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THE IMPACTS OF BIOFUELS ON TRANSPORTATION AND LOGISTICS IN INDIANA

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16. Abstract <p>Like the rest of the US, the ethanol industry in Indiana has rapidly expanded, growing from one plant in 2006 to a projected 13 by 2010. One result of this expansion is that truck and rail traffic flows in Indiana are shifting, as more corn and beans are processed in state. Most of the change in transportation requirements will likely be concentrated in regions of Indiana where the ethanol plants are constructed.</p> <p>The goal of this work was to determine how the entry of ethanol and biodiesel plants changes the inbound and outbound transportation flows of corn, soybeans, DDGS, and ethanol at the county level in Indiana between 2006 and 2010, focusing on modal and market shifts.</p> <p>The addition of 12 ethanol and 2 biodiesel plants from 2006 to 2010 increases total annual truckloads by 8%, but VMTs by 39%. This is due to fewer short hauls of corn and beans to local grain elevators replaced by longer hauls to ethanol plants. In addition, the movement of DDGS and ethanol is largely by truck. As more grain is processed within Indiana, less is shipped to out-of-state users by rail. However, outbound rail movements of ethanol and DDGS offset this somewhat. Finally, the changes in traffic flows are heavily concentrated in those counties with ethanol plants.</p> <p>As more ethanol plants are constructed, transportation requirements will change. Increases in the volume of truck traffic (more trucks and more miles traveled by each truck) will increase damage on local roads. This research identifies regions with large increases in truck traffic resulting from new ethanol and biodiesel plants. In turn, transportation planners can anticipate a reallocation of maintenance budgets to maintain key highways and bridge</p>			
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Chapter 1 Assessment of the Indiana Biofuels Industry

The rapid growth of ethanol production since 2005 is leading to far-reaching changes in grain marketing and transportation. Federal and state legislation are key drivers underlying this change, with policy changes leading to the current rapid expansion in industry capacity. In turn, this expansion has affected markets for corn, other crops, and the principal co-product of ethanol production, distillers dried grains and solubles (DDGS). After investigating national trends for biofuels expansion, impacts are considered for Indiana. This chapter will discuss the legislative history of biofuels, U.S. ethanol and biodiesel demand and supply, corn and soybean production and utilization, and DDGS. Information in this report is based on a literature review, focusing on publications since 2002.

1.1. Legislative History

The success of the ethanol industry has been closely tied to agricultural and energy policies since 1978. Over the past 30 years, federal biofuels policy has included tax exemptions, production credits, and tariffs on ethanol imports. The Energy Tax Act of 1978 created a 4 cent per gallon federal tax exemption for gasoline containing at least a 10 percent ethanol (E10). This is equivalent to a 40 cent per gallon subsidy on ethanol. Since then, tax exemptions have fluctuated between 40 and 60 cents per gallon of ethanol, and currently is 45 cents per gallon (Table 1.1). Initially, ethanol subsidies were justified as both a means of rural economic development (by increasing a local demand for corn) and for producing energy domestically from renewable sources. With the passage of the Clean Air Act in 1990, ethanol was also

Table 1.1. History of Biofuels Federal Legislation, 1978 to 2008

Act	Key Features
Energy Tax Act of 1978	\$0.40 per gallon of ethanol tax exemption on the \$0.04 gasoline excise tax
Crude Oil Windfall Profit Tax Act and the Energy Security Act - 1980	Promoted energy conservation and domestic fuel development
Surface Transportation Assistance Act - 1982	Increased tax exemption to \$0.50 per gallon of ethanol and increased the gasoline excise tax to \$0.09 per gallon
Tax Reform Act - 1984	Increased tax exemption to \$0.60 per gallon of ethanol
Alternative Motor Fuels Act - 1988	Created research and development programs and provided fuel economy credits to automakers
Omnibus Budget Reconciliation Act - 1990	Ethanol tax incentive extended to 2000 but decreased to \$0.54 per gallon of ethanol
Clean Air Act - 1990	Acknowledged contribution of motor fuels to air pollution
Energy Policy Act – 1992	Tax deductions allowed on vehicles that could run on E85
Transportation Efficiency Act of the 21st Century - 1998	Ethanol subsidies extended through 2007 but reduced to \$0.51 per gallon of ethanol by 2005
Jobs Creation Act -2004	Changed the mechanism of the ethanol subsidy to a blender tax credit instead of the previous excise tax exemption. Extended the ethanol tax exemption to 2010.
Energy Policy Act – 2005	Established the Renewable Fuel Standard starting at 4 billion gallons in 2006 and rising to 7.5 billion in 2012.
Energy Independence and Security Act of 2007	Raised the RFS to 36 billion gallons, with 15 billion gallons per year (BGY) from corn ethanol, 1 BGY from biodiesel and 20 BGY from advanced biofuels by 2022.)
Food, Conservation, and Energy Act of 2008	Lowers per gallon ethanol subsidy for starch based ethanol to \$0.45, adds subsidy of \$1.01 for cellulosic ethanol.

Source: Clean Fuels Development Coalition (2007) and Sissine (2007).

viewed as an oxygenate with environmental benefits as compared to methyl tertiary-butyl ether (MTBE). The Energy Policy Act of 2005 lacked provisions shielding MTBE manufacturers from water contamination lawsuits, which in effect ended blenders' usage of MTBE in July of 2006. Most recently, ethanol and other alternative domestic fuels are seen as a means of reducing the national security cost of imported oil.

The Energy Conservation Reauthorization Act of 1998 allowed biodiesel to qualify as a renewable fuel to meet public utility alternative fuel requirements (Table 1.1). Governmental agencies led the switch to biodiesel. In 2005, the biodiesel blenders' tax credit was established, providing \$1.00 per gallon for agri-biodiesel produced from virgin oils, either from crops or animal fats. A small biodiesel producer tax credit is available for producers of biodiesel who annually produce less than 60 million gallons.

In 2005, the Renewable Fuel Standard (RFS) mandated a minimum amount of renewable fuel that must be used for US automobile fuel consumption. The volume of renewable fuel required to be blended into gasoline started at 4.0 billion gallons in calendar year 2006. The Energy Independence and Security Act of 2007 increased the RFS to 36 billion gallons of biofuels by 2022 (Yacobucci and Capehart, 2008). Of this, up to 15 billion gallons is starch based ethanol (typically corn), up to 1 billion gallons is biodiesel, and the remainder is advanced biofuels (Figure 1.1). Concerns have been expressed that ethanol might not achieve the reduction in life cycle greenhouse gas emissions relative to emissions from gasoline and diesel, as required by the law (Searchinger et al., 2008).

States also provide various types of incentives for biofuels production and/or retailing to promote development within their boundaries (Table 1.2). Retailer incentives are found in 44 states, including 11 states with excise tax exemptions, 11 states with programs for new gas station infrastructure (E85 pumps) and 22 states with both. Producer incentives, such as low interest loans or grants, are found in 30 states. In addition, 24 states ban MTBEs and 13 states require use of biofuels through renewable fuels standards. Only the District of Columbia, Nevada, and West Virginia have no state level program of any type for ethanol or biodiesel.

Figure 1-1. Renewable Fuels Standards, 2006 to 2022

Source: Yacobucci and Capehart, 2008.

Table 1.2. Summary of State Laws for Biofuels

State	Renewable Fuel Standard	Retailer Incentive	Producer Incentive	MTBE Ban
Alabama		Pumps		
Alaska		Tax		
Arizona		Pumps		MTBE Ban
Arkansas		Tax and Pumps	Loan/grant	
California		Pumps		MTBE Ban
Colorado		Pumps	Loan/grant	MTBE Ban
Connecticut			Loan/grant	MTBE Ban
Delaware		Tax		
DC				
Florida	Ethanol Blend	Tax	Loan/grant	
Georgia		Tax and Pumps	Loan/grant	
Hawaii	RFS	Tax	Loan/grant	
Idaho		Tax and Pumps		
Illinois		Tax and Pumps	Loan/grant	MTBE Ban
Indiana		Tax and Pumps	Loan/grant	MTBE Ban
Iowa	RFS	Tax and Pumps	Loan/grant	MTBE Ban
Kansas		Tax and Pumps	Loan/grant	MTBE Ban
Kentucky		Pumps	Loan/grant	MTBE Ban

Table 1-2 continued

State	Renewable Fuel Standard	Retailer Incentive	Producer Incentive	MTBE Ban
Louisiana	RFS	Pumps		
Maine		Tax and Pumps	Loan/grant	MTBE Ban
Maryland			Loan/grant	
Massachusetts	Biodiesel Blend	Tax		
Michigan		Tax and Pumps		MTBE Ban
Minnesota	Biofuels Blend	Tax and Pumps	Loan/grant	MTBE Ban
Mississippi			Loan/grant	
Missouri	Ethanol Blend	Tax and Pumps	Loan/grant	MTBE Ban
Montana	Ethanol Blend	Tax	Loan/grant	MTBE Ban
Nebraska		Tax and Pumps	Loan/grant	MTBE Ban
Nevada				
N Hampshire		Pumps		MTBE Ban
New Jersey		Pumps		MTBE Ban
New Mexico	Biodiesel Blend	Tax and Pumps		
New York		Tax and Pumps	Loan/grant	MTBE Ban
North Carolina	Ethanol Blend	Tax and Pumps	Loan/grant	MTBE Ban
North Dakota		Tax	Loan/grant	
Ohio		Tax and Pumps	Loan/grant	MTBE Ban
Oklahoma		Tax and Pumps	Loan/grant	
Oregon	RFS	Tax and Pumps	Loan/grant	
Pennsylvania	RFS	Tax and Pumps	Loan/grant	
Rhode Island		Tax		MTBE Ban
South Carolina		Tax and Pumps	Loan/grant	
South Dakota		Tax	Loan/grant	MTBE Ban
Tennessee		Pumps	Loan/grant	
Texas		Tax		
Utah		Pumps		
Vermont				MTBE Ban
Virginia		Tax and Pumps	Loan/grant	
Washington	RFS	Tax and Pumps	Loan/grant	MTBE Ban
West Virginia				
Wisconsin		Pumps		
Wyoming		Tax		

Adapted from American Coalition for Ethanol (2007) and Renewable Fuels Association (2009).

1.2. Ethanol Demand

In the late 1970s, ethanol was viewed as a domestic alternative to gasoline and the market power of OPEC. When oil prices declined in the mid-1980s, so did the idea of ethanol as a gasoline alternative. From 1978 to 2004, subsidies were the primary factor driving the ethanol markets (Sarmiento and Wilson, 2008). Oil price increases since 2004 once again led to legislation supporting ethanol as a gasoline alternative. However, as important to the renewed interest in ethanol were state level bans on MTBE and the lack of federal legislative support for MTBE. As recent as 2002, MTBE held 60% of the market for oxygenates (Figure 1-2). In 2008, ethanol was 93% of the US oxygenates, while small amounts of MTBE are still being produced.

Figure 1-2. U.S. Oxygenate Production (Ethanol and MTBE), 1992-2008

Source: Energy Information Administration, 2009e. [Oxygenate Production](#).

From 1982 to 2004, oil price per barrel was relatively steady, hovering between \$10 and \$30 per barrel (Figure 1-3). Over this time, ethanol production grew steadily from 175 million gallons per year (MGY) in 1982 to 1.6 billion gallons per year (BGY) in 2001 (Figure 1-4). Since 2004, oil prices quadrupled in response to economic growth in China and India, supply

Figure 1-3. U.S. Refiner Acquisition Cost of Crude Oil, 1975 to 2008

Source: Energy Information Administration, 2009g. [Refiner Acquisition Cost of Crude Oil.](#)"

Figure 1-4. US Production of Ethanol

SOURCE: Energy Information Administration, 2009e. [Oxygenate Production.](#)

disruptions from hurricanes, and turmoil in the Mideast and other oil producing regions, before sliding in 2008 with the global economic meltdown. In response to higher oil prices, ethanol production more than doubled from rose from 2.1 to 9.2 BGY from 2002 to in 2008.

Ethanol demand is complicated given ethanol's dual nature of being both a component of and a substitute for gasoline. Initially, ethanol was primarily an oxygenate additive to gasoline. Thus, its demand was derived from motorist's demand for gasoline. However, an additional demand for ethanol arises from its use as an alternative fuel to gasoline, especially when run in flexible fuel vehicles (FFVs). Over 6 million FFVs have been produced since 1992, in part because auto manufacturers can offset CAFE requirements (Energy Information Administration, 2007a). The number of FFVs is projected to grow to 10 million vehicles by 2010 (Denicoff, 2007). The adoption of E85 will require an expansion in the number of E85 gas stations. Only around 1 percent of the gasoline stations (1,877 of 170,000) handle E85 as of May 2009 (Energy Information Administration, 2009a).

Focusing on E10, demand is driven by "the need for ethanol as a fuel oxygenate to meet Federal gasoline specifications and as an octane enhancer and because of the blender's tax credit" (Energy Information Administration, 2007a). All cars and light trucks manufactured since the late 1970s can run on E10. If all gasoline in the US were blended as E10, demand would be approximately 14 billion gallons (Table 1.3). The US Department of Energy reports information for petroleum on the basis of Petroleum Administration for Defense Departments (PADDs) (Figure 1-5). The market potential for E10 is strong across the country, but especially so in the Central and Lower Atlantic States, the Gulf Coast (i.e., Texas), and California.

Table 1.3. E10 Potential Demand and 2007 Ethanol Consumption, by PADD

PADD	States	E10 Potential Demand	2007 Ethanol Consumption	Potential Growth
Million gallons of ethanol				
IA – New England	CT, MA, ME, NH, RI, VT	687	498	189
IB – Central Atlantic	DC, DE, MD, NJ, NY, PA	1,860	1,122	738
IC – Lower Atlantic	FL, GA, NC, SC, VA, WV	2,539	488	2,051
IIA – Midwest	IL, IN, KY, MI, OH, TN	2,413	1,503	910
IIB – Upper Plains	MN, ND, SD, WI	609	482	127
IIC – Lower Plains	IA, KS, MO, NE, OK	903	386	517
III – Gulf Coast	AL, AR, LA, MS, NM, TX	2,061	673	1,388
IV – Rocky Mountain	CO, ID, MT, UT, WY	463	160	303
V – West Coast	AK, AZ, CA, HI, NV, OR, WA	<u>2,461</u>	<u>1,441</u>	<u>1,020</u>
US Total		13,996	6,752	7,244

Adapted from: Denicoff (2007) and Energy Information Administration, 2009j. [Updates by Energy Source.](#)

Figure 1-5. Description of PADDs

Debate continues over the levels of ethanol that can be blended into gasoline because of concerns over increasing emissions of nitrous oxide and because blending ethanol into gasoline raises Reid Vapor pressures, causing fuel to evaporate (Muehlegger, 2006). In November 2008, the EPA raised the renewable fuel standard to 10.21 percent blend of ethanol which leads to the use of 11.1 billion gallons of ethanol, up from 7.76 percent blend rate in November 2007 (EPA, 2008). During the hearings, the National Petrochemical & Refiners Association argued that the mandate is impossible to meet given various infrastructure and technical barriers (Drevna, 2008). A GAO report questions whether the DOE has considered issues related to infrastructure to serve a larger ethanol market (Gaffigan, 2007).

While 14 BGY of ethanol is a good approximation for the use of ethanol as E10, the usage of ethanol varies by region (Table 1.3). The US gasoline market consists of reformulated and conventional gasoline (Figure 1-6). The difference between the two types is that reformulated gasoline is blended to meet EPA regulations per the Clean Air Act.

Figure 1-6. Map of Reformulated Gasoline, 2006

Source: Energy Information Administration, 2007b. [Map of Reformulated Gasoline](#).

Nationwide in 2008, around 35% or 1 billion barrels of gasoline was reformulated, most of which (99.4%) was blended with ethanol (Table 1.4). On the East and West Coasts over 63% of the gasoline is reformulated, while 20% is reformulated in the Midwest, 11% in the Gulf Coast, and none in the Rocky Mountains. Nationwide, 46.0% of the conventional gasoline was also blended with ethanol. This was especially true for the East Coast and the Midwest (PADD II), in part because ethanol's readily available. Large portions of the country, especially in the Southeast and Gulf Coast, adapted ethanol on a widespread basis in 2008.

Table 1.4. US Gasoline Consumption by Type, and Proportion Blended with Ethanol, 2008

PADD	Type of Finished Motor Gasoline			Proportion Blended with Ethanol		
	Reformulated Conventional		All Gas	Reformulated Conventional		All Gas
	Thousand barrels			Percent		
I – East Coast	435,695	253,406	689,101	100.0%	93.9%	97.8%
II – Midwest	136,366	553,409	689,775	100.0%	86.8%	89.4%
III – Gulf Coast	135,128	921,140	1,056,268	97.9%	5.8%	17.6%
IV – Rockies	0	109,359	109,359	0.0%	40.6%	40.6%
V – West Coast	<u>385,359</u>	<u>142,528</u>	<u>527,887</u>	<u>99.2%</u>	<u>66.5%</u>	<u>90.4%</u>
US Total	1,092,548	1,979,842	3,072,390	99.4%	46.0%	65.0%

Source: Energy Information Administration, 2009h. [Refinery & Blender Net Production](#).

1.3. Ethanol Supply

Long range projections of ethanol capacity have been made by the Economic Research Service of the US Department of Agriculture (USDA) and the Energy Information Administration of the US Department of Energy (DOE). The DOE projected ethanol production through 2030 for both corn based ethanol and cellulosic based ethanol, while the USDA projection is for ten years for corn based ethanol.

The DOE projects that ethanol production will rapidly expand from 2007 through 2010, at which time it will reach 12.8 BGY, all from domestic corn mills (Figure 1-7). Over the next 20 years, ethanol will expand to reach 29.3 BGY. DOE projections see cellulosic ethanol production of 5.1 BGY in 2030, well below provisions of the Renewable Fuels Standards. Nevertheless, the DOE forecast assumes that a scientific breakthrough occurs that allows for production of cellulosic ethanol on a commercial scale. The DOE also projects imports to increase from 0.7 BGY in 2006 to 7.5 BGY by 2030. Compared to the DOE, the USDA forecast anticipates less expansion in ethanol production from corn through 2010, reaching a peak of 13.6 BGY. Both reports indicate that the current construction frenzy will continue until 2010. After this, expansion likely will return to the slow growth seen during the 1990s (Figure 1-4).

Figure 1-7. USDA and DOE Forecasts of Ethanol Production and Imports, 2007 to 2030

SOURCES: Energy Information Administration, 2009b and Westcott, 2009.

Keeping track of industry capacity has been a challenge given the explosive growth. Ethanol industry capacity numbers are reported by at least three entities (Table 1.5.) Lists of

Table 1.5. Ethanol Capacity and Number of Plants, by Association, Spring 2009

Reporting Association	Current Capacity		Idle Capacity		Expansion	
	No. of Plants	Capacity (MGY)	No. of Plants	Capacity (MGY)	No. of Plants	Capacity (MGY)
Renewable Fuels Assn ¹	195	12,657	28	2,116	23	1,887
<i>Ethanol Producer Magazine</i> ²	207	12,751	38	2,331	16	1,473
Nebraska Energy Statistics ³	180	11,223	16	969	27	2,289

¹ www.ethanolrfa.org/industry/locations (May 2009)

² ethanolproducer.com/plant-list.jsp (May 2009)

³ <http://www.neo.ne.gov/statshtml/122.htm> (March 2009)

plants are maintained by the state of Nebraska, the Renewable Fuels Association, and the e-magazine, *Ethanol Producer*. There is general agreement among the three sources that industry capacity during Spring 2009 is around 12.6 BGY at 200 plants. Capacity utilization is around 86%, meaning that roughly 1.7 BGY of capacity is currently idle. These numbers also include 15 to 20 plants that process a feedstock other than corn, such as cheese whey or brewery waste. Typically, these other plants are very small compared to corn ethanol plants.

The expansion in ethanol capacity will exceed the ramp up in Renewable Fuels Standards for the next few years. The rapid expansion in ethanol capacity may be outpacing the ability of the market to absorb the product. In turn, this is leading to short term concerns of industry overexpansion. *Ethanol Producer* reports that 38 plants with a capacity of 2.3 BGY are shut down in May 2009. However, given the requirements of the Renewable Fuels Standards, this capacity will eventually be needed.

Operating and idled corn ethanol plants were divided into two groups, 83 plants built before 2006 (Old) and 110 plants built since 2006 (New). The median size New is slightly larger than the Old plant, at 57.3 MGY versus 48.0 MGY (Figure 1-8). The New plants are near the size

Figure 1-8. Size Distribution of Ethanol Plants, 2009

Calculated using data from: Ethanol Producer Magazine and Nebraska Energy Statistics

that achieves minimum operating cost on a basis of economies of size (Gallagher et al., 2007). Around 73% of the Old plants are less than 60 MGY. In contrast, over 47% of the New plants have more than 60 MGY of capacity. Thus, newer plants are being sized on the basis of economics while older plants were sized on the basis of subsidy programs. This implies that the newer plants will have larger draw areas for inbound transportation of corn.

In May 2009, most of the corn ethanol industry capacity was concentrated in PADD 2, or the Corn Belt and Great Plains states. Combined, these states US have 91% of the US corn ethanol built capacity, or 13.0 billion gallons. A total of 25 states currently produce ethanol. Iowa leads the nation in ethanol capacity, with 3.5 BGY of current capacity (Figure 1-9). Other major ethanol producing states include Nebraska, Illinois, Minnesota, South Dakota, and Indiana. As of May 2009, 82 percent of industry corn ethanol capacity is operating.

Figure 1-9. Built and Operating Capacity for Corn Ethanol Plants, by State, 2009

Calculated using data from: *Ethanol Producer Magazine* and Nebraska Energy Statistics.

1.4. U.S. Biodiesel Market

Compared to ethanol, biodiesel is in an early phase of market development in the USA, although it is widely adopted in Europe. The proportion of biodiesel blended into diesel has risen from virtually nil in 2001 to 0.6% in 2008 (Table 1.6). The 320 million gallons of biodiesel consumed in the US in 2008 is expected to grow to 1 billion gallons (Biomass Research and Development Board, 2009). Tax subsidies rules changed in March 2009 to discourage the practice of “splash and dash” or adding small amounts of diesel to imported biodiesel and then exporting the shipment, most likely to Europe (Energy Information Administration, 2009c).

Biodiesel is “composed of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats” (National Biodiesel Board, 2007). A variety of inputs can be used as feedstock for biodiesel, including vegetable oils (soy, rapeseed, palm oil, etc.) and yellow grease (tallow and animal fats, or restaurant waste and trap grease). “The properties of the biodiesel (cloud point, pour point, and cetane number) depend on the type of feedstock used”

Table 1.6. Diesel and Biodiesel Production, 2001 to 2008

Year	Diesel Sold in the US	US Biodiesel Production	US Biodiesel Consumption	Biodiesel Consumed as a % of Diesel Sold
Million gallons per year				
2001	45,119	8.6	10.2	0.02%
2002	44,145	10.5	16.2	0.04%
2003	45,635	14.2	13.5	0.03%
2004	47,186	28.0	26.9	0.06%
2005	49,153	90.8	90.8	0.18%
2006	52,544	250.4	260.6	0.50%
2007	55,296	489.8	358.2	0.65%
2008	53,316	682.5	320.2	0.60%

¹Energy Information Agency, 2009f, [Prime Supplier Sales Volumes](#).

²Energy Information Agency, 2009c, [Biodiesel Supply and Consumption](#).

(Energy Information Administration, 2007b). Clean air regulations have led to a new generation of engines using ultra low-sulfur diesel, which in turn leads to a demand for biodiesel because of its high lubricity. Engine manufacturers specify acceptable blends, but most equipment can run B5 or a 5% blend of a biodiesel with diesel.

Soybeans are the most common feedstock in the US, with over 70 percent of biodiesel (Gray, 2006). A difference with ethanol is that soybean oil is a co-product of the milling process. Thus, until volumes of biodiesel reach around 500 MGY per year, the feedstock supply is plentiful. Like ethanol, usage varies on a regional basis. “The cloud and pour points for biodiesel are higher than those for petroleum diesel” which means that at cold temperatures the fuel can gel and clog fuel lines (Radich, 2007).

The nation’s biodiesel capacity in May 2009 totaled 3.2 BGY (Table 1.7). This included 138 plants with 2.29 BGY of operating capacity, 47 plants with 596 MGY of idle capacity, and 14

Table 1.7. Biodiesel Plant Capacity, By PADD, 2009

PADD	States	Operating	Idle	Construction	Total
Million gallons of biodiesel					
IA – New England	ME, NH, RI, VT	6.2	0.0	3.0	9.2
IB – Central Atl	DE, MD, NJ, NY, PA	203.5	6.0	110.0	319.5
IC – Lower Atlantic	FL, GA, NC, SC, VA, WV	167.4	36.0	11.2	214.6
IIA – Midwest	IL, IN, KY, MI, OH, TN	437.0	153.0	2.0	592.0
IIB – Upper Plains	MN, ND, SD, WI	190.6	8.0	3.0	201.6
IIC – Lower Plains	IA, KS, MO, NE, OK	504.9	61.0	15.0	580.9
III – Gulf Coast	AL, AR, LA, MS, NM, TX	642.1	209.0	7.0	858.1
IV – Rocky Mtn	CO, ID, WY	22.0	10.0	16.8	48.8
V – West Coast	AK, AZ, CA, HI, NV, WA	<u>120.1</u>	<u>113.4</u>	<u>112.0</u>	<u>345.5</u>
US Total		2,293.8	596.4	280.0	3,170.2

Adapted from: *Biodiesel Magazine*.

plants with 280 MGY of new construction. The Energy Independence and Security Act of 2007 calls for 1 billion gallons of biodiesel as part of the RFS mandate. Thus, the current biodiesel capacity of 3.2 BGY suggests severe excess capacity (Yacobucci and Capehart, 2008).

Compared to ethanol, biodiesel production is widespread across the US, with plants in 45 states. PADD 2 only accounts for 43% of the nation's total biodiesel production as opposed to 91 percent of the nation's ethanol capacity (Table 1.7). The top 10 states in terms of productive capacity are Texas, Iowa, Alabama, Illinois, Missouri, New York, Ohio, Indiana, and Mississippi, accounting for 62 percent of productive capacity.

Biodiesel plants are typically much smaller than ethanol plant, with a median sized plant of 6 MGY and an average sized plant of 15.9 (Figure 1-10). The 149 biodiesel plants that can use soy oil as a feedstock are twice as large as the 50 other plants using other feedstock, with a median size of 10.0 versus 5.0 MGY.

Figure 1-10. Size Distribution of Biodiesel Plants, 2009

Adapted from: *Biodiesel Magazine*.

The USDA and DOE also have long-run forecasts for biodiesel production. The USDA forecast is only for the use of soy oil to produce methyl esters (or biodiesel), while the DOE forecast includes all forms of biodiesel. The USDA forecast is a relatively flat for the next decade, at roughly 430 million gallons per year (Figure 1-11). The DOE forecast is much higher than the USDA forecast as early as 2010, in part to reach the goals of the RFS (Figure 1-1). The production of biodiesel beyond the 1.0 billion gallon level is considered part of the advanced biofuels requirement.

1.5. Corn and Soybean Utilization

The demand for corn swells with increases in production of ethanol. In 2008, about 3.75 billion bushels of corn was used for ethanol production, or about 31% of the 2008 U.S. corn crop (Figure 1-12). The future effects of this growth are unknown but might include increasing corn prices, an expansion in corn acreage, less corn fed to livestock, or less corn available for export. USDA projections for total usage of U.S. corn are to rise from 14.1 billion bushels in 2008 to 16.5 billion bushels a decade later. Feed, food, and export uses are constant at around 5.8, 1.4,

Figure 1-11. USDA and DOE Forecasts of Biodiesel Production

SOURCES: Energy Information Administration, 2009b and Westcott, 2009.

and 2.2 billion bushels, respectively. In contrast, the USDA estimates that 5.1 billion bushels of corn will be used to produce ethanol by 2018, or 35 percent of production. However, the use of corn to produce ethanol increases only about 100,000 bushels per year over the next decade as opposed to an increase of almost 2 billion bushels from 2006 to 2009.

Unlike corn, soybean utilization is forecast to be relatively stable over the next decade (Figure 1-13). Soybean crush will increase from 1.6 billion bushels in 2008 to 1.9 billion bushels in 2018, while exports will be flat. The usage of soybeans for biodiesel is forecast to rise to roughly 250 million bushels per year, or around 16 percent of the domestic oil crush, but then remain relatively flat.

Historically, corn and soybean production are interrelated. Thus, changes in corn production have had an effect on soybean production and vice versa. Throughout much of the past decade corn and soybean harvested acres have seen little volatility (Figure 1-14). In 2007,

Figure 1-12. Corn Utilization for Feed, Food, Exports, and Ethanol, 2001 to 2018

Source: United States Department of Agriculture (2009b) and Westcott (2009).

Figure 1-13. Soybean Utilization for Crush, Seed, Biodiesel and Exports, 2001 to 2018

Source: United States Department of Agriculture (2009b) and Westcott (2009).

Figure 1-14. Corn and Soybean Harvested Acres in United States, 1990-20087

Source: United States Department of Agriculture (2009b) and Westcott (2009)

this trend deviated with a sharp increase in corn acres and decrease in soybean acres. This change can be explained partially in an increase in ethanol demand as well as in corn price. USDA forecasts assume that the volatility in harvested acres of corn and soybeans will diminish over the next decade. Compared to the past decade, corn acreage will increase, while soybean acreage will slightly decrease.

1.6. DDGS

The production of ethanol creates a co-product called distillers dried grains and solubles (DDGS), which is commonly sold as a livestock feed source. DDGS is produced after the starch portion of corn is converted to ethanol and carbon dioxide leaving components of protein, fat, fiber, vitamins and minerals which are then concentrated and dried to produced DDGS. DDGS is more valuable as a feed in ruminant animals (cattle and sheep) because rations fed to mono-gastric livestock (swine and poultry) must add several synthetic amino acids (Urbanchuk 2003).

DDGS is used as a feed supplement, meaning it cannot be considered a primary feed source in livestock feed rations. The percentage of DDGS in the diet varies among livestock species ranges from 20 percent for sheep and beef cattle rations, dairy cattle can consume up to 25 percent DDGS, while poultry and hogs can only consume 10 percent of DDGS in a ration.

Historically, DDGS has been an important source of revenue for an ethanol plant. A study examining profit margins for a 40 million gallon ethanol plant, found 15% to 20% of the plant's revenue was from DDGS sales (Tiffany and Eidman, 2003). Due to the increase in ethanol prices coupled with payments through tax incentives, the percent of plant revenue in 2007 from DDGS sales fell to approximately 10% (McElroy 2006). However, as ethanol prices fell in late 2008, DDGS once again became important plant revenue stream.

Advantages of DDGS as a feed supplement include high protein content, high available phosphorus, high fiber content, and substitutability (Matthews and McConnell, 2009). However, DDGS has its disadvantages as well, including supplementation, high nitrogen uptake, nutrition composition, quality consistency, transportation, and market volumes. The lack of consistency in DDGS production among differing plants and batches within a particular plant is seen as a key detriment. Variations in nutrient content cause livestock producers to use less DDGS as a supplement. For example, fat content has been found to range from 1% to 30%, protein from 24% to 29%, and moisture 9% from 15% (McElroy 2006).

"The biggest obstacle to providing co-products to livestock feeders is transporting the feeds from the processing plant to the livestock feeding operation" (Matthews and McConnell, 2009). For example, the Burlington Northern Santa Fe and Union Pacific, two of the nation's largest railroads, have banned hauling DDGS in their own equipment, although they will

transport DDGS loaded in shipper owned cars (Cooper, 2005). Transportation difficulties can arise unless DDGS is properly manufactured, as it can become difficult to unload from hopper rail cars due to caking occurring during transport. Segregation of particles also occurs during handling and transportation, adding to the already existing quality and consistency issues.

As a co-product of ethanol, DDGS production tracks the explosive growth in ethanol capacity. Each bushel of corn yields 2.81 gallons of denatured ethanol and 16.58 pounds of DDGS (Wu, 2008). Given projections for corn used to produce ethanol (Figure 1-12), DDGS production was 31.09 million tons in 2008 and will climb to 40 million tons by 2015. Roughly 24.2 million tons of DDGS was consumed domestically in 2008, with the remainder being exported (Dooley, 2008b).

1.7. Production of Biofuels in Indiana

Ethanol has been produced by New Energy in South Bend since 1985 at a 100 million gallon per year (MGY) plant (Table 1.8). In 2007, five plants opened adding 355 MGY, while four more plants opened an additional 335 MGY in 2008. As of March 2009, 9 plants around the state have the capacity to produce 690 million gallons of ethanol. Plants at Cloverdale and Linden are currently shutdown, idling 140 MGY, because of firm bankruptcies. An additional 198 MGY is under construction by two different firms near Mount Vernon. The Indiana ethanol industry can produce 2.035 million tons, with the potential for another 997,000 tons from the idle plants and plants under construction.

The biodiesel plant at Claypool, Indiana that opened in January 2008 is among the seven largest plants in the U.S, with 88 MGY of capacity (Table 1.9). Other operating biodiesel plants

Table 1.8. Indiana Ethanol Plants, by Year, Location, and Capacity, March 2009

Company	Year	City/County	Million Gallons		
			Operating	Idle	Construction
New Energy.	1985	South Bend/St. Joseph	100		
Iroquois Bio-Energy	2007	Rensselaer/Jasper	40		
The Andersons	2007	Clymers/Cass	110		
Central Indiana Ethanol	2007	Marion/Grant	40		
POET	2007	Portland/Jay	65		
VeraSun/ West LB	2007	Linden/Montgomery		100	
POET	2008	Alexandria/Madison	60		
Altra	2008	Cloverdale/Putnam		60	
POET	2008	N Manchester/Wabash	65		
Indiana Bio-Energy	2008	Bluffton/Wells	110		
Cardinal Ethanol	2008	Harrisville/Randolph	<u>100</u>		
Abengoa Bioenergy		Mt. Vernon/Posey			88
Aventine Renewable		Mt. Vernon/Posey			<u>110</u>
Indiana Total Ethanol Capacity (million gallons)			690	140	198
Indiana Total DDGS Capacity (million tons)			2.035	.413	.584

Source: Indiana State Department of Agriculture, 2009.

Table 1.9. Indiana Biodiesel Plants, by Year, Location, and Capacity, March 2009

Company	Year	City/County	Operating Capacity (MGY)
Evergreen Renewables	2006	Hammond/Lake	5
Integrity Biofuels.	2006	Morristown/Shelby	5
E-biofuels	2007	Middletown/Henry	10
Louis Dreyfus	2008	Claypool/Kosciusko	88
Xenerga	2008	Kingsbury/LaPorte	<u>10</u>
Indiana Total Ethanol Capacity (million gallons)			118

Source: Indiana State Department of Agriculture, 2009.

in Indiana are found at Middletown (10 MGY), Hammond (5 MGY), Kingsbury (10 MGY), and Morristown (5 MGY). The Xenerga plant at Kingsbury is the only one that does not use soybeans as a feedstock.

1.8. Conclusions

Since 2006, there have been major changes in corn and soybean production, grain marketing, and the like surrounding the expansion in biofuels production. If anything, Indiana appears to have seen more expansion than most states. At this point, it is likely that most of the changes in production have occurred. In other words, additional ethanol or biodiesel expansion is not anticipated in the next five years.

The changes that have take place over the past three years, however, have had profound ramifications for transportation in the state. The remainder of this report investigates the volume of these changes.

Chapter 2 .DATA, ASSUMPTIONS AND MODEL DEVELOPMENT

This chapter discusses the data sources, key assumptions, and development of the model. The goal of the model is to compare and evaluate the effects that ethanol expansion will have on transportation requirements in Indiana. The model is developed for three time periods such that changes in transportation requirements can be determined before (2006), during (2008), and after (2010) ethanol expansion takes place in Indiana. Thus, the 2006 model served as a baseline model, which is compared with a short term adjustment model (2008), and a long term adjustment model (2010). The only changes between time periods are adjustments to corn and soybean production, the addition of ethanol and biodiesel plants, and changes in livestock consumption of corn as more DDGS is fed.

The biofuels capacity reflects reported operating capacities as of yearend for 2006 and 2008 (Table 1.8 and 1.9). In the long run (2010), all plants under construction are assumed to come online and idle capacity is assumed to reopen. Thus, the total production of ethanol rose from 100 to 690 million gallons of ethanol between 2006 and 2008, and in the long run is modeled to reach just over 1 billion gallons (Table 2.1).

Table 2.1. Assumed Indiana Ethanol and Biodiesel Capacity and Grain Requirements, by Year

Year	No. of Ethanol Plants	Indiana Ethanol Capacity	Corn Required	DDGS Produced	No. of Biodiesel Plants	Indiana Biodiesel Capacity	Soybeans Required
		MGY	million bushels	million tons		million bu.	million bushels
2006	1	100	35.59	.29	2	10	6.71
2008	9	690	245.55	2.045	5	118	79.19
2010	13	1,048	372.95	3.09	5	118	72.19

A bushel of corn is assumed to produce 2.81 gallons of denatured ethanol and 16.6 pounds of ethanol (Wu, 2008). Thus, the corn utilized to produce ethanol rose sevenfold from 2006 to 2008, from 35.6 to 245.6 million bushels (Table 2.1). With continued expansion of capacity, corn utilization for ethanol will rise to 372.9 million bushels in the long run. The production of DDGS tracks the expanded use of corn, rising from 295,000 tons in 2006 to 3.1 million tons long run.

A bushel of soybeans is assumed to produce 1.49 gallons of biodiesel (Gray, 2006). Thus, the use of soybeans to produce biodiesel is expected to increase from 6.7 to 79.2 million bushels as Industry capacity grows from 10 to 118 million gallons (Table 2.1).

The model determines transportation flows from each county level supply point to demand point for corn, soybeans, DDGS, and ethanol. To capture changes in transportation requirements over the three time periods, the model estimates total truck loads, average length of haul (LOH), total truck miles as measured by vehicle miles traveled (VMT), and rail carloads at a county level for commodity flows of corn, soybeans, ethanol, and DDGS. The change in truck loads, LOH, VMTs, and rail carloads across the three periods captures the effects that biofuels expansion has on transportation requirements.

Production data are collected at the county level for corn, soybeans, ethanol, and DDGS. The data are collected for all 92 counties in Indiana, as well as the 39 border counties in the adjacent states of Illinois, Michigan, Ohio, and Kentucky. Demand data are also collected at the county level for feeding livestock, food processing plants, soybean crushing facilities, ethanol and biodiesel plants, and grain elevators. Linear programming transportation models are used to allocate various commodities from supply points to demand points.

Briefly the eight steps to estimate transportation requirements are:

1. Establish corn and soybean production for three time periods at the county level.
2. Establish livestock populations for ten species of livestock, and then estimate feed demand for DDGS. A linear programming transportation model is used to allocate available supplies of DDGS from ethanol plants to demand points.
3. Estimate county level feed demand for corn, after adjustments are made for feeding DDGS.
4. Estimate the transportation requirements (average trip, total truck loads, and VMT) required to supply livestock with corn and DDGS.
5. After livestock demand for corn is met, use a linear programming transportation model to allocate remaining corn to food processing and ethanol plants and Estimate transportation requirements to supply food processing and ethanol plants with corn. Allocate any remaining corn to country elevators; estimate transportation requirements for such movements.
6. Develop a linear programming transportation model to allocate soybeans to soybean crushing and biodiesel plants. Estimate transportation requirements to supply soybean crushers and biodiesel plants with soybeans. Like corn, allocate any remaining soybeans to country elevators; estimate transportation requirements for such movements.
7. Use a linear programming transportation model to allocate ethanol within the truck market area and estimate transportation requirements to supply ethanol to blending terminals. Remaining ethanol is assumed to be shipped by rail.
8. Allocate any remaining corn and soybeans from local county elevators to out-of-state demands via truck and rail.

2.1. Step 1 – Grain Production

Data for county level corn and soybean yields and harvested acres were obtained from the National Agriculture Statistic Service (NASS) for the years 2005 to 2008.¹ Data for 2010 adjusts 2008 values based on long term USDA forecasts (Westcott, 2009). Total crop production is

¹ County level data are available on “Statistics by State” portion of NASS website http://www.nass.usda.gov/Data_and_Statistics/Quick_Stats/index.asp.

calculated by multiplying harvested acres by the yield for each respective year and county. Crop production for 2006 is based on a two-year average of harvested acres and yields for 2005 and 2006, while 2008 data reflect the 2007 and 2008 crop years.

While total grain acres are relatively constant at 11.1 million acres over the three time periods, the last two time periods reflect a shift as more acres are planted to corn than beans (Table 2.2). Long run corn yields are expected to be 5 percent higher than the 2008 yields, while soybean yields are relatively stable. Thus, overall grain production is expected to climb from 1.14 to 1.18 to 1.25 billion bushels from 2006 to 2008 to 2010, respectively.

Table 2.2. Indiana Corn and Soybean Production, by Year

Year	Corn	Beans	Total
Acreage (1,000 acres)			
2006	5,575.0	5,530.0	11,105.0
2008	5,915.0	5,110.0	11,025.0
2010	5,911.4	5,283.7	11,195.1
Yield in Bushels per Acre			
2006	155.5	49.5	
2008	157.0	45.5	
2010	164.9	48.6	
Production (million bushels)			
2006	866.9	277.3	1,143.2
2008	928.1	249.0	1,177.1
2010	974.0	275.0	1,249.0

SOURCES: National Agriculture Statistic Service (2009) and Westcott (2009).

2.2. Step 2 – Livestock Feed Demand for DDGS

Estimating livestock feed demand for DDGS requires data for animal numbers and assumed feeding rates. Livestock numbers by county for each of ten species were obtained from the

2007 Census of Agriculture (United States Department of Agriculture, 2009a). Species included in livestock numbers are dairy cows, beef cows, other cattle, cattle on feed, breeding swine, market swine, broilers, layers, pullets, and turkeys (Table 2.3). Numbers of animals in Indiana from the Census are assumed to be constant for all three time periods (Table 2.4).

Table 2.3. Definitions of Livestock Species

Specie	Definition	Size Classification for Large Farms
Dairy Cows	Breeding cows for milk and dairy production	> 100 head
Beef Cows	Breeding cows for beef production	> 100 head
Other Cattle	Includes all heifers, heifer calves, steers, steer calves, bulls, and bull calves	> 100 head
Cattle on Feed	Cattle and calves being fed a grain or other concentrate ration for slaughter market that will produce a carcass that will grade select or better	All farms
Breeding Swine	Swine produced for breeding purposes	> 1,000 head
Market Swine	Swine produced for market	> 1,000 head
Broilers	Chicks produced for market and meat consumption	> 60,000 birds
Layers	Layer hens in molt and other layers and pullets of 20 weeks old	> 20,000 birds
Pullets	Chicks for layer hen replacement younger than 20 weeks old	> 100,000 birds
Turkeys	All turkeys produced for slaughter or breeding	> 30,000 birds

Source: National Agriculture Statistic Service, 2009.

While all livestock are assumed to eat corn, DDGS are only fed to livestock raised on larger sized farms (Dooley, 2008b). Thus, animal populations are also obtained for all livestock and livestock on large farms (Table 2.4). Size thresholds are defined in Table 2.3 for each species. The use of DDGS in animal rations is increasing, in part because of greater availability.

Table 2.4. Animal Populations in Study Area, 2007

Class of Livestock	Small Farms	Large Farms	Total
	Number of animals		
Dairy Cows	67,447	178,762	246,209
Beef Cows	312,623	77,776	390,399
Other Cattle	329,433	409,466	738,899
Cattle on Feed	0	179,403	179,403
Breeding Swine	60,620	325,478	386,098
Market Swine	470,749	4,044,796	4,515,545
Broilers	18,698,054	39,350,741	58,048,795
Layers	3,691,460	40,372,868	44,064,328
Pullets	1,602,357	9,576,237	11,178,594
Turkeys	556,816	7,854,193	8,411,009

Source: National Agriculture Statistic Service, 2009.

For the 2006 and 2008 scenarios, the DDGS feeding rate is based on a NASS (2007) survey of livestock feeding practices (Table 2.5). In the long run, DDGS inclusion rates are expected to rise as farmers become more familiar with feeding DDGS. Thus, the DDGS feeding rate for 2010 is based on work by Berger and Good (2007), who summarized the literature for DDGS consumption for dairy, cattle, hogs, and poultry.

The county level feed demand for DDGS is determined as:

$$2-1. \quad DDGSFed_{i,s,t} = \sum_s LargeFarmHerd_{i,s,t} * Feed\ rate_{i,s,t}$$

where: i is the county of production,
s is the species of animal, and
t is the time period, t = 2006, 2008, 2010.

The DDGS demand is calculated for each of the ten species (s), and is then summed to reach a county total. DDGS demand in Indiana counties is 289,266 tons in 2006 and 2008, and 824,919 tons in the long run. It is assumed that DDGS demand in Indiana is fulfilled via truck

Table 2.5. DDGS and Corn Annual Feeding Rates per Head, by Species, by Year

Class of Livestock	DDGS Feeding Rate		Corn Feeding Rate		
	2006 and 2008 ^a	2010 ^b	Corn Alone ^c	Corn with DDGS in 2006/2008 ^d	Corn with DDGS in 2010 ^d
(lbs/yr/head)					
Dairy Cows	1,002.00	1,642.50	5,824.0	5,091.5	4,623.3
Beef Cows	396.00	720.00	1,111.0	637.4	249.9
Other Cattle	346.50	630.00	862.9	448.5	109.4
Cattle on Feed	916.00	2,555.00	6,151.6	5,056.1	3,095.8
Breeding Swine	105.53	372.00	1,229.2	1,135.3	898.1
Market Swine	51.77	182.50	574.0	527.9	411.6
Broilers	0.33	1.16	6.3	6.0	5.3
Layers	3.37	11.86	56.0	53.0	45.4
Pullets	1.03	3.61	56.0	55.1	52.8
Turkeys	1.80	6.36	59.4	57.8	53.7

SOURCES:

^aNational Agricultural Statistics Service, 2007.

^bBerger and Good, 2007.

^cQuear, 2008.

^dCalculated.

with a capacity of 25 tons. Remaining DDGS after Indiana demand is fulfilled is transported out of the state via rail cars with a capacity of 100 tons (Denicoff, 2007).

Since DDGS production is concentrated in a few counties while demand is spread across the state, a linear programming transportation model is used to allocate DDGS from ethanol plants to counties. The objective of the model is to minimize total distance traveled.

Great circle distances are calculated for all 131 county pairs (Ballou, 2005). Using latitude and longitude (Lat, Long) coordinates for an origin county i and destination county j pair, distance d_{ij} between the counties is calculated as:

$$2-2 \quad Y = \sin\left(\frac{\text{Lat}_i}{180/\pi}\right) * \sin\left(\frac{\text{Lat}_j}{180/\pi}\right) + \cos\left(\frac{\text{Lat}_i}{180/\pi}\right) * \cos\left(\frac{\text{Lat}_j}{180/\pi}\right) * \cos\left(\frac{\text{ABS}(\text{Long}_i - \text{Long}_j)}{180/\pi}\right)$$

$$2-3 \quad d_{ij} = 3959 * \text{ATAN}\left(\sqrt{\frac{1-Y^2}{Y}}\right)$$

Since d_{ij} provides an estimate of mileage “as the crow flies” it is multiplied by a circuitry factor of 1.21 to adjust for true one-way distance.

The linear programming transportation model is specified as:

Objective function: Minimize $\sum_i \sum_j d_{ij} x_{cij}$

subject to:

$$2-4 \quad \text{Supply limit of } c \text{ at plant } i: \sum_j x_{cij} \leq a_i \text{ for all } i$$

$$\text{Demand for } c \text{ in county } j: \sum_{ij} x_{cij} \geq b_j \text{ for all } j$$

where: c is the commodity shipped (corn, beans, DDGS, or ethanol)

i is an index for county of origin (ethanol plants producing DDGS)

j is an index for destination county or demand point to feed livestock

d_{ij} is the distance from plant i to market j

x_{cij} is the tons of commodity c (DDGS) shipped from plant i to market j , all $x_{cij} \geq 0$

a_i is the available supply of DDGS at ethanol plant i

b_j is the DDGS demand at market j

The output of this model provides tons of DDGS allocated from an ethanol plant to fulfill feed demand by county. In 2006, not all demand for DDGS is met on Indiana farms, while in 2008 and 2010 the available supply is much greater than instate demand. Outbound DDGS is allocated to livestock in Indiana via truck using distances from equation 2-3. Daily truck loads of DDGS are estimated as:

$$2-5 \quad \text{Daily truck loads}_{cij} = \frac{\text{Tons DDGS allocated from } i \text{ to } j}{\text{Days of operation} / \text{Truck capacity}}$$

Daily truck miles of DDGS are then calculated as:

$$2-6 \quad \text{Daily truckmiles}_{cij} = \text{Daily Truck Loads}_{cij} * d_{ij}$$

Any DDGS remaining after all demand by Indiana livestock is fulfilled is assumed to be transported out of state by rail. Daily rail shipments are calculated as:

$$2-7 \quad \text{Daily Rail Carloads}_{cij} = \frac{\text{Excess Production}_{cj}}{\text{Rail Carload Capacity / Days of Operation}_{cj}}$$

2.3. Step 3 – Livestock Feed Demand for Corn

Corn feeding rates by species depend on whether the animal also consumes DDGS as part of its ration. Assumed feeding rates for corn alone were taken from Quear (2008) and are assumed to be constant over time (Table 2.5). In 2008 and 2010, the supply of DDGS in Indiana meets demand, while there is a shortage in 2006. DDGS fed to animals displaces corn in diets at a rate of .731 pounds of DDGS per pound of corn for dairy cattle, 1.196 for all other cattle, and 0.0890 for swine and poultry, respectively a rate of 1.196 pounds (Arora, Wu, and Wang, 2008).

The county level feed demand for corn is determined by:

$$2-8 \quad \text{CornFed}_{i,s,t} = \sum_s [\text{SmallFarmHerd}_{i,s,t} * \text{Feed rate}_{i,s,t} + \text{LargeFarmHerd}_{i,s,t} * \text{Feed rate}_{i,s,t}]$$

where: i is the county of production,
s is the species of animal, and
t is the time period, t = 2006, 2008, 2010.

Livestock and corn production are found in every county in the study area. Livestock are assumed to consume corn raised in the same county. Once livestock feed demand is known for all counties, corn is allocated to fulfill livestock corn demand using a LP transportation model (equation 2-4). Livestock corn demand is fulfilled from production within the county. Daily truckloads are then calculated using equation 2-5.

2.4. Step 4 – Estimate Livestock Transportation Requirements

Miles traveled by each truck is calculated based on the density of grain within the county, or:

$$2-9 \quad \text{CropDensity}_{gi} = \frac{\text{Crop Acres}_{gi}}{\text{Total Acres}_i} * \text{Yield}_{gi} * 640 \text{ acres}, \quad \text{where } g \text{ is corn/beans for county } i$$

Crop acres are defined as total harvested acres and total acres are defined as total land area in county i. Yield is in terms of bushels per acre for corn and beans per county. By multiplying by 640 (the number of acres per square mile), crop density is calculated per square mile basis. Equation 2-9 is solved separately for corn and soybeans for each county and time period.

Distance traveled by each truck is based on radii extending from a demand point j. Corn flows to meet livestock demand are assumed to occur 365 days per year via 500 bushel capacity trucks. Given the demand in a particular county for corn to feed livestock, the total trucks required to meet that demand is determined by equation 2-5 by substituting corn for DDGS. The one-way distance to haul corn to feed livestock is then calculated for each truck as:

$$2-10 \quad d_{ij} = \sqrt{\frac{\text{Truck}_n * \text{Truck Capacity}_u}{\pi * \text{Crop Density}_{gi} / \text{Days of Operation}_u}} * 1.21$$

where g is the type of grain (corn or soybeans) and u is the grain utilization (feed, food, ethanol, crushing, or grain elevator). This equation is solved iteratively for each truck required to meet demand such that a summation of the distances traveled by each truck provides total miles driven by all trucks, from 1 to n.

2.5. Step 5 – Corn for Food Processing and Ethanol

The second category of corn utilization is food processing which includes dry grind and wet grind corn mills. The location and annual corn demanded for seven food processing plants in Indiana is included in the model (Table 2.6). The capacity and location of each plant was obtained from the Milling and Baking News (2008). The 241 million bushels of corn used in Indiana for food processing is 18.3 percent of the U.S. total. Thus, food processing is a key user of corn for Indiana.

Table 2.6. Location and Annual Utilization of Corn by Food Processing Plants in Indiana, 2009

City ¹	County	Bushels of Corn Processed per Year
Lafayette	Tippecanoe	92,125,000
Hammond	Lake	67,000,000
Indianapolis	Marion	33,835,000
Daviess	Washington	32,160,000
Evansville	Vanderburgh	8,375,000
Marion	Grant	4,020,000
Rochester	Fulton	<u>4,020,000</u>
Total		241,535,000

¹Lafayette, Indianapolis, and Evansville have more than one corn plant. Corn required is total for all plants in the county.

Source: Milling and Baking News, 2008

Corn utilization by ethanol is a third source of corn consumption. Location and capacities of each plant for the three time periods are needed. For 2006, only the plant at South Bend was in operation. The 2008 data are for the nine plants in operation at the end of 2008 (Table 1.8). The 2010 plants include the two idle plants as well as the two plants under construction.

Food processing plants in Indiana in production in 2006 are assumed to produce at the same rate through 2010. It is also assumed that all plants run at full capacity for 350 days per year. Furthermore, it is assumed that corn is transported to these plants in semi-trailers with a capacity of 920 bushels. Ethanol plants are assumed to operate at full capacity for 354 days per year and also transport corn in 920 bushel semi-trailers (Denicoff, 2007).

Once livestock demand for corn is fulfilled, corn is then allocated to food processing and ethanol plants. Because of the volume of corn demanded by both food processing and ethanol plants is large relative to local production, the draw area for each plant will likely extend into adjacent counties. A linear programming transportation model like equation 2-4 is used to allocate corn by minimizing total distance traveled when allocating corn for all food processing and ethanol plants. The output of this model provides bushels of corn allocated from a production county i to a destination county j with an ethanol or food processing plant.

The same process to calculate truckloads of corn to meet livestock demand is used for to meet food processing and ethanol utilization of corn. Equations 2-5, 2-9, and 2-10 are used to determine daily inbound trucks and miles traveled by each truck focusing on county level corn production data and food processing and ethanol utilization of corn. A sum of distances for all trucks provides total daily miles traveled. This provides total inbound truck loads and miles traveled for counties with food processing and ethanol plants.

For counties without a food processing or ethanol plants, corn is allocated to destination counties on the basis of the linear programming transportation model. Equations 2-5 and 2-6 are used to determine truck miles.

Corn remaining after allocation to livestock, food processing, and ethanol plants is transported to local county elevators. Equations 2-5, 2-9, and 2-10 are used to determine daily truckloads required and miles traveled by each truck focusing on corn production (i) and elevator use of corn (u). By summing miles traveled by each truck, total daily truck miles are known.

2.6. Step 6 –Soybeans for Crushing and Biodiesel

Soybean demand at the county level is also required which principally is soybean crushing facilities. The location and annual soybean demanded for six soybean crushing facilities are included in the model for all three time periods (Table 2.7). In addition, soybeans are demanded by the biodiesel plants found in the state (Table 1.9). Thus, processing demand for soybeans is 184.9 million bushels in 2006 and 257.4 million bushels in 2008 and 2010. Crushing and biodiesel plants are assumed to operate at full capacity for 350 days per year and be supplied with soybeans via 920 semi-trailers.

Soybeans are then allocated to soybean crushing facilities. Like food processing and corn ethanol plants, the large quantity of soybeans demanded by soybean crushing facilities means that the draw area of each facility will extend into adjacent counties. Thus, the same type of linear programming transportation model is used to allocate soybeans to crushing facilities (equation 2 4). The output of this model provides the allocation of soybeans from production counties to counties with crushing facilities.

Equations 2-5, 2-9, and 2-10 are used to estimate daily inbound truck loads of beans required for each crushing facility and miles traveled by each truck. All equations are used

Table 2.7. Location and Capacity of Soybean Crushing Plants

City	County	Bushels of Soybeans per Year
Morristown	Shelby	57,750,000
Decatur	Adams	41,580,000
Frankfort	Clinton	27,286,875
Mt. Vernon	Posey	22,435,875
Lafayette	Tippecanoe	19,404,000
Seymour	Jackson	<u>9,702,000</u>
TOTAL		178,158,750

Source: Milling and Baking News, 2008

focusing on soybean production data (i) and crushing facility utilization of soybeans (u). A sum of distances traveled by each truck provides total daily miles traveled for inbound shipments of beans to each crushing facility. Soybeans remaining after demand for all crushing facilities are met are transported to county elevators.

2.7. Step 7 – Transportation Requirements for Ethanol to Blenders

Ethanol demand is also needed for the model. The primary demand point for ethanol is gasoline blending terminals where ethanol is blended with gasoline. The location and capacities of blending terminals are obtained from Reynolds (2002).

Ethanol markets west of Indiana are assumed to be satisfied with ethanol from Iowa and Illinois. In addition, it is assumed that demands in Kentucky, Michigan, and Ohio are open to ethanol from Indiana by truck. Thus, it is assumed that 760 MGY of ethanol demand can be served from Indiana ethanol plants as a truck market (Table 2.8). After truck markets are served, any remaining ethanol is railed from the region. It is assumed that ethanol transported

within the truck market is done so via trucks with 8,000 gallon capacities, while ethanol railed out of the region is done so via rail cars with a capacity of 29,400 gallons (Denicoff, 2007).

Table 2.8. Assumed Location and Annual Demands for Ethanol Truck Markets

Location	Capacity (MGY)
Evansville, IN	40
Huntington, IN	20
Indianapolis, IN	155
South Bend, IN	75
Brookston, IN	10
Muncie, IN	20
Lexington, KY	30
Louisville, KY	200
Detroit, MI	160
Marshall, MI	15
Jackson, MI	35
TOTAL	760

Source: (Reynolds 2002)

Outbound ethanol is allocated to truck markets which include gasoline blending terminals in Indiana, Michigan, and Kentucky. Distances between each ethanol plant and each truck market location were obtained from Google Maps. With distances known, a linear programming transportation model like equation 2-4 was used to allocate ethanol between ethanol plants and truck markets. Output from this model provides gallons of ethanol allocated between ethanol plants and blending terminals. Daily truck loads of ethanol are then calculated by the same types of relationships as used for corn, beans, and DDGS.

2.8. Step 8 – Grain Shipped from Grain Elevators

After corn and soybean demands are fulfilled in each county, all remaining grain is transported to local county elevators where it is stored before being shipped out of Indiana. According to Census Data, 81.8 percent of the grain shipped from the state of Indiana moves by rail, with truck involved in the remainder of the movements (which may include a truck/barge haul) (Bureau of Transportation Statistics, 2004). Given the seasonal nature of the elevator industry, elevators operate 250 days per year and grain is received by a combination of 920 bushel semi-trailers and 500 bushel farm trucks.

A partial list of 68 county elevators from 42 counties was found in the Milling and Baking News (2008). For each county, the grain elevators are assigned as being either truck, rail, or split on the basis of elevator operating characteristics. For counties with unit train elevators, 98% of the grain was assumed to be shipped by rail, while if the county had a rail/truck split 92% was shipped by rail. Counties with truck houses were largely concentrated near the Ohio River.

If an elevator within a particular county has a rail load out capacity of 35,000 bushels per hour or more, the county is classified as being a unit train rail shipper. The 19 counties with “rail” elevators in Indiana are assumed to ship 95% of the grain by rail (Table 2.9). If no elevator was discovered in a county with rail shipping capability, the county was classified as truck. The 30 truck counties are concentrated near the Ohio River. The remaining 43 counties were classified as split, meaning they ship by some combination of rail and truck. The Excel function Goal Seek was used so that the percent of grain shipped by rail was consistent with the Census tons of 81.8 percent. The “split” counties shipped 83.1% by rail and the remainder by truck.

Table 2.9. Distribution of Outbound Shipments by Mode and Bushels Shipped, 2002

Mode	Number of Counties with Mode	Total Bushels shipped by Rail	Total Bushels Shipped by Truck
Rail	19	94,178,187	4,956,747
Split	43	251,408,375	50,969,862
Truck	<u>30</u>	<u>0</u>	<u>20,964,289</u>
Total	92	345,586,562	76,890,898

SOURCE: Bureau of Transportation Statistics, 2004.

2.9. Summary of Model

The eight steps estimate daily truck loads and miles for corn, soybeans, ethanol, and DDGS as well as daily rail carloads of ethanol, DDGS, and grain leaving Indiana at the county level. Results of the model are discussed in the next chapter.

Chapter 3 – Empirical Results

To determine changes in transportation requirements among the three time periods, differences in truck and rail loads, miles driven (VMTs), and average length of haul are compared. Differences between time periods signal expected changes in transportation requirements caused by the expansion of biofuels in Indiana.

The model described in Chapter 2 was built in Excel, using output from four linear programming models providing allocations of corn, soybeans, DDGS, and ethanol. Three models were estimated for all 92 counties in Indiana, plus 39 border counties in adjacent states. The three models are a baseline (2006) which can be compared with a short term adjustment (2008) and a long term adjustment (2010). In this chapter, state level results are reported for Indiana.

This chapter will examine the statewide results in detail. A wealth of information is available, including: 1) changes in grain production and utilization, 2) inbound truckloads of corn and soybeans to meet demands for livestock, food processing, ethanol, oilseed crushing, and grain elevators, and 3) outbound shipments of corn, soybeans, DDGS, and ethanol, by truck and rail. Results are first reported at the state level for average one-way LOH, number of loads per day, and daily and annual VMT for the various inbound and outbound movements. Next annual totals are reported, with a focus on the relative contributions of the different inbound and outbound movements. Finally, annual totals are compared for four types of counties, those counties with new and incumbent biofuels plants, the counties bordering those with ethanol plants, and all other counties.

3.1. Statewide Grain Production

Since 2006, higher corn and bean prices, in part due to the growth in biofuels, have led to increased grain production in Indiana. From 2006 to 2008, total corn bushels in Indiana rose by 7.1 percent, and are projected to grow by an additional 4.9 percent from 2008 to 2010 (Table 3.1). Soybean production fell by 10.3 percent from 2006 and 2008, but then rebounds from 2008 to 2010 by 10.4 percent. Total bushels of corn and beans grow from 1.14 to 1.18 billion to 1.25 billion bushels in 2006, 2008, and 2010, respectively. This represents a total growth of 2.9 and 6.1 percent between the time periods in available bushels to be moved. Thus, part of the growth in grain transportation in Indiana is simply that there is more production. However, in part this is offset because corn and soybean density also increase over time, meaning that grain production is more concentrated.

Table 3.1. Indiana Grain Production, Yield, and Density, by Year

Grain Production	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn Production (M bu)	866.9	928.1	974.0	7.1%	4.9%
Soybean Production (M bu)	<u>277.4</u>	<u>249.0</u>	<u>275.0</u>	<u>-10.2%</u>	<u>10.4%</u>
Total bushels (M bu)	1,144.3	1,177.1	1,248.9	2.9%	6.1%
Corn Yield (bu/acre)	151.0	149.7	157.2	-0.8%	5.0%
Soybean Yield (bu/acre)	49.3	45.2	48.2	-8.3%	6.8%
Corn Density (bu/section)	23,531	25,163	26,405	6.9%	4.9%
Soybean Density (bu/section)	7,613	6,833	7,546	-10.3%	10.4%

Livestock consumption of corn fell from 2006 to 2008 by 3.0 percent, and is forecast to fall an additional 16.3 percent from 2008 to 2010 (Table 3.2). The sole reason underlying the

Table 3.2. Truckloads, VMT, and Average LOH for Livestock Utilization of Corn, by Year

Livestock Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	116.5	113.0	94.5	-3.0%	-16.3%
Daily Loads	686	666	560	-2.9%	-15.9%
Daily VMT (miles)	3,470	2,703	2,011	-22.1%	-25.6%
Average LOH (miles/trip)	5.1	4.1	3.6	-19.8%	-11.5%
Annual Loads	250,390	243,090	204,400	-2.9%	-15.9%
Annual VMT (000 miles)	1,266.6	986.6	734.2	-22.1%	-25.6%

decline is the replacement of corn by DDGS in livestock feed rations (see Table 2.5). The assumed livestock consumption of DDGS is saturated in Indiana in 2008. Consumption increases from 2008 to 2010 because inclusion rates of DDGS in animal rations are forecast to increase as farmers become familiar with the using DDGS.

Reliable data about DDGS consumption are not available. Most likely the assumed DDGS feeding rates likely overstate the adoption of DDGS as a substitute for corn and should be viewed as a measure of DDGS market potential. To that extent, the model understates outbound shipments of DDGS from Indiana via rail and overstates available corn, which likely was consumed by livestock. VMTs for Indiana corn fed to livestock decreased by 22.1 percent between 2006 and 2008, and are forecast to fall an additional 25.6 percent from 2008 to 2010. VMTs fell more than corn bushels consumed by livestock because corn density increased over time (Table 3.1). The average one-way LOH fell from 5.1 to 3.6 miles per trip. Thus, livestock consumption represents very short one-way hauls.

The number of food processing plants were unchanged over the three time periods and therefore, corn consumption and daily truckloads for food processing also were stable (Table

3.3). However, changes in corn production and density as well as changes in other types of corn utilization cause daily VMT traveled to change slightly. From 2006 to 2008, VMTs decreased by a few thousand miles, but will drop by 2.4 percent from 2008 to 2010. Although VMTs change, one way average LOH remains virtually constant, near 27 miles per trip, because the change in miles is very small. Compared to livestock, average LOH is much further due to the large volume of corn consumed at one location by each food processing plant.

Table 3.3. Truckloads, VMT, and Average LOH for Food Processing Utilization of Corn, by Year

Food Processing Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	241.5	241.5	241.5	0.0%	0.0%
Daily Loads	768	767	766	-0.1%	-0.1%
Daily VMT (miles)	21,287	21,280	20,853	0.0%	-2.0%
Average LOH (miles/trip)	27.7	27.7	27.2	0.1%	-1.9%
Annual Loads	268,800	268,450	268,100	-0.1%	-0.1%
Annual VMT (000 miles)	7,450.3	7,447.8	7,298.5	0.0%	-2.0%

The number of ethanol plants in Indiana for 2006, 2008, and 2010 are 1, 9, and 13, respectively (Table 1.8). As large users of corn, each additional ethanol plant causes in-state corn utilization to grow. Statewide, daily and annual truckloads to ethanol plants increased by 590.0 percent with annual loads increasing from 39,648 to 271,164 from 2006 to 2008 and then by an additional 51.4 percent to 410,640 from 2008 to 2010 (Table 3.4). VMTs increase by 443.1 percent, from 696,100 to 3.78 million miles, and 59.59 percent to 6.03 million miles over the same periods. Although truckloads and VMTs sharply increased, one-way average LOH for ethanol remained fairly constant, between 14 and 17 miles. The decrease in average trip miles

Table 3.4. Truckloads, VMT, and Average Trip Miles for Ethanol Utilization of Corn, by Year

Ethanol Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	35.6	245.6	373.0	590.0%	51.9%
Daily Loads	112	766	1,160	583.9%	51.4%
Daily VMT (miles)	1,966	10,680	17,039	443.1%	59.5%
Average LOH (miles/trip)	17.6	13.9	14.7	-20.6%	5.4%
Annual Loads	39,648	271,164	410,640	583.9%	51.4%
Annual VMT (000 miles)	696.1	3,780.6	6,031.7	443.1%	59.5%

between 2006 and 2008 can be explained in that ethanol plants constructed were located in the northern half of Indiana where corn density is much higher. Ethanol average LOH is approximately half the distance of food processing. This is because food processing plants are dispersed throughout the entire state (including southern Indiana where corn density is lower) whereas ethanol plants are primarily located in the northern half of Indiana (Figure 3-1).

Because corn is only transported to country elevators after livestock, food processing, and ethanol demands are first met, the addition of ethanol plants in 2008 and 2010 directly affects the amount of corn available to be allocated to elevators. Bushels of corn, daily loads, and annual loads decrease by roughly 25 percent from 2006 to 2008 with annual loads decreasing from 860,500 to 648,000 and then by an additional 3.45 percent to 625,750 loads from 2008 to 2010 (Table 3.5). VMTs decreased from 7.3 to 5.5 to 5.3 million miles from 2006 to 2008 to 2010. Average LOH was constant at 8.4 miles per trip. As anticipated, trips to haul corn to elevator are typically a short distance.

Figure 3-1. Classification of Indiana Counties

Table 3.5. Truckloads, VMT, and Average LOH for Elevator Utilization of Corn, by Year

Elevator Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn consumed (M bu)	511.5	384.6	371.6	-24.8%	-3.4%
Daily Loads	3,442	2,592	2,503	-24.7%	-3.4%
Daily VMT (miles)	29,038	22,016	21,039	-24.2%	-4.4%
Average LOH (miles/trip)	8.4	8.5	8.4	0.7%	-1.0%
Annual Loads	860,500	648,000	625,750	-24.7%	-3.4%
Annual VMT (000 miles)	7,259.4	5,503.9	5,259.7	-24.2%	-4.4%

The changes in soybean crushing utilization of soybeans occur in the 2008 model with the addition of biodiesel plants at Claypool in Kosciusko County and Middletown in Henry County. Changes between 2006 and 2008 were substantial. Soybean bushels consumed and number of loads increased by 36 percent with annual loads increasing from 209,650 to 285,950 (Table 3.6). VMTs increased by 62.5 percent, rising from 5.1 to 8.3 million miles, while average LOH increased by 19.1 percent from 24.2 to 28.8 miles. With no additional crushing, changes for soybeans from 2008 to 2010 were minor for VMTs as well as average trips, representing changes in production and density.

Table 3.6. Truckloads, VMT, and Average LOH for Crushers Utilization of Soybeans, by Year

Crushing Facility Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Beans consumed (M bu)	184.9	250.6	250.6	35.6%	0.0%
Daily Loads	599	817	816	36.4%	-0.1%
Daily VMT (miles)	14,479	23,529	22,382	62.5%	-4.9%
Average LOH (miles/trip)	24.2	28.8	27.4	19.1%	-4.8%
Annual Loads	209,650	285,950	285,600	36.4%	-0.1%
Annual VMT (000 miles)	5,067.7	8,235.0	7,833.6	62.5%	-4.9%

Because of the addition of a crushing capacity and a decrease in total soybean production from 2006 to 2008, soybeans allocated to country elevators, number of loads, and VMTs decreased by approximately 64 percent with annual loads decreasing from 216,750 to 79,500 and VMTs from 1.9 million to 680,400 miles (Table 3.7). However, this had no effect on average LOH, remaining around 8.6 miles. From 2008 to 2010, crushing capacity remained constant while soybean production increased. This increased the soybeans transported to elevators and loads by around 50 percent during this time. VMTs increased by 50 percent and average LOH was unchanged due to the increase in soybean production

Table 3.7. Truckloads, VMT, and Average LOH for Elevator Utilization of Soybeans, by Year

Elevator Utilization	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Beans consumed (M bu)	125.1	43.9	66.2	-64.9%	50.6%
Daily Loads	867	318	480	-63.3%	50.9%
Daily VMT (miles)	7,714	2,722	4,090	-64.7%	50.3%
Average LOH (miles/trip)	8.9	8.6	8.5	-3.8%	-0.4%
Annual Loads	216,750	79,500	120,000	-63.3%	50.9%
Annual VMT (000 miles)	1,928.4	680.4	1,022.5	-64.7%	50.3%

3.2. Statewide Outbound Ethanol, DDGS, and Grain Flows

With the addition of 8 ethanol plants from 2006 to 2008, ethanol production and outbound deliveries of ethanol to blenders increased by 590 percent from 36 to 248 truckloads per day (Table 3.8). The truck market for ethanol produced in Indiana is 760 million gallons, with most of the ethanol demand in Indiana or a short distance into bordering states. From 2006 to 2008, VMTs increased 2,323 percent with annual miles increasing from 445,400 to 10,793,900.

Table 3.8. Truck and Rail Loads, VMT, and LOH for Outbound Ethanol, by Year

Outbound Ethanol	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Ethanol Production (BGY)	100.0	690.0	1,048.0	590.0%	51.9%
Daily Truckloads	36	248	273	588.9%	10.1%
Daily VMT (miles)	1,258	30,491	28,386	2323.3%	-6.9%
Average LOH (miles/trip)	35.0	122.9	104.0	251.8%	-15.4%
Daily Rail Tankloads	0.0	0.0	30.0	NA	NA
Annual Truckloads	12,744	87,792	96,642	588.9%	10.1%
Annual VMT (000 miles)	445.4	10,793.9	10,048.7	2323%	-6.9%
Annual Rail Tankloads	0.0	0.0	10,620.0	NA	NA

Initially, as more ethanol plants are constructed, they serve truck markets. In turn, this causes the average LOH to increase by 251 percent from 35.6 to 122.9 miles per trip. In both 2006 and 2008, total ethanol production is less than the total truck market demand, and thus no ethanol is transported via rail. From 2008 to 2010, four additional ethanol plants come online, which increases capacity by 51.9 percent. This additional capacity fulfills the truck market demand of 760 million gallons, meaning ethanol is also transported by rail in 2010. From 2008 to 2010, truckloads increase an additional 10.1 percent with annual loads increasing from 87,792 to 96,642, while VMTs fall by 7 percent as annual VMTs drop to 10,048,700 miles. Miles traveled fall because plants open closer to some of the blending markets. Annual rail tanker carloads increase from 0 in 2008 to 10,620 in 2010.

An increase in ethanol production also means an increase in DDGS production. As mentioned earlier, the decrease in corn consumption by livestock is supplemented by the addition of DDGS into livestock diets which is the truck market demand. From 2006 to 2008, the number of truckloads per day rose from 22 to 34 (Table 3.9). Given the proximity of the

Table 3.9. Truck and Rail Loads, VMT, and Average LOH for Outbound DDGS, by Year

Outbound DDGS	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
DDGS Production (M tons)	0.30	2.04	3.09	590.0%	51.9%
Daily Truckloads	22	34	99	54.5%	191.2%
Daily VMT (miles)	1,802	1,519	3,303	-15.7%	117.5%
Average LOH (miles/trip)	81.9	44.7	33.4	-45.5%	-25.3%
Daily Rail Carloads	3.0	55.0	72.0	1733.3%	30.9%
Annual Truckloads	7,788	12,036	35,046	54.5%	191.2%
Annual VMT (000 miles)	637.8	537.7	1,169.2	-15.7%	117.5%
Annual Rail Carloads	1,062.0	19,470.0	25,488.0	1733.3%	30.9%

one ethanol plant in 2006 (St. Joseph County) to the border with Michigan, some of the output is shipped by rail to out of state markets, although it likely moves by truck. By 2008, DDGS production greatly exceeds the local truck market demand, leading the amount to be shipped by rail to jump by 1,733 percent from 1,062 to 19,470 rail carloads. Truckloads of DDGS increased during this time by 35 percent from 7,788 to 12,036. During this time, ethanol plants are more dispersed throughout the state causing average LOH for trucks to fall by 45 percent from 81.9 to 44.7 miles. DDGS production increases an additional 51.9 percent from 2008 to 2010, but more DDGS is assumed to be fed within the local truck market as inclusion rates increase. Thus, truckloads rise by 191 percent to 35,046 per year, while rail carloads climb to 25,488 per year. The average LOH for trucks drops to 33.4 miles per trip.

The changes in corn utilization by livestock and ethanol over the three time periods affect outbound shipments of corn from elevators via rail and truck. From 2006 to 2008, total bushels of outbound corn decreased by 25 percent as that corn is now processed in Indiana

Table 3.10). During this time, daily outbound truckloads fell 13 percent, from 450 to 393, while daily rail carloads decreased by 28 percent from 506 to 364. VMTs decreased by 38.1 percent and average LOH decreased by 29.1 percent. From 2008 to 2010 corn available for outbound shipment decreases an additional 3.4 percent to 371.6 million bushels. Daily truckloads decrease by 1.8 percent, but VMTs and LOH increase by 29.7 and 32.1 percent, respectively. Rail carloads decrease by 5.8 percent during this time. These changes in outbound corn flows can be explained primarily by the increase in instate consumption of corn from ethanol plants which reduces the amount of corn available for outbound shipment.

Table 3.10. Truckloads, Rail Carloads, VMT, and Average LOH for Outbound Corn, by Year

Outbound Corn	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Corn in Elevator (M bu)	511.5	384.6	371.6	-24.8%	-3.4%
Daily Truckloads	450.0	393.0	386.0	-12.7%	-1.8%
Daily VMT (miles)	24,666.9	15,271.4	19,810.6	-38.1%	29.7%
Average LOH (miles/trip)	54.8	38.9	51.3	-29.1%	32.1%
Daily Rail Carloads	506.0	364.0	343.0	-28.1%	-5.8%
Annual Truckloads	112,500	98,250	96,500	-12.7%	-1.8%
Annual VMT (000 mi)	6,166.7	3,817.8	4,952.6	-38.1%	29.7%
Annual Rail Carloads	126,500.0	91,000.0	85,750.0	-28.1%	-5.8%

The addition of two biodiesel plants in 2008 was the only major change in soybean utilization. Coupled with a decrease in soybean production in 2008 caused soybeans available for shipment from Indiana to decrease by 65 percent from 2006 to 2008 (Table 3.11). Truckloads, VMTs, and average LOH decrease 50.0, 51.6, and 3.3 percent, respectively, while

Table 3.11. Truckloads, Rail Carloads, VMT, and Average LOH for Outbound Soybeans, by Year

Outbound Soybeans	Model			% change from:	
	2006	2008	2010	06 to 08	08 to 10
Soybeans in Elevator (M bu)	125.1	43.9	66.2	-64.9%	50.6%
Daily Truckloads	158.0	79.0	114.0	-50.0%	44.3%
Daily VMT (miles)	6,851.7	3,312.9	4,378.6	-51.6%	32.2%
Average LOH (miles/trip)	43.4	41.9	38.4	-3.3%	-8.4%
Daily Rail Carloads	137.0	54.0	85.0	-60.6%	57.4%
Annual Truckloads	39,500	19,750	28,500	-50.0%	44.3%
Annual VMT (000 miles)	1,712.9	828.2	1,094.6	-51.6%	32.2%
Annual Rail Carloads	34.3	13.5	21.3	-60.6%	57.4%

rail carloads decrease 60.6 percent during this time. From 2008 to 2010, the only change is an increase in soybean production of 10.4 percent (Table 3.1). As a result, truckloads increase by 44.3 percent while VMTs increase by 32.2 percent. Average LOH decreases by an additional 8.4 percent during this time. Rail carloads increase by 27.4 percent.

An additional way to examine the results is to focus on the relative contributions of different inbound and outbound shipments. Corn utilization by livestock, food processors, ethanol plants, and elevators shift as additional ethanol plants begin production. Livestock's share of utilization of corn declines from 12.9 percent of the crop in 2006 to 8.7 percent in 2010 (Table 3.12). This occurs due to the incorporation of DDGS in livestock rations in lieu of corn. Although no food processing plants were constructed between 2006 and 2010, their share of corn utilization falls slightly from 26.7 to 22.4 percent due to increased corn production. Because the major difference between each model year are additions of ethanol plants,

Table 3.12. Summary of Corn Utilization by Type, by Year

Corn Utilization	2006		2008		2010	
	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total
Livestock	116.5	12.9%	113.0	11.5%	94.5	8.7%
Food	241.5	26.7%	241.5	24.5%	241.5	22.4%
Ethanol	35.6	3.9%	245.6	24.9%	373.0	34.5%
Elevators	<u>511.5</u>	<u>56.5%</u>	<u>384.6</u>	<u>39.1%</u>	<u>371.6</u>	<u>34.4%</u>
Total	905.1	100.0%	984.7	100.0%	1,080.6	100.0%

ethanol's share of corn utilization increases from 3.9 percent in 2006 to 24.9 percent in 2008 to 34.5 percent by 2010. Elevator utilization of corn declines from 56.5 percent in 2006 to 32.4 percent in 2010 which can be interpreted as a decline in corn available for shipment from Indiana since corn shipped to elevators is assumed to leave Indiana.

Likewise, soybean share between crushing facilities and country elevators shifts with the addition of two biodiesel plants in the 2008 model. Crushing facility's share of utilization of soybeans increases from 59.6 percent in 2006 to 79.1 percent in 2010 (Table 3.13). Thus, elevator's share of the soybean market declines from 40.4 percent to 20.9 percent during this time.

Table 3.13. Summary of Soybean Utilization by Type, by Year

Soybean Utilization	2006		2008		2010	
	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total	Bushels (M bu)	Percent of Total
Crushing	184.9	59.6%	250.6	85.1%	250.6	79.1%
Elevators	<u>125.1</u>	<u>40.4%</u>	<u>43.9</u>	<u>14.9%</u>	<u>66.2</u>	<u>20.9%</u>
Total	309.9	100.0%	294.6	100.0%	316.8	100.0%

Annual totals inbound and outbound truckloads and outbound railcars for 2006, 2008, and 2010 are compared in evaluate the overall change between each period (Table 3.14). To further understand changes between each period, annual VMTs are also compared for each year (Table 3.15). Inbound truckloads include grain shipments to livestock, food processing, ethanol, crushers, and grain elevators. Outbound truckloads include corn and soybeans shipped from elevators to destinations outside of Indiana and ethanol and DDGS shipped from ethanol plants to their respective truck markets.

Table 3.14. Annual Truckloads and Rail Carloads by Commodity, by Year

Movement/Mode/Utilization	2006	2008	2010	% change
	Truckloads (in thousands)			from 06 to 10
Inbound Corn - Livestock	250.4	243.1	204.4	-18.4%
Inbound Corn - Food Processing	268.8	268.5	268.1	-0.3%
Inbound Corn - Ethanol	39.6	271.2	410.6	935.7%
Inbound Corn - Elevator	860.5	648.0	625.8	-27.3%
Inbound Soybeans - Crushing	209.7	286.0	285.6	36.2%
Inbound Soybeans - Elevator	<u>216.8</u>	<u>79.5</u>	<u>120.0</u>	<u>-44.6%</u>
Total Inbound Truck Movements	1,845.7	1,796.2	1,914.5	3.7%
Outbound Truck - Ethanol	12.7	87.8	96.6	658.3%
Outbound Truck - DDGS	7.8	12.0	35.0	350.0%
Outbound Truck - Corn	112.5	98.3	96.5	-14.2%
Outbound Truck - Beans	<u>39.5</u>	<u>19.8</u>	<u>28.5</u>	<u>-27.8%</u>
Total Outbound Truck	172.5	217.8	256.7	48.8%
Total Truck Loads	<u>2,018.27</u>	<u>2,013.98</u>	<u>2,171.18</u>	<u>7.6%</u>
	Rail Carloads			
Outbound Rail - Ethanol	0	0	10,620	NA
Outbound Rail - DDGS	1,062	19,470	25,488	2300.0%
Outbound Rail - Corn	126,500	91,000	85,750	-32.2%
Outbound Rail - Soybean	34,250	13,500	21,250	<u>-38.0%</u>
Total Outbound Rail Carloads	161,812	123,970	143,108	-11.6%

Table 3.15. Annual VMT by Commodity, by Year

Annual VMT	2006	2008	2010	% change from 06 to 10
	000 VMT in miles			
Inbound Corn: Livestock	1,266.6	986.6	734.2	-42.0%
Inbound Corn: Food Processing	7,450.3	7,447.8	7,298.5	-2.0%
Inbound Corn: Ethanol	696.1	3,780.6	6,031.7	766.5%
Inbound Corn: Elevator	7,259.4	5,503.9	5,259.7	-27.5%
Inbound Soybeans: Crushing	5,067.7	8,235.0	7,833.6	54.6%
Inbound Soybeans: Elevator	<u>1,928.4</u>	<u>680.4</u>	<u>1,022.5</u>	<u>-47.0%</u>
Total Inbound Truck	<u>23,668.41</u>	<u>26,634.35</u>	<u>28,180.20</u>	<u>19.1%</u>
Outbound Truck: Ethanol	445.4	10,793.9	10,048.7	2155.9%
Outbound Truck: DDGS	637.8	537.7	1,169.2	83.3%
Outbound Truck: Corn	6,166.7	3,817.8	4,952.6	-19.7%
Outbound Truck: Beans	<u>1,712.9</u>	<u>828.2</u>	<u>1,094.6</u>	<u>-36.1%</u>
Total Outbound Truck	8,962.9	15,977.7	17,265.2	92.6%
Total Truck Loads	32,631.34	42,612.04	45,445.39	39.3%

Overall, inbound truckloads within Indiana remain fairly constant with a 3.7 percent increase from 1.85 to 1.91 million loads from 2006 to 2010 (Table 3.14), while annual VMTs increase 19.1 percent, from 23.69 to 28.18 million miles (Table 3.15). Although this is not a large overall change, major changes occur across commodity types. Annual truckloads of corn to livestock decrease 18.4 percent, which account for a decline in VMTs of 532,400 miles, or 42.0 percent from 2006 to 2010. A major shift occurs as corn previously transported to elevators is shifted to ethanol plants. From 2006 to 2010, annual truckloads of corn to ethanol plants increase from 39,600 to 410,600 (936 percent), leading to an increase in VMTs from 696,000 miles to 6.03 million miles (767 percent). Annual elevator truckloads of corn to elevators decreased from 860,500 to 625,800 loads (a fall of 27.3 percent), which decrease VMTs from 7.26 to 5.26 million miles (a fall of 27.5 percent).

A shift also occurs between soybeans transported to elevators and crushing facilities. Annual truckloads of soybeans to crushers increase by 36.2 percent, from 209,700 to 285,600 (Table 3.14) and VMTs from 5.07 to 7.83 million (54.62 percent) miles from 2006 to 2010 (Table 3.15). During this time, annual truckloads of soybeans to elevators decreased from 216,800 to 120,000 (-44.6 percent) and VMTs from 1.93 to 1.02 million miles (-47.0 percent).

Total outbound truckloads increase by 48.8 percent, from 172,500 to 256,700 from 2006 to 2010 (Table 3.14). Additionally, total outbound annual VMT almost double from 8.96 to 17.26 million miles (114.8 percent) during this time (Table 3.15). This can be attributed to less outbound grain and more outbound ethanol and DDGS, which travel further to their respective destination markets. From 2006 to 2010, annual outbound truckloads of corn decrease from 112,500 to 96,500 and soybeans from 39,500 to 28,500. VMTs decrease from 6.17 to 4.95 million and 1.71 to 1.09 million miles for corn and soybeans, respectively. This decrease is compensated by the increase in loads of ethanol and DDGS. Truckloads of ethanol rise from 12,700 to 96,600, while truckloads of DDGS increase from 7,800 to 35,000. VMTs for ethanol rise from .45 to 10.05 million, while VMTs for DDGS rise from 637,800 to 1.17 million miles.

Total annual outbound rail carloads decrease from 161,812 to 143,108 from 2006 to 2010 (Table 3.14). However, there is a shift from outbound rail movements from grain to ethanol and DDGS. Rail carloads of corn decline from 126,500 to 85,750 and soybeans from 34,250 to 21,250 rail carloads. Ethanol rail tanker loads increased from 0 in 2006 to 10,620 in 2010, while DDGS increased from 0 rail hopper car loads in 2006 to 25,488 in 2010.

3.3. Results for Counties with Biofuels Plants

Changes between each model year are due in large part to the addition of ethanol and biodiesel plants. Thus, it is likely that a large portion of the change that occurs between each year is concentrated in counties in which biofuels plants are constructed. Data are evaluated on changes in truckloads and VMTs for 13 counties (Cass, Grant, Henry, Jasper, Jay, Kosciusko, Madison, Montgomery, Posey, Putnam, Randolph, Wabash, and Wells) that added new ethanol and biodiesel plants between 2006 and 2010 to determine whether transportation impacts are concentrated (Figure 3-1.) Changes in truckloads and VMTs for the counties with new biofuels plants are compared against counties in the rest of the state. Miles and loads are credited to the county that originates the shipment. Thus, the results underestimate the effects on counties with new biofuels plants.

Total inbound truckloads fell by 54,400 loads in counties with new biofuels plants and by rose by 123,100 loads in the rest of the state (Table 3.16). In the counties with new plants, loads of corn and beans shifted from elevators to ethanol and biodiesel plants. Loads to ethanol plants also drove the traffic shift in the rest of the state. Overall, 41.9 and 22.3 percent of the loads to the new ethanol and biodiesel plants, respectively, came from the host counties. The rest of the state also saw a increase in shipments to biofuels plants that was offset by fewer loads to livestock and grain elevators. In addition, patterns to serve food plants change, with roughly 30,000 loads shifting from counties with new biofuels plants to the rest of the state.

Total inbound VMTs rose by 1.27 million miles in counties with new biofuels plants, and 3.2 million miles in the rest of the state (Table 3.17). The change in VMTS was driven by trips

Table 3.16. Annual Inbound Truckloads for Counties with New Biofuels Plants

Inbound Trucks Within Indiana (Thousands)	Model		Change in Truckloads 06 to 10		2010 % of Truck Traffic in New Biofuels Counties
	2006	2010	New Biofuels Counties	Rest of State	
Corn to Livestock	55.8	47.1	-8.8	-37.2	23.0%
Corn to Food	38.2	8.1	-30.1	29.4	3.0%
Corn to Ethanol	0.0	169.7	169.7	201.3	41.3%
Corn to Elevator	199.3	27.3	-172.0	-62.8	4.4%
Beans to Crusher	34.7	63.7	29.1	46.9	22.3%
Beans to Elevator	<u>52.0</u>	<u>9.8</u>	<u>-42.3</u>	<u>-54.5</u>	<u>8.1%</u>
Total	379.9	325.5	-54.4	123.1	17.0%

Table 3.17. Annual Inbound VMT for Counties with New Biofuels Plants

Inbound VMT Within Indiana (000 miles)	Model		Change in VMTs 06 to 10		2010 % of Truck Traffic in New Biofuels Counties
	2006	2010	New Biofuels Counties	Rest of State	
Corn to Livestock	280.3	183.8	-96.5	-435.9	25.0%
Corn to Food	1,057.1	239.6	-817.5	665.7	3.3%
Corn to Ethanol	0.0	3,063.3	3,063.3	2,272.4	50.8%
Corn to Elevator	1,682.2	198.4	-1,483.8	-515.9	3.8%
Beans to Crusher	870.8	1,870.5	999.7	1,766.2	23.9%
Beans to Elevator	<u>487.4</u>	<u>92.6</u>	<u>-394.8</u>	<u>-511.2</u>	<u>9.1%</u>
Total	4,377.8	5,648.2	1,270.5	3,241.3	20.0%

to ethanol plants (3 million new miles) and oil crushers (1 million new miles). This increase led to a decrease of 1.8 million miles to country elevators in counties with new biofuels plants. In the rest of the state, VMTs rose by 4.7 million miles to food processors and biofuels plants. Again, part of these miles are in fact traveled in the counties with the new plants.

Compared to the 1.9 million inbound shipments by truck, there are only 256,700 outbound movements (Table 3.14). In part this explained that inbound loads of corn and

soybeans are shipped out of state by rail or barge. With the growth of the biofuels industry in Indiana, outbound truckloads increased by 94,400 loads in counties with new plants, but fell by 10,200 loads in the rest of the state (Table 3.18). The greatest increase in outbound truckloads came from the ethanol market with 83,900 new loads and DDGS with 31,500 loads. Overall, the counties with new biofuels plants account for 46.6 percent of outbound truckloads.

Table 3.18. Annual Outbound Trucks from Indiana for Counties with New Biofuels Plants

Outbound Trucks From Indiana (Thousands)	Model		Change in Truckloads 06 to 10		2010 % of Truck Traffic in New Biofuels Counties
	2006	2010	New Biofuels Counties	Rest of State	
Ethanol	0.0	83.9	83.9	0.0	86.8%
DDGS	0.0	31.5	31.5	-4.2	89.9%
Corn From Elevators	19.8	2.8	-17.0	1.0	2.8%
Beans From Elevators	<u>5.5</u>	<u>1.5</u>	<u>-4.0</u>	<u>-7.0</u>	<u>5.3%</u>
Total	25.3	119.7	94.4	-10.2	46.6%

The 13 counties with new ethanol and biodiesel plants are the source for 64.0 percent of the VMTs for outbound truck movements from Indiana (Table 3.19). Virtually all of the traffic to out-of-state destinations is ethanol to blenders in border states. VMTs rose from 1.7 million to 11.1 million miles in the counties with new plants, while they fell in the rest of the state by 1 million miles. DDGS miles in the rest of the state fell because livestock feeders in Indiana can source DDGS from ethanol plants near their operation in 2010, while in 2006 the only source was the ethanol plant in St. Joseph County.

Table 3.19. Annual Outbound VMT for Counties with New Biofuels Plants

Outbound VMTs From Indiana (000 miles)	Model		Change in VMTs 06 to 10		2010 % of Truck Traffic in New Biofuels Counties
	2006	2010	New Biofuels Counties	Rest of State	
Ethanol	0.0	9,687.9	9,687.9	-84.6	96.4%
DDGS	0.0	1,072.0	1,072.0	-540.7	91.7%
Corn From Elevators	1,373.1	212.2	-1,160.9	-53.2	4.3%
Beans From Elevators	<u>356.5</u>	<u>83.2</u>	<u>-273.3</u>	<u>-345.0</u>	<u>7.6%</u>
Total	1,729.5	11,055.2	9,325.7	-1,023.4	64.0%

Ethanol begins being shipped via rail in the 2010 model going from 0 annual rail carloads in 2006 to 10,600 thousand in 2010 (Table 3.20). Likewise, DDGS is shipped by rail starting in 2006 going from 0 annual carloads to 23,000 in 2010. Rail carloads of corn from the counties with new biofuels plants decrease 26,800 car loads. Overall, the counties with new ethanol and biodiesel plants represent 27.5 percent of the outbound rail traffic.

Table 3.20. Annual Outbound Rail Carloads from Counties with Biofuels Plants

Outbound Rail Carloads From Indiana (Thousands)	Model		Change in Rail Cars 06 to 10		2010 % of Truck Traffic in New Biofuels Counties
	2006	2010	New Biofuels Counties	Rest of State	
Ethanol	0.0	10.6	10.6	0.0	100.0%
DDGS	0.0	23.0	23.0	1.4	90.3%
Corn From Elevators	31.0	4.3	-26.8	-14.0	5.0%
Beans From Elevators	<u>9.3</u>	<u>1.5</u>	<u>-7.8</u>	<u>-5.3</u>	<u>7.1%</u>
Total	40.3	39.4	-0.9	-17.8	27.5%

3.4. Results for Counties Adjacent to Biofuels Production Counties

Much of the statewide change is observed in counties with new biofuels plants. Yet draw areas for these plants extend into adjacent counties. As a result, transportation systems in these counties are also likely affected. Therefore, changes for inbound and outbound truckloads, VMTs, and rail loadings are analyzed for four classifications of counties. The first group consists of the thirteen counties home to new biofuels plants since 2006 (Figure 3-1). Second, results are also considered for seven counties with existing food processing plants (classified as incumbents) because they continue to be large destinations for shipments. Finally, the other 72 counties are classified 32 border counties to counties with new plants or as the 40 other counties. As before, miles and loads are attributed to origin county. In addition, loads to food, ethanol and biodiesel plants in Indiana from the 39 counties in Illinois, Michigan, Ohio, and Kentucky that border Indiana are included.

With respect to inbound truckloads, the Border and Other counties account for almost 60 percent of the inbound truckloads generated in 2010 (Table 3.21). Corn and bean processors source 8.5 percent of their inbound loads from other states by truck. While the counties with new biofuels plants generate 17 percent of the inbound truckloads, they are responsible for 46.6 percent of the outbound loads of corn, beans, ethanol, and DDGS. The seven incumbent counties likely generate significant outbound truckloads of food based products. Rail car shipments are split across the New Plant, Border and Other Counties, with shipments of DDGS and ethanol from the New Plant counties and grain from the Border and Other counties.

Table 3.21. Annual Distribution of Loads, By Type of County, 2010

County Type	Truckloads In	% of Trucks In	Truckloads Out	% of Trucks Out	Rail Cars Out	% of Rail Cars Out
New	329,295	17.2%	119,654	46.6%	40,380	28.2%
Incumbent	110,117	5.8%	18,534	7.2%	4,978	3.5%
Border New	755,938	39.5%	41,500	16.2%	56,000	39.1%
Other	557,300	29.1%	77,000	30.0%	41,750	29.2%
Out of State	<u>161,840</u>	<u>8.5%</u>	<u>0</u>	<u>0.0%</u>	<u>0</u>	<u>0.0%</u>
Total	1,914,490	100.0%	256,688	100.0%	143,108	100.0%

On a basis of VMTs, the distribution of inbound truckloads mirrors the distribution of truckloads. VMTs from Out of State origins are higher, which makes sense given the longer length of haul to Indiana food processors and biofuels plants. For outbound VMTs, the 13 counties with New Plants account for 64 percent of the annual miles generated (Table 3.22.)

Table 3.22. Annual Distribution of VMTs, By Type of County, 2010

County Type	VMTs for Inbound	% of VMT for Inbound	VMTs for Outbound	% of VMT for Outbound
New	4,273.6	15.2%	11,055.2	64.0%
Incumbent	1,169.7	4.2%	658.0	3.8%
Border New	11,374.6	40.4%	2,459.1	14.2%
Other	7,057.3	25.0%	3,092.9	17.9%
Out of State	<u>4,304.9</u>	<u>15.3%</u>	<u>0.0</u>	<u>0.0%</u>
Total	28,180.2	100.0%	17,265.2	100.0%

Finally, the change from 2006 to 2010 in loads and VMTs are considered by type of county for each type of inbound truck movement (corn to livestock, food processing, ethanol or elevators, and beans to crushers and elevators), outbound truck and rail movements of corn

and beans from elevators and DDGS and ethanol from ethanol plants. Inbound truckloads fall from 2006 to 2010 for counties with New Plants. In contrast to all other types of counties, inbound truck movements only decrease in counties with New Plants (Table 3.23). However, the increase in truckloads in Border and Other Counties ends up traversing roads in counties with New Plants. In contrast, the increase in annual outbound truckloads is largely driven by additional shipments of ethanol and DDGS. For rail shipments, the decline in total cars comes largely from the reduction in shipments of corn and beans, especially from Border Counties.

Table 3.23. Net Change in Annual Loads from 2006 to 2010, by Type of County

Use/Mode	Type of County Originating Shipment (in 000 loads per year)					
	New	Incumbent	Border	Other	Out of State	Total
Inbound Truckloads	(in 000 loads per year)					
Livestock	-8.8	-1.8	-14.6	-20.8	0.0	-46.0
Food	-30.1	2.1	8.1	10.2	9.1	-0.7
Ethanol	173.5	9.2	125.7	-2.8	65.5	371.0
Elevator	-172.0	-1.0	-102.8	41.0	0.0	-234.8
Crusher	29.1	6.3	23.5	7.4	9.8	76.0
Elevator	<u>-42.3</u>	<u>-10.0</u>	<u>-32.3</u>	<u>-12.3</u>	<u>0.0</u>	<u>-96.8</u>
Total Inbound Truck	-50.6	4.8	7.6	22.6	84.4	68.8
Outbound Truckloads	(in 000 loads per year)					
Corn	-17.0	-0.8	-7.3	9.0	0.0	-16.0
Beans	-4.0	-3.3	-2.3	-1.5	0.0	-11.0
Ethanol	83.9	0.0	0.0	0.0	0.0	83.9
DDGS	<u>31.5</u>	<u>-4.2</u>	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>	<u>27.3</u>
Total Outbound Truck	94.4	-8.2	-9.5	7.5	0.0	84.2
Outbound Rail loads	(in 000 loads per year)					
Corn	-26.8	-0.3	-17.0	3.3	0.0	-40.8
Beans	-6.8	-0.5	-3.8	-2.0	0.0	-13.0
Ethanol	10.6	0.0	0.0	0.0	0.0	10.6
DDGS	<u>23.0</u>	<u>1.4</u>	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>	<u>24.4</u>
Total Rail	0.1	0.7	-20.8	1.3	0.0	-18.7

With respect to inbound traffic, the increase in total VMTs is largely driven by more miles to ethanol and crushers among all types of counties (Table 3.24). This increase is offset by fewer inbound miles among all types of counties to grain elevators. In addition, counties with new plants ship less corn to food processors, choosing to use the corn to manufacture ethanol. This loss is offset by an increase in VMTs from all other types of counties to food processors. The increase of 8.3 million VMTs is again driven by shipments of ethanol and DDGS from the New Plant counties. The only other outbound increase in VMTs occurs for corn shipped from the Other Counties.

Table 3.24. Net Change in Annual VMTs from 2006 to 2010, by Type of County

Use/Mode	New	Incumbent	Border	Other	Out of State	Total
Inbound Truckloads	(in 000 miles per year)					
Livestock	-96.5	-29.7	-140.9	-265.3	0.0	-532.4
Food	-817.5	7.5	129.1	236.5	292.5	-151.8
Ethanol	1,688.7	161.5	2,136.9	-58.0	1,406.6	5,335.7
Elevator	-1,483.8	-11.9	-925.5	421.5	0.0	-1,999.7
Crusher	999.7	227.6	773.1	292.4	473.1	2,766.0
Elevator	<u>-394.8</u>	<u>-94.3</u>	<u>-291.4</u>	<u>-125.4</u>	<u>0.0</u>	<u>-905.9</u>
Total Inbound	-104.1	260.6	1,681.3	501.7	2,172.2	4,511.8
Outbound Truckloads	(in 000 miles per year)					
Corn	-1,160.9	-40.3	-614.3	601.5	0.0	-1,214.1
Beans	-273.3	-183.4	-115.5	-46.0	0.0	-618.3
Ethanol	9,687.9	-84.6	0.0	0.0	0.0	9,603.2
DDGS	<u>1,072.0</u>	<u>-540.7</u>	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>	<u>531.4</u>
Total Outbound	9,325.7	-849.1	-729.8	555.4	0.0	8,302.3

County level VMTs are provided for each county in Appendix A. Figure 3.2 shows the top 10 counties in terms of VTMS for 2006 and 2010. The panel for 2010, also shows the counties with the top 10 percentage changes in VTM.

Figure 3-2. Top Ten Counties for VMTs, 2006 and 2010

Chapter 4 – Summary and Conclusions

4.1. Overview

Ethanol and biodiesel producers constantly deal with transportation issues from allocating feedstock to shipping end products to destination points. The addition of more ethanol plants can lead to cases of congestion on rural roads. The objective of this analysis is to determine how the entry of biofuel plants affects inbound and outbound transportation flows of corn, soybeans, DDGS, and ethanol at the county level in Indiana. To accomplish this, transportation flows of corn, soybeans, ethanol, and DDGS were examined for three time periods, 2006 (baseline), 2008 (short term), and 2010 (long term).

The U.S. biofuels industry has experienced rapid growth since 2005. The ethanol industry alone has increased production capacity from just over 1 billion gallons in 1997 to nearly 12.5 billion in spring 2009. Further expansion is an open question that will depend on political decisions as much as economic ones. Ethanol production in the state of Indiana has the potential to grow to over 1 billion by 2010. Growth in this industry has provided opportunities not only to the biofuels industry but also to agriculture and transportation industries.

Additional demand for grain from biofuels expansion affects decisions farmers must make. Rather than shipping grain short distances to country elevators, they have an additional option of shipping grain direct to biofuels plants which could mean longer haul distances. This means less grain will be handled by elevators and that grain will be shipped through new

transportation routes to biofuels plants. End users of ethanol and DDGS also will be affected. Much more of both products in terms of volume has become available.

As more grain is hauled to biofuels plants, and more ethanol and DDGS is transported to demand points, it is apparent that transportation routes will likely be altered which farmers, ethanol producers, and elevator operators will adapt to. The addition of biofuels plants also presents an opportunity for rural economic development as more grain is transported to biofuels plants change. Policy makers have the opportunity to give careful thought as how to best plan for expansion in this industry such that possible transportation concerns can be addressed and rural economic development can occur.

4.2. Model and Results

Distance minimizing transportation linear programming models were developed to allocate grain, ethanol, and DDGS among production and consumption points. Output from these models was then used in an Excel spreadsheet model to estimate transportation requirements at the county level for corn, soybeans, ethanol, and DDGS. This procedure was performed at the county level for all counties in Indiana. The models described were used for three separate time periods (2006, 2008, and 2010) using forecasted data when necessary. End results from the Excel spreadsheet model include truckloads, VMTs, average LOH, and rail carloads required to transport each commodity. Results were calculated at the county level for every county in Indiana. Because the major change between time periods is the addition of biofuels plants, the difference in results between each year can be largely attributed to ethanol expansion in Indiana.

4.3. Conclusions

Three main conclusions that are identified based on results from this research:

1. Truck traffic in Indiana associated with grain, ethanol, and DDGS movements will increase by 12.8 million VMT or 39.3 percent due to the expansion of a biofuels industry.
2. Elevators will handle 31 percent less grain.
3. The rail industry will have less grain to handle, but more ethanol and DDGS.

Results show that both statewide total truckloads and VMT increase between each time period with most of this change occurring in counties with biofuels plants and adjacent counties. Results also show that truckloads of grain to elevators decline between each period. These results imply that a shift is occurring from grain being shipped to elevators to grain being shipped directly to biofuels plants. Compared to elevators, biofuels plants average LOH for grain is further by approximately 10 miles per load. This means that grain is being transported by truck further distance in 2008 and 2010 than in 2006. Although it is not entirely clear from this research which roads will be most affected, it is likely that some of the increased truck traffic will occur on secondary roads given the rural nature of grain production and biofuels plant location in Indiana.

Furthermore, as more grain is transported directly to biofuels plants and less to elevators, transportation flows of corn will also change. Historically, grain transported to elevators usually maintains similar transportation flows year to year. Shipments of grain to elevators are also very seasonal being concentrated during grain harvest season. Because biofuels plants demand grain consistently throughout the year, grain transportation traffic will

be less seasonal compared to elevator grain flows. This means routes taken by trucks will likely be new transportation routes and will incur truck traffic more consistently throughout the year.

The results show a significant decline in bushels of corn, approximately 140 million bushels, and soybeans, approximately 59 million bushels, transported to elevators. With most elevators running on small profit margins per bushel of grain handled, a large reduction in volume of grain going through an elevator could lead to significant affects in profits generated by elevators. Although this study does not examine the direct effects of biofuels production on elevator profitability, it is possible to infer that some elevators could be shut down due to the reduction in grain handled by elevators. From results from this study, it also remains uncertain what role elevators will have during biofuels expansion. It is quite possible the affects of biofuels expansion experienced by elevators throughout the state will be determined by several factors. One possible factor is an elevator's location in proximity to a biofuels plant. One possibility is that biofuels plants may not have sufficient storage capabilities on site which provides opportunity for nearby elevators to assist with grain movements to the plant. Elevators located further away may not have this opportunity.

A decline in grain being shipped to elevators also means that less grain will be transported from elevators out of state. Truckloads transporting grain from elevators out of Indiana usually travel longer distances compared to trucks delivering corn to processing plants and elevators. A reduction in truckloads from elevators means less long haul truckloads within Indiana. However, a majority of grain leaving Indiana from elevators happens via rail which means the rail industry will be affected as well.

Results show a reduction in rail carloads of grain leaving Indiana but an increase in loads of ethanol and DDGS. This means that the reduction in grain being transported by rail is partially offset by the increase in ethanol and DDGS. Combined loads of corn, soybeans, ethanol, and DDGS decline by 11.6 percent from 2006 to 2010. Additionally, transportation of grain by rail is seasonal where ethanol and DDGS most likely will not be. Although the change in total loads is relatively small, the rail industry will need to adapt to differences in transporting ethanol and DDGS rather than grain. It should be noted that both ethanol and DDGS have issues in being transported by rail. Unit train receiving destination points for ethanol are limited, therefore logistical constraints will likely play a factor in ethanol shipments by rail. DDGS is very bulky in nature and solidifies in rail cars during transport. This increases the time and labor requirement to load and unload cars with DDGS. The results of this study do not take these factors into account and it remains unclear exactly how this will affect rail transportation.

4.4. Caveats

As with any model, the results of this model are a product of the assumptions made. Assumptions made in this research with regard to truck capacities leave room for further development. For example, it is not likely that all trucks delivering grain to food processing and ethanol plants have a 920 bushel capacity, but rather are a mix of different capacity trucks. This is true for all inbound grain and outbound grain, ethanol, and DDGS trucks. Incorporating a more accurate distribution of different truck capacities will provide more accurate calculations for truckloads and miles. Different truck sizes also damage roadways differently. A more

accurate estimation of truckloads and VMT for different truck sizes allows for the possibility of better analyzing road damage and upkeep requirements due to biofuels expansion.

The assumption that ethanol and DDGS truck markets are satisfied before rail shipments are considered is made in this research. Many ethanol plants being constructed in Indiana have rail access. Therefore, it is likely they will use rail access regardless of truck market demand. It is more likely that the decision to ship outbound ethanol and DDGS will be based primarily on costs and price offered by a demand location. If a gasoline blending terminal is offering higher prices for ethanol and the costs to transport via rail are competitive relative to the truck market, then an ethanol plant is likely to engage in rail shipments regardless of the status of truck market demand. Further research could incorporate a decision variable that incorporates ethanol and DDGs prices, transport costs, and location in terms of rail and highway access to determine the distribution of outbound rail and truck shipments of ethanol and DDGS.

This research assumes historic cropping patterns will hold true through 2010. However, this research does not include the affects biofuels expansion has on crop prices which in turn could affect farmers' decisions on crop acreage. It remains unclear at this time exactly how the agriculture industry will adapt to increasing commodity prices (specifically corn and soybeans). As this research is used in the future, it should be known that results could be altered based on shifts in corn and soybean production acres.

This research examines inbound grain flows and outbound grain, ethanol, and DDGS on a county level basis and how the flows are affected when a biofuels plant is introduced. The results of this research indicate changes in transportation flows due to additional biofuels plants being constructed. However, it is difficult to examine the affects an individual plant has

from the results. Future research could develop a similar model to this, but also examine an individual plant. This would help local transportation planners better prepare and allocate funds for infrastructure development and upkeep. It would also benefit ethanol plants in modeling and planning transportation modes.

The results from this research provide information about changes in terms of truckloads and VMT due to biofuels production. One shortcoming is this model does not address which roadways will be affected. Future research could incorporate Geographic Information Systems (GIS) to model which transportation routes are affected and which new transportation routes are taken. This would especially aid transportation planners in the future. However, given aggregate impacts and knowledge of plant locations, planners are able to make informed judgments in using information from this research to estimate local transportation infrastructure impacts.

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Appendix A – VTMS by County

County	VTMS per Year			% Change in VTMS from:		
	2006	2008	2010	06 to 08	08 to 10	06 to 10
Adams	207,558	166,650	178,656	-19.7%	7.2%	-13.9%
Allen	436,492	410,303	434,750	-6.0%	6.0%	-0.4%
Bartholomew	356,335	357,692	568,972	0.4%	59.1%	59.7%
Benton	676,875	708,898	790,347	4.7%	11.5%	16.8%
Blackford	84,069	107,732	114,109	28.1%	5.9%	35.7%
Boone	731,355	1,095,972	569,068	49.9%	-48.1%	-22.2%
Brown	20,920	22,707	6,090	8.5%	-73.2%	-70.9%
Carroll	404,451	505,499	455,826	25.0%	-9.8%	12.7%
Cass	426,702	1,595,490	510,688	273.9%	-68.0%	19.7%
Clark	84,924	100,764	90,788	18.7%	-9.9%	6.9%
Clay	269,599	247,976	244,652	-8.0%	-1.3%	-9.3%
Clinton	587,538	673,222	745,907	14.6%	10.8%	27.0%
Crawford	20,609	22,871	9,592	11.0%	-58.1%	-53.5%
Daviess	436,750	450,966	512,236	3.3%	13.6%	17.3%
De Kalb	180,664	251,266	287,359	39.1%	14.4%	59.1%
Dearborn	21,606	28,620	32,895	32.5%	14.9%	52.2%
Decatur	350,664	311,279	362,649	-11.2%	16.5%	3.4%
Delaware	452,254	278,571	333,692	-38.4%	19.8%	-26.2%
Dubois	316,993	413,317	503,045	30.4%	21.7%	58.7%
Elkhart	201,969	212,817	214,179	5.4%	0.6%	6.0%
Fayette	167,052	143,873	167,307	-13.9%	16.3%	0.2%
Floyd	10,561	12,960	12,917	22.7%	-0.3%	22.3%
Fountain	397,278	408,732	450,675	2.9%	10.3%	13.4%
Franklin	296,264	229,475	281,425	-22.5%	22.6%	-5.0%
Fulton	414,753	317,134	452,369	-23.5%	42.6%	9.1%
Gibson	485,899	523,088	517,848	7.7%	-1.0%	6.6%
Grant	422,535	753,742	441,233	78.4%	-41.5%	4.4%
Greene	260,943	204,853	219,264	-21.5%	7.0%	-16.0%
Hamilton	598,671	306,110	596,234	-48.9%	94.8%	-0.4%
Hancock	717,949	711,091	821,429	-1.0%	15.5%	14.4%
Harrison	133,122	119,105	134,079	-10.5%	12.6%	0.7%
Hendricks	611,416	662,928	734,041	8.4%	10.7%	20.1%
Henry	460,026	416,934	427,454	-9.4%	2.5%	-7.1%
Howard	338,842	323,729	365,808	-4.5%	13.0%	8.0%
Huntington	469,490	337,969	396,466	-28.0%	17.3%	-15.6%

County	VTMS per Year			% Change in VTMS from:		
	2006	2008	2010	06 to 08	08 to 10	06 to 10
Jackson	209,038	184,680	199,556	-11.7%	8.1%	-4.5%
Jasper	803,900	1,077,306	598,816	34.0%	-44.4%	-25.5%
Jay	319,236	1,837,187	1,882,904	475.5%	2.5%	489.8%
Jefferson	112,738	105,502	114,606	-6.4%	8.6%	1.7%
Jennings	240,140	229,555	235,877	-4.4%	2.8%	-1.8%
Johnson	474,046	448,005	530,876	-5.5%	18.5%	12.0%
Knox	699,305	669,914	761,634	-4.2%	13.7%	8.9%
Kosciusko	511,395	388,849	459,368	-24.0%	18.1%	-10.2%
La Grange	156,730	155,088	189,540	-1.0%	22.2%	20.9%
La Porte	587,921	679,443	709,294	15.6%	4.4%	20.6%
Lake	139,264	141,968	145,735	1.9%	2.7%	4.6%
Lawrence	84,645	73,843	86,898	-12.8%	17.7%	2.7%
Madison	654,915	1,884,891	929,321	187.8%	-50.7%	41.9%
Marion	25,855	17,496	38,785	-32.3%	121.7%	50.0%
Marshall	360,647	389,689	418,590	8.1%	7.4%	16.1%
Martin	125,947	93,136	80,478	-26.1%	-13.6%	-36.1%
Miami	309,200	347,075	412,664	12.2%	18.9%	33.5%
Monroe	29,283	70,607	102,089	141.1%	44.6%	248.6%
Montgomery	661,284	617,138	1,093,553	-6.7%	77.2%	65.4%
Morgan	289,531	248,360	305,606	-14.2%	23.0%	5.6%
Newton	409,624	467,450	519,855	14.1%	11.2%	26.9%
Noble	282,569	263,102	312,533	-6.9%	18.8%	10.6%
Ohio	17,368	15,480	14,000	-10.9%	-9.6%	-19.4%
Orange	88,948	93,684	101,018	5.3%	7.8%	13.6%
Owen	263,198	206,579	261,627	-21.5%	26.6%	-0.6%
Parke	278,876	279,297	289,088	0.2%	3.5%	3.7%
Perry	55,105	65,677	68,456	19.2%	4.2%	24.2%
Pike	164,724	166,686	176,964	1.2%	6.2%	7.4%
Porter	235,972	320,434	267,611	35.8%	-16.5%	13.4%
Posey	256,412	246,902	3,047,342	-3.7%	1134.2%	1088.5%
Pulaski	537,384	662,264	771,496	23.2%	16.5%	43.6%
Putnam	273,855	368,441	1,599,193	34.5%	334.0%	484.0%
Randolph	439,623	2,312,981	1,022,793	426.1%	-55.8%	132.7%
Ripley	416,348	332,651	404,606	-20.1%	21.6%	-2.8%
Rush	500,107	468,285	542,432	-6.4%	15.8%	8.5%
Scott	63,578	59,874	62,750	-5.8%	4.8%	-1.3%
Shelby	457,924	395,194	461,354	-13.7%	16.7%	0.7%

County	VTMS per Year			% Change in VTMS from:		
	2006	2008	2010	06 to 08	08 to 10	06 to 10
Spencer	225,467	239,035	269,686	6.0%	12.8%	19.6%
St. Joseph	1,370,567	615,868	689,814	-55.1%	12.0%	-49.7%
Starke	306,908	321,443	375,715	4.7%	16.9%	22.4%
Steuben	153,960	180,918	147,430	17.5%	-18.5%	-4.2%
Sullivan	279,730	290,646	308,754	3.9%	6.2%	10.4%
Switzerland	34,050	44,332	35,777	30.2%	-19.3%	5.1%
Tippecanoe	254,584	252,157	257,580	-1.0%	2.2%	1.2%
Tipton	336,878	391,001	372,557	16.1%	-4.7%	10.6%
Union	167,788	148,548	167,363	-11.5%	12.7%	-0.3%
Vanderburgh	97,710	92,554	144,505	-5.3%	56.1%	47.9%
Vermillion	103,044	118,895	129,758	15.4%	9.1%	25.9%
Vigo	208,281	185,199	201,491	-11.1%	8.8%	-3.3%
Wabash	496,464	1,379,278	632,324	177.8%	-54.2%	27.4%
Warren	568,316	622,299	692,104	9.5%	11.2%	21.8%
Warrick	290,735	265,673	130,587	-8.6%	-50.8%	-55.1%
Washington	113,479	97,993	98,969	-13.6%	1.0%	-12.8%
Wayne	388,321	326,927	361,332	-15.8%	10.5%	-7.0%
Wells	380,955	2,796,732	2,683,890	634.1%	-4.0%	604.5%
White	814,816	827,741	904,353	1.6%	9.3%	11.0%
Whitley	316,878	282,495	333,168	-10.9%	17.9%	5.1%