansas feedlots. In 2008, 450 cars of DDG (dried distillers grain) were shipped from Kansas ethanol plants by Class I railroads. The primary destination was California.

IMPACTS OF ETHANOL PLANT-RELATED TRUCK TRAFFIC ON COUNTY ROADS

As noted previously, the 10 Kansas ethanol plants receive nearly all of their corn and sorghum by motor carrier. In a single business day they collectively unload about 670 trucks or 67 per plant. A similar number of trucks are involved in outbound movements of ethanol and distillers grain. Nearly all these trucks are five axle, 80,000 pound GVW (gross vehicle weight) semis. The purpose of this part of the paper is to assess the impact of this truck traffic on county roads in the eight Kansas counties that have ethanol plants.

Current Condition of County Roads

Collectively, the eight counties are responsible for 6,882 miles of county roads and 1,805 bridges. Of the 6,882 miles, only 34 are concrete, 1,551 are asphalt (22.5% of the total), and the majority (5,297 miles or 77%) are unpaved (gravel or dirt). The county engineer or road supervisor of each of the eight counties were asked to rate the current condition of their county roads, and the results are summarized in Table 8. For the 34 miles of concrete road, 8.9% were rated Poor, but nearly 56% were rated Good or Very Good. For the asphalt roads, 10.9% were rated Very Poor or Poor and 61.5% were rated Good or Very Good. The county representatives said only 3.7% of the county's unpaved roads were Poor or Very Poor, while 48% were rated Good or Very Good.

Table 7: 2008 Class I Railroad Ethanol Shipments from Kansas by Destination Market

Market Destination	Percent of Shipments
West (California, Oregon, Washington)	30.8%
South (Texas, Oklahoma, Louisiana)	29.5%
East of the Mississippi River	19.1%
Arizona	16.1%
Midwest (Illinois, Missouri, Wisconsin)	3.2%
Mountain (Colorado, Nevada, Utah)	1.3%

Sedgwick County accounts for 37% of the 1,551 miles of asphalt road in the eight county sample. Sedgwick County representatives rated all 575 miles of their asphalt roads as being in Very Good condition. Sedgwick County is the most urbanized county in the state with a large tax base and dedicated funding sources. When Sedgwick County is removed from the eight county sample, a different picture of asphalt road conditions emerges in the other seven counties. The percentage of asphalt roads rated Very Poor or Poor increases from 10.9% to 17.2%, while the percentage rated as Good or Very Good falls from 61.5% to 38.9%.

Overall, the current condition of the roads in the eight counties is reasonably good for all road surface types with very few miles in the Very Poor and Poor categories.

Change in County Road Conditions

The county engineers/road supervisors were asked if truck traffic entering or leaving the ethanol plant has had an impact on the condition of the county roads. Six of the eight county representatives responded in the affirmative, while the other two respondents said they were not sure if there had been an impact.

Modifications to county roads generated by ethanol plant-related truck traffic include rebuilt roads, construction of turn lanes and widened turn radius, accelerated chip-seal maintenance rotation that includes asphalt overlay on roads that access the ethanol plant, and blading of roads to smooth out ruts. Representatives of counties with ethanol plants located on state highways said their county road condition had not been affected very much by truck traffic in and out of the plant.

Table 8: Ratings of the Current Condition of County Roads

Road Surface Type	Very Poor % (miles)	Poor % (miles)	Fair % (miles)	Good % (miles)	Very Good % (miles)
Concrete	-	8.9 (3)	35.3 (12)	38.2 (13)	17.6 (6)
Asphalt	2.3 (35)	8.6 (133)	27.6 (428)	21.7 (336)	39.8 (619)
Unpaved	-	3.7 (196)	48.3 (2,555)	45.7 (2,423)	2.3 (123)

Ratings of the Current Condition of Asphalt County Roads (Exc. Sedgwick County)

Very Poor % (miles)	Poor % (miles)	Fair % (miles)	Good % (miles)	Very Good % (miles)
3.6 (35)	13.6 (133)	43.9 (428)	34.4 (336)	4.5 (44)

The county representatives were asked if ethanol plant-related truck traffic had affected the county's annual expenditure for road and bridge maintenance. The respondents were divided on this question with three replying that maintenance expenditure had been affected, while three said there

had been no impact, with the other two representatives not sure if an impact had occurred. One of the respondents that said there had been no impact modified this response by stating that although total maintenance expenditure was unaffected, the county was redirecting maintenance resources to ethanol plant-related maintenance.

Although the majority of the eight county representatives revealed that ethanol plant-related truck traffic had affected the condition of the county's roads, seven of the eight respondents said that the incremental truck traffic had not impaired the ability of the county to maintain an adequate level of service on the county's roads. However, several respondents indicated that the ethanol plant had opened recently, and that it was too soon to tell what the longer run impact would be on the condition of the county's roads.

CONCLUSION

In 2008, Kansas ethanol plants processed 156.2 million bushels of corn and sorghum, 22.3% of the combined Kansas production of corn and sorghum. Since the inbound grain transport movements are relatively short hauls, trucks dominate these shipments, accounting for 91% of the total inbound feedstock (corn and sorghum), with railroads accounting for the remaining 9%. Most of the corn shipments to Kansas ethanol plants originated in the local area of the ethanol plant, with 91% of the shipments originating within 100 miles of the plant. The remaining 9% are rail shipments originating primarily in Iowa.

The outbound transportation of Kansas ethanol plants includes shipments of ethanol and co-products DDG and WDG. Shipments of ethanol occur by rail and truck; however, rail is the dominant mode, accounting for 60% of the volume of shipments. In 2008, two Class I railroads shipped a combined total of 8,200 cars of ethanol from Kansas ethanol plants. The West region (California, Oregon, and Washington) and the South region (Texas, Oregon, and Louisiana) accounted for the largest percentage of ethanol shipments with 30.8% and 29.5%, respectively. The East of the Mississippi River region and the state of Arizona accounted for 19.1% and 16.1% of the total ethanol rail shipments from Kansas. Relatively minor amounts were shipped to the Midwest region (Illinois, Missouri, and Wisconsin) and the Mountain region (Colorado, Nevada, and Utah). In general, rail was the preferred mode for long distance ethanol shipments.

Population centers in the states bordering Kansas were the principal destination markets for truck shipments of ethanol. These include Denver, Colorado; Oklahoma City, Oklahoma; and Dallas-Fort Worth, Houston, and Amarillo, Texas. Kansas refineries, fuel blending locations, and retail outlets also received ethanol by truck. In general, motor carrier was the preferred mode for relatively short distance ethanol shipments.

Most of the transportation of DDG and WDG is handled by motor carrier since these co-products are shipped relatively short distances to livestock feeding locations, primarily Kansas feedlots for cattle and hogs.

The growth of Kansas ethanol production has affected the traditional markets for Kansas corn and sorghum. In the corn market, the percentage of shipments from country grain elevators to feedlots has declined and the percentage shipped to ethanol plants has increased. However, as before, nearly all of these shipments are by motor carrier, and feedlots remain the largest single market for Kansas corn. The impact in the sorghum market has been an increase in the percentage of truck shipments from country grain elevators to Kansas ethanol plants, and a decrease in the percentage of rail shipments to distant livestock feeding locations and Texas Gulf ports. The percentage of truck shipments of sorghum to feed mills and feed yards has also declined. Ethanol plants have increased the demand for Kansas corn and sorghum, resulting in higher bid prices for both grains.

It is difficult to identify recommendations for Kansas transportation policy given the uncertainties that exist in the ethanol market. At this time the critical determinants of the demand and supply of ethanol are unknown. Will the demand for Kansas ethanol emerge from the current downturn and increase in the future? Will corn supply in Kansas increase enough to supply the ethanol market as

well as the other non-ethanol corn markets? The answers to these and other questions will be partly determined by national agricultural and energy policy. Another source of uncertainty is that half of the Kansas ethanol plants have been in operation for less than four years. Thus, the long run impact of Kansas ethanol plants on Kansas transportation is unknown at this time. Motor carriers and railroads are both involved in the transportation of corn and sorghum to Kansas ethanol plants and the transportation of ethanol and distillers grain from these plants. Therefore, it seems prudent for Kansas to maintain its current transportation programs of maintaining a high quality state highway system, state aid to county roads, and aid programs for Class II and III railroads.

References

Denicoff, Marina. *Ethanol Transportation Backgrounder: Expansion of U.S. Corn-based Ethanol from the Agricultural Transportation Perspective*. Agricultural Marketing Service, U.S. Department of Agriculture, November, 2008. (http://www.ams.usda.gov/AMSvl.0/getfile?dDocName=STELPRDC5063605&acct=atpub).

Kansas Corn Commission, Kansas Corn Growers, and Kansas Grain Sorghum Producers Association. *Kansas Ethanol Production*. (http://www.ksgrains.com/ethanol).

Kansas Department of Agriculture, Kansas Agricultural Statistics Service. *Kansas Grain Transportation*. Topeka, Kansas, 2002.

Kansas State Board of Agriculture, Kansas Crop and Livestock Reporting Service. *Kansas Grain Marketing and Transportation Data for 1979*. Topeka, Kansas, 1980.

Khachatryan, H., E. Jessup, and K. Casavant. "Derivation of Crop Residue Feedstock Supply Curves Using Geographic Information Systems." *Journal of the Transportation Research Forum* 48 (1), (2009): 5-22.

Renewable Fuels Association. *Changing the Climate: Ethanol Industry Outlook 2008*, pp. 10-13 (http://www.ethanolrfa.org).

Thompson, W. and S. Meyer, "Simulated Ethanol Transportation Patterns and Costs." *Journal of the Transportation Research Forum* 48 (1), (2009): 23-28.

U.S. Department of Agriculture, National Agriculture Statistics Service (NASS) and the Kansas Department of Agriculture. *Kansas Farm Facts*, Topeka, Kansas, various years.

U.S. Department of Energy, Energy Information Administration, State Energy Data System. *State Energy Consumption Estimates, 1960-2007*, Table 11. (www.eia.doe.gov/energy/states/_seds.html).

Wu, Fang (Lisa) and K. Markham. "Opportunity for Class II and III Railroads in Ethanol and its Co-product Transportation: A Survey Study in Minnesota." Transportation Research Forum meeting in Fort Worth, Texas, March 2008.

Yu, Tun-Hsiang (Edward) and C. Hart. *The 2006/07 Iowa Grain and Biofuel Study: A Survey Report*. Center for Agricultural and Rural Development, Iowa State University, November 2008. (http://www.card.iastate.edu/publications/DBS/PDFFiles/08sr102.pdf).

Acknowledgements

The research on which this paper is based was funded by the Kansas Department of Transportation, but the author is solely responsible for the facts and conclusions contained in the paper.

Michael W. Babcock *is a professor of economics at Kansas State University (KSU). In his 38 year career at KSU, he has published 75 articles in professional journals, along with numerous monographs and technical reports, and his research has been cited in more than 75 books, the transportation press, and professional journals. He has presented 90 papers at professional meetings, and he was principal investigator or co-investigator on 33 federal and state government research grants worth a total of more than $2.3 million. Babcock is recognized as a leading national and international authority in three research areas, including short line railroad transportation, agricultural transportation, and impact of public policy on transportation market shares.*

He has received numerous national awards for his transportation research. He has been recognized five times by the Transportation Research Forum for outstanding research in transportation economics. In addition, Babcock has received the Edgar S. Bagley Award four times from the KSU Department of Economics for outstanding achievement in transportation economics research. In 1999 he was awarded the ISBR Senior Faculty Award for Research Excellence in the Social and Behavioral Sciences from KSU. Babcock has served as an advisor to former Kansas Governor Bill Graves on transportation policy, and contributed testimony to congressional hearings on transportation issues.

APPENDIX: KANSAS ETHANOL PRODUCTION PLANTS

Company Name _____

PART A: PRODUCTION AND CAPACITY

1. What year and month did your plant begin operations? _____

2. What is the annual capacity of the plant to produce ethanol?
   Designed Capacity (millions of gallons) _____
   Actual Capacity (millions of gallons) _____

3. What is the annual capacity of the plant to produce dried distillers grain (DDG)?
   Designed Capacity (tons) _____
   Actual Capacity (tons) _____

4. What was the annual ethanol production of your plant for the previous three years? If not available for calendar years, please specify your fiscal year.
   2006 million gallons _____
   2007 million gallons _____
   2008 (to date) million gallons _____

5. What was the annual DDG production of your plant for the previous three years? If not available for calendar years, please specify your fiscal year.
   2006 tons _____
   2007 tons _____
   2008 (to date) tons _____

6. What was the annual amount of corn (and sorghum if applicable) processed at your plant in the past three years? If not available for calendar years, please specify your fiscal year.

	Corn	Sorghum
(a) 2006 bushels	_____	_____
(b) 2007 bushels	_____	_____
(c) 2008 (to date) bushels	_____	_____

7. What percent of the plant's total revenue is derived from sales of ethanol and DDG in the past three years (2006-2008)?

	Percent
(a) ethanol	_____
(b) DDG	_____
(c) other(specify)	_____

PART B: INBOUND TRANSPORTATION

8. In the past 12 months, what percent of your total corn (and sorghum if applicable) were delivered to your plant in the following types of trucking equipment? Sum of percents must add to 100.

	Percent
(a) single axle truck	_____
(b) tandem axle truck	_____
(c) semi-tractor trailer	_____
(d) other(please specify)	_____

9. In a typical business week, how many trucks of each of the types listed below deliver grain to your plant?

	Number of Trucks
(a) single axle truck	_____
(b) tandem axle truck	_____
(c) semi-tractor trailer	_____
(d) other(please specify)	_____

10. Please provide your inbound corn (and sorghum if applicable) receipts by truck and railroad (if applicable) for the 2006-2008 period.

	Inbound Corn Bushels	
Year	Truck	Rail
2006	_____	_____
2007	_____	_____
2008 (to date)	_____	_____

	Inbound Sorghum Bushels	
Year	Truck	Rail
2006	_____	_____
2007	_____	_____
2008 (to date)	_____	_____

11. In the past 12 months what percent of your total inbound corn (and sorghum if applicable) receipts originate in the following miles from your plant? Percents must add to 100.

	Percent
(a) 1 to 10 miles from plant	_____
(b) 11 to 30 miles from plant	_____
(c) 31 to 50 miles from plant	_____
(d) 51 to 100 miles from plant	_____
(e) over 100 miles from plant	_____

12. In the past 12 months what percent of your corn (and sorghum if applicable) originated in the following states? Percents must add to 100.

	Percent
(a) Kansas	_____
(b) Nebraska	_____
(c) Missouri	_____
(d) Iowa	_____
(e) Other (please specify)	_____

13. In the last 12 months, what percent of your corn or milo receipts have been obtained from farmers (farmer-owned trucks) and country elevators? Percents must add to 100.

From	Percent of Total Corn Receipts	Percent of Total Milo Receipts
Farmers	_____	_____
Country Elevators	_____	_____
Other (please specify)	_____	_____

PART C: OUTBOUND TRANSPORTATION

14. Please list the most important destinations (markets) for your outbound ethanol shipments during the last 12 months. Also estimate the percent shipped by rail and truck to each destination market. Percents should add to 100 for each market.

Outbound Ethanol

Current Markets(previous 12 months)

	Market Name (City, State)	Percent Shipped by Truck	Percent Shipped by Rail
1.	_____	_____	_____
2.	_____	_____	_____
3.	_____	_____	_____
4.	_____	_____	_____
5.	_____	_____	_____
6.	_____	_____	_____
7.	_____	_____	_____

15. Please list the most important destinations (markets) for your outbound DDG shipments during the last 12 months. Also estimate the percent shipped by rail and truck to each destination market. Percents should add to 100 for each market. Please include any exports to foreign markets.

Outbound DDG
Current Markets(previous 12 months)

	Market Name (City, State)	Percent Shipped by Truck	Percent Shipped by Rail
1.	_____	_____	_____
2.	_____	_____	_____
3.	_____	_____	_____
4.	_____	_____	_____
5.	_____	_____	_____
6.	_____	_____	_____
7.	_____	_____	_____

PART D: CARRIER CHOICE QUESTIONS

16. Is your plant's location on a railroad?
Yes __
No __

If answer is No, skip to Part E.

17. What type of railroad is your plant located on?
(a) Class I __
(b) Class II or III __

If answer is (b), skip to question 19.

18. What is the primary reason the plant is located on a Class I railroad? Pick the primary reason from among the group listed below and put a 1 next to it, then put a 2 next to the second most important reason and 3 next to the third most important factor.
(a) transportation cost ___
(b) equipment availability ___
(c) ability to ship to many markets ___
(d) reliable transit time ____
(e) fast transit time ___
(f) shipment tracing capability ___
(g) amount of weekly service ____
(h) other, please specify ___

19. What is the primary reason the plant is located on a Class II or Class III railroad? Select the primary reason from the group listed below and put a 1 next to it, put a 2 next to the second most important reason, and a 3 next to the third most important factor:
(a) reliable transit times _____
(b) fast transit times _____
(c) transportation cost _____
(d) equipment availability _____
(e) amount of weekly service ____
(f) ability to ship to many markets_____
(g) other, please specify _____

PART E: KANSAS TRANSPORTATION INFRASTRUCTURE

20. How would you rate Kansas transportation infrastructure? Circle one answer per row:

	Poor		Average		Excellent	N/A
(a) Rail lines	1	2	3	4	5	N/A
(b) Roads	1	2	3	4	5	N/A
1. Interstate highways	1	2	3	4	5	N/A
2. Primary State highways	1	2	3	4	5	N/A
3. Paved county roads	1	2	3	4	5	N/A
4. Unimproved county roads	1	2	3	4	5	N/A

21. What are the most important transportations issues for your company? Are there any constraints or problems in the logistics system for either ethanol or DDGs?

PART F: THE FUTURE

22. What changes do you see occurring in your transportation requirements in the next five years? Check all of the following that apply.
(a) an increase in ethanol shipments_____
(b) a decrease in ethanol shipments_____
(c) an increase in DDG shipments _____
(d) a decrease in DDG shipments _____
(e) a change in the sources of corn supply _____
(f) a change in principal transportation mode _____
(g) a change in ethanol markets _____
(h) a change in DDG markets _____

23. In your opinion what is the future of ethanol production in Kansas?