OPTIMAL DISTILLERS DISTRIBUTION PLANNING IN AN ETHANOL SUPPLY CHAIN

A Thesis by

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The following faculty has examined the final copy of this thesis for form and content, and recommend that it be accepted in partial fulfillment of the requirement for the degree of Master of Science with a major in Industrial Engineering

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CHAPTER 1

INTRODUCTION

1.1 Background

With the increasing growth of the ethanol industry, the number of co-products is also expanding at a rapid rate. These co-products, namely distillers, can be used as cattle feed in feedlots. Currently, the major feed for cattle is corn, but if distillers are marketed successfully and farmers are educated about their usefulness and how to store them, then they could be remarkably successful in the feedstock market. Some issues associated with distillers need to be addressed and will be discussed in the next section. Since producing distillers does not require building new plants or purchasing new machinery, they are simply a welcome co-product (or by-product) of corn fermentation during ethanol production. Ethanol owners could make good revenue by marketing distillers, since they produce 3.2 million metric tons of dried distillers grains plus solubles annually.

Currently, corn to distillers ratio being fed to livestock is 11:1 (ScienceDaily, 2007). In some of the states the feedlots are not able to feed distillers because of unavailability of distillers or uneconomical to feed due to higher distance between ethanol plants and feedlots. Livestock is consuming 60% of the corn produced at national level. A recent study by National corn growers association shows that this percentage has reduced to 55% from 2002 to 2007 and consumption of corn by ethanol sector has increased from 8% to 14% in this time period (ScienceDaily, 2007). Rapidly higher demand of corn by ethanol industry has made corn expensive for feeding livestock. This opens avenues for distillers to offset price of corn by increasing their market in livestock industry. This study aims to focus how distillers can be made less expansive and readily available for livestock feeds. Initially, this study is based on Kansas livestock and ethanol markets but the same approach can be used for other others.

Kansas is rich in the feedlot industry, so distillers can be distributed in wet form directly from ethanol plants to these feedlots, which would save the cost of drying. In a dry milling process, the resulting co-products include dry distillers grains (DDG), dry distillers grains with solubles (DDGS), wet distillers grains (WDG), wet distillers grains with solubles (WDGS), and condensed distillers solubles (CDS). The remaining solid portion may be sold wet (WDG), combined with CDS (WDGS), dried (DDG), or dried and combined with CDS (DDGS). Roughly, WDG and WDGS have 70 percent moisture (30 percent dry matter), and DDG and DDGS contain 10 percent moisture (90 percent dry matter). Studies have shown that wet distillers have greater energy content than dry distillers. Distillers can also be marketed in partially dried form, called modified wet distillers grains plus solubles (MWDGS), which contain 50 percent distillers moisture (DM).

1.2 Overview

Distillers in any form serve as an excellent source of energy, protein, and phosphorous. The energy value is 120 to 127 percent of the value of corn in a finishing diet (Klopfenstein and Erickson, 2005). Distillers grains are also a good source of undegraded intake protein (UIP) or bypass protein. The UIP-level requirement depends on the type of cattle feed and other ration composition. Table 1 compares the energy content of distillers grains and other feeds, showing that distillers are dominating in their energy content.

TABLE 1

NUTRIENT CONTENT OF SELECTED FEED

Feed	**Nutrient Content (percent DM)**							
	CP	**ADF**	**NDF**	**Fat**	**TDN**	**Ca**	**P**	**S**
Distillers Grains	**29.7**	**19.7**	**38.8**	**10**	**79.5**	**0.22**	**0.83**	**0.44**
Soy Hulls	13.9	44.6	60.3	2.7	67.5	0.63	0.17	0.12
Beet Pulp	10	23.1	45.8	1.1	69.1	0.91	0.09	0.3
Corn Silage	8.8	28.1	45	3.2	68.8	0.28	0.26	0.14
Corn Stalks	5.4	46.5	77	1.1	54.1	0.35	0.16	0.1
Oat Straw	4.4	47	70	2.2	50	0.24	0.06	0.23
Wheat Straw	4.8	49.4	73	1.6	47.5	0.31	0.1	0.11

Several studies comparing the feed value of dry and wet distillers show that wet distillers grains contain higher energy content than dry distillers grains.

Table 2 shows how live cattle are receiving co-products from different sources. The majority of feedlots (52 percent) are obtaining co-products directly from the plant, while the remaining feedlots obtain these co-products via feed companies or brokers.

TABLE 2

OPERATIONS PURCHASING CO-PRODUCTS BY SOURCE
(AGRICULTURE STATISTICS BOARD, NASS, USDA, 2007)

Item	**Directly from Ethanol and Other Processing Plants (%)**	**Through Feed Companies/Co-ops (%)**	**Through Brokers and Other (%)**
Dairy Cattle	11	77	12
Cattle on Feed	52	33	15
Beef Cattle	20	66	14
Hogs	21	74	5

The price of co-products is linked with the price of corn for the majority of feedlot and cow-calf operations. However, for hog and dairy operations, distillers pricing is based on both corn and soybean meal prices.

The question then becomes this: If distillers carry these advantages, then why are they not being used to a greater extent for livestock? A number of reasons are cited to answer this question. First, distillers are not efficiently available—one-fourth to two-fifths of livestock producers have claimed that the availability of distillers is not satisfactory (USDA, 2005). Second, there is a lack of infrastructure, storage, and handling procedures. Third, distillers vary in energy content—hog producers are mainly concerned with the nutrition value of co-products for their operation. Fourth, there is a lack of knowledge about distillers and their advantages.

If we compare the use of wet distillers and dry distillers in the livestock industry, then dry distillers seem to capture more of the market than wet distillers. The low shelf life of distillers and higher transportation costs due to higher moisture content are the main reasons for the insignificant popularity of wet distillers. Various studies have tried to address this issue, which will be discussed in later sections.

This chapter provides a brief introduction of the ethanol industry and distillers. The objectives and scope of this research are also presented at great length in this chapter. Section 1.3 provides an overview of the Kansas ethanol industry. After summarizing the research objective in section 1.4, the scope of this thesis is presented in section 1.5.

1.3 Kansas Feedlot and Ethanol Industry

According to the Kansas Livestock Association, the state of Kansas has 97 feedlot points, with 220,400 heads and 13 ethanol plants. According to the Kansas Corn Commission website, total ethanol production is 504.5 million gallons per year (MGY). These ethanol plants use 180 million bushels of corn to produce ethanol. Since one bushel of corn produces 18 pounds of dry distillers (0.9 DM) or 40 pounds of wet distillers (0.3 DM), the total production capacity in terms of dry and wet distillers will be 3,434.2 million pounds per year (MPY) and 7,631 MPY, respectively. If ethanol plants were able to distribute these distillers to feedlots in Kansas, they would be earning a large amount of additional revenue. Furthermore, feedlots are purchasing corn and soybeans to feed their livestock, which is much more expensive than using distillers. Feedlots would be saving money if they fed livestock distillers instead of corn or soybeans. The breakeven analysis section of this research will compare the savings of dry distillers, wet distillers, and corn.

1.3.1 Will Distillers Distribution in Kansas be Successful?

It is important to recommend distillers in Kansas for feedlots. As discussed, the failure of distillers to receive attention in the feedlot industry is mainly due to their non-availability, handling/storage, and variability of energy content. As can be learned from previous discussion, Kansas is rich in producing distillers, and the distance between feedlots and ethanol plants is small, thus eliminating both the availability and handling issues. That leaves only proper distribution planning to save costs and maximize profits. Since distillers come in both dry and wet forms, it is only a matter of time to determine which form of distillers and in what ratio they should be distributed from each ethanol plant to feedlots that will result in maximum profit. Variation in corn and gas prices may result in unstable distillers' prices in Kansas. But the ability to accommodate these variations into the distribution cycle will solve the unstable price problem as well.

1.4 Research Objective

This research will test the hypothesis that DDGS/WDGS produced and consumed in Kansas is more economical than other feed available in Kansas. Also, it will evaluate whether DDGS or WDGS is more profitable. Although other feeds like corn and soybeans are extensively used in the feedstock industry, distillers grains have not gained a position of being the primary feedstock in this industry, especially in Kansas, due to lack of research. No comparative study has been done to support distillers grains against corn by providing a comprehensive cost analysis from production to distribution of distillers to its end customers. Network design and optimization for distillers distribution also have not been discussed extensively in the literature. The objectives of this research, relative to the issues discussed above, are as follows:

- To perform a comparative cost analysis of dry and wet distillers and corn.
- To select a production/transportation model to maximize the profit of the ethanol industry by distributing wet and dry distillers form ethanol plant to feedlots in Kansas.
- To modify the multiple commodity network model, based on which distillers are more economical, when both dry and wet distillers are transported.

An extensive breakeven analysis in the next section will discuss different scenarios to reaching the breakeven point of dry and wet distillers and corn. Based on these breakeven points, models will be formulated and data points will be set. The end result of these models will be to assign ethanol plant(s) to feedlot(s) to maximize their profit in the distribution chain considering the demand and supply constraints. Sensitivity analysis will involve different scenarios that may impact the model, and models will be modified to accommodate all possible issues and cases.

1.5 Scope

The basic assumption is that the technology needed to increase the shelf life of WDGS is available. This paper will present a model to minimize the overall supply chain cost for bagged wet distillers, considering trucks as the transportation mode. The data used in this model are only applicable for Kansas. However, the methodology used in the model is also applicable to other feedlot industries. A cost benefit analysis will be provided for both wet and dry distillers to reach multiple breakeven points for wet distillers, dry distillers, and corn. Data will be obtained using all ethanol plants and all feedlot points in Kansas. Other transportation modes will not be considered. Different packaging options for dry and wet distillers are also discussed in this paper, but experimental methods to increase the shelf life of wet distillers will not be discussed. The chemistry and environmental issues regarding wet and dry distillers also are not included in this paper.

First, the distribution network for 100 percent dry and wet distillers will be developed, and then the assignment of ethanol plants to feedlots in order to maximize profit will be made. In the second stage of this research, a model will be developed to maximize profit when distillers are distributed in optimal ratios of wet and dry distillers. The model will reveal the optimal commodity ratio that each ethanol plant should use to distribute distillers in order to maximize profit.

1.4 Thesis Organization

This thesis is organized as follows: Chapter 2 presents a detailed literature review, which covers the feeds used in feedlots, their cost comparison and energy content, markets and scope of distillers, production of ethanol and distillers, pros and cons associated with distillers distribution and production, feasibility of using distillers, and distribution planning of distillers. With the conclusion that distillers have a great future in Kansas, Chapter 3 presents multiple scenarios and an extensive breakeven analysis of wet and dry distillers and corn. Chapter 4, which formulates the distribution planning into models using data points, is the focal point of the thesis and provides multiple solutions for the distribution of distillers. This chapter also presents a sensitivity analysis, which is a continuation of the modeling section presented in this chapter. Chapter 5 will conclude the thesis, show the results produced, and discuss future research.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses ethanol production, its distribution, the raw materials used in its production, and the by-products of ethanol fermentation in the United States and Kansas. Furthermore, it extends the discussion on ethanol by-products. Distillers are the co-products of ethanol fermentation. Knowledge of the energy content in distillers is very important in understanding its use as an alternate feed for livestock. A detailed comparison of distillers and other feeds are presented in this chapter. It is unfortunate that regardless of the fact that distillers contain equivalent energy content and are less expensive than corn, they do not figure prominently in the feedstock market. This chapter will discuss the reasons why distillers are underrated in the feedstock market.

This chapter is divided into two parts. The first part discusses the ethanol industry outlook in the United States (section 2.2), the primary raw materials used in ethanol fermentation (section 2.3), and the ethanol distribution structure (section 2.4). The second, and most important, part is based on the by-products of the ethanol production process, that is, distillers, which includes the form of distillers (section 2.5), their energy content (section 2.6), and associated issues (section 2.7).

2.2 Ethanol Industry in United States and Kansas

There is an ongoing debate on whether ethanol is a good substitute for gasoline. Some scholars and researchers agree on producing ethanol, while others disagree. Various studies have been conducted in this area. Researchers at the University of California, Berkeley, claim that ethanol made from corn is 10 to 15 percent better than gasoline in terms of greenhouse gas production (Kennman, 2007). Research conducted by David Pimentel (2003) at Cornell University shows that ethanol is not economical to produce and that it takes more energy to produce ethanol than it can create.

It seems that the government is encouraging ethanol production by providing subsidies to boost the ethanol sector. President Bush signed the Renewable Fuel Standard (RFS) of the Energy Policy Act of 2005. This target aimed to increase the production and use of renewable fuels from 4 to 7.5 billion gallons.

In the United States, there are currently more than 130 ethanol plants, with production capacity of 7,229 MGY (RFA, 2007). The majority of production occurs in the Midwest and north-central states of Indiana, Illinois, Iowa, Minnesota, and Nebraska (RFA, 2007). Seventy-seven plants are under construction, thus totaling an additional capacity of 6,216 MGY. According to RFA statistics, the current ethanol demand exceeds 5,380 MGY, whereas the total ethanol production reaches 4,860 MGY. The U.S. is listed as the second largest ethanol producer in the world after Brazil (RFA, 2007).

Kansas has been producing ethanol since 1940. Currently there are ten ethanol plants in Kansas, with a total capacity of 330 MGY. Four plants under construction will provide an additional capacity of 190 MGY. According to the Kansas ethanol fact sheet, "for every bushel of grain used, 1/3 goes to ethanol, 1/3 goes to distillers grains, and 1/3 goes to carbon dioxide" (Kansas Farm Bureau, 2007).

Corn the primary raw material for ethanol production in Kansas, are priced lowest in Kansas, which attracts investors to build ethanol plants in Kansas. The low demand of ethanol in Kansas forces the state to ship it to neighboring states, which results in higher transportation costs (KSA, 2006).

2.3 Raw Materials for Ethanol

Ethanol is produced by fermenting grains and feedstock. Feedstock includes corn, cellulose, wheat barley, and sugarcane. In the U.S., 95 percent of ethanol is produced from corn (Mester, 2006). In 2005–06, the total amount of corn used for ethanol production was 1.603 billion bushels. According to a USDA forecast, the demand will increase to 3.4 billion bushels in 2007–08. Stocks of U.S. corn reached 2.114 billion bushels in 2005 but dropped to 1.967 billion bushels in 2006. The USDA forecast corn stocks at 937 million bushels in 2007. Consumption during 2006–07 was expected to be 11.575 billion bushels, which is more than produced in 2006. Due to this imbalance of demand-supply, the corn prices moved up in September 2006 (Good and Irwin, 2007). Kansas produced 345 million bushels in 2006, and the forecast was for 459 million bushels in 2007 (USDA, 2007).

In Kansas, ethanol is mainly produced from sorghum not from corn because the price of sorghum is more competitive than the price of corn. Kansas is a leading producer of sorghum; in 2005, nearly 50 percent of the sorghum in the U.S. was produced in Kansas. In 2006, total sorghum production was 278 million bushels. Kansas is also rich in the feedlot industry, which supports shipping in the form of WDGS instead of DDGS. Table 3 shows that sorghum is priced lowest among other feeds, which supports the theory that sorghum should be used as primary feed for livestock in Kansas.

2.4 Ethanol Distribution

Ethanol is shipped to destination markets by truck, rail, river barge/ship, or a combination, depending on geographic location, as shown in Figure 1. There are some issues associated with shipping via pipeline. The pipeline is considered to be the most economical method of delivery; however, the infrastructure challenges are too great to justify the shipment of ethanol via pipeline. The percentage of volume shipped by each mode is as follows: 30–35 percent by barge/ship, 30–35 percent by rail, and 30–35 percent by trucks.

TABLE 3

ESTIMATED COSTS AND RETURNS FOR SORGHUM COMPARED WITH OTHER CROPS IN KANSAS[11]

	Yield	Price	Gov't payments	Gross/ acre	Variable costs	Return above variable costs	Fixed costs *	Return above all costs
Southeast Kansas								
Grain sorghum	80	$2.35	$8.20	$196	$117	$79	$75	$4
Soybeans	28	6.00	8.20	176	107	69	75	– 6
Corn	90	2.60	8.20	242	167	75	75	0
Wheat	35	3.90	8.20	145	94	51	75	– 24
* Based on $625 per acre land at 6 percent; $3.13 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $34.								
Northeast Kansas								
Grain sorghum	75	$2.35	$9.34	$186	$124	$62	$86	– $24
Soybeans	35	6.00	9.34	219	118	101	86	15
Corn	100	2.60	9.34	269	177	92	86	6
Wheat	35	3.90	9.34	146	92	54	86	– 32
* Based on $800 per acre land at 6 percent; $4 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $34.								
South Central Kansas								
Grain sorghum	65	$2.35	$14.79	$168	$109	$59	$78	– $19
Soybeans	28	6.00	14.79	183	114	69	78	– 9
Corn	85	2.60	14.79	236	172	64	78	– 14
Wheat	35	3.90	14.79	151	86	65	78	– 13
* Based on $700 per acre land at 6 percent; $3.50 per acre taxes. Depreciation, interest, and insurance on $240 per acre machinery investment equals $32.								
North Central Kansas								
Grain sorghum	70	$2.35	$12.78	$177	$114	$63	$75	– $12
Soybeans	28	6.00	12.78	181	106	75	75	0
Corn	80	2.60	12.78	221	169	52	75	– 23
Wheat	35	3.90	12.78	149	88	61	75	– 14
* Based on $650 per acre land at 6 percent; $3.25 per acre taxes. Depreciation, interest, and insurance on $245 per acre machinery investment equals $33.								
Western Kansas								
Grain sorghum	75	$2.35	$13.23	$189	$96	$93	$77	$16
Corn	75	2.60	13.23	208	121	87	77	10
Wheat	40	3.90	13.23	189	84	105	77	28
* Based on 1.5 acres of land for each acre harvested. $525 per acre land at 6 percent; $3.94 per acre taxes. Depreciation, interest, and insurance on $190 per acre machinery investment equals $26.								
Irrigated Crops								
Grain sorghum	110	$2.35	$13.23	$272	$183	$89	$143	– $54
Soybeans	50	6.00	13.23	313	165	148	143	5
Corn	190	2.60	13.23	507	329	178	143	35
Wheat	70	3.90	13.23	286	133	153	143	10

Source: Langemeier, Kansas State University.

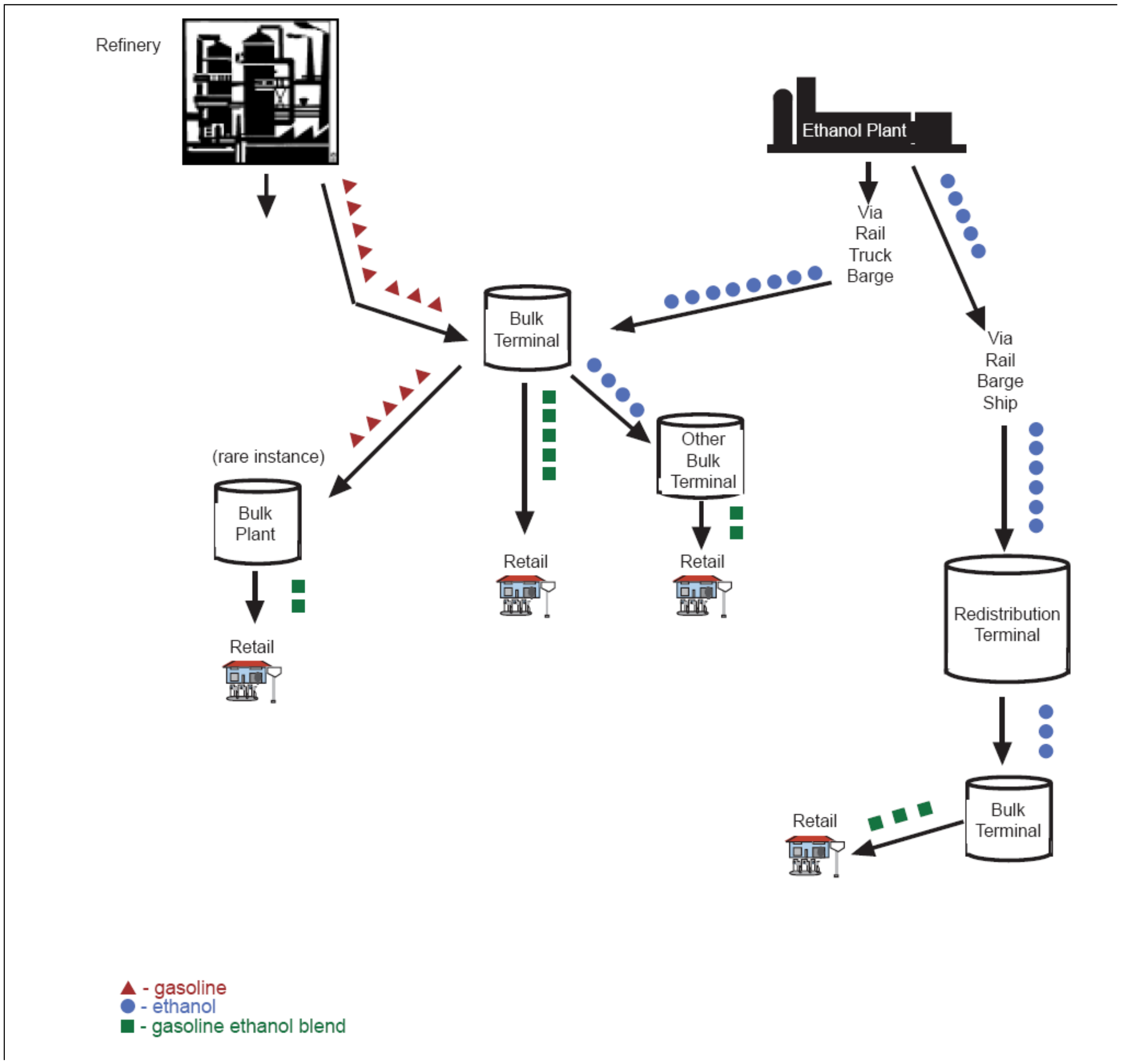


Figure 1. Ethanol distribution infrastructure (source: Downstream Alternatives Inc.).

2.5 Distilllers

One bushel of corn produces 17–18 pounds of dry distillers and 17 pounds of carbon dioxide (IOWA, 2007). Distillers are primary feed for feedlots. According to the Kansas Corn Growers Association (NCGA), about sixty percent of the corn grown in the U.S. is consumed by livestock. Since distillers are a good replacement of corn as feed for livestock, they have a growing market and demand in the U.S. The current production of distillers is more than 25 million metric tons (MMT) per year (IOWA, 2007).

With the increasing production of distillers grains, within the next five to six years, new markets will have to be developed. Marketing distillers grains is extremely important. Those plants that consider the future demand and supply of distillers will have a competitive advantage in the future. Distillers obtained from ethanol production are used in feedlot cattle because they have higher energy content and are easily digestible. Typically there are three forms of distillers: dry distillers grains with solubles (DDGS), wet distillers grains with solubles (WDGS), and modified WDGS, with moisture contents of 10 percent, 50 percent, and 70 percent, respectively. The pros and cons associated with these distillers are discussed below.

2.5.1 Wet Distillers

WDGS are a good source of protein and other energy content, and serve as a good replacement of corn. They can be fed directly to feed cattle, thus reducing the cost of drying. Since they contain more than 80 percent water, they incur high transportation costs (Klopfenstein, 2003). Another downside of wet distillers is the storage issue. According to the IOWA research board, untreated wet distillers have a shelf life of approximately 4–5 days, depending on weather conditions. The shelf life can be increased by different methods, which are discussed below.

Two options are available for preserving wet distillers, either alone or in combination with feeds. The conditions required are as follows: air exclusion, adequate composition, and low pH (3–3.5). Ensiling in silo bags is advantageous because it offers high air exclusion, which results in low spoilage and dry matter losses (Garcia and Kalscheur, 2006). Wet distillers grains already come from processing plants with pH of 3. Since they are a rich source of protein and other energy contents, care should be taken when ensiling WDG with other feed. They should be paired with feed that complements its nutrient profile. Blending options are listed in Table 4, which shows that the pH of the blend is in the range of 3 to 4. Also, the product going into the silage bags should not contain more than 50 percent dry matter.

TABLE 4

RECOMMENDED BLENDING RATIOS WITH WDG

Item	pH at Day 0
Corn silage: WDG (75:25 as fed)	4
Soy hulls: WDG (70:30 as fed)	4.3
Beet pulp: WDG (66:34 as fed)	3.9

Source: Garcia and Kalscheur, 2006.

Preservation causes the bag to swell after a few hours; therefore, the bag should not be filled to maximum capacity. Also, the bag should be left open for a few hours before sealing, thus allowing gases to escape. Other ensiling options are as follows: bunker silos, covered piles, and upright silos (Kalscheur, 2005).

2.5.2 Dry Distillers

Initially, distillers are in wet form, normally containing 70 percent moisture. They can be dried to reduce the moisture content up to 10 percent; these are called dry distillers. In order to dry distillers, a large drying cost is involved, but they incur less transportation cost. A cost benefit analysis is presented in Chapter 3. Dry distillers have a larger market than do wet distillers. Most ethanol companies are producing dry distillers over wet distillers, because dry distillers do not have any preservation issues.

2.6 Nutrient Content

As mentioned previously, distillers contain more protein than corn and other feeds. Table 5 shows a comparison of nutrient contents in different feed. Table 5 shows that multiple alternatives are available to replace corn but that the starch content in corn is higher than many of the other alternatives. This makes it harder for any feed to be a perfect replacement of corn.

Replacing some of the corn grain in the feedstock diet means including feed that is high in starch.

TABLE 5

NUTRIENT CONTENTS IN DIFFERENT FEED

Commodity	**Starch (%)**	**Protein (%)**	**Phosphorus (%)**
Barley	55-60	12	0.39
Beet pulp, dry	2	10	10
Brewers grains	10	29	0.67
Canola meal	2	41	1
Corn	**65-70**	**9**	**0.3**
Corn gluten feed	12	24	1
Corn silage	25-30	8	0.2
Cottonseed	1	24	0.6
Distillers grains	**5**	**30**	**0.83**
Sorghum grain	65-80	12	0.35
Soybean hulls	1	14	0.17
Wheat	65-70	14	0.43
Wheat middlings	15-20	19	1.02

Source: Schroeder, NDSU, 2005

2.7 Issues with Distillers

In addition to the advantages of using distillers for feed and replacing corn with them, there are some associated issues: (1) variation in nutrient content from plant to plant and within plants (Table 6); (2) handling, storage, and transportation of distillers; and (3) milk quality and animal performance.

2.7.1 Variation in Nutrient Content

Table 6 highlights the considerable variation in energy contents in distillers. This variation may be the result of a number of reasons. For example, the amount of solubles added back to the distillers grains and the drying process is responsible for the variation in nutrient content (Lemenager et al., 2007). Sodium that is used as a drying agent and sulfuric acid that is used to adjust pH during the drying process may affect the nutritional contents of distillers. Studies also show that heat damage during drying process may bind the nutrients, which further reduces nutritional content.

TABLE 6

VARIATION IN NUTRIENT CONTENTS IN DISTILLERS

Nutrient/Component (%)	**Corn**	**Distillers Dry Grains + Solubles**		
	Reference	**Range**	**Digestibility (%)**	**Availability (%)**
Crude protein	8.5-9.9	28-32	60-90	16.8-28.8
Lysine	0.20-0.28	0.85-0.90	50-90	0.42-0.81
Methionine	0.16-0.20	0.40-0.55	50-90	0.20-0.50
Crude fiber	1.5-3.3	5.0-14	-	5.0-14
Fat	3.5-4.7	3.0-12	85-90	3.0-12
Phosphorus	0.28-0.34	0.7-1.3	80-90	0.56-1.17
Sodium	0.00-0.02	0.05-0.17	100	0.05-0.17
Sulfur	0.12	0.4-0.8	100	0.4-0.8
	-	<400->600	-	-

Source: Lemenager et al., 2007

2.7.2 Milk Quality and Animal Performance

Milk quality and digestibility is linked with the oil content of distillers. Higher oil content adversely affects milk quality and fiber digestion. Studies show that when distillers grains are added at concentrations greater than 30 percent of the milk protein, the protein percentage decreases by 0.13 percentage units (Kalscheur, 2006). High levels of distillers grains inclusion results in lower protein digestibility, lower lysine concentrations, and an unbalanced amino acid profile, which contributes to a lower milk protein percentage.

2.7.3 Marketing of Distillers

Marketing of distillers offsets much of the ethanol production cost. Plant managers view distillers as by-products of ethanol production, in turn paying less attention to them. Instead, they devote most of their effort, resources, and time to managing ethanol production and do not invest any time to addressing issues with distillers. The variation in distillers composition results in variable nutrient and energy content from company to company and from batch to batch. Due to this uncontrolled variation, marketing of distillers is a challenge. Lack of testing standards for distillers aggravates the situation. Thus, the quality of distillers is seriously affected, which makes marketing of distillers even more challenging. These issues are discussed below.

2.7.4 Product Identification

Customers do not understand the implications of the energy content of distillers. Since energy content varies among distillers, a good understanding of their nutrient composition is necessary. If they are unaware of impact the different composition of distillers on the performance of cattle they will not be able to feed proper feed to feed cattle. This may affect health and milk quality of feed cattle. Customer training and proper guidance are extremely necessary if distillers feed replaces corn successfully.

2.7.5 Misrepresentation

Due to marketing competition, sellers often do not properly inform customers of the nutrient specifications of distillers. This misrepresentation results in improper feed going to a feedlot. Blending distillers with other ingredients increases the risk of feeding a higher nutrient content than required in the diet (Shurson, 2006).

2.7.6 Flowability Issue

To effectively utilize distillers, they are transported via rail and truck to distant places. During transportation, they must be stored in various structures, such as bins and silos. Due to caking and bridging between particles, which occur during storage and transport, the discharge flow is adversely affected. This problem negatively affects the marketing, distribution, and utilization of distillers. Workers are forced to hammer the car sides and hopper bottom to increase flow, which results in extensive damage to trucks and railcars (Rosentrater, 2006).

2.7.7 Standardized Testing Procedures

There exists a serious shortage in standardized testing procedures to determine the nutrient content of DDGS. The number of claims regarding DDGS nutrient content is increasing. Even moisture content in DDGS lacks repeatability among laboratories. This occurs because each laboratory uses a different method for determining the moisture content of distillers. There is no standard procedure for testing. Some laboratories dry distillers in an oven for one hour at 130^{o}C, while others dry for four hours at 104^{o}C (Shurson, 2005).

2.7.8 Quality Management System

Statistics show that 15 to 30 percent of the revenue stream of an ethanol plant is from the distillers. It is necessary to develop a quality management system and procedures to ensure consistent and standard quality distillers. It has been shown that producers of ethanol take less interest in distillers and do not invest time to know the distillers customers needs and requirements. Currently, no quality standards exist for distillers in the ethanol industry of the U.S.

Domestic and international customers of distillers demand product guarantees in terms of moisture, fat, fiber, and energy content. International Feed Ingredient Standard (IFIS) quality assurance was introduced in Europe in 2005, which requires feed ingredient exporters to be GMP

(Good Manufacturing Practices)-certified if distillers export to the European Union. Based on the demand of the international and domestic feed industries, a national DDGS certification program must be developed (Shurson, 2005).

2.8 Distillers a Better Substitute?

Over the past few years, the biofuel slogan has increased the construction of new ethanol plants all over the United States. Due to an increasing number of ethanol plants, the consumption of corn has drastically increased. This has put pressure on corn prices. Since the feedlot industry is the major consumer of corn, it is purchasing corn at higher prices, which in turn increases the cost of meat and livestock. Anderson (2007) mentioned “Feeder cattle and calf prices are adjusted to the price of corn. Higher feed cost resulted in reduced production in terms of cattle weights and profitability. A livestock industry became less competitive in the world market.” This cause–and-effect relationship will result in a higher number of distillers in the market. There are currently 110 ethanol plants with the capacity to produce 15 MMT of DDGS and 73 under-construction plants with the capacity to produce 17 MMT of DDGS (Sauer, 2007). The total demand of distillers in the United States is 39.7 MMT, which obviously exceeds the supply of distillers, but with the pace of new ethanol plant production, the supply of distillers will exceed demand in the future. Anderson (2007) maintained “At that rate of growth, supplies will exceed demand, leading to lower distiller grains prices relative to corn.” This opens up a huge opportunity for distillers. More and rapid research is needed to eliminate the concerns of farmers using distillers as livestock feed. The ethanol industry may also play a better role to establish a proper distillers distribution network to make it more accessible.

2.9 Current Consumption of Distillers

The primary customers of distillers are the livestock industry, but due to lack of research and poor accessibility of distillers to feedlots, distillers have not gained a prominent position in the feedlot market. An extensive research on the consumption and use of distillers was conducted by Hawkeye Renewable Inc. Figure 2 shows that in early 2000, the production capacity of DDGS was not significant. However, it gained tremendous improvement after 2004. In early 2000, almost 25 percent of the total distillers produced was exported, due to less consumption in the local and national market. But in 2007–08, exports remained at only 10 percent, which indicates that distillers are gaining popularity in the local market—a very positive signal.

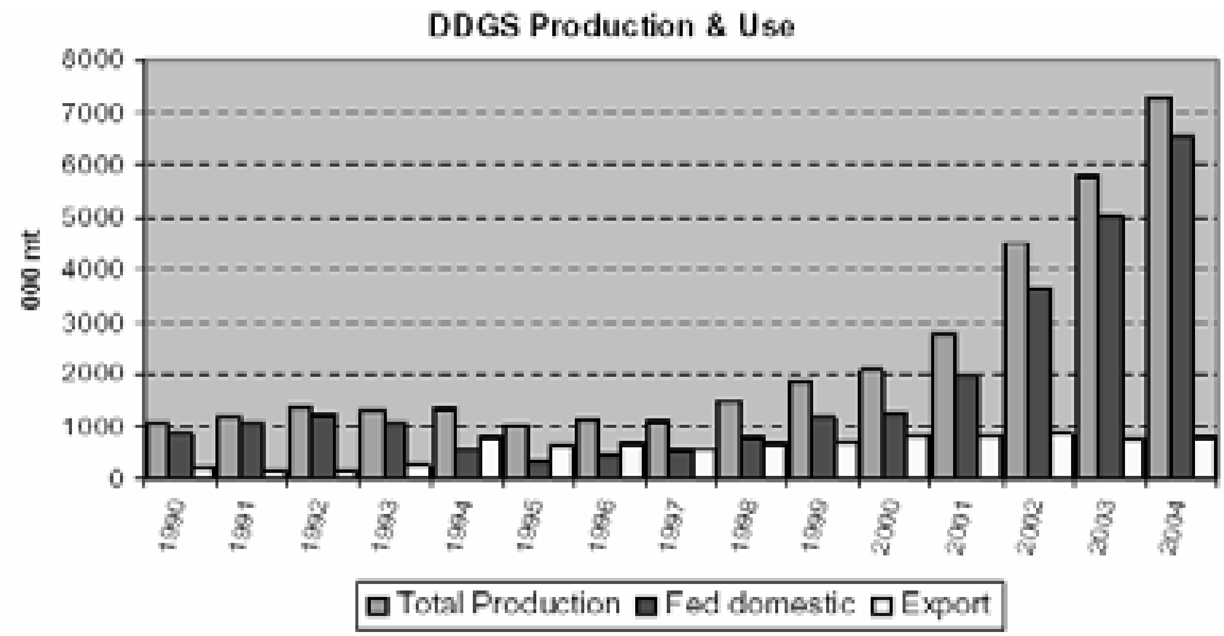


Figure 2. Distillers production and export (National Corn Growers Association, 2007).

Table 7 suggests that the major demand for distillers is in the cattle industry. If the cattle industry begins using distillers, then the ethanol industry will take in a large amount of revenue. More focus is needed by the ethanol industry to attract the cattle industry in using distillers.

TABLE 7

DISTILLERS CONSUMPTION IN LIVESTOCK INDUSTRY (HAWKEYE, 2007)

Cattle Market		Swine Market		Poultry Market	
Category	**Demand**	**Category**	**Demand**	**Category**	**Demand**
Dairy	6375	Slaughter	2590	Broilers	4024
Feeder Cattle	15475	Breeding	415	Layers	1372
Beef	9245			Turkey	232
Total	31095	**Total**	3005	**Total**	5628

The demand for each feedstock market is based on the following assumptions.

- Dairy: 10% inclusion rate, 1533 lbs/animal/yr, 9.04 million head
- Feeder Cattle: 40% inclusion rate, 1320 lbs/animal, 25.79 million head
- Beef: 600 lbs/animal/yr., 33.3 million head
- Slaughter: 10% inclusion rate, 55 lbs/animal, `03.5 million head
- Breeding: 10 % inclusion rate, 150 lbs/animal/yr, 6.09 million head
- Broilers: 10% inclusion, 1 lb/bird, 8.853 billion birds
- Layers: 10% inclusion, 8.7 lbs/bird/yr., 350 million birds
- Turkeys: 10% inclusion, 2 lbs/bird, 256.2 million birds

In summary, the total supply potential of distillers is 32 MMT, and the demand potential is still higher than 39 MMT. In the future, the supply of distillers is expected to increase demand. Therefore, it is necessary to look for other DDGS market around the world, including Asia, Mexico, and Canada.

Figure 3 suggests that besides ethanol, DDGS has great revenue opportunities and potential. The ethanol industry is making less revenue in DDGS compared to ethanol in recent years due to the rapid increase of ethanol consumption over distillers. The figure reveals opportunities in the distillers area.

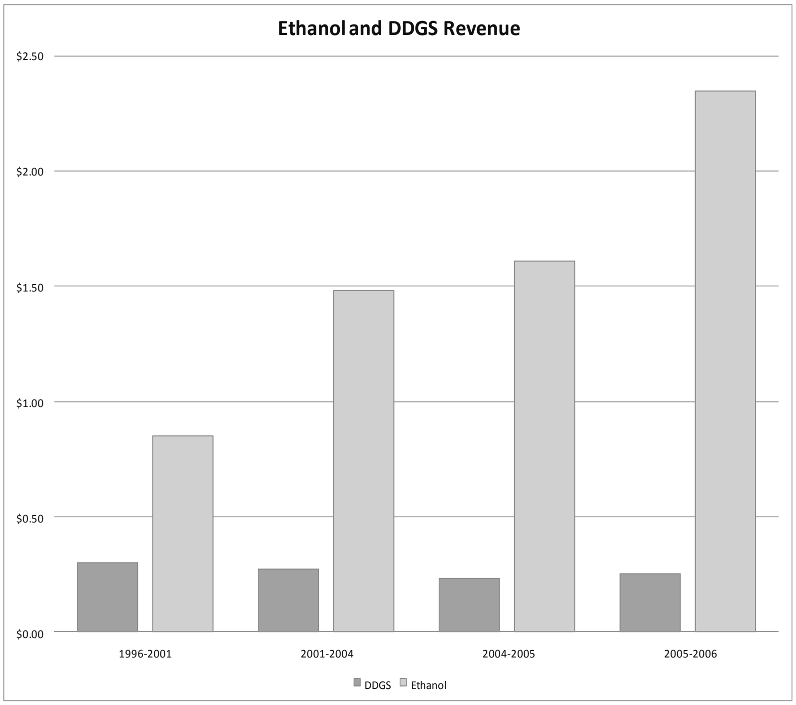


Figure 3. Ethanol/DDGS revenue for actual consumption (Hawkeye, 2007).

2.10 Feed Used in Livestock Industry and Its Economies

Corn and soybeans are widely used feeds for livestock. In 2005–06, approximately 156 million metric tons of corn and 30 million metric tons of soybeans were consumed domestically by livestock. This was 93.5% and 88.7%, respectively, of the total amount of grain feed to livestock (Berger and Good, 2007). A detailed analysis can be seen in Table 8.

The magnitude of other feeds, for example DDGS and corn gluten, are not available or collected by the public sector. Since these feeds were not extensively used in the past, compared to corn and soybeans, less importance was given to collecting data on them. Since the major ethanol industry uses the dry milling process and since DDGS is the by-product of the dry milling process, production and availability of DDGS have increased in recent years. Table 8 suggests that if all the corn were used in the dry milling process, then 10.65 million tons of DDGS in 2004–05 ,12.91 million tons in 2005–06, and 17.31 million tons in 2006–7 would have been produced (Berger and Good, 2007). This 10.65 million tons of DDGS is equivalent to 6.25 percent of domestic grain fed, 4.25 percent of domestic grain fed plus exports, and so on.

TABLE 8

FEED USED BY LIVESTOCK (BERGER AND GOOD, 2007)

Commodity	Year 2004-05	2005-06	2006-07
Corn		million metric tons	
Domestic Feed	156.42	155.99	151.77
Export	46.18	54.54	57.15
Total	202.60	210.53	208.92
Sorghum			
Domestic Feed	4.85	3.56	2.79
Export	4.67	4.95	3.81
Total	9.52	8.51	6.60
Barley			
Domestic Feed	2.24	1.13	1.09
Export	.50	.61	.54
Total	2.74	1.74	1.63
Oats			
Domestic Feed	1.97	1.97	1.81
Export	.04	.03	.03
Total	2.01	2.00	1.84
Wheat			
Domestic Feed	4.95	4.16	3.95
Export	29.01	27.46	23.81
Total	33.96	31.62	27.76
Grains			
Domestic Feed	170.43	166.81	161.41
Export	80.40	87.59	85.34
Total	250.83	254.40	246.75
Soybean Meal			
Domestic Feed	30.45	30.07	30.75
Export	6.66	7.32	7.89
Total	37.11	37.39	38.64
Other Oilseed Meals			
Domestic Feed	3.45	3.83	3.86
Export	.30	.33	.30
Total	3.75	4.16	4.16
Total Oilseed Meals			
Domestic Feed	33.90	33.90	34.61
Export	6.96	7.65	8.19
Total	40.86	41.55	42.80
DDGS (equivalent)			
Total Produced (est.)	10.65	12.91	17.31
Percent of:		Percent	
Domestic Grain Fed	6.25	7.74	10.73
Domestic + Exports	4.25	5.07	7.02
Domestic Meal Fed	31.41	38.08	50.01
Domestic + Exports	26.06	31.07	40.44
Domestic Grain + Meal	5.21	6.43	8.83
Domestic + Exports	3.65	4.36	5.98

2.11 Ethanol Plants and Livestock Locations by State

Ethanol plants are increasing at a rapid rate, which shows that consumption of biofuels is increasing with time. Total production capacity in 2006 was 6,243 MGY, and in 2007 it was 9,123 MGY. Table 9 lists the top ten states in ethanol production capacity. From 2006 to 2007, the increase was 46 percent. The major increase was in Kansas and Nebraska. Both have 110 percent increases from 2006 to 2007. Only a small change can be noticed in South Dakota and Indiana. The increase there is only 20 percent in both states from 2006 to 2007.

TABLE 9

ETHANOL PRODUCTION CAPACITY BY STATE[30]

	Capacity in MGY	
State	**2006**	**2007**
Iowa	1717	2557
Nebraska	677	1437
Illinois	943	1107
Minnesota	768	947
South Dakota	711	867
Indiana	470	571
Wisconsin	311	493
Kansas	214	454
Ohio	232	390
Texas	200	300

In terms of total production capacity, Iowa is the largest ethanol-producing state, and Kansas is number seven. Table 10 lists the top ten states by number of cattle on feed.

TABLE 10

NUMBER OF CATTLE ON FEED 1,000 + CAPACITY

	Capacity in 1000	
State	**2006**	**2007**
Texas	3030	2800
Kansas	2580	2430
Nebraska	2490	2540
Colorado	1110	1040
California	550	540
Iowa	520	530
Oklahoma	375	350
Arizona	346	334
Idaho	265	255
South Dakota	210	230

Source: Berger and Good, 2007

Table 10 shows that the livestock industry is not growing, declining 3.7 percent from 2006 to 2007. This analysis shows that compared to the ethanol industry or distillers production, livestock production is not expanding or growing. In the future, the supply of distillers will be higher than the demand, so considerable revenue can be earned by exporting distillers. When the supply of distillers increases in the future, distillers prices will be reduced due to the economy of scale. Corn prices may go up in the future, but distillers prices should go down. This analysis also suggests that in terms of demand for distillers, more ethanol plants can be built in Kansas, as well as Texas.

2.8 Summary

This chapter shows that the production of distillers is increasing daily as a result of the expanding ethanol industry. New plants have started operations and some are under construction. Due to this growth in the ethanol industry, corn is becoming expensive because ethanol dry milling process uses corn as a basic raw material. This increase in corn prices opens the door for alternate feeds for livestock. It is necessary to establish a comprehensive distribution, which makes accessibility of distillers easier and more convenient. This research endeavors to ensure that distillers are available at feedlots at cheaper rates than any other feeds, which will encourage feedlots to purchase distillers as the primary feed for their facility.

CHAPTER 3

BREAKEVEN ANALYSIS FOR DISTRIBUTION OF WET DISTILLERS, DRY DISTILLERS, AND CORN

3.1 Introduction

The starting point for formulating a distribution model of distillers is a detailed breakeven analysis, which provides an understanding of cost and profit points by using multiple commodities under different scenarios. If distillers are available at a much cheaper rate than corn, then the livestock industry will find it attractive to purchase them. This is possible only if there is a detailed breakeven analysis of distillers compared to corn. The equivalent distillers' price can be obtained using energy content comparison, which is discussed later in the chapter. The understanding of equivalent price will ensure that distillers prices are not sold higher than corn prices. In reality, distillers manufacturers have less understanding of how they can compare distillers prices with corn prices.

Also, once the breakeven points are known, a better distribution network can be planned in order for manufacturers of distillers to make better revenue. In the distillers market, two kinds of distillers are traded extensively. One is dry distillers, which contain 90 percent dry matter, and the other is wet distiller, which contain, 30 percent dry matter. It is important to determine which distillers will yield a higher profit to the distillers manufacturers. Thus a breakeven analysis between these distillers considering multiple conditions is necessary.

In general, profit is affected by price and the cost of production and distribution. Cost is mainly affected by the cost of unit transportation and truck capacity. Breakeven points are calculated using multiple transportation costs and truck capacity when distillers are priced at different rates. These breakeven points will show how profit is affected by varying these variables and which distillers are more profitable at what price and cost.

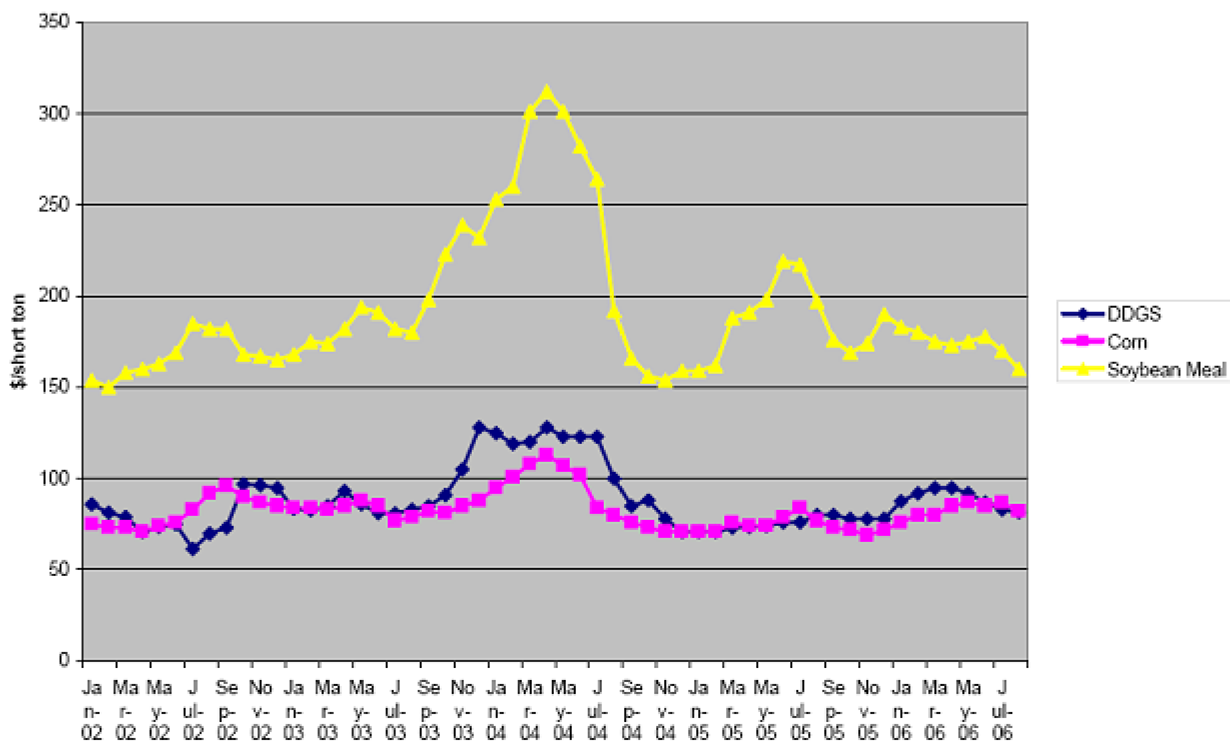
The organization of this chapter is as follows. Section 3.2 discusses the breakeven points of dry and wet distillers considering different scenarios. Section 3.3 presents a sensitivity analysis of the breakeven analysis. And section 3.4 explains the breakeven analysis and solutions between corn and distillers.

3.2 Breakeven Analysis for Dry and Wet Distillers

According to the past history of corn and Distillers prices it seemed that DDGS prices are fluctuated by corn prices. In 2006, DDGS are traded on average $ 80 per ton. In the 2007, the DDGS prices went up and are traded at more than $ 120 per ton.

Table 11a

DDGS Prices Per Year



Source: USDA, 2007

According to USDA data, as shown in Table 11, dry distillers are priced from $155/0.9 DM ton to $195/0.9 DM ton at the plant in Kansas in 2007 (http://www.ams.usda.gov/mnreports/sj_gr225.txt).

TABLE 11b

DDGS PRICES IN DIFFERENT REGION ()

Region	**DDGS (0.9 DM ton)**
Eastern Corn-Belt	115-152
Chicago, IL Area	135-140
Lawrenceburg, IN	150
Nebraska	160-177
Minnesota	134-140
Kansas	**155-195**
Iowa	135-145
Northern Missouri	140-170

Source: USDA, 2007

Transportation costs vary from company to company and are time dependent. According to a conversation with some distributors of corn and distillers, the 2007 transportation cost on average is $3.5/truck/mile (two-way). This two-way cost means the truck goes from its origin to a destination and back again. If a truck carries 25 tons, then the transportation cost is $ 0.14/ton.

This section establishes breakeven points between dry and wet distillers using a multiple price range of distillers, and shows how price variation can affect breakeven points.

3.2.1 DDGS Priced at $155/Ton

When DDGS is priced at $155/ton (taking the lowest price in Kansas), the formula to calculate the price of dry distillers available at a feedlot point can be generalized (for Kansas) as follows:

$/ton (155 + 0.14*x*); where "*x*" is the transportation distance

Kansas is ranked at 8th highest natural gas producing state (Merriam, 2007). Ethanol industries in Kansas use natural gas for drying wet distillers (Coltrain, 2001). According to data obtained from ICM Inc. in 2007 the average cost of drying per ton is \$9.56 (ICM, 2007). So the equivalent price of wet distillers (30% DM) can be calculated as \$155–9.56/3 = \$48.48 per ton. Therefore, the formula to calculate total cost (production and transportation) can be generalized as follows:

\$/ton (3*48.48 + 0.42*x*); where "*x*" is the transportation distance

Table 12 lists the DDGS and WDGS total cost using the above equations at various transportation distances.

TABLE 12

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE
(DDGS AT \$155/TON AND TRANSPORTATION COST AT \$3.50/TRUCK/MILE)

Miles	DDGS (\$/ton)	WDGS (\$/0.9 DM ton)
25	158.5	155.94
50	162	166.44
75	165.5	176.94
100	169	187.44
125	172.5	197.94
150	176	208.44
175	179.5	218.94
200	183	229.44
225	186.5	239.94
250	190	250.44
275	193.5	260.94
300	197	271.44
600	239	397.44

It can be observed from Table 12 that the breakeven point of dry and wet distillers will lie at a transportation distance of 34 miles between ethanol plant and feedlot. The breakeven point suggests that if the transportation distance is less than 34.14 miles, it is less expansive to ship wet distillers.

⇨ $155 + 0.14x = 3*48.48 + 0.42x$
⇨ $x = 34.14$ miles

The breakeven cost would be as follows:

= $155 + 0.14(34.14)
= $159.78/0.9 DM ton

The same tabulated data has been plotted into a graph, as shown in Figure 4. The breakeven price is approximately $159.78/0.9 DM ton.

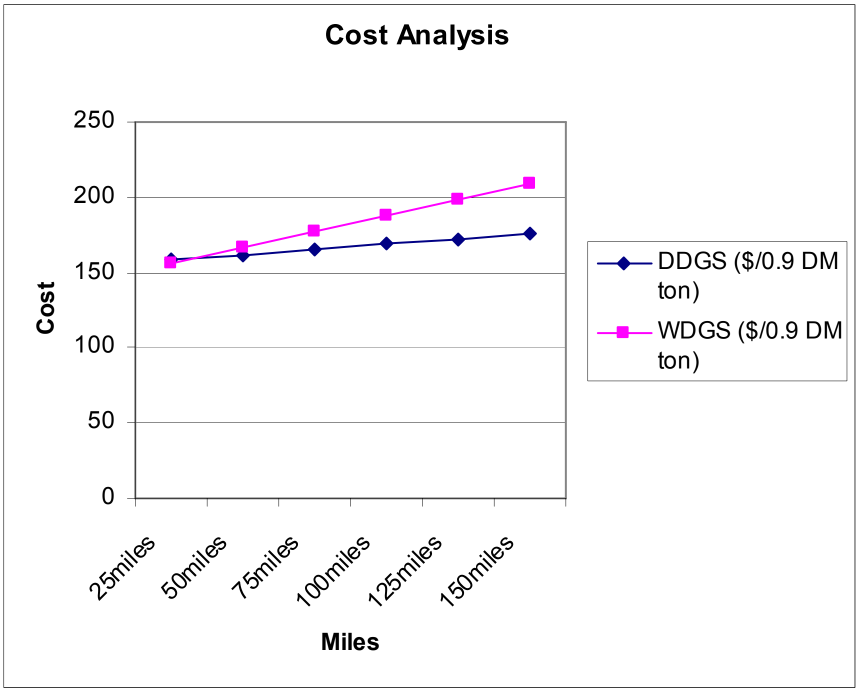


Figure 4. Breakeven point of dry and wet distillers when DDGS is $155/ton (breakeven = 34.14 miles).

3.2.2 DDGS Priced at $195/0.9 DM Ton

When DDGS is priced at $195/0.9 DM ton (taking the highest price in Kansas), the formula to calculate total cost of dry distillers can be generalized (for Kansas) as follows:

$/ton (195 + 0.14*x*); where "*x*" is the transportation distance

The cost of drying per ton 0.9 DM is $9.56. So the equivalent price of wet distillers (30% DM) can be calculated as $195–9.56/3 = $61.81 per ton. So the formula to calculate total cost (production and transportation) can be modified as follows:

$/ton (3*61.81 + 0.42*x*); where "*x*" is the transportation distance

Table 13 compares the WDGS and DDGS total cost using the above equations.

TABLE 13

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE (DDGS AT $195/TON AND TRANSPORTATION COST AT $3.5/TRUCK/MILE)

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	198.5	195.93
50	202	206.43
75	205.5	216.93
100	209	227.43
125	212.5	237.93
150	216	248.43
175	219.5	258.93
200	223	269.43
225	226.5	279.93
250	230	290.43
275	233.5	300.93
300	237	311.43
600	279	437.43

In this case, the breakeven point of dry and wet distillers will again lie at a transportation distance of 34 miles between ethanol plant and feedlot, as shown in Figure 5. The breakeven point suggests that if the transportation distance is less than 34.14 miles, then it is less expansive to ship wet distillers.

⇨ $195 + 0.14x = 3*61.81 + 0.42x$

⇨ $x = 34.14$ miles

The breakeven cost would be as follows:

= $195 + 0.14(34.14)

= $199.78/0.9 DM ton

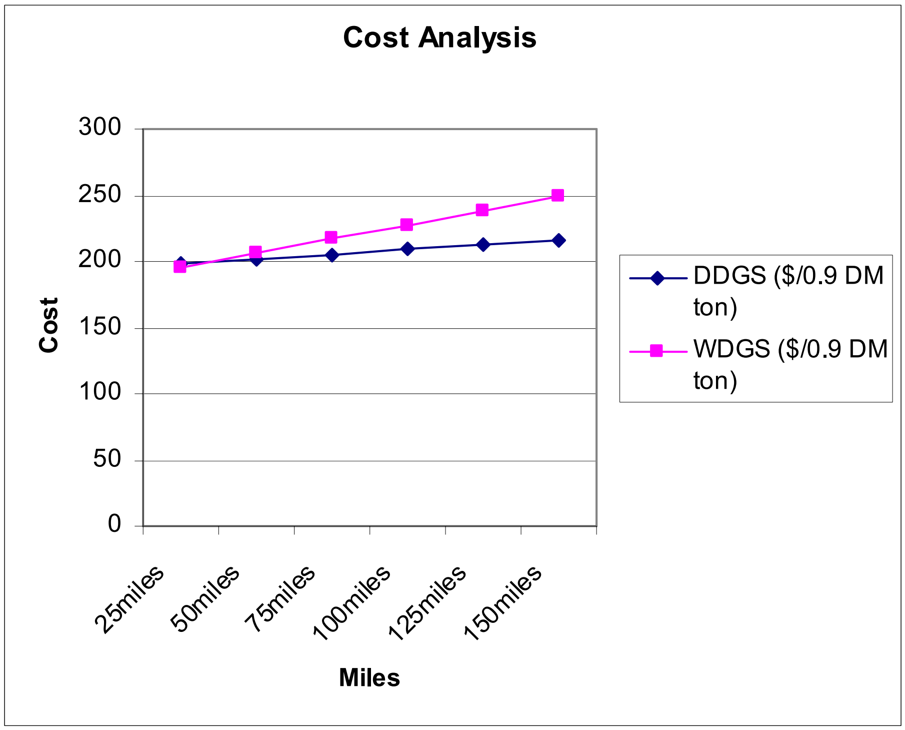


Figure 5. Breakeven point of dry and wet distillers when DDGS is at $195/ton (breakeven = 34.14 miles).

3.2.3 DDGS Priced at $175/0.9 DM Ton

When DDGS is priced at $175/0.9 DM ton (taking the average value), the formula to calculate total cost of dry distillers can be modified as follows:

$/ton (175 + 0.14*x*); where "*x*" is the transportation distance

The cost of drying to contain only 10 percent moisture in distillers, which is called DDGS, is $9.56 (Loest, ICM Inc.). So the equivalent price of wet distillers (30% DM) can be calculated as $175–9.56/3 = $55.14 per ton. Therefore, the formula to calculate total cost (production and transportation) can be modified as follows:

$/ton (3*55.14+0.42*x*); where "*x*" is the transportation distance

The comparison in Table 14 is drawn using the above total cost equations.

TABLE 14

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE
(DDGS AT $175/TON AND TRANSPORTATION COST AT $3.50/TRUCK/MILE)

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	178.5	175.92
50	182	186.42
75	185.5	196.92
100	189	207.42
125	192.5	217.92
150	196	228.42
175	199.5	238.92
200	203	249.42
225	206.5	259.92
250	210	270.42
275	213.5	280.92
300	217	291.42

In this case, the breakeven point of dry and wet distillers does not change and will again lie at transportation distance of 34 miles between ethanol plant and feedlot, as shown in Figure 6, but the breakeven cost will change. The breakeven point suggests that if the transportation distance is less than 34.14 miles, then it is less expansive to ship wet distillers.

⇨ $175 + 0.14x = 3*55.14 + 0.42x$
⇨ $x = 34.14$ miles

The breakeven cost would be as follows:

= $175 + 0.14(34.14)
= $179.77/0.9 DM ton

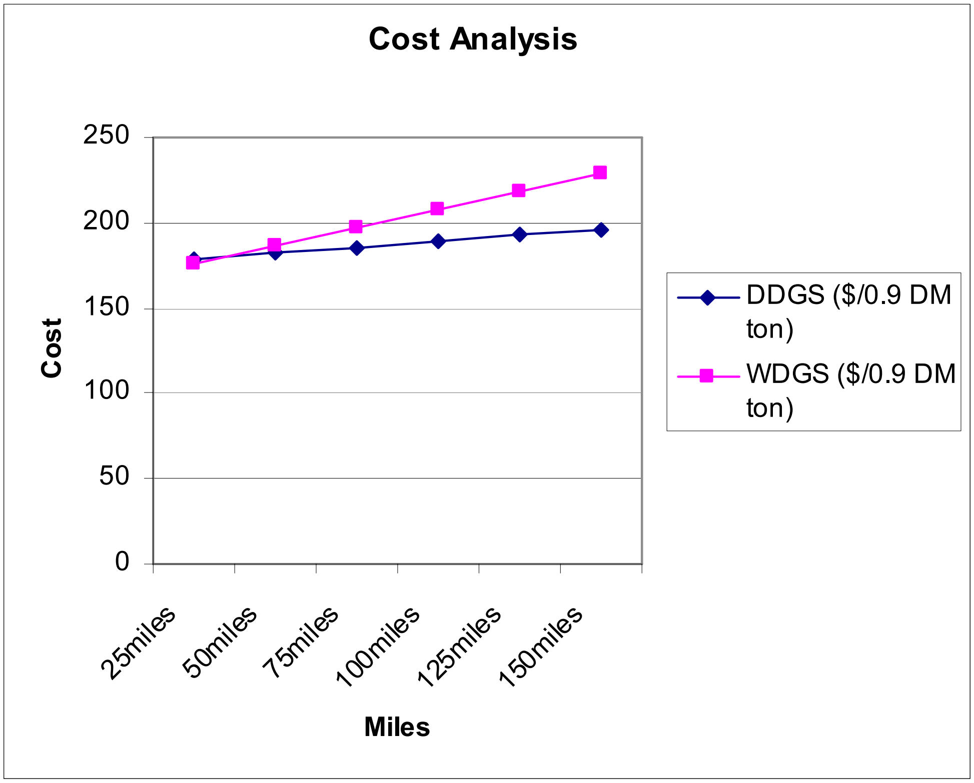


Figure 6. Breakeven point of dry and wet distillers when DDGS is at $175/ton (breakeven = 34.14 miles).

The above results are summarized in Table 15.

TABLE 15

BREAKEVEN POINT AT MULTIPLE DDGS PRICE

DDGS Price ($/ton)	Breakeven Point (miles)	Breakeven Cost ($/0.9 DM ton)
155	34.14	159.78
175	34.14	179.77
195	34.14	199.78

These results suggest that when transportation cost and truck capacity are constant, the breakeven distance between dry and wet distillers will remain unchanged at any DDGS price level.

3.3 Sensitivity Analysis of Breakeven Point

Until now, the breakeven point has been calculated keeping truck capacity and transportation cost constant. In the real world, these two variables change with time and requirements. Transportation cost fluctuates with gas prices, and various truck sizes are available in the market. This sensitivity analysis shows the breakeven effects and trends by changing these two variables.

3.3.1 Change in Transportation Cost

The first place to observe the breakeven is by varying the transportation cost. Previous calculations used three transportation costs: $3.00 per truck per mile, $3.50 per truck per mile, and $4.00 per truck per mile. The breakeven points have been discussed for $3.50 per truck per mile. This section will consider $3.00 per truck per mile as a decrease in transportation cost, and $4.00 per truck per mile as an increase in transportation cost.

3.3.1.1 Scenario # 1—Increase in Transportation Cost

Suppose the transportation cost is increased to $4.00/truck/mile (two ways) and the capacity of each truck is assumed to be the same. The transportation cost will be changed to $0.16/ton. Three cases are presented for each scenario according to DDGS prices.

Case 1A: When DDGS is Priced at $155/Ton

In this case, DDGS is priced at $155/ton (lowest price in Kansas). Table 16 reflects this particular case.

TABLE 16

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE
WHEN TRANSPORTATION COST INCREASES
(DDGS AT $155/TON AND TRANSPORTATION COST AT $4.0/TRUCK /MILE)

Miles	**DDGS ($/ton)**	**WDGS ($/0.9 DM ton)**
25	159	157.44
50	163	169.44
75	167	181.44
100	171	193.44
125	175	205.44
150	179	217.44
175	183	229.44
200	187	241.44
225	191	253.44
250	195	265.44
275	199	277.44
300	203	289.44

⇨ $155 + 0.16x = 3*48.48 + 0.48x$

⇨ $x = 29.87$ miles

The breakeven cost would be as follows:

= 155 + 0.16(29.87)

= $159.77/0.9 DM ton

As shown in Figure 7, the breakeven distance is reduced when the transportation cost increases, which implies that dry distillers become less expansive when the transportation cost increases.

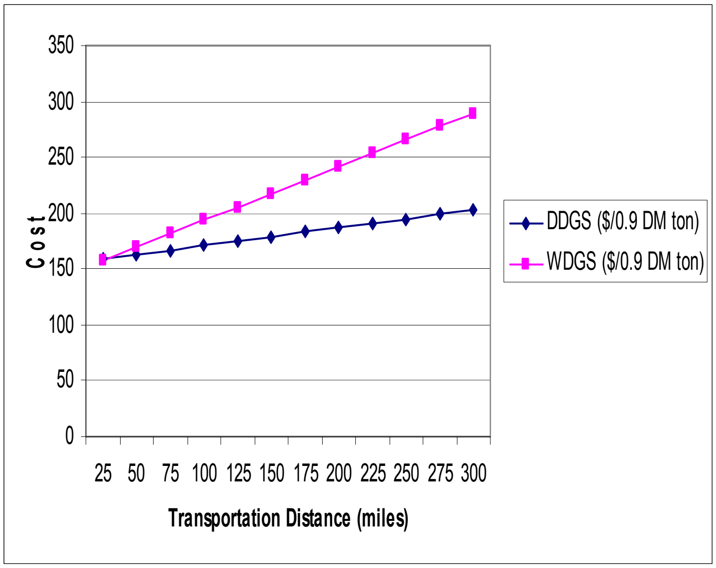


Figure 7. Effect on breakeven point when transportation distance increases (DDGS at $155/ton and breakeven = 29.87 miles).

Case 1B: When DDGS is Priced at $195/Ton

Table 17 and Figure 8 show the effect when DDGS is priced at its highest rate in Kansas, which is $195/ton. The same implication can be derived from the graphs. When the transportation cost increases, dry distillers become less expensive than wet distillers.

TABLE 17

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE WHEN TRANSPORTATION COST INCREASES
(DDGS AT $195/TON AND TRANSPORTATION COST AT $4.0/TRUCK/MILE)

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	199	197.43
50	203	209.43
75	207	221.43
100	211	233.43
125	215	245.43
150	219	257.43
175	223	269.43
200	227	281.43
225	231	293.43
250	235	305.43
275	239	317.43
300	243	329.43

⇨ $195 + 0.16x = 3*61.81 + 0.48x$
⇨ $x = 29.87$ miles

The breakeven cost would be as follows:

= $195 + 0.16(29.87)$
= $199.78/0.9 DM ton

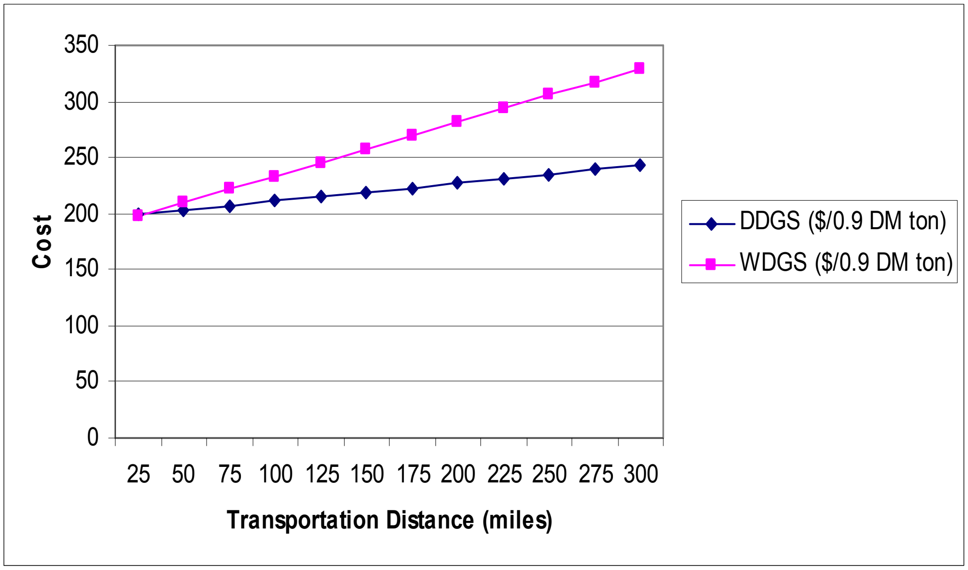


Figure 8. Effect on breakeven point when transportation cost increases (DDGS at $195/ton and breakeven = 29.87 miles).

Case 1C: When DDGS is Priced at $175/Ton

Table 18 and Figure 9 show the effect when DDGS is priced at an average rate in Kansas, i.e., $175/ton.

TABLE 18

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE WHEN TRANSPORTATION COST INCREASES (DDGS AT $175/TON AND TRANSPORTATION COST AT $4.0/TRUCK/MILE)

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	179	177.42
50	183	189.42
75	187	201.42
100	191	213.42

125	195	225.42
150	199	237.42
175	203	249.42
200	207	261.42
225	211	273.42
250	215	285.42
275	219	297.42
300	223	309.42

⇨ $175 + 0.16x = 3*55.14 + 0.48x$

⇨ $x = 29.87$ miles

The breakeven cost would be as follows:

= 175 + 0.16(29.87)

= $179.78/0.9 DM ton

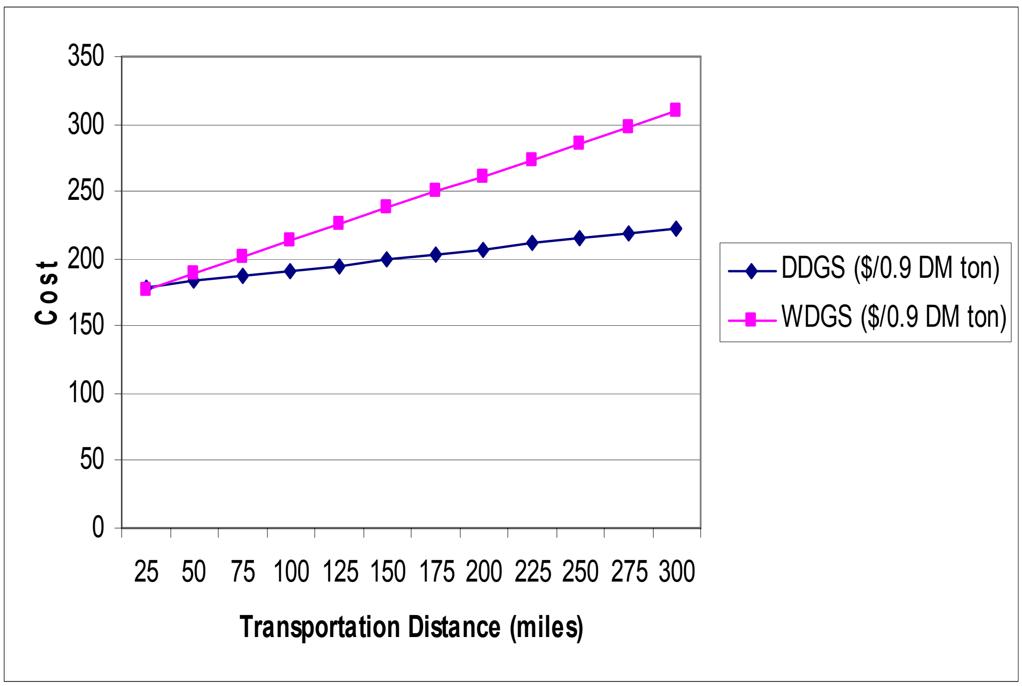


Figure 9. Effect on breakeven point when transportation distance increases (DDGS at $175/ton and breakeven = 29.87 miles).

3.3.1.2 Scenario # 2—Decrease in Transportation Cost

Here the above three cases are considered when the transportation cost is reduced, assuming that transportation cost is decreased to $3.00 per truck per mile (two ways), and the capacity of each truck is assumed to be the same. The transportation cost would be reduced to $0.12 per ton.

Case 2A: When DDGS is Priced at $155/Ton

In the first case, it is assumed that DDGS is priced at the lowest rate in Kansas, which is $155/ton. The data points are shown in Table 19, and the graph is plotted in Figure 10.

TABLE 19

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE
WHEN TRANSPORTATION COST DECREASES
(DDGS AT $155/TON AND TRANSPORTATION COST AT $3.0/TRUCK/MILE)

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	158	154.44
50	161	163.44
75	164	172.44
100	167	181.44
125	170	190.44
150	173	199.44
175	176	208.44
200	179	217.44
225	182	226.44
250	185	235.44
275	188	244.44
300	191	253.44

⇨ $155 + 0.12x = 3*48.48 + 0.36x$
⇨ $x = 39.83$ miles

The breakeven cost would be as follows:

= $155 + 0.12(39.83)
= $159.78/0.9 DM ton

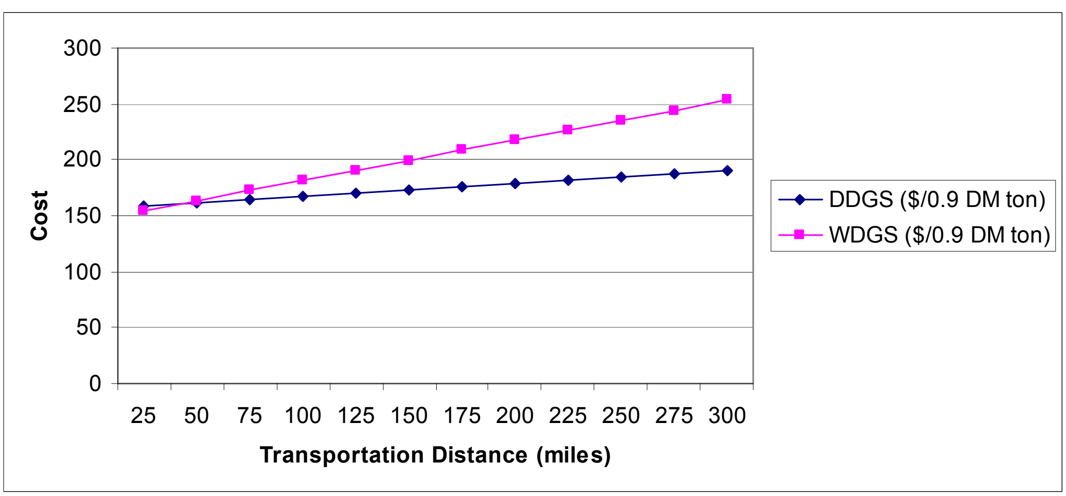


Figure 10. Effect on breakeven point when transportation cost decreases (DDGS at $155/ton and breakeven = 39.83 miles)

Case 2B: When DDGS is Priced at $195/Ton

In the second case, DDGS is priced at the highest rate, which is $195/ton. Table 20 and Figure 11 show the results in this case.

TABLE 20

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE WHEN TRANSPORTATION COST DECREASES
(DDGS AT $195/TON AND TRANSPORTATION COST AT $3.0/TRUCK/MILE)

Miles	**DDGS ($/0.9 DM ton)**	**WDGS ($/0.9 DM ton)**
25	198	194.43
50	201	203.43
75	204	212.43
100	207	221.43
125	210	230.43
150	213	239.43
175	216	248.43
200	219	257.43
225	222	266.43
250	225	275.43
275	228	284.43
300	231	293.43

⇨ $195 + 0.12x = 3*61.81 + 0.36x$
⇨ $x = 39.83$ miles

The breakeven cost would be as follows:

= $195 + 0.12(39.83)
= $199.78/0.9 DM ton

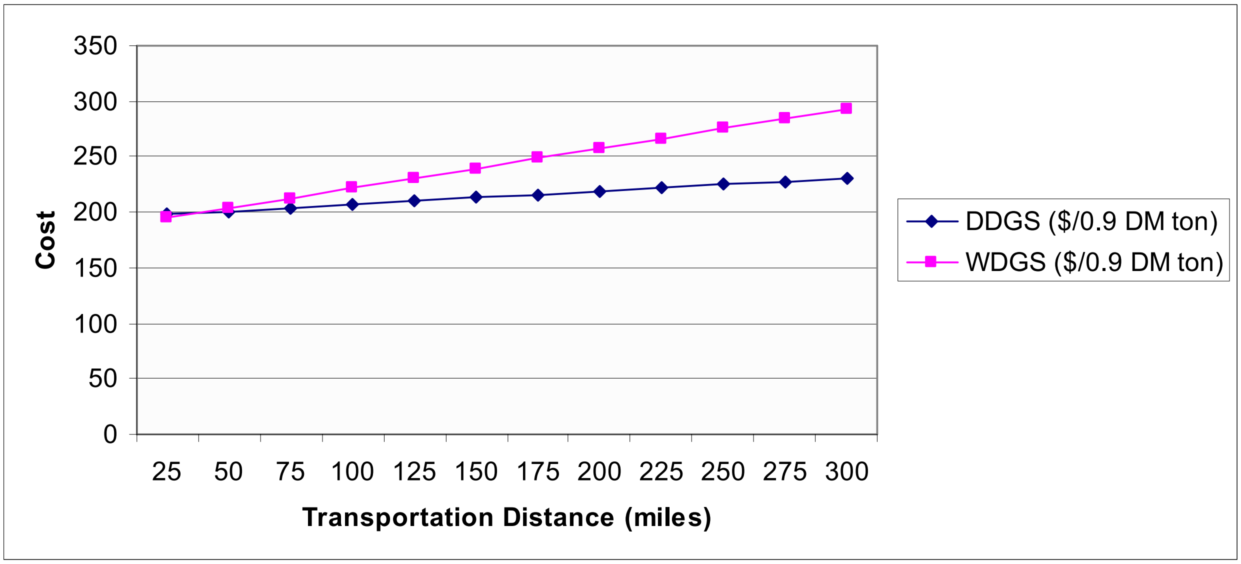


Figure 11. Effect on breakeven point when transportation cost decreases (DDGS at $195/ton and breakeven at 39.83 miles)

Case 2C: When DDGS is Priced at $175/Ton

The third case is when DDGS is priced at an average rate, which is $175/ton. Table 21 and Figure 12 show the effect on the breakeven point.

TABLE 21

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION
WHEN TRANSPORTATION COST DECREASES
(DDGS AT $175/TON AND TRANSPORTATION COST AT $3.0/TRUCK/MILE)

Miles	**DDGS ($/0.9 DM ton)**	**WDGS ($/0.9 DM ton)**
25	158	154.44
50	161	163.44
75	164	172.44
100	167	181.44
125	170	190.44
150	173	199.44
175	176	208.44
200	179	217.44
225	182	226.44
250	185	235.44
275	188	244.44
300	191	253.44
600	227	361.44

⇨ $175 + 0.12x = 3*55.14 + 0.36x$
⇨ $x = 39.83$ miles

The breakeven cost would be as follows:

= $175 + 0.12 (39.83)
= $179.78/0.9 DM ton

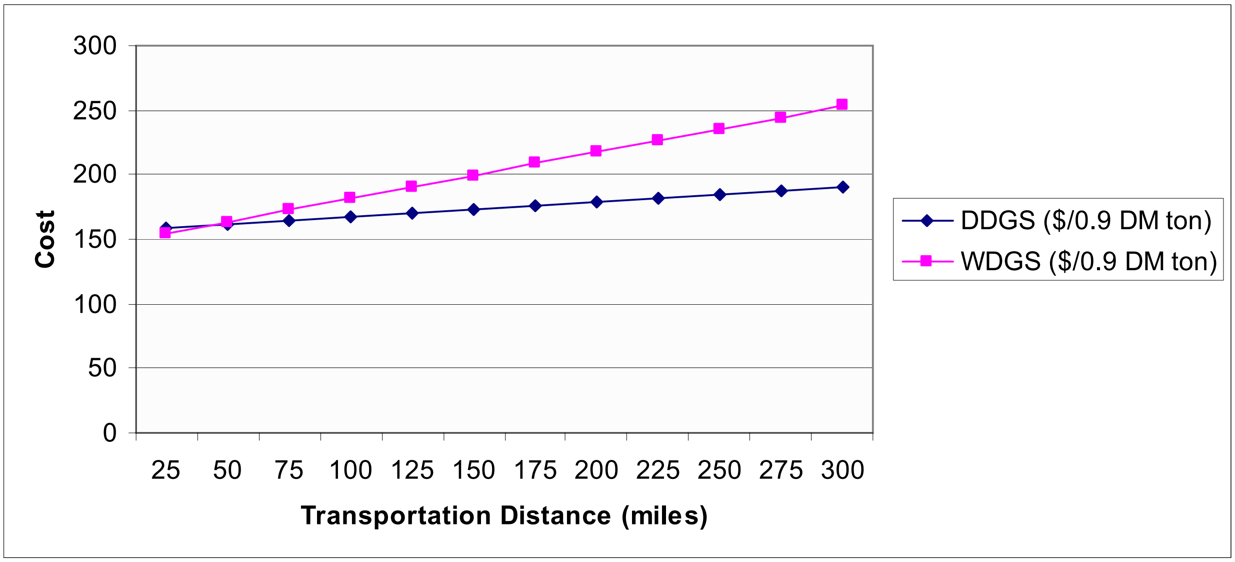


Figure 12. Effect on breakeven point when transportation cost decreases (DDGS at $175/ton and breakeven at 39.83 miles)

The results of both scenarios are summarized in Table 22 and Figure 13. It can be seen that the breakeven distance decreases when the transportation cost increases, which implies that dry distillers become less expansive when the transportation cost increases. The points do not change with an increasing or decreasing price of DDGS.

TABLE 22

SUMMARY OF BREAKEVEN POINTS ON INCREASE/DECREASE OF TRANSPORTATION COST

		Transportation Cost					
		Increase ($4/mile)		Increase ($3.5/mile)		Decrease ($3/mile)	
	DDGS Price ($/ton)	Breakeven Distance	Breakeven Cost	Breakeven Distance	Breakeven Cost	Breakeven Distance	Breakeven Cost
Case A	155	29.87	159.78	34.14	159.78	39.83	159.78
Case B	195	29.87	199.78	34.14	199.78	39.83	199.78
Case C	175	29.87	179.78	34.14	179.78	39.83	179.78

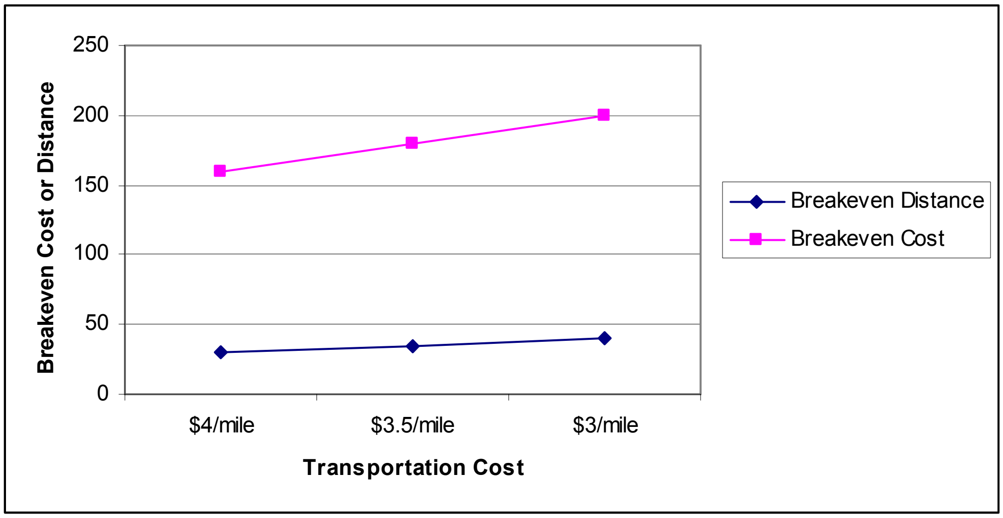


Figure 13. Breakeven point vs. transportation cost.

Table 23 shows a detailed analysis of breakeven point movement with transportation distance. Figure 14 suggests that as truck transportation cost increases, the breakeven point between wet and dry distillers is reduced. This means that dry distillers are more profitable when the transportation cost increases.

TABLE 23

BREAKEVEN POINT MOVEMENT WITH TRANSPORTATION DISTANCE

Transportation Cost		Breakeven Distance
$/truck/mile	**$/ton/mile**	
0.5	0.02	$239.50
1	0.04	$119.75
1.5	0.06	$79.83
2	0.08	$59.87
2.5	0.1	$47.90
3	0.12	$39.92
3.5	0.14	$34.21
4	0.16	$29.94
4.5	0.18	$26.61
5	0.2	$23.95
5.5	0.22	$21.77
6	0.24	$19.96

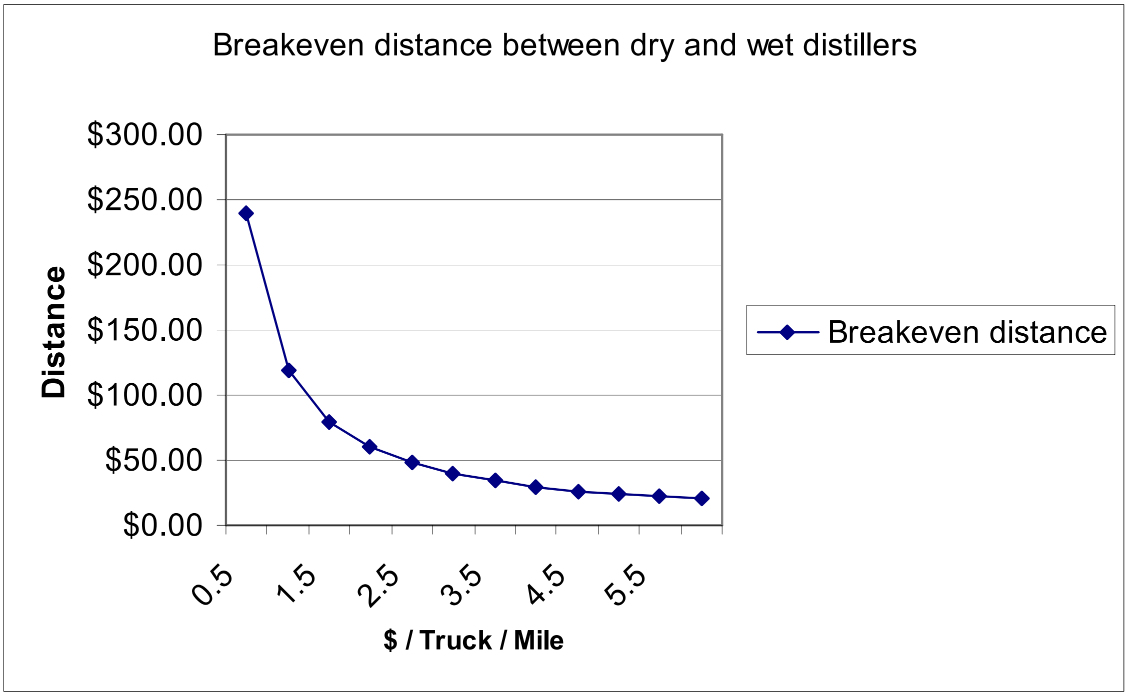


Figure 14. Breakeven distance trendline (truck capacity constant).

3.3.2 Change in Truck Capacity

It has been shown that breakeven points move when the transportation cost changes. These are inversely proportion, as explained in the previous section. Relative to changes in the second variable, three truck capacities were considered: 15 tons, 25 tons, and 50 tons. The most widely used truck capacity for distillers distribution is 25 tons, which has been discussed previously. This section will discuss calculations based on 15-ton and 50-ton truck capacities.

3.3.2.1 Scenario # 1—Increase in Truck Capacity

Assuming that truck capacity increases from 25 tons to 50 tons while transportation costs remain unchanged at $3.50 per mile per truck (delivery and return inclusive), transportation costs in tons will come out to be $3.5/50/ton = $0.07/ton. Table 24 compares the total production costs for DDGS and WDGS. It can be inferred that increasing truck capacity will move the breakeven point upwards, as shown in Figure 15.

TABLE 24

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE WHEN TRUCK CAPACITY (50 TONS) INCREASES

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	156.75	150.69
50	158.5	155.94
75	160.25	161.19
100	162	166.44
125	163.75	171.69
150	165.5	176.94
175	167.25	182.19
200	169	187.44
225	170.75	192.69
250	172.5	197.94
275	174.25	203.19
300	176	208.44

⇨ $155 + 0.07x = 3*48.48 + 0.21x$

⇨ $x = 68.28$miles

The breakeven cost would be as follows:

= $155 + 0.07(68.28)

= $159.8/0.9 DM ton

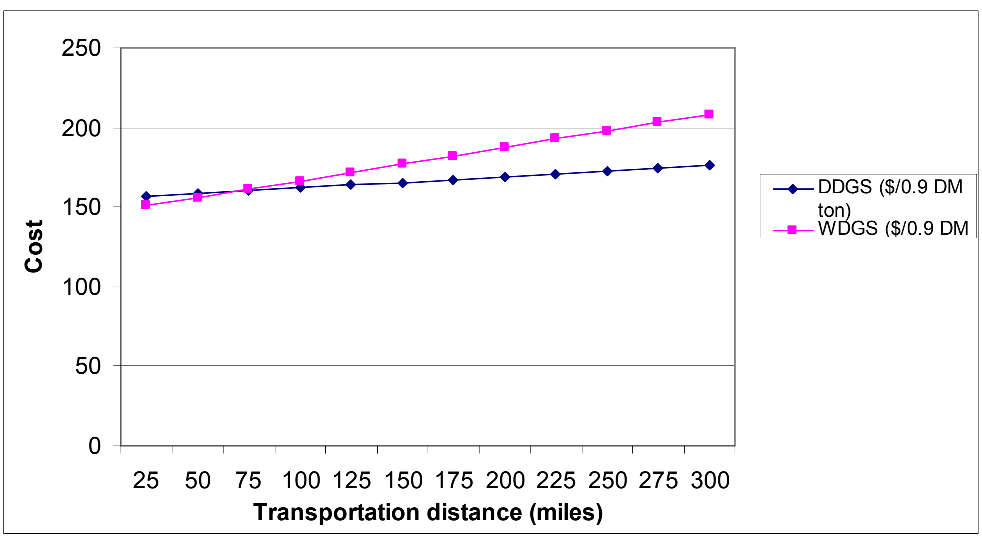


Figure 15. Effect on breakeven point when truck capacity increases.

3.3.2.2 Scenario # 2—Decrease in Truck Capacity

This section discusses what happens to the breakeven point when the truck capacity is reduced. Assuming that the truck capacity is reduced to 15 tons and keeping the transportation cost constant at $3.50 per mile per truck (two ways), then the transportation cost in tons would be $0.233/ton. Table 25 shows this price variation. It can be inferred that decreasing truck capacity will move the breakeven point downwards, as shown in Figure 16.

TABLE 25

PRICE VARIATION OF DDGS AND WDGS BY TRANSPORTATION DISTANCE WHEN TRUCK CAPACITY (15 TONS) DECREASES

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
0	155	145.44
25	160.75	162.94
50	166.5	180.44
75	172.25	197.94
100	178	215.44
125	183.75	232.94
150	189.5	250.44
175	195.25	267.94
200	201	285.44
225	206.75	302.94
250	212.5	320.44
275	218.25	337.94
300	224	355.44

⇨ $155 + 0.23x = 3*48.48 + 0.7x$

⇨ $x = 20.3$ miles

The breakeven cost would be as follows:

= $155 + 0.233(20.3)

= $159.8/0.9 DM ton

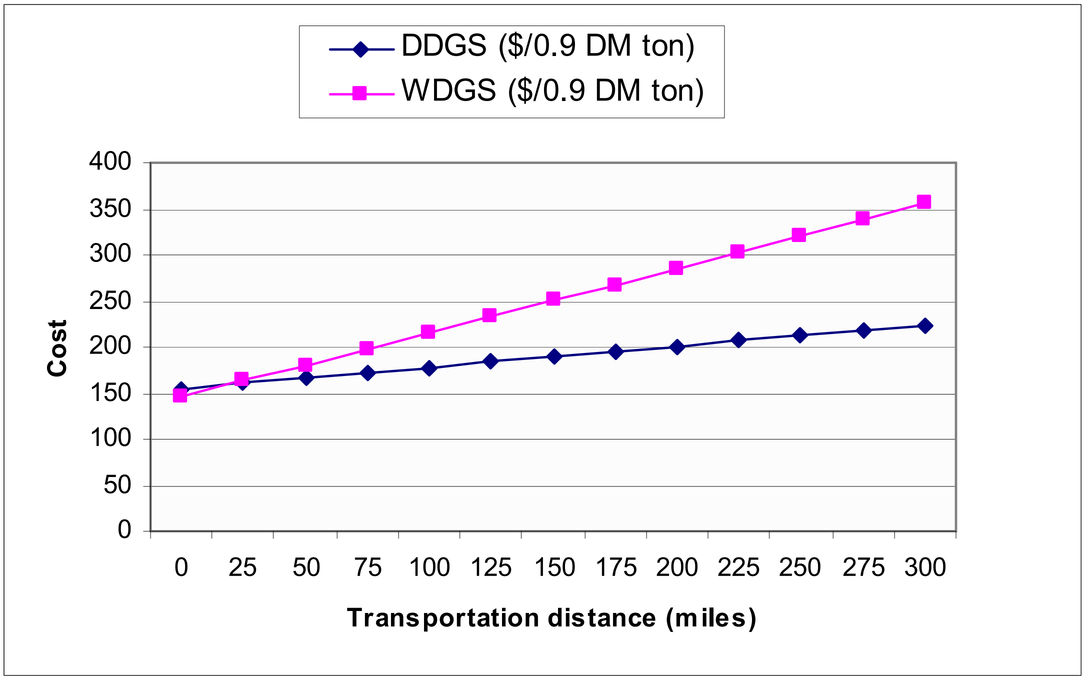


Figure 16. Effect on breakeven point when truck capacity decreases.

A detailed analysis is tabulated in Table 26, and Figure 17 shows the linear relationship between the breakeven point and truck capacity if transportation cost per mile is constant.

TABLE 26

SUMMARY OF BREAKEVEN POINTS WHEN TRUCK CAPACITY CHANGES

Truck capacity (tons)	Breakeven Distance
10	13.66
15	20.49
20	27.31
25	34.14
30	40.97
35	47.80
40	54.63
45	61.46
50	68.29
55	75.11
60	81.94
65	88.77
70	95.60
75	102.43

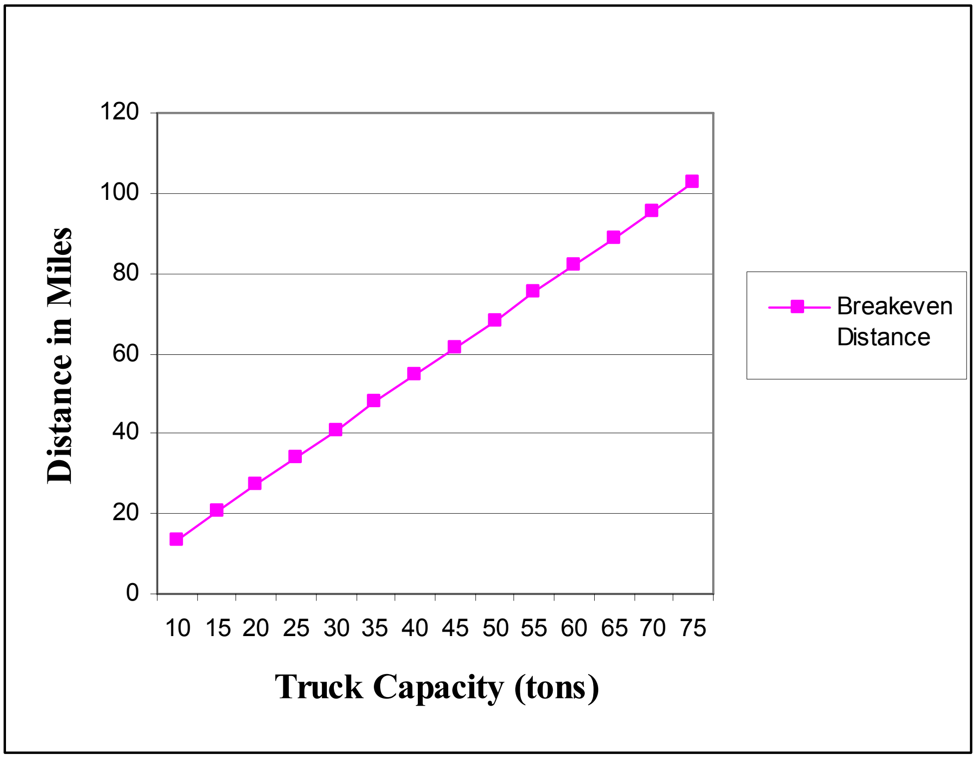


Figure 17. Breakeven distance trend line (transportation cost per mile constant).

3.3.3 Variable Truck Capacity and Variable Transportation Cost

The effect on breakeven point by keeping one feature constant was shown previously. For example, to see the breakeven point movement by truck capacity change, the unit transportation cost was kept constant. Similarly, in order to see the effect on breakeven by transportation cost, the truck capacity was assumed constant in the calculation. Now a scenario that happens in the real world must be considered: when both features are variable. Using the breakeven formulas from previous sections, Table 27 and Figure 18 can be constructed. It can be inferred from the graph in Figure 18 that no linear relationship exists between transportation cost per mile and breakeven distance under variable truck capacity. This distribution is called parabolic distribution. The breakeven distance increases with respect to the increase in transportation cost. At higher transportation costs, the effect on breakeven distance is minimal.

TABLE 27

BREAKEVEN POINT MOVEMENT UNDER VARIABLE CONDITIONS

Truck Capacity (tons)	Transportation Cost	Breakeven Distance
10	2.75	17.38
15	3	23.90
20	3.25	29.42
25	3.5	34.14
30	3.75	38.24
35	4	41.83
40	4.25	44.99
45	4.5	47.80
50	4.75	50.32
55	5	52.58
60	5.25	54.63
65	5.5	56.49
70	5.75	58.19
75	6	59.75

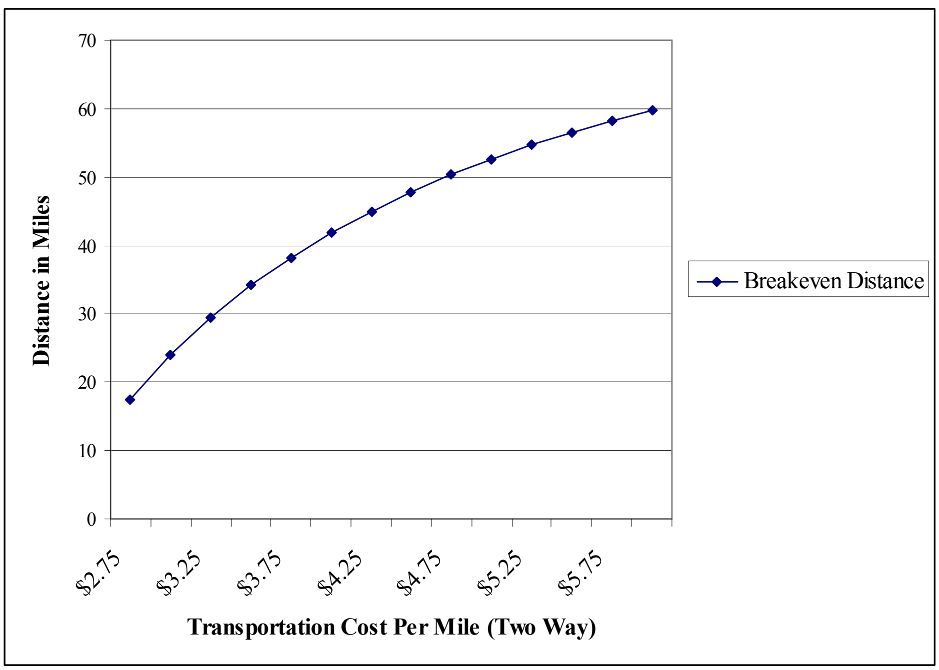


Figure 18. Breakeven point movement under variable conditions.

3.4 Economic Analysis of Corn and Distillers

Previous discussion has focused on the breakeven points of dry and wet distillers. Since corn is a major competitor of distillers, it is now time to discuss the breakeven points of corn and distillers. The formula to calculate breakeven point between dry distillers and corn is given by Ohio State University Animal Sciences Department (Ohio State University Animal Sciences, 2007), who was able to develop a formula for the equivalent price of dry distillers if corn and soybeans prices are known. This formula is based on a comparison of energy content between the two. Literature is available in this department. The formula is given by the following:

Breakeven price of DDGS ($/ton) = {Corn ($/bu) x 17.85} + {Soybean ($/ton) x 0.5}

The average prices of corn and soybeans for 2007 is listed as follows:

Corn ($/bu) = $4 per bushel (http://www.ksgrains.com/kcc/talkingpts.html)

SBM ($/ton) = $235/ton (http://www.cropdocs.com/crop_market_summary.htm)

Substituting the above values into the breakeven formula, the breakeven point can be calculated as follows:

Breakeven price of DDGS ($/ton) = (4 x 17.85) + (235 x 0.5) = 188.9

3.4.1 How Far Can We Ship Dry Distillers to Remain Profitable?

The above breakeven point indicates that it is not profitable to ship distillers to feedlots when the distance to the feedlot is longer than 189 miles. The next section takes a look at how far distillers can be shipped when they are priced at $155 per ton, $175 per ton, and $195 per ton.

3.4.1 Distillers Priced at $155/Ton

When dry distillers are priced at $155/ton, the breakeven distance will vary according to the transportation cost and truck capacity. The most common truck capacity in the market is 25 tons, and the freight cost ranges from \$3 per truck per mile to \$6 per truck per mile (two ways). The following section discusses the breakeven distance considering both shipping costs.

3.4.1.1 25 Tons—\$3 per Truck

In this scenario, the breakeven distance is calculated as follows:

⇨ $155 + 0.12(x) = 188.9$
⇨ 282.5 miles

This analysis shows that if the transportation distance between the supplier of DDGS and feedlot points is less than 282.5 miles, then dry distillers are more profitable. A price variation of corn, DDGS, and WDGS at \$3 per truck by transportation distance is shown in Table 28.

TABLE 28

PRICE VARIATION OF CORN, DDGS, AND WDGS BY TRANSPORTATION DISTANCE

Miles	DDGS Cost	WDGS Cost (\$/0.9 DM ton)
25	158	154.44
50	161	163.44
75	164	172.44
100	167	181.44
125	170	190.44
150	173	199.44
175	176	208.44
200	179	217.44
225	182	226.44
250	185	235.44
275	188	244.44
300	191	253.44

3.4.1.2 25 Tons—\$6 per Truck

If the truck capacity remains constant but the shipment cost is increased to \$6 per truck, then the break even distance will be modified as follows:

⇨ $155 + 0.24(x) = 188.9$
⇨ 141.25 miles

The above result shows that if the shipment cost is increased, then the breakeven point will decrease. For $6 per truck per mile, the breakeven distance is $141.25/ton, which means that dry distillers are more profitable to feedlots if they are purchased at a price less than $141.25/ton.

A price variation of corn, DDGS, and WDGS at $6 per truck by transportation distance is shown in Table 29.

TABLE 29

PRICE VARIATION OF CORN, DDGS AND WDGS BY TRANSPORTATION DISTANCE

Miles	DDGS ($/0.9 DM ton)	WDGS ($/0.9 DM ton)
25	161	163.44
50	167	181.44
75	173	199.44
100	179	217.44
125	185	235.44
150	191	253.44
175	197	271.44
200	203	289.44
225	209	307.44
250	215	325.44
275	221	343.44
300	227	361.44
600	299	577.44

3.4.2 Distillers Priced at $175/Ton and $195/Ton

This section observes the change in breakeven distance when the price of distillers varies. The same calculations have been done for $175/ton and $195 per ton, and the results are summarized in Table 30. Table 30 suggests that when DDGS prices go up, DDGS becomes less competitive than corn. And selling DDGS at $195/ton is not an option, because it does not give feedlot owners an edge on corn.

TABLE 30

BREAKEVEN DISTANCE OF CORN AND DISTILLERS
WITH RESPECT TO VARIABLE DDGS PRICE

	Breakeven Distance (miles)	
	Dry	
DDGS price ($/ton)	**$3/ton**	**$6/ton**
155	282.5	141.25
175	115.8	57.9
195	Not Valid	

3.5 Summary

This chapter explained how the breakeven distance is changed by transportation cost and truck capacity when dry distillers are priced from $155/ton to $195/ton. Also, distillers priced above $188/ton are not competitive with corn, based on the average price of corn and soybeans last year. Wet distillers at a shorter transportation distance are more profitable than dry distillers. These breakeven points are very important in making a decision about whether an ethanol manufacturer should sell wet or dry distillers to a particular customer. These points will be validated by a multi-commodity model in the next chapter. If the exact distance from a particular ethanol plant to a feedlot is known, then this will guide them in selling to those customers that will result in a higher profit. Also, this will ensure at what price distillers will be competitive with corn and other feeds.

CHAPTER 4

MATHEMATICAL MODELING OF DISTRIBUTION NETWORK

4. 1 Introduction

This chapter deals with selecting a model to satisfy the demand of distillers with the available supply of distillers in Kansas. The previous chapter presented a detailed breakeven analysis to explain the breakeven points of dry and wet distillers. According to the demand at each feedlot and supply at each ethanol plant, it must be ensured that the ethanol plant is able to make maximum profit while supplying distillers to these feedlots. Thus the idea is to develop an optimal distribution network that verifies the breakeven points discussed in the last chapter.

The organization of this chapter is as follows. Section 4.1 discusses the formulation of the distribution models, whereby models are applied to satisfying demand points by supplying 100 percent DDGS and 100 percent WDGS. Section 4.2 presents the multi-commodity model, which maximizes the profits of the producers of distillers when both wet and dry distillers can be sold. Then the model results are presented and sensitivity analysis is discussed. Section 4.3 summarizes the results and findings

4.2 Transportation Assignment Model

Two forms of distillers, wet and dry, can be supplied to feedlots. Ethanol plants must know which distillers they should sell to make more profit. This is only possible when the total profits of supplying wet and distillers are compared. The single-commodity transportation assignment model can serve this purpose. The model must be modified to using dry and wet distillers, which gives the optimal solution. In this model the objective function will be to maximize the total profits of suppliers of distillers if they sell dry distillers or wet distillers. Then the results are compared to assess which form of distillers is more profitable. First, it is assumed that 100 percent of DDGS is supplied from ethanol plants. The same model will be used to test for 100 percent of the WDGS supply. Figure 19 depicts the transportation network of distillers from ethanol plants to feedlots. Depending on the profit margin, ethanol plants are supplying both dry and wet distillers, shown with green and yellow lines, respectively.

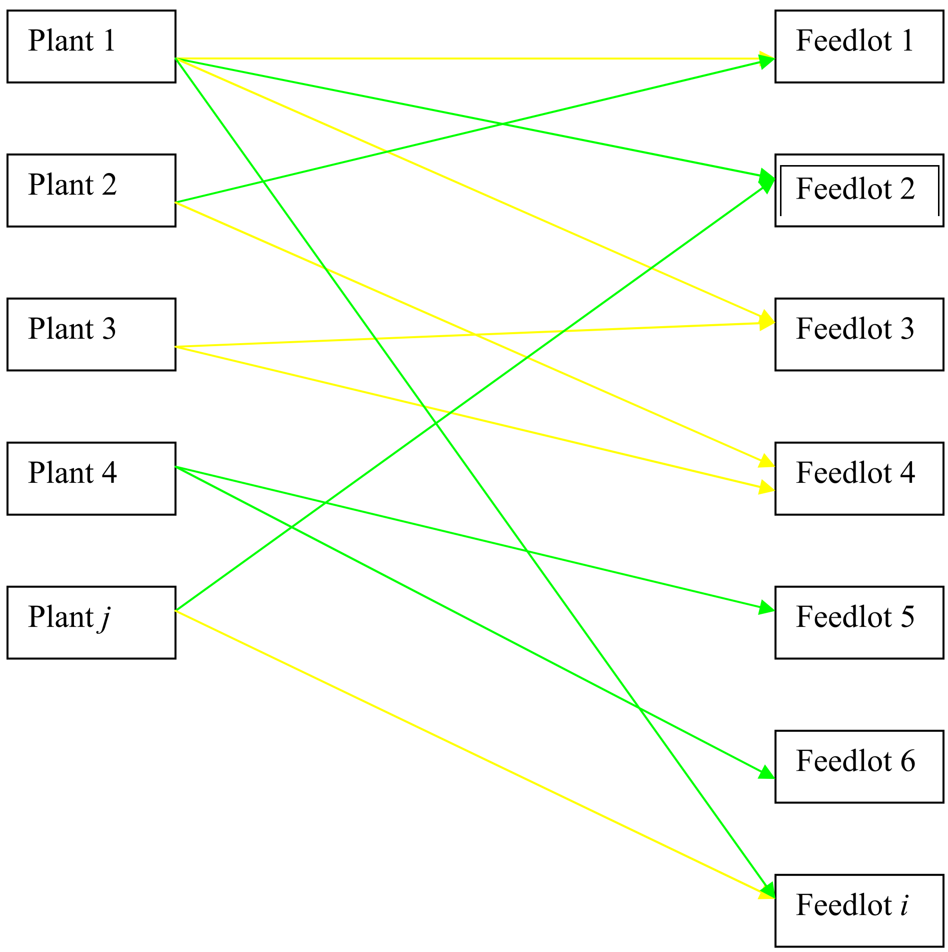


Figure 19. Multi-commodity distribution network for dry and wet distillers.

This model considers all ethanol plants in Kansas. The output of ethanol plants is in million bushels used. Each bushel produces 18 pounds of dry distillers and 40 pounds of wet distillers (http://www.farmersfuel.com/distillers_grain.html). The total usage of the ethanol plant is 180.2 million bushels of corn per year, which equals 3,243.6 million pounds of dry distillers and 7,208 million pounds of wet distillers per year. The 13 Kansas ethanol plants (Kansas Ethanol, 2007) and their capacities of producing dry distillers are shown in Table 31 and wet distillers in Table 32. The production unit is million pounds per year. Let i = 1,..,13 be the index for the ethanol plant and a_i be the corresponding dry matter capacity at ethanol plant i.

TABLE 31

DRY DISTILLERS PRODUCTION CAPACITY OF ETHANOL PLANTS IN KANSAS

Plant	Kansas Ethanol	Nesika Energy	Arkalon Energy	Gateway Ethanol	Bonanaza Bioenergy	US Energy Partners	Prairie Horizon Agri Energy	Western Plains	East Kansa Agri Energy	Abengoa Bio-Energy	Reeve Agri-Energy	MGP Ingredients	ESE Alcohol
Location	Republic	Washin	Seward	Pratt	Garden Cit	Russel	Phillipsburg	Sheridan	Grant	Sedgwick	Garden city	Atchison	Wichita
Productio	352.8	64.8	702	548.8	352.8	309.6	257.4	289.8	225	160.2	97.2	64.8	9

TABLE 32

WET DISTILLERS PRODUCTION CAPACITY OF ETHANOL PLANTS IN KANSAS

Plant	Kansas Ethanol	Nesika Energy	Arkalon Energy	Gateway Ethanol	Bonanaza Bioenergy	US Energy Partners	Prairie Horizon Agri Energy	Western Plains	East Kansa Agri Energy	Abengoa Bio-Energy	Reeve Agri-Energy	MGP Ingredients	ESE Alcohol
Location	Republic	Washin	Seward	Pratt	Garden Cit	Russel	Phillipsburg	Sheridan	Grant	Sedgwick	Garden city	Atchison	Wichita
Productio	784	144	1560	1219.6	784	688	572	644	500	356	216	144	20

The customers of distillers are feedlots. In this model, all feedlot points in Kansas are considered. There are 95 feedlots in Kansas with a total of 2,204,300 head of cattle (Kansas Livestock Association, 2007). Details of Kansas feedlots are shown in Table 33. Details of the consumers of distillers are shown in Table 34. Let j = 1,…,95 be the index of the feedlot points (distillers consumers in Kansas) and b_j is the corresponding distillers requirement at feedlot point j. This model requires a determination of the quantity of distillers that should be shipped from the ethanol plant to the feedlot. Let X_{ij} be the amount of distillers shipped from the ethanol plant i to the feedlot point j.

TABLE 33

DETAILS OF KANSAS FEEDLOTS

Feedlots	Heads	Location
Century Feeders	10000	Goodland
David Ranch & Feedlot	3000	Lenora
Decatur County Feed Yard	38000	Oberlin
Hays Feeders, LLC	22000	Hays
Jewell County Feeders, LLC	5000	Mankato
MP&K Land and Livestock	3200	Lebanon
Rooks County Feeders	8000	Plainville
Solomon Valley Feeders	17000	Beloit
T Bone Feeders	6500	Goodland
Thomas County Feeders	18000	Colby
Valley Feeds, Inc	8000	Long Island
Beef Belt Feedlot, Inc	12000	Scott City
Brookover Cattle Company	20000	Scott City
Cadillac Feeders	4000	Scott City
Cargill Cattle Feeders, LLC	125000	Leoti
Cutler Cattle Company	6000	Scott City
Fairleigh Feed Yards, Inc	45000	Scott City
Doornbos Cattle Co	2000	Scott City
H R C Feedyard, Inc	30000	Scott City
Hess Cattle Company, Inc	2400	Scott City
KFY-Division of Beef Belt Fe	6000	Scott City
Lane County Feeders, Inc	42000	Dighton
Ox Town Cattle Feeders, LLC	21000	Tribune
Pawnee Valley Feeders, Inc	20000	Hanston
Pioneer, Inc	30000	Oakley
Poky Feeders, Inc	34800	Scott City
Ranger Feeders	10100	Dighton
Royal Beef/Division of Irsik &	40000	Scott City
Hay Hook Cattle Company, L	10000	Tribune
Stampede Feeders	10000	Scott City
5N Feeders, Inc	7000	Johnson
Bartlett III	30000	Sublette
Brookover Feedyard	45000	Garden City
Brookover Ranch Feed Yard	35000	Garden City
Cattle Empire, L.L.C	140000	Satanta
Garden City Feedyard, LLC	90000	Garden City
G & G Cattle, Inc	3000	Holcomb
Grant County Feeders		Ulysses
Hitch Feeders II, Inc	50000	Garden City
J O Cattle Company	2000	Holcomb
Miller Feedyard	17500	Satanta
River Bend Feed Yard, Inc	15500	Ulysses
Heritage Feeders Sublette	50000	Sublette
Sunbelt Feeders, Inc	30000	Hugoton
Supreme Cattle Feeders, LLC	70000	Liberal
Syracuse Feed Yard	40000	Syracuse
Triangle H Grain & Cattle	4000	Garden City
Ulysses Feed Yard	35000	Ulysses
Ulysses Feed Yard	35000	Ulysses
Western Feed Yard, Inc	42000	Johnson
Winger Feedyard, Inc	12500	Johnson
Beefland	35000	Garden City
Boot Hill Feeders, Inc	17000	Dodge City
Cimarron Feeders of Kansas	20000	Cimarron
Dewey Feedyard	5000	Cimarron
Diamond O Feeders		Jetmore
Clark County Feedyard	12500	Minneola
DM&M Farms, Inc	20000	Cimarron
Ford County Feed Yard, Inc	52000	Ford
Fowler Feeders	15000	Fowler
Gray County Feedyard	30000	Cimarron
Hy-Plains Feedyard, LLC	50000	Montezuma
Ingalls Feedyard, Inc	40000	Ingalls
Irsik & Doll Feed Yard	30000	Garden City
Meade County Feeders, L.L.C	10000	Meade
Meade County Feeders II	4400	Meade
Midwest Feeders, Inc	20000	Ingalls
Pratt Feeders, Inc. dba Ashla	40000	Ashland
Sublette Feeders	42000	Sublette
Wilroads Feed Yard	11500	Dodge City
Barton County Feeders	20000	Ellinwood
Haw Ranch Feedlot, LLC	30000	Turon
Golden Belt Feeders	6000	Lyons
Dudrey Cattle Company	5000	Saint John
Golden Belt Feeders	21000	Saint John
Golden Belt Feeders-Kinsley	33000	Kinsley
Great Bend Feeding, Inc	27000	Great Bend
Knight Feedlot	16000	Lyons
Mull Farms & Feeding, Inc.	13000	Pawnee Rock
Heritage Feeders Larned	30000	Larned
Pratt Feeders, LLC	34500	Pratt
Quality Feeders, Inc	7600	Great Bend
Sellers Feedlot	12000	Lyons
Smoky Hill Feeders, Inc	8000	Falun
Ward Feed Yard, Inc	25000	Larned
Zimm's Feedlot	3000	Sterling
2K Feeders	3500	Burns
Haw Ranch Feedlot II, LLC	25000	Potwin
Cow Camp Feedyard, Inc	4900	Ramona
Tiffany Cattle Company	12500	Herington
Handke Farms, Inc	4500	Muscotah
Kansas State University Dep	1700	Manhattan
Neosho Valley Feeders	18500	Parsons
Ottawa County Feeders, Inc	8000	Minneapolis
Palenske Ranch, Inc	8500	Strong City
Peddicord Land & Cattle Co.	4200	Wamego
Porter Cattle Co	5000	Reading

TABLE 34

CONSUMPTION OF DISTILLERS

	Co-Product Maximum Inclusion Rate (lb)				
Cattle Type	**Weight Range (lbs)**	**WDG[a]**	**MDGS[a]**	**DDG[a]**	**Cds[b]**
Growing calf	500-700	10-12	5.5-7	3-3.5	4-6
Finishing steer	900-1200	15-20	9-12	4.5-6	7.5-10
Cow	1200-1500	16-20	9.5-12	5-7	8-10

[a]assuming inclusion rate is 20% of dry matter intake; WDG, 30% DM; MDGS, 50% DM; DDG, 90% DM.

[b]assuming maximum inclusion rate is 10% of dry matter intake; CDS, 30% DM.

As shown in Table 35, a growing calf consumes wet distillers at the average rate of 11 pounds per day and dry distillers at the rate of 3.25 pounds per day, which equals 8,850.26 million pounds of wet distillers per year and 2,615 million pounds of dry distillers per year. Using the same comparison, the requirement for a finishing steer would be 14,079 million pounds of wet distillers per year and 4,224 million pounds of dry distillers per year. In the case of cows, this comparison is 14,482 pounds of wet distillers per year and 4,827 pounds of dry distillers per year.

TABLE 35

WET AND DRY DISTILLERS REQUIRED PER YEAR FOR FEEDSTOCK

	Wet Distillers		Dry Distillers	
	Inclusion Rate (lb)	**MPY Required**	**Inclusion Rate (lb)**	**MPY Required**
Calf	11	8850.26	3.25	2615
Steer	17.5	14079	5.25	4224
Cow	18	14482	6	4827
Average	15.5	12470	4.83	3889

This model uses average values for wet and dry distillers. Truck transportation and production cost will be considered. The approximate distance between each feedlot and ethanol plant (d_{ji}) is shown in Table 36.

TABLE 36

TRANSPORTATION DISTANCE BETWEEN ETHANOL PLANT AND FEEDLOT

		Kansas Eth	Nesika En	Arkalon E	Gatew	Bonanaz	US Energ	Prairie H	Western I	East Kans	Abengoa	Reeve Agri-E
Feedlots	Location	Rice	Washingto	Seward	Pratt	Finney	Russell	Phillipsb	Sheridan	Grant	Sedgwick	Finney
Century Fe	Goodland	238	279	225	257	157	170	156	73.3	215	314	157
David Ranch	Lenora	177	175	164	196	171	110	52.7	39.9	125	253	171
Decatur Co	Oberlin	213	189	200	232	158	145	66.2	37.8	166	289	158
Hays Feede	Hays	97.6	192	84.6	117	128	29.9	63.9	81.9	74.6	173	128
Jewell Cou	Mankato	164	62.8	141	173	249	97.4	59.9	146	68.2	175	249
MP&K Land	Lebanon	185	83.6	139	171	233	81.1	43.7	130	59.4	196	233
Rooks Cou	Plainville	118	158	105	137	153	50.5	37.6	104	63.2	194	153
Solomon V	Beloit	83.7	85.2	114	146	211	82.3	87.3	187	40.8	140	211
T Bone Fee	Goodland	238	279	225	257	157	170	156	73.3	215	314	157
Thomas Co	Colby	202	239	189	221	121	134	117	33.7	179	277	121
Valley Feed	Long Island	177	144	164	196	214	109	21.4	76.2	122	253	214
Beef Belt Fe	Scott City	150	319	137	164	52	157	172	84	202	301	52
Brookover	Scott City	150	319	137	164	52	157	172	84	202	301	52
Cadillac Fee	Scott City	150	319	137	164	52	157	172	84	202	301	52
Cargill Catt	Leoti	175	344	161	188	76.3	182	197	108	226	325	76.3
Cutler Catt	Scott City	150	319	137	164	52	157	172	84	202	301	52
Fairleigh Fe	Scott City	150	319	137	164	52	157	172	84	202	301	52
Doornbos C	Scott City	150	319	137	164	52	157	172	84	202	301	52
H R C Feedy	Scott City	150	319	137	164	52	157	172	84	202	301	52
Hess Cattle	Scott City	150	319	137	164	52	157	172	84	202	301	52
KFY-Divisio	Scott City	150	319	137	164	52	157	172	84	202	301	52
Lane Count	Dighton	127	300	113	145	44.3	138	172	64.7	183	202	44.3
Ox Town Ca	Tribune	197	366	183	214	102	204	208	130	248	347	102
Pawnee Va	Hanston	89.2	233	56.2	102	57.6	99.6	134	123	144	165	57.6
Pioneer, In	Oakley	181	275	168	200	97.5	113	126	39.9	158	256	97.5
Poky Feede	Scott City	150	319	137	164	52	157	172	84	202	301	52
Ranger Fee	Dighton	127	300	113	145	44.3	138	172	64.7	183	202	44.3
Royal Beef/	Scott City	150	319	137	164	52	157	172	84	202	301	52
Hay Hook C	Tribune	70.1	300	113	145	44.3	138	172	64.7	183	202	44.3
Stampede I	Scott City	150	319	137	164	52	157	172	84	202	301	52
5N Feeders	Johnson	228	424	205	192	89.4	262	277	188	306	282	89.4
Bartlett III	Sublette	167	310	131	139	48.6	184	247	159	229	229	48.6
Brookover	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7
Brookover	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7
Cattle Empi	Satanta	175	319	139	145	53.9	207	252	164	251	234	53.9
Garden City	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7
G & G Cattle	Holcomb	164	360	142	138	25.7	198	213	125	243	227	25.7
Hitch Feede	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7
J O Cattle C	Holcomb	164	360	142	138	25.7	198	213	125	243	227	25.7
Miller Feed	Satanta	175	319	139	145	53.9	207	252	164	251	234	53.9
River Bend	Ulysses	206	403	184	171	68.2	241	256	167	285	261	68.2
Heritage Fe	Sublette	167	310	131	139	48.6	184	247	159	229	229	48.6
Sunbelt Fee	Hugoton	203	347	195	156	82.1	235	284	196	280	246	82.1
Supreme C	Liberal	197	341	172	133	80.9	215	249	191	260	223	80.9
Syracuse F	Syracuse	206	402	183	180	67.6	240	255	167	285	269	67.6
Triangle H C	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7
Ulysses Fe	Ulysses	206	403	184	171	68.2	241	256	167	285	261	68.2
Ulysses Fe	Ulysses	206	403	184	171	68.2	241	256	167	285	261	68.2
Western Fe	Johnson	228	424	205	192	89.4	262	277	188	306	282	89.4
Winger Fee	Johnson	228	424	205	192	89.4	262	277	188	306	282	89.4
Beefland	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7

TABLE 36 (Continued)

Boot Hill Fe	Dodge City	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5
Cimarron F	Cimarron	134	277	97.8	93.9	27	151	185	154	196	184	27
Dewey Fee	Cimarron	134	277	97.8	93.9	27	151	185	154	196	184	27
Clark Coun	Minneola	137	280	112	72.5	67	154	188	163	199	162	67
DM&M Farn	Cimarron	134	277	97.8	93.9	27	151	185	154	196	184	27
Ford Count	Ford	123	267	96.8	57.7	63.2	141	175	149	186	147	63.2
Fowler Fee	Fowler	148	292	123	84	78.5	166	200	174	210	174	78.5
Gray Count	Cimarron	134	277	97.8	93.9	27	151	185	154	196	184	27
Hy-Plains F	Montezuma	143	287	107	102	39	161	195	166	205	192	39
Ingalls Fee	Ingalls	140	284	104	100	21.4	158	192	148	203	190	21.4
Irsik & Doll	Garden City	167	311	131	127	14.7	194	209	121	239	217	14.7
Meade Cou	Meade	158	302	133	94.2	63.2	176	210	201	221	184	63.2
Meade Cou	Meade	158	302	133	94.2	63.2	176	210	201	221	184	63.2
Midwest Fe	Ingalls	140	284	104	100	21.4	158	192	148	203	190	21.4
Pratt Feede	Ashland	163	307	121	82	96.8	172	209	192	211	172	96.8
Sublette Fe	Sublette	167	310	131	139	48.6	184	247	159	229	229	48.6
Wilroads Fe	Dodge City	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5
Barton Cou	Ellinwood	21.2	177	28	60.1	125	49.7	135	154	81.8	96.9	125
Haw Ranch	Turon	47.3	198	46.5	21.6	142	97.1	182	202	136	68.8	142
Golden Belt	Lyons	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146
Dudrey Catt	Saint John	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122
Golden Belt	Saint John	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122
Golden Belt	Kinsley	96.9	223	43.1	57.8	82	96.7	131	150	141	120	82
Great Bend	Great Bend	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116
Knight Feed	Lyons	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146
Mull Farms	Pawnee Roc	45.8	189	28.2	60.3	101	54.4	130	150	93.7	121	101
Heritage Fe	Larned	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6
Pratt Feede	Pratt	81.3	255	39.3	4	121	90	175	194	129	89.9	121
Quality Fee	Great Bend	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116
Sellers Fee	Lyons	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146
Smoky Hill	Falun	45	120	86.4	115	184	89.4	174	194	84.2	73.6	184
Ward Feed	Larned	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6
Zimm's Fee	Sterling	9	175	36.5	59.6	156	79.9	165	184	75.3	62.6	156
2K Feeders	Burns	100	134	138	127	247	170	255	275	165	54.3	247
Haw Ranch	Potwin	84.9	185	119	112	233	155	240	259	150	25.8	233
Cow Camp	Ramona	78.5	103	127	162	224	117	202	222	112	73.7	224
Tiffany Catt	Herington	90.7	95.2	165	161	262	137	222	242	132	73	262
Handke Far	Muscotah	222	102	249	267	346	221	224	325	215	191	346
Kansas Stat	Manhattan	137	69.3	163	195	261	135	220	240	130	122	261
Neosho Val	Parsons	215	273	239	208	328	285	370	389	280	150	328
Ottawa Cou	Minneapolis	87.6	82.1	114	147	212	86.7	140	191	47.5	99	212
Palenske R	Strong City	114	148	152	156	260	184	270	289	179	68.4	260
Peddicord I	Wamego	154	83.6	181	213	278	153	238	258	148	140	278
Porter Catt	Reading	151	185	188	182	303	207	292	311	202	105	303

Indices:

i = Ethanol Plants

j = Feed Lots

Data:

a_i = supply of distillers of ethanol plant i (in MPY)

b_j = demand for commodity at market feedlot j (in MPY)

p_{ij} = profit per unit shipment between plant i and market j ($/mile)

Decision Variable:

X_{ij} = amount of distillers to shipped from ethanol plant i to feedlot point j, where $X_{ij} \geq 0$, for all i, j

Constraints:

$$\sum_{i=1}^{n} X_{ij} \leq a_i \qquad \text{for } i = 1,\ldots,n$$

$$\sum_{j=1}^{m} X_{ij} \leq b_j \qquad \text{for } j = 1,\ldots,m$$

Objective Function:

$$\text{Max} \sum_{i=1}^{n} \sum_{j=1}^{m} P_{ij} X_{ij} \qquad \text{for i} = 1,\ldots,n \quad \& \quad \text{j} = 1,\ldots,m$$

The amount of distillers shipped from ethanol plants to feedlots is dependent on the capacity of the plants and the requirements for distillers at the feedlots. Altogether, the distillers' requirements at feedlots are higher than the capacity of ethanol plants in both cases of wet and dry distillers. This shows that all distillers produced in existing ethanol plants in Kansas can be easily utilized.

Following the model parameters described above, the objective function and constraints associated in using the models for the distribution of distillers will be described. The results of the models will then be presented and discussed in detail.

Objective Function:

A profit-maximization linear programming model will be used. In assigning an ethanol plant to each feedlot, the result should give the optimal solution, which means the minimum cost a feedlot should absorb in purchasing distillers from available ethanol plants. In other words, this will maximize the profit of distributing or selling distillers to feedlots.

Constraints:

There are two sets of constraints: First, it is known that the demand of distillers is higher than the supply in Kansas. This condition must be considered when using the linear programming model. Second, it is known that it not possible to produce more than the available production capacity of the ethanol plants. More constraints will be incorporated when considering different scenarios.

Following a discussion of the model parameters, objective functions, and constraints, the transportation assignment model will be used for 100 percent DDGS and 100 percent WDGS distribution planning.

4.2.1 Distributing 100 Percent Dry Distillers

Considering the situation when ethanol plants are supplying 100 percent of dry distillers, this model will suggest how much profit will be made and which ethanol plant(s) should supply which feedlot point(s) to maximize the profit of the entire distribution network.

Profit Calculation:

In simple terms, profit of an ethanol plant should satisfy the following equation:

Profit = Selling Price – (Transportation Cost + Drying Cost + Miscellaneous Cost)

Selling Price: The selling price (SP) of dry distillers ranges from $155 to $195/0.9 DM ton in Kansas in 2008 (http://www.ams.usda.gov/mnreports/sj_gr225.txt). The highest, lowest, and average values will be used in the distribution models.

Transportation Cost: Based on correspondence with ethanol plants in Kansas, the conclusion was reached that the most common capacity used for truck transportation is 25 tons. Trucking cost ranges from $3.00 per ton to as high as $6.00 per ton (two ways).

Drying Cost: According to the data provided by ICM Inc., we are using $239 per truck (25-ton) is used.

Miscellaneous Cost: Various costs are incurred during the handling and storage of dry distillers. A fixed value of $100 per truck for a 25-ton capacity truck is assumed.

4.2.1.1 Dry Distillers at $155 Per Ton

This scenario tests the model when dry distillers are priced at $155 per ton. Here three cases are possible. First, when the transportation cost is $3 per mile, second when the transportation cost is $3.5 per mile, and third when the transportation cost is increased to $4 per mile. As mentioned in the last chapter, $3.5 per mile is the average transportation cost of trucks in 2007. The other two costs are used to observe the results and sensitivity of the model.

Case 1: Transportation Cost of $3 Per Ton Per Mile

This situation is when the transportation cost is at the lowest level. The model will reveal how much profit the supply chain will make if 100 percent of dry distillers are used. The model can be modified as follows:

Selling Price: $155*25 = $3,875/truck

Drying Cost: $9.56*25 = $239/truck

Freight Cost: $3.00 per truck per mile (two ways)

Miscellaneous Cost: $100 per truck

The profit equation can be written as

$$P_{ji} = S.P - (3*d_{ji} + 239 + 100)$$

while the objective function and other constraints remain the same as mentioned in the above discussion.

The total capacity of ethanol plants to supply dry distillers is 3,432 million pounds per year and total demand in feedlots is 3,886 million lbs per year, which shows that the availability of distillers in Kansas is insufficient to satisfy the demand of distillers at the feedlot points. The optimal solution found at $11,191,533 per year, which means that ethanol plants will be able to make this amount of profit per year by selling distillers to feedlot.

Case 2: Transportation Cost of $3.50 or $4.00 Per Ton Per Mile

What if the transportation cost changes? Does it affect the ethanol supply chain profit? What changes does it bring in the assigning distillers? The profit equations can be modified as follows:

$$P_{ji} = \text{S.P} - (3.5*d_{ji} + 239 + 100) \text{ (when transportation cost = \$3.5 per ton per mile)}$$

$$P_{ji} = \text{S.P} - (4*d_{ji} + 239 + 100) \text{ (when transportation cost = \$4 per ton per mile)}$$

In this case, the optimal solutions are found at $11,032,900 per year and $10,874,267 per year, respectively.

4.2.1.2 Dry Distillers at $175 Per Ton

All formulations will remain the same for this scenario, but the selling price will be calculated as follows:

Selling Price: $175*25 = $4375/truck

4.2.1.3 Dry Distillers at $195 per ton

In this case, the selling price will be as follows:

Selling Price: 195*25 = $4875 / truck

The results of this distribution model are presented in Table 37. This table proves that plants can only produce 3,434 MPY of dry distillers, whereas the total demand is 3,886 MPY, which means that only 88 percent of the demand can be satisfied. The results also show that out of 95 feeders, only 9 are unable to satisfy their demands. In other words, 90 percent of feeders are able to satisfy their 100 percent demand, i.e., there is no partially satisfied feedlot.

It is also interesting to know to what extent ethanol plants were able to satisfy demands. Table 38 summarizes this information in miles. The yellow highlighted areas are those points that have been satisfied by corresponding ethanol plants. Table 38 shows that in order to maximize profit, ethanol plants are satisfying only those feedlots that are closer to them. The largest distance over which an ethanol plant has satisfied a customer is 201 miles, which is Neosho Valley Feeders, satisfied by MPG ingredients.

In order to maximize profit, ethanol plants were unable to satisfy the demands for 5N feeders, Miller Feedyard, River Bend Feedyard, Sunbelt feeders, Syracuse Feedyard, Ulysses Feedyard 1, Ulysses Feedyard 2, Western Feedyard, and Winger Feedyard. Most of these feeders are in Ulysses and Johnson counties. Therefore, these feedlots are forced to rely on corn or soybean feeds.

TABLE 37

DRY DISTILLERS DISTRIBUTION IN KANSAS

	Kansas Ethanol	Nesika E	Arkalon	Gatewa	Bonanaz	US Ener	Prairie Hori	Western F	East Kansas .	Abengoa	Reeve Agri-E	MGP Ingre	ESE Alcohol
Feedlots	Republic	Washingt	Seward	Pratt	Garden C	Russel	Phillipsburg	Sheridan	Grant	Sedgwic	Garden city	Atchison	Wichita
	352.8	64.8	702	548.8	352.8	309.6	257.4	289.8	225	160.2	97.2	64.8	9
Century Feeders							17.62						
David Ranch & Feedlot							5.29						
Decatur County Feed Yard							67						
Hays Feeders, LLC						38.79							
Jewell County Feeders, LLC		8.8											
MP&K Land and Livestock		5.64											
Rooks County Feeders									14.1				
Solomon Valley Feeders									29.97				
T Bone Feeders							11.46						
Thomas County Feeders							31.73						
Valley Feeds, Inc							14.1						
Beef Belt Feedlot, Inc							21.15						
Brookover Cattle Company							31.26						
Cadillac Feeders						2.15	4.9						
Cargill Cattle Feeders, LLC								220.37					
Cutler Cattle Company						10.58							
Fairleigh Feed Yards, Inc						66.31		13.02					
Doornbos Cattle Co								3.52					
H R C Feedyard, Inc								52.89					
Hess Cattle Company, Inc						4.23							
KFY-Division of Beef Belt Feeders						10.58							
Lane County Feeders, Inc	74.04												
Ox Town Cattle Feeders, LLC													
Pawnee Valley Feeders, Inc	19.23								16.06				
Pioneer, Inc							52.89						
Poky Feeders, Inc						61.35							
Ranger Feeders	17.8												
Royal Beef/Division of Irsik & Doll						70.5							
Hay Hook Cattle Company, LLC	17.63												
Stampede Feeders						17.63							
5N Feeders, Inc													
Bartlett III	52.89												
Brookover Feedyard	6.59										72.74		
Brookover Ranch Feed Yard, LLC					37.24						24.46		
Cattle Empire, L.L.C	5.08		245										
Garden City Feedyard, LLC					158.66								
G & G Cattle, Inc	5.29												
Hitch Feeders II, Inc					88.14								
J O Cattle Company	3.53												
Miller Feedyard													
River Bend Feed Yard, Inc													
Heritage Feeders Sublette			88.15										
Sunbelt Feeders, Inc													
Supreme Cattle Feeders, LLC				123.4									
Syracuse Feed Yard													
Triangle H Grain & Cattle					7.06								
Ulysses Feed Yard													
Ulysses Feed Yard													
Western Feed Yard, Inc													
Winger Feedyard, Inc													
Beefland					61.7								
Boot Hill Feeders, Inc	29.97												
Cimarron Feeders of Kansas, L.L.C			35.26										
Dewey Feedyard			8.81										
Clark County Feedyard				22.03									
DM&M Farms, Inc			35.36										
Ford County Feed Yard, Inc				91.63									
Fowler Feeders				26.44									
Gray County Feedyard			52.88										
Hy-Plains Feedyard, LLC				88.14									
Ingalls Feedyard, Inc			28.02	42.48									
Irsik & Doll Feed Yard			52.89										
Meade County Feeders, L.L.C				17.63									
Meade County Feeders II				7.76									
Midwest Feeders, Inc			35.26										

Pratt Feeders, Inc. dba Ashland Feeders				70.52									
Sublette Feeders			74.04										
Wilroads Feed Yard	20.2												
Barton County Feeders	35.2												
Haw Ranch Feedlot, LLC										52.89			
Golden Belt Feeders	10.58												
Dudrey Cattle Company										8.81			
Golden Belt Feeders										37.02			
Golden Belt Feeders-Kinsley LLC			46.94							11.24			
Great Bend Feeding, Inc						14.09			33.51				
Knight Feedlot	28.2												
Mull Farms & Feeding, Inc.									22.9				
Heritage Feeders Larned									52.89				
Pratt Feeders, LLC				58.77									2.05
Quality Feeders, Inc						13.39							
Sellers Feedlot	21.15												
Smoky Hill Feeders, Inc		2.6							11.5				
Ward Feed Yard, Inc									44.07				
Zimm's Feedlot	5.29												
2K Feeders										6.17			
Haw Ranch Feedlot II, LLC										44.07			
Cow Camp Feedyard, Inc		8.63											
Tiffany Cattle Company		22.03											
Handke Farms, Inc												7.93	
KSU Deppt of Animal Sc. & Industry		3											
Neosho Valley Feeders												25.67	6.95
Ottawa County Feeders, Inc		14.1											
Palenske Ranch, Inc												14.99	
Peddicord Land & Cattle Co., Inc												7.4	
Porter Cattle Co												8.81	

4.2.2 Distributing 100 Percent Wet Distillers

Distillers can also be sold in wet form, and debate is ongoing among researchers about whether to sell it in dry or wet form. Some claim that distillers should be sold in wet form to reduce drying costs, thus resulting in higher profits. Some argue that dry distillers are more feasible for storage and transporting at longer distances. The better answer to this question is only possible following analysis and comparison of the profit made by selling these distillers in multiple suppliers and multiple consumers' environment. The previous discussion analyzed the situation when 100 percent of dry distillers was produced and distributed. Now discussion will focus on the effect on the distribution network and its profit when 100 percent of wet distillers is produced and supplied.

The model will be tested for all three cases, as done in the previous section (100 percent DDGS case). A WDGS cost of \$155 per ton, \$175 per ton, and \$195 per ton will be used in the models.

TABLE 38

DISTANCE SHIPPED FROM ETHANOL PLANT TO FEEDLOT BY DDGS

Feedlots	Rice	Washington	Seward	Pratt	Finney	Russell	Phillipsburg	Sheridan	Grant	Sedgwick	Finney	Atchison	Wichita
Century Feeders	238	279	225	257	157	170	156	73.3	215	314	157	396	325
David Ranch & Feedlot	177	175	164	196	171	110	52.7	39.9	125	253	171	296	264
Decatur County Feed Yard	213	189	200	232	158	145	66.2	37.8	166	289	158	309	299
Hays Feeders, LLC	97.6	192	84.6	117	128	29.9	63.9	81.9	74.6	173	128	255	184
Jewell County Feeders, LL	164	62.8	141	173	249	97.4	59.9	146	68.2	175	249	183	186
MP&K Land and Livestock	185	83.6	139	171	233	81.1	43.7	130	59.4	196	233	204	207
Rooks County Feeders	118	158	105	137	153	50.5	37.6	104	63.2	194	153	276	205
Solomon Valley Feeders	83.7	85.2	114	146	211	82.3	87.3	187	40.8	140	211	206	150
T Bone Feeders	238	279	225	257	157	170	156	73.3	215	314	157	396	325
Thomas County Feeders	202	239	189	221	121	134	117	33.7	179	277	121	360	288
Valley Feeds, Inc	177	144	164	196	214	109	21.4	76.2	122	253	214	264	264
Beef Belt Feedlot, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Brookover Cattle Company	150	319	137	164	52	157	172	84	202	301	52	383	242
Cadillac Feeders	150	319	137	164	52	157	172	84	202	301	52	383	242
Cargill Cattle Feeders, LLC	175	344	161	188	76.3	182	197	108	226	325	76.3	407	266
Cutler Cattle Company	150	319	137	164	52	157	172	84	202	301	52	383	242
Fairleigh Feed Yards, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Doornbos Cattle Co	150	319	137	164	52	157	172	84	202	301	52	383	242
H R C Feedyard, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Hess Cattle Company, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
KFY-Division of Beef Belt F	150	319	137	164	52	157	172	84	202	301	52	383	242
Lane County Feeders, Inc	127	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Ox Town Cattle Feeders, L	197	366	183	214	102	204	208	130	248	347	102	429	292
Pawnee Valley Feeders, In	89.2	233	56.2	102	57.6	99.6	134	123	144	165	57.6	296	176
Pioneer, Inc	181	275	168	200	97.5	113	126	39.9	158	256	97.5	339	267
Poky Feeders, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Ranger Feeders	127	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Royal Beef/Division of Irsik	150	319	137	164	52	157	172	84	202	301	52	383	242
Hay Hook Cattle Company,	70.1	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Stampede Feeders	150	319	137	164	52	157	172	84	202	301	52	383	242
5N Feeders, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Bartlett III	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Brookover Feedyard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Brookover Ranch Feed Yar	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Cattle Empire, L.L.C	175	319	139	145	53.9	207	252	164	251	234	53.9	382	223
Garden City Feedyard, LLC	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
G & G Cattle, Inc	164	360	142	138	25.7	198	213	125	243	227	25.7	424	216
Hitch Feeders II, Inc	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
J O Cattle Company	164	360	142	138	25.7	198	213	125	243	227	25.7	424	216
Miller Feedyard	175	319	139	145	53.9	207	252	164	251	234	53.9	382	223
River Bend Feed Yard, Inc	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Heritage Feeders Sublette	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Sunbelt Feeders, Inc	203	347	195	156	82.1	235	284	196	280	246	82.1	424	234
Supreme Cattle Feeders, L	197	341	172	133	80.9	215	249	191	260	223	80.9	401	211
Syracuse Feed Yard	206	402	183	180	67.6	240	255	167	285	269	67.6	465	258
Triangle H Grain & Cattle	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Ulysses Feed Yard	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Ulysses Feed Yard	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Western Feed Yard, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Winger Feedyard, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Beefland	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Boot Hill Feeders, Inc	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5	323	153
Cimarron Feeders of Kans	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Dewey Feedyard	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Clark County Feedyard	137	280	112	72.5	67	154	188	163	199	162	67	340	150
DM&M Farms, Inc	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Ford County Feed Yard, Inc	123	267	96.8	57.7	63.2	141	175	149	186	147	63.2	325	136
Fowler Feeders	148	292	123	84	78.5	166	200	174	210	174	78.5	352	162
Gray County Feedyard	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Hy-Plains Feedyard, LLC	143	287	107	102	39	161	195	166	205	192	39	350	180
Ingalls Feedyard, Inc	140	284	104	100	21.4	158	192	148	203	190	21.4	347	178
Irsik & Doll Feed Yard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Meade County Feeders, L.	158	302	133	94.2	63.2	176	210	201	221	184	63.2	362	172

Meade County Feeders II	158	302	133	94.2	63.2	176	210	201	221	184	63.2	362	172
Midwest Feeders, Inc	140	284	104	100	21.4	158	192	148	203	190	21.4	347	178
Pratt Feeders, Inc. dba Asl	163	307	121	82	96.8	172	209	192	211	172	96.8	350	160
Sublette Feeders	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Wilroads Feed Yard	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5	323	153
Barton County Feeders	21.2	177	28	60.1	125	49.7	135	154	81.8	96.9	125	241	108
Haw Ranch Feedlot, LLC	47.3	198	46.5	21.6	142	97.1	182	202	136	68.8	142	261	72.2
Golden Belt Feeders	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Dudrey Cattle Company	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122	264	96.9
Golden Belt Feeders	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122	264	96.9
Golden Belt Feeders-Kinsl	96.9	223	43.1	57.8	82	96.7	131	150	141	120	82	286	136
Great Bend Feeding, Inc	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116	239	118
Knight Feedlot	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Mull Farms & Feeding, Inc.	45.8	189	28.2	60.3	101	54.4	130	150	93.7	121	101	253	132
Heritage Feeders Larned	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6	263	142
Pratt Feeders, LLC	81.3	255	39.3	4	121	90	175	194	129	89.9	121	268	78.2
Quality Feeders, Inc	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116	239	118
Sellers Feedlot	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Smoky Hill Feeders, Inc	45	120	86.4	115	184	89.4	174	194	84.2	73.6	184	183	84.4
Ward Feed Yard, Inc	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6	263	142
Zimm's Feedlot	9	175	36.5	59.6	156	79.9	165	184	75.3	62.6	156	238	72.9
2K Feeders	100	134	138	127	247	170	255	275	165	54.3	247	162	49.6
Haw Ranch Feedlot II, LLC	84.9	185	119	112	233	155	240	259	150	25.8	233	171	35.2
Cow Camp Feedyard, Inc	78.5	103	127	162	224	117	202	222	112	73.7	224	154	84.5
Tiffany Cattle Company	90.7	95.2	165	161	262	137	222	242	132	73	262	143	83.8
Handke Farms, Inc	222	102	249	267	346	221	224	325	215	191	346	22.3	190
Kansas State University De	137	69.3	163	195	261	135	220	240	130	122	261	107	133
Neosho Valley Feeders	215	273	239	208	328	285	370	389	280	150	328	201	130
Ottawa County Feeders, In	87.6	82.1	114	147	212	86.7	140	191	47.5	99	212	181	110
Palenske Ranch, Inc	114	148	152	156	260	184	270	289	179	68.4	260	125	79.2
Peddicord Land & Cattle C	154	83.6	181	213	278	153	238	258	148	140	278	87.2	151
Porter Cattle Co	151	185	188	182	303	207	292	311	202	105	303	107	105

4.2.2.1 WDGS at $155 Per Ton

The first case assumes that wet distillers sell at $155 per ton. Model parameters will be modified to accommodate this price. In the case of wet distillers, the profit equation should be modified as follows:

Profit Calculation:

Profit = Selling Price – (Transportation Cost + Miscellaneous Cost)

Transportation Cost: The truck capacity used in this calculation is 25 tons, and the cost per mile varies depending on gas prices.

Miscellaneous Cost: Various handling cost incur during handling and storage of wet distillers. We assume a fixed value of $100 per truck for 25-ton capacity truck.

Drying Cost: No drying cost is involved.

Case 1: Transportation Cost of $3 Per Ton Per Mile

When transportation costs are at the lowest level, the model will reveal how much profit the supply chain will make if they produce 100 percent wet distillers. The model equations must be modified to accommodate this price by calculating the equivalent selling price of the WDGS when DDGS is priced at $155 per ton. The model can be modified as follows:

Equivalent Selling Price at the Plant:	($155 – 9.56)/3 = $48.48 per ton
Selling Price Per Truck:	48.48*25 = $1,212/truck
Freight Cost:	$3 per truck per mile (two ways)
Miscellaneous Cost:	$100 per truck

The profit equation can be written as follows:

$$P_{ji} = \text{SP of equivalent 90\% DM} - (3*3*d_{ji} + 239 + 100)$$

or

$$P_{ji} = 3(\text{SP of WDGS} - 3*d_{ji} + 239 + 100)$$

One ton of DDGS is equivalent to three tons of WDGS to have the same dry matter content (90 percent). The entire equation is multiplied by three to compare the profit at the same dry matter content level, as shown above, while the objective function and other constraint remain the same as mentioned in the above discussion.

The total capacity of ethanol plants to supply wet distillers and the total demand at feedlots can be calculated. Since one bushel of corn produces 18 pounds of dry distillers and 40 pounds of wet distillers, the demand of wet distillers will be 2.222 *3432 = 7,630 million pounds per year. The inclusion rate of WDGS from the previous discussion is 15.5 pounds per day. So the total demand per year would be total head of cattle*15.5*365/1,000,000 million pounds per year, which equals 12,470 MPY per year. The data shows that ethanol plants supplying wet distillers can only satisfy 61 percent of the total demand in Kansas.

When the program to maximize profit of ethanol plants is run, the optimal solution is found at $11,143,902 per year.

Case 2: Transportation Cost $3.5 or $4 Per Truck Per Mile

It the last section, the total profit of wet distillers at a transportation cost $3 per truck per mile was analyzed. The same model will be run at other transportation price levels and the total profit will observed. For $3.5 per mile and $4 per mile, the profit equation can be modified as follows:

$$P_{ji} = 3(\text{S.P of WDGS} - 3.5*d_{ji} + 239 + 100)$$

$$P_{ji} = 3(\text{S.P of WDGS} - 4*d_{ji} + 239 + 100)$$

In this case, the optimal solution is found at $10417,827 per year and $10,781,446 per year, respectively. It can be observed that the total profit of wet distillers has been reduced. The results verify that when transportation costs increase, ethanol suppliers make less money.

4.2.2.2 WDGS at $175 Per Ton

All formulations will remain same but the selling price will be calculated as follows:

Equivalent Selling Price Per Ton: (175-9.56)/3 = $55.14/ton

Equivalent Selling Price Per Truck: 55.14*25 = $1,378 per truck

4.2.2.3 WDGS at $195 Per Ton

In this case the selling price will be as follows:

Equivalent Selling Price Per Ton: (195-9.56)/3 = $61.81/ton

Equivalent Selling Price Per Truck: 61.81*25 = $1,545 per truck

Results for this scenario are shown in Appendix A.

Out of 95 feedlots, 23 of them were either partially satisfied or not satisfied. In other words, 24 percent of the feeders were not able to satisfy 100 percent of the demand from available ethanol capacity. Since the total demand of a feedlot is 12,470 MPY and the available capacity is 7,631 MPY, only 62 percent of the demand for distillers can be satisfied. Table 39 shows that only the demand of Royal Beef feeders and Hitch feeders were partially filled, whereas all others in the list satisfy zero percent of the demand. In order to know how much distillers each ethanol plant has shipped and the maximum distance among all ethanol plants, table 40 is prepared. An analysis on table 40 is presented in the following pages.

TABLE 39

FEEDLOT DEMAND NOT SATISFIED

	Kansas Ethanol	Nesika Energy	Arkalon	Gatewa	Bonanaz	US Ener	Prairie Hori	Western F	East Kansas	Abengoa	Reeve Agri-E	MGP Ingre	ESE Alcohol
Feedlots	Republic	Washington	Seward	Pratt	Garden C	Russel	Phillipsburg	Sheridan	Grant	Sedgwic	Garden city	Atchison	Wichita
	784	144	1560	1219.6	784	688	572	644	500	356	216	144	20
Century Feeders							56.57						
David Ranch & Feedlot							16.9						
Decatur County Feed Yard							214.98						
Hays Feeders, LLC						124.46							
Jewell County Feeders, LLC		28.2											
MP&K Land and Livestock									18.1				
Rooks County Feeders									45.26				
Solomon Valley Feeders									96.17				
T Bone Feeders							36.77						
Thomas County Feeders							101.8						
Valley Feeds, Inc							45.26						
Beef Belt Feedlot, Inc								67.9					
Brookover Cattle Company								113.15					
Cadillac Feeders								22.63					
Cargill Cattle Feeders, LLC													
Cutler Cattle Company								33.94					
Fairleigh Feed Yards, Inc								254.6					
Doornbos Cattle Co								11.31					
H R C Feedyard, Inc						99.23		70.49					
Hess Cattle Company, Inc						13.6							
KFY-Division of Beef Belt Feeders						33.94							
Lane County Feeders, Inc	237.6												
Ox Town Cattle Feeders, LLC													
Pawnee Valley Feeders, Inc			113.15										
Pioneer, Inc							99.72	69.98					
Poky Feeders, Inc						196.9							
Ranger Feeders	56.5												
Royal Beef/Division of Irsik & Doll						137.51							
Hay Hook Cattle Company, LLC	56.5												
Stampede Feeders													
5N Feeders, Inc													
Bartlett III													
Brookover Feedyard					38.6						216		
Brookover Ranch Feed Yard, LLC					198.01								
Cattle Empire, L.L.C													
Garden City Feedyard, LLC					509.17								
G & G Cattle, Inc													
Hitch Feeders II, Inc					38.22								
J O Cattle Company													
Miller Feedyard													
River Bend Feed Yard, Inc													
Heritage Feeders Sublette													
Sunbelt Feeders, Inc													
Supreme Cattle Feeders, LLC													
Syracuse Feed Yard													
Triangle H Grain & Cattle													
Ulysses Feed Yard													
Ulysses Feed Yard													
Western Feed Yard, Inc													
Winger Feedyard, Inc													
Beefland													
Boot Hill Feeders, Inc			96.2										
Cimarron Feeders of Kansas, L.L.C			113										
Dewey Feedyard			28.3										
Clark County Feedyard				70.7									
DM&M Farms, Inc			113.1										
Ford County Feed Yard, Inc				294.2									
Fowler Feeders				84.9									
Gray County Feedyard			169.7										
Hy-Plains Feedyard, LLC			16.67	266.23									
Ingalls Feedyard, Inc			226.3										
Irsik & Doll Feed Yard													
Meade County Feeders, L.L.C				56.58									
Meade County Feeders II				24.89									
Midwest Feeders, Inc			113.15										

Pratt Feeders, Inc. dba Ashland Feeders				226.3									
Sublette Feeders													
Wilroads Feed Yard			65.1										
Barton County Feeders	113.1												
Haw Ranch Feedlot, LLC	33.61									136.19			
Golden Belt Feeders	33.9												
Dudrey Cattle Company			28.3										
Golden Belt Feeders			118.8										
Golden Belt Feeders-Kinsley LLC			186.7										
Great Bend Feeding, Inc	76.65					39.36			36.79				
Knight Feedlot	90.52												
Mull Farms & Feeding, Inc.									73.54				
Heritage Feeders Larned			30.1						139.62				
Pratt Feeders, LLC				195.2									
Quality Feeders, Inc						43							
Sellers Feedlot	68												
Smoky Hill Feeders, Inc									45.26				
Ward Feed Yard, Inc			141.43										
Zimm's Feedlot	16.98												
2K Feeders										19.8			
Haw Ranch Feedlot II, LLC										141.43			
Cow Camp Feedyard, Inc		27.72											
Tiffany Cattle Company		70.7											
Handke Farms, Inc												25.46	
KSU Deppt. of Animal Sc. & Industry		9.6											
Neosho Valley Feeders									45.26	10.48		74.18	20
Ottawa County Feeders, Inc													
Palenske Ranch, Inc										48.1			
Peddicord Land & Cattle Co., Inc		7.69										16.07	
Porter Cattle Co												28.29	

Table 40 presents a complete distance analysis, showing how far an ethanol plant was able to ship to maximize its profit. The maximum distance in the table is 280 miles, which means that up to 280 miles, the WDGS can be served from ethanol plants to feedlots. This is the Neosho plant served by the East Kansas ethanol plant.

TABLE 40

DISTANCE SHIPPED FROM ETHANOL PLANT TO FEEDLOT BY WDGS

	Kansas Etha	Nesika Energ	Arkalon Ener	Gateway Eth	Bonanaza Bi	US Energy P	Prairie Horizo	Western Plai	East Kansas	Abengoa Bio	Reeve Agri-E	MGP Ingredie	ESE Alcohol
Feedlots	Rice	Washington	Seward	Pratt	Finney	Russell	Phillipsburg	Sheridan	Grant	Sedgwick	Finney	Atchison	Wichita
Century Feeders	238	279	225	257	157	170	156	73.3	215	314	157	396	325
David Ranch & Feedlot	177	175	164	196	171	110	52.7	39.9	125	253	171	296	264
Decatur County Feed Yard	213	189	200	232	158	145	66.2	37.8	166	289	158	309	299
Hays Feeders, LLC	97.6	192	84.6	117	128	29.9	63.9	81.9	74.6	173	128	255	184
Jewell County Feeders, LL(	164	62.8	141	173	249	97.4	59.9	146	68.2	175	249	183	186
MP&K Land and Livestock	185	83.6	139	171	233	81.1	43.7	130	59.4	196	233	204	207
Rooks County Feeders	118	158	105	137	153	50.5	37.6	104	63.2	194	153	276	205
Solomon Valley Feeders	83.7	85.2	114	146	211	82.3	87.3	187	40.8	140	211	206	150
T Bone Feeders	238	279	225	257	157	170	156	73.3	215	314	157	396	325
Thomas County Feeders	202	239	189	221	121	134	117	33.7	179	277	121	360	288
Valley Feeds, Inc	177	144	164	196	214	109	21.4	76.2	122	253	214	264	264
Beef Belt Feedlot, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Brookover Cattle Company	150	319	137	164	52	157	172	84	202	301	52	383	242
Cadillac Feeders	150	319	137	164	52	157	172	84	202	301	52	383	242
Cargill Cattle Feeders, LLC	175	344	161	188	76.3	182	197	108	226	325	76.3	407	266
Cutler Cattle Company	150	319	137	164	52	157	172	84	202	301	52	383	242
Fairleigh Feed Yards, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Doornbos Cattle Co	150	319	137	164	52	157	172	84	202	301	52	383	242
H R C Feedyard, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Hess Cattle Company, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
KFY-Division of Beef Belt Fe	150	319	137	164	52	157	172	84	202	301	52	383	242
Lane County Feeders, Inc	127	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Ox Town Cattle Feeders, LL	197	366	183	214	102	204	208	130	248	347	102	429	292
Pawnee Valley Feeders, Inc	89.2	233	56.2	102	57.6	99.6	134	123	144	165	57.6	296	176
Pioneer, Inc	181	275	168	200	97.5	113	126	39.9	158	256	97.5	339	267
Poky Feeders, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Ranger Feeders	127	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Royal Beef/Division of Irsik &	150	319	137	164	52	157	172	84	202	301	52	383	242
Hay Hook Cattle Company, L	70.1	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Stampede Feeders	150	319	137	164	52	157	172	84	202	301	52	383	242
5N Feeders, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Bartlett III	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Brookover Feedyard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Brookover Ranch Feed Yard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Cattle Empire, L.L.C	175	319	139	145	53.9	207	252	164	251	234	53.9	382	223
Garden City Feedyard, LLC	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
G & G Cattle, Inc	164	360	142	138	25.7	198	213	125	243	227	25.7	424	216
Hitch Feeders II, Inc	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
J O Cattle Company	164	360	142	138	25.7	198	213	125	243	227	25.7	424	216
Miller Feedyard	175	319	139	145	53.9	207	252	164	251	234	53.9	382	223
River Bend Feed Yard, Inc	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Heritage Feeders Sublette	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Sunbelt Feeders, Inc	203	347	195	156	82.1	235	284	196	280	246	82.1	424	234
Supreme Cattle Feeders, LI	197	341	172	133	80.9	215	249	191	260	223	80.9	401	211
Syracuse Feed Yard	206	402	183	180	67.6	240	255	167	285	269	67.6	465	258
Triangle H Grain & Cattle	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Ulysses Feed Yard	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Ulysses Feed Yard	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Western Feed Yard, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Winger Feedyard, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Beefland	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Boot Hill Feeders, Inc	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5	323	153
Cimarron Feeders of Kansa	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Dewey Feedyard	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Clark County Feedyard	137	280	112	72.5	67	154	188	163	199	162	67	340	150
DM&M Farms, Inc	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Ford County Feed Yard, Inc	123	267	96.8	57.7	63.2	141	175	149	186	147	63.2	325	136
Fowler Feeders	148	292	123	84	78.5	166	200	174	210	174	78.5	352	162
Gray County Feedyard	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Hy-Plains Feedyard, LLC	143	287	107	102	39	161	195	166	205	192	39	350	180
Ingalls Feedyard, Inc	140	284	104	100	21.4	158	192	148	203	190	21.4	347	178
Irsik & Doll Feed Yard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Meade County Feeders, L.L	158	302	133	94.2	63.2	176	210	201	221	184	63.2	362	172

Meade County Feeders II	158	302	133	94.2	63.2	176	210	201	221	184	63.2	362	172
Midwest Feeders, Inc	140	284	104	100	21.4	158	192	148	203	190	21.4	347	178
Pratt Feeders, Inc. dba Ashl	163	307	121	82	96.8	172	209	192	211	172	96.8	350	160
Sublette Feeders	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Wilroads Feed Yard	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5	323	153
Barton County Feeders	21.2	177	28	60.1	125	49.7	135	154	81.8	96.9	125	241	108
Haw Ranch Feedlot, LLC	47.3	198	46.5	21.6	142	97.1	182	202	136	68.8	142	261	72.2
Golden Belt Feeders	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Dudrey Cattle Company	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122	264	96.9
Golden Belt Feeders	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122	264	96.9
Golden Belt Feeders-Kinsley	96.9	223	43.1	57.8	82	96.7	131	150	141	120	82	286	136
Great Bend Feeding, Inc	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116	239	118
Knight Feedlot	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Mull Farms & Feeding, Inc.	45.8	189	28.2	60.3	101	54.4	130	150	93.7	121	101	253	132
Heritage Feeders Larned	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6	263	142
Pratt Feeders, LLC	81.3	255	39.3	4	121	90	175	194	129	89.9	121	268	78.2
Quality Feeders, Inc	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116	239	118
Sellers Feedlot	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Smoky Hill Feeders, Inc	45	120	86.4	115	184	89.4	174	194	84.2	73.6	184	183	84.4
Ward Feed Yard, Inc	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6	263	142
Zimm's Feedlot	9	175	36.5	59.6	156	79.9	165	184	75.3	62.6	156	238	72.9
2K Feeders	100	134	138	127	247	170	255	275	165	54.3	247	162	49.6
Haw Ranch Feedlot II, LLC	84.9	185	119	112	233	155	240	259	150	25.8	233	171	35.2
Cow Camp Feedyard, Inc	78.5	103	127	162	224	117	202	222	112	73.7	224	154	84.5
Tiffany Cattle Company	90.7	95.2	165	161	262	137	222	242	132	73	262	143	83.8
Handke Farms, Inc	222	102	249	267	346	221	224	325	215	191	346	22.3	190
Kansas State University Dep	137	69.3	163	195	261	135	220	240	130	122	261	107	133
Neosho Valley Feeders	215	273	239	208	328	285	370	389	280	150	328	201	130
Ottawa County Feeders, Inc	87.6	82.1	114	147	212	86.7	140	191	47.5	99	212	181	110
Palenske Ranch, Inc	114	148	152	156	260	184	270	289	179	68.4	260	125	79.2
Peddicord Land & Cattle Co.	154	83.6	181	213	278	153	238	258	148	140	278	87.2	151
Porter Cattle Co	151	185	188	182	303	207	292	311	202	105	303	107	105

4.3 Distribution Design with Dry and Wet Distillers

Discussion has been presented for both scenarios when dry and wet distillers are supplied either in 100 percent DDGS or 100 percent WDGS form. Practically, ethanol plants may earn better revenue if they produce wet and dry distillers in proportion, rather than selling in 100 percent dry and 100 percent wet distillers form. Finding the optimal ratio of dry and wet distillers that maximizes the profit of ethanol plants is the next goal. The last chapter provides breakeven points depending on truck capacity and transportation cost, which are based on the single-commodity model in which it is assumed that ethanol plants can only sell distillers in either wet or dry form. This section aims to develop a multi-commodity model, which will ensure that both forms of distillers can be sold to feedlots at the same time. This model will maximize the profits of suppliers of distillers. After formulating the model, a detailed output analysis will be provided and results will be compared to the single-commodity models presented in previous sections.

4.3.1 Formulation

First, the model and its parameters will be formulated. Since we are producing both wet and dry distillers will be produced, both forms must be incorporated into the model. Subscripts *w* and *d* are used to denote wet and dry distillers, respectively. Both capacity and demand constraints can be written as

$$\sum_{j=1}^{100} (X_{ij}^{d} + 0.45 * X_{ij}^{w}) \leq Cap_i \qquad \text{for } i = 1,\ldots,13$$

$$\sum_{i=1}^{13} (X_{ij}^{d} + 0.45 * X_{ij}^{w}) \leq Dem_j \qquad \text{for } j = 1,\ldots,100$$

In the above equations, 0.45 is the conversion factor used to convert from wet distillers to dry distillers. One bushel of corn produces 18 pounds of dry distillers (0.9 DM) and 40 pounds of wet distillers (0.3 DM). The profit equation will also need to be modified to ensure that this equation takes into account both wet and dry distillers. The equation can be written as follows:

Profit = Selling price – (Transportation Cost + Drying Cost + Miscellaneous Cost)

Profit = $P_{ij} = S.P_k - (C_{ijk} + D_k + M)$,

where

k = 1 for dry distillers and 2 for wet distillers

C_{ijk} = cost of Transporting dry/wet distillers

D_k = cost of drying dry/wet distillers

The next goal is to formulate an objective function, which can be modified as

$$\max \sum_{i=1}^{n} \sum_{j=1}^{m} P_{ij}^{d} X_{ij}^{d} + \sum_{i=1}^{n} \sum_{j=1}^{m} 0.45 * P_{ij}^{w} X_{ij}^{w}$$

The output, which provides the optimal ratio of dry and wet distillers shipped from each ethanol plant to respective feedlot points, is shown in Table 41. The optimal solution is found at $11,318,814 per year. This suggests that ethanol plants altogether are able to make this much profit per year. This amount of profit is higher than producing 100 percent dry or wet distillers, which proves that the distribution model is giving the optimal solution. Output shows that only 88 percent of the feedlots can be satisfied with available distillers from ethanol plants. Of these, 28 percent of the feedlots are served by WDGS and the remaining 72 percent can be served with DDGS.

TABLE 41

WET/DRY OPTIMAL RATIO DISTRIBUTION IN KANSAS

	1		2		3		4		5		6		7		8		9		10		11		12		13	
Feedlots	nsas Etha		esika Ener		kalon Ener		teway Etha		naza Bioe		nergy Pa		orizon Agr		n Plains		nsas Agri		goa Bio-E		e Agri-En		P Ingredie		ESE Alcohol	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
		784		144		1560		1220		784		688		572		644		500		356		216		144		20
Century Feeders													18													
David Ranch & Feedlot													5.3													
Decatur County Feed Yard													67													
Hays Feeders, LLC												86														
Jewell County Feeders, LLC			8.8																							
MP&K Land and Livestock			5.6																							
Rooks County Feeders														31												
Solomon Valley Feeders																	30									
T Bone Feeders													11													
Thomas County Feeders																71										
Valley Feeds, Inc														31												
Beef Belt Feedlot, Inc													21													
Brookover Cattle Company													31													
Cadillac Feeders													7.1													
Cargill Cattle Feeders, LLC															95		125									
Cutler Cattle Company													11													
Fairleigh Feed Yards, Inc											6.8		4.9		68											
Doornbos Cattle Co															3.5											
H R C Feedyard, Inc											53															
Hess Cattle Company, Inc											4.2															
KFY-Division of Beef Belt Feeders											11															
Lane County Feeders, Inc															74											
Ox Town Cattle Feeders, LLC																										
Pawnee Valley Feeders, Inc																	35									
Pioneer, Inc													53													
Poky Feeders, Inc											61															
Ranger Feeders															18											
Royal Beef/Division of Irsik & Doll											71															
Hay Hook Cattle Company, LLC	18																									
Stampede Feeders											18															
5N Feeders, Inc																										
Bartlett III					6.01						47															
Brookover Feedyard							6.59															162				
Brookover Ranch Feed Yard, LLC										83												54				
Cattle Empire, L.L.C	49				201																					
Garden City Feedyard, LLC										353																
G & G Cattle, Inc	5.3																									
Hitch Feeders II, Inc										196																
J O Cattle Company	3.5																									
Miller Feedyard																										
River Bend Feed Yard, Inc																										
Heritage Feeders Sublette					88.2																					
Sunbelt Feeders, Inc																										
Supreme Cattle Feeders, LLC							123																			
Syracuse Feed Yard																										
Triangle H Grain & Cattle										16																
Ulysses Feed Yard																										
Ulysses Feed Yard																										
Western Feed Yard, Inc																										
Winger Feedyard, Inc																										
Beefland										137																
Boot Hill Feeders, Inc	30																									
Cimarron Feeders of Kansas, L.L.C					35.3																					
Dewey Feedyard					8.81																					
Clark County Feedyard							20																		2.1	
DM&M Farms, Inc					35.2																					
Ford County Feed Yard, Inc							91.6																			
Fowler Feeders							26.4																			
Gray County Feedyard					53																					
Hy-Plains Feedyard, LLC							88.1																			
Ingalls Feedyard, Inc					35.7		34.8																			
Irsik & Doll Feed Yard	53																									
Meade County Feeders, L.L.C							17.6																			
Meade County Feeders II							7.76																			
Midwest Feeders, Inc					35.3																					

TABLE 41(Continued)

Pratt Feeders Inc. dba Ash Feed							70.5																			
Sublette Feeders	74																									
Wilroads Feed Yard	20																									
Barton County Feeders		78																								
Haw Ranch Feedlot, LLC		2.5																52								
Golden Belt Feeders		24																								
Dudrey Cattle Company						19.6																				
Golden Belt Feeders						82.3																				
Golden Belt Feeders-Kinsley LLC																		58								
Great Bend Feeding, Inc						106																				
Knight Feedlot		63																								
Mull Farms & Feeding, Inc.																23										
Heritage Feeders Larned						118																				
Pratt Feeders, LLC								135																		
Quality Feeders, Inc						29.8																				
Sellers Feedlot		47																								
Smoky Hill Feeders, Inc			2.6													12										
Ward Feed Yard, Inc						97.9																				
Zimm's Feedlot		12																								
2K Feeders																		6.2								
Haw Ranch Feedlot II, LLC																			98							
Cow Camp Feedyard, Inc			8.6																							
Tiffany Cattle Company			22																							
Handke Farms, Inc																						18				
KSU Deppt of Animal Sc & Industry			3																							
Neosho Valley Feeders																					26		7			
Ottawa County Feeders, Inc			14																							
Palenske Ranch, Inc																					15					
Peddicord Land & Cattle Co., Inc																					7					
Porter Cattle Co																					9					

The results shown in Table 42 indicate that in order to maximize profit, ethanol plants were unable to satisfy demands, whether dry distillers or wet distillers were supplied, for the following feeders: 5N Feeders, Miller Feedyard, River Bend Feedyard, Sunbelt Feeders, Syracuse Feedyard, Ulysses Feedyard 1, Ulysses Feedyard 2, Western Feedyard, and Winger Feedyard. Most of these feeders are in the Ulysses and Johnson counties. Based on the distillers demand ethanol plants should be built into this region. The total distillers' demand of these feedlots is 462 MPY if dry distillers are supplied and 1025 MPY if wet distillers are served. Since one bushel of corn produces 18 lbs of dry distillers and 2.8 gallons of ethanol, therefore to satisfy the demands of these feedlots an ethanol plant with production capacity of 71.56 MGY of ethanol can be built. This ethanol plant will need 25.66 million bushel of corn.

TABLE 42

FEEDLOT DEMANDS NOT SATISFIED

Feedlots	Demand	Supply	Demand - Supply
Brookover Cattle Company	35.26	31.26	4.00
Ox Town Cattle Feeders, LLC	37.02	0.00	37.02
5N Feeders, Inc	12.34	0.00	12.34
Brookover Feedyard	176.12	168.23	7.89
Miller Feedyard	30.85	0.00	30.85
River Bend Feed Yard, Inc	27.33	0.00	27.33
Sunbelt Feeders, Inc	52.89	0.00	52.89
Syracuse Feed Yard	70.52	0.00	70.52
Ulysses Feed Yard	61.70	0.00	61.70
Ulysses Feed Yard	61.70	0.00	61.70
Western Feed Yard, Inc	74.04	0.00	74.04
Winger Feedyard, Inc	22.04	0.00	22.04
Neosho Valley Feeders	32.61	0.00	32.61

The following discussion shows how far DDGS and WDGS can be served in a multi-commodity environment. Table 43 shows how far ethanol plants were able to serve feedlots. Highlighted with yellow are those feedlots that have been served by dry distillers, and highlighted with blue are those that are served by wet distillers. The maximum distance WDGS is able to serve is 47.3 miles. This is the Haw Ranch Feedlot satisfied by Kansas Ethanol Inc. The case of DDGS shows 202 miles, in which Neosho Valley Distillers were satisfied by MPG Ingredients Inc. The output confirms that to maximize profit, DDGS are a better solution for larger transportation distances, where WDGS is favorable when the shipping distance is considerably lower.

TABLE 43

DISTANCE SHIPPED FROM ETHANOL PLANT TO FEEDLOT IN MULTI-COMMODITY ENVIRONEMNT

Feedlots	Rice	Washington	Seward	Pratt	Finney	Russell	Phillipsburg	Sheridan	Grant	Sedgwick	Finney	Atchison	Wichita
Century Feeders	238	279	225	257	157	170	156	73.3	215	314	157	396	325
David Ranch & Feedlot	177	175	164	196	171	110	52.7	39.9	125	253	171	296	264
Decatur County Feed Yard	213	189	200	232	158	145	66.2	37.8	166	289	158	309	299
Hays Feeders, LLC	97.6	192	84.6	117	128	29.9	63.9	81.9	74.6	173	128	255	184
Jewell County Feeders, LLC	164	62.8	141	173	249	97.4	59.9	146	68.2	175	249	183	186
MP&K Land and Livestock	185	83.6	139	171	233	81.1	43.7	130	59.4	196	233	204	207
Rooks County Feeders	118	158	105	137	153	50.5	37.6	104	63.2	194	153	276	205
Solomon Valley Feeders	83.7	85.2	114	146	211	82.3	87.3	187	40.8	140	211	206	150
T Bone Feeders	238	279	225	257	157	170	156	73.3	215	314	157	396	325
Thomas County Feeders	202	239	189	221	121	134	117	33.7	179	277	121	360	288
Valley Feeds, Inc	177	144	164	196	214	109	21.4	76.2	122	253	214	264	264
Beef Belt Feedlot, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Brookover Cattle Company	150	319	137	164	52	157	172	84	202	301	52	383	242
Cadillac Feeders	150	319	137	164	52	157	172	84	202	301	52	383	242
Cargill Cattle Feeders, LLC	175	344	161	188	76.3	182	197	108	226	325	76.3	407	266
Cutler Cattle Company	150	319	137	164	52	157	172	84	202	301	52	383	242
Fairleigh Feed Yards, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Doornbos Cattle Co	150	319	137	164	52	157	172	84	202	301	52	383	242
H R C Feedyard, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Hess Cattle Company, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
KFY-Division of Beef Belt Feed	150	319	137	164	52	157	172	84	202	301	52	383	242
Lane County Feeders, Inc	127	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Ox Town Cattle Feeders, LLC	197	366	183	214	102	204	208	130	248	347	102	429	292
Pawnee Valley Feeders, Inc	89.2	233	56.2	102	57.6	99.6	134	123	144	165	57.6	296	176
Pioneer, Inc	181	275	168	200	97.5	113	126	39.9	158	256	97.5	339	267
Poky Feeders, Inc	150	319	137	164	52	157	172	84	202	301	52	383	242
Ranger Feeders	127	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Royal Beef/Division of Irsik & D	150	319	137	164	52	157	172	84	202	301	52	383	242
Hay Hook Cattle Company, LL	70.1	300	113	145	44.3	138	172	64.7	183	202	44.3	363	213
Stampede Feeders	150	319	137	164	52	157	172	84	202	301	52	383	242
5N Feeders, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Bartlett III	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Brookover Feedyard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Brookover Ranch Feed Yard, L	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Cattle Empire, L.L.C	175	319	139	145	53.9	207	252	164	251	234	53.9	382	223
Garden City Feedyard, LLC	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
G & G Cattle, Inc	164	360	142	138	25.7	198	213	125	243	227	25.7	424	216
Hitch Feeders II, Inc	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
J O Cattle Company	164	360	142	138	25.7	198	213	125	243	227	25.7	424	216
Miller Feedyard	175	319	139	145	53.9	207	252	164	251	234	53.9	382	223
River Bend Feed Yard, Inc	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Heritage Feeders Sublette	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Sunbelt Feeders, Inc	203	347	195	156	82.1	235	284	196	280	246	82.1	424	234
Supreme Cattle Feeders, LLC	197	341	172	133	80.9	215	249	191	260	223	80.9	401	211
Syracuse Feed Yard	206	402	183	180	67.6	240	255	167	285	269	67.6	465	258
Triangle H Grain & Cattle	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Ulysses Feed Yard	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Ulysses Feed Yard	206	403	184	171	68.2	241	256	167	285	261	68.2	466	249
Western Feed Yard, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Winger Feedyard, Inc	228	424	205	192	89.4	262	277	188	306	282	89.4	487	270
Beefland	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Boot Hill Feeders, Inc	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5	323	153
Cimarron Feeders of Kansas,	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Dewey Feedyard	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Clark County Feedyard	137	280	112	72.5	67	154	188	163	199	162	67	340	150
DM&M Farms, Inc	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Ford County Feed Yard, Inc	123	267	96.8	57.7	63.2	141	175	149	186	147	63.2	325	136
Fowler Feeders	148	292	123	84	78.5	166	200	174	210	174	78.5	352	162
Gray County Feedyard	134	277	97.8	93.9	27	151	185	154	196	184	27	341	172
Hy-Plains Feedyard, LLC	143	287	107	102	39	161	195	166	205	192	39	350	180
Ingalls Feedyard, Inc	140	284	104	100	21.4	158	192	148	203	190	21.4	347	178
Irsik & Doll Feed Yard	167	311	131	127	14.7	194	209	121	239	217	14.7	374	205
Meade County Feeders, L.L.C	158	302	133	94.2	63.2	176	210	201	221	184	63.2	362	172

TABLE 43 (Continued)

Meade County Feeders II	158	302	133	94.2	63.2	176	210	201	221	184	63.2	362	172
Midwest Feeders, Inc	140	284	104	100	21.4	158	192	148	203	190	21.4	347	178
Pratt Feeders, Inc. dba Ashlan	163	307	121	82	96.8	172	209	192	211	172	96.8	350	160
Sublette Feeders	167	310	131	139	48.6	184	247	159	229	229	48.6	374	217
Wilroads Feed Yard	115	259	79.5	75.5	45.5	133	167	141	178	165	45.5	323	153
Barton County Feeders	21.2	177	28	60.1	125	49.7	135	154	81.8	96.9	125	241	108
Haw Ranch Feedlot, LLC	47.3	198	46.5	21.6	142	97.1	182	202	136	68.8	142	261	72.2
Golden Belt Feeders	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Dudrey Cattle Company	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122	264	96.9
Golden Belt Feeders	57.4	201	15.4	25.4	122	66.1	151	171	105	86.6	122	264	96.9
Golden Belt Feeders-Kinsley L	96.9	223	43.1	57.8	82	96.7	131	150	141	120	82	286	136
Great Bend Feeding, Inc	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116	239	118
Knight Feedlot	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Mull Farms & Feeding, Inc.	45.8	189	28.2	60.3	101	54.4	130	150	93.7	121	101	253	132
Heritage Feeders Larned	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6	263	142
Pratt Feeders, LLC	81.3	255	39.3	4	121	90	175	194	129	89.9	121	268	78.2
Quality Feeders, Inc	31.6	175	18.2	50.3	116	39.7	125	144	84.3	107	116	239	118
Sellers Feedlot	0.6	165	48.8	80.9	146	70.4	155	175	65.8	76.2	146	229	87
Smoky Hill Feeders, Inc	45	120	86.4	115	184	89.4	174	194	84.2	73.6	184	183	84.4
Ward Feed Yard, Inc	55.8	199	19.4	56.5	92.6	64.5	122	142	104	132	92.6	263	142
Zimm's Feedlot	9	175	36.5	59.6	156	79.9	165	184	75.3	62.6	156	238	72.9
2K Feeders	100	134	138	127	247	170	255	275	165	54.3	247	162	49.6
Haw Ranch Feedlot II, LLC	84.9	185	119	112	233	155	240	259	150	25.8	233	171	35.2
Cow Camp Feedyard, Inc	78.5	103	127	162	224	117	202	222	112	73.7	224	154	84.5
Tiffany Cattle Company	90.7	95.2	165	161	262	137	222	242	132	73	262	143	83.8
Handke Farms, Inc	222	102	249	267	346	221	224	325	215	191	346	22.3	190
Kansas State University Depar	137	69.3	163	195	261	135	220	240	130	122	261	107	133
Neosho Valley Feeders	215	273	239	208	328	285	370	389	280	150	328	201	130
Ottawa County Feeders, Inc	87.6	82.1	114	147	212	86.7	140	191	47.5	99	212	181	110
Palenske Ranch, Inc	114	148	152	156	260	184	270	289	179	68.4	260	125	79.2
Peddicord Land & Cattle Co., I	154	83.6	181	213	278	153	238	258	148	140	278	87.2	151
Porter Cattle Co	151	185	188	182	303	207	292	311	202	105	303	107	105

4.4 Summary

A total of 27 combinations were investigated by changing transportation cost, truck capacity, and the selling price of distillers. In all cases, 100% of the distillers are consumed which are produced by ethanol plants. The resulting profit made by ethanol plants on each case is summarized in Table 44. Here are listed the profits when the truck capacity is 25 tons because this is the most widely used truck capacity used in transportation. A detailed analysis is available in Appendix B. In Table 44, the notation 155-3-25 is used, which indicates that the selling price is \$155 per ton, the transportation cost \$3 per mile, and the truck capacity is 25 tons. DP, WP, and PP stand for DDDGS Profit, WDGS Profit, and Wet/Dry Percent Profit. This table is plotted in Figure 20. Analysis shows that profit made by supplying both dry and wet distillers is higher than supplying either dry or wet distillers. As discussed in the last chapter, wet distillers are profitable when supplier and consumer locations are closer (less than breakeven distance), and dry distillers are more profitable when the distance between these two stakeholders is higher (more than breakeven points). The mathematical model results have verified this hypothesis. If only dry distillers are sold, then ethanol plants are able to make a better profit then producing only wet distillers, because more than 75 percent of the plants are at a higher distance than the breakeven distance miles (34.14) that was established in the previous chapter. Similarly, if both dry and wet distillers are sold, ethanol plants can make the highest profit, because for closer distances, the model automatically assigns wet distillers, and for higher distances, the model assigns dry distillers.

TABLE 44

PROFIT OF ETHANOL PLANTS

	Total Profit		
Combination	**DP**	**WP**	**PP**
155-3-25	11191533	10781446	11318814
155-3.5-25	11032900	10417827	11143902
155-4-25	10874267	10054207	10971499
175-3-25	12908633	12498421	13035914
175-3.5-25	12750000	12134802	12861002
175-4-25	12591367	11771182	12688599
195-3-25	14625733	14215396	14753014
195-3.5-25	14467100	13851777	14578102
195-4-25	14308467	13488157	14405698

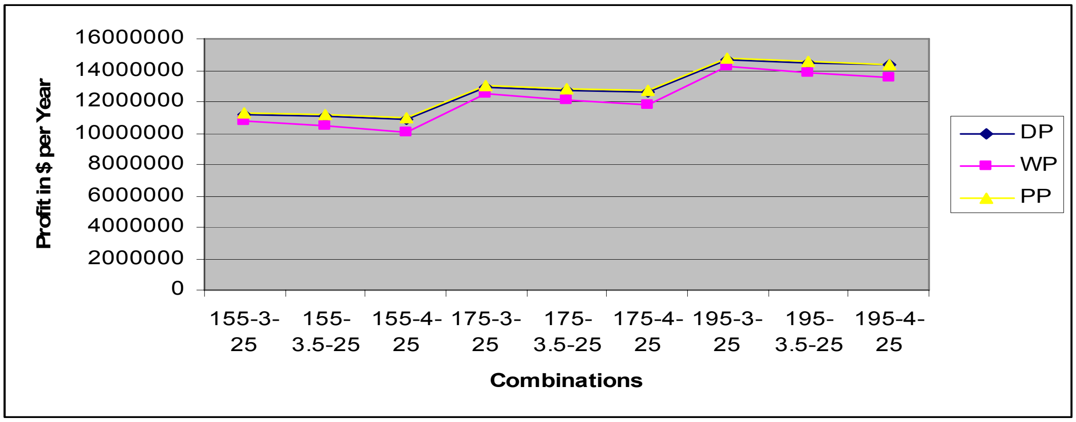


Figure 20. Total profit at different distribution combinations of distillers.

CHAPTER 5

CONCLUSIONS AND FUTURE RESEARCH

5.1 Conclusions and Findings

The goal and objective of this study was to identify whether distillers are competitive with corn prices and how distillers can be made more profitable than corn. The second part of the research was to test whether dry or wet distillers are a better substitute of corn in terms of profit. In general, the study has answered these questions by providing a breakeven analysis and detailed mathematical model solutions. The model also gives complete assignment solutions, that is, which ethanol plant(s) serve(s) which feedlot(s). The findings and conclusions of this research are discussed as follows:

- Ethanol plants are unable to satisfy all the demand for distillers in Kansas. Kansas is the second highest state in the number of feed cattle. The total supply of DDGS is 3,434 MPY, and the total supply of WDGS is 7,631 MPY, whereas the total demand of DDGS and WDGS are 3,886 MPY and 12,470 MPY, respectively, which indicates that ethanol plant(s) could be built to fill the supply demand gap.
- Breakeven analysis suggests that dry distillers must be sold at $188 per ton or less to be competitive with corn (when corn is $4 per ton and soybeans are $235 per bushel).
- At a higher transportation distance, DDGS is more competitive than WDGS. Table 45 summarizes the breakeven points.

TABLE 45
BREAKEVEN DISTANCE MOVEMENT VIA TRANSPORTATION COST

		Transportation Cost					
		Increase ($4/mile)		Increase ($3.5/mile)		Decrease ($3/mile)	
	DDGS Price ($/ton)	Breakeven Distance	Breakeven Cost	Breakeven Distance	Breakeven Cost	Breakeven Distance	Breakeven Cost
Case A	155	29.87	159.78	34.14	159.78	39.83	159.78
Case B	195	29.87	199.78	34.14	199.78	39.83	199.78
Case C	175	29.87	179.78	34.14	179.78	39.83	179.78

As shown in Table 44, when the transportation cost increases, wet distillers become less profitable and the breakeven point decreases. At a DDGS price of $155 per ton, the breakeven point is at 29.87 miles when the transportation cost is $4 per mile, which means that WDGS should be supplied when the distance between ethanol plant and feedlot is less than 29.87 miles. The following also apply:

- It is not always profitable to supply 100 percent DDGS or 100 percent of WDGS; rather it depends on many factors, including transportation cost, drying cost, and truck capacity. The model provides solutions for which ethanol plants should supply which feedlot points and what form of distillers to maximize profit. When multiple suppliers and customers are operating in a network, both forms of distillers can be served at the same time, whichever results in a higher profit.
- Consistently, some of feedlots are not able to satisfy their demands no matter whether 100 percent WDGS, 100 percent DDGS, or a combination is supplied. Those feedlots are 5N Feeders, Miller Feedyard, River Bend Feedyard, Sunbelt Feeders, Syracuse Feedyard, Ulysses Feedyard 1, Ulysses Feedyard 2, Western Feedyard, and Winger Feedyard. It is more expansive to sell distillers to these feedlots than others due to the comparatively higher transportation distance between supply and demand points. These are in Ulysses and Johnson counties. In the future, an ethanol plant could be built in these regions considering the DDGS demands.

5.1.1 Corn and DDGS Consumption

The biggest contribution of this research is that it allows corn to be used for other areas by replacing corn feed with distillers for livestock. In 2007, total corn produced in Kansas is 518 million bushels (Kansas Grains, 2007). Corn inclusion rate for livestock is 0.25% of their weight (Wright, 2005). We have 2,204,300 cattle in Kansas. Let's calculate how much corn can be consumed by livestock per year. We have different weights of cattle available at feedlots. The calculations of corn consumptions by livestock in Kansas is summarized in the following table.

Table 46

CORN CONSUMPTION BY LIVESTOCK IN KANSAS

Weight(lbs)	% of Cattle	No of Cattle	Corn Consumption (lbs per year)
500-700	37	815,591	446.535,890
700-1200	32	705,376	675,838,380
1200 above	31	683,333	841,780,520
Total			1,964,154,790

One bushel of corn is equal to 56 lbs so total number of bushels consumed by livestock is 36 million bushels per year. Total DDGS required by livestock in Kansas is 3,889 MPY but in reality we only 3,244 MPY DDGS can be produced in Kansas by available ethanol plants. The amount of distillers can be utilized to save 30.1 million bushels of corn. These corn will be available for ethanol, human feeds or for other purposes. This will reduce pressure on corn prices and corn will be available at lower cost for ethanol industry thus encouraging bio-fuels production and making them competitive to gasoline.

5.2 Future Research

The distribution model can be modified for other states. The model is tested for variable truck capacity, transportation cost, and selling price. Since the demand of distillers is higher than the capacity, there are some feedlots that are not able to obtain distillers. These are in Johnson and Ulysses counties. Research is necessary to assess the ethanol demand in those regions. A detailed feasibility analysis for building ethanol plants in those regions is also necessary. The distribution of distillers is purely related to the price of corn. When corns prices are higher, distillers are a good alternate feed. And when corn prices are lower, distillers become less competitive. Ethanol plants should take this into consideration while selling distillers. They should adjust the price of distillers according to the price of corn. For example, DDGS was priced from \$155 to \$195 per ton in Kansas in 2007, but the breakeven point (when corn is at \$4 per bushel) suggests that DDGS becomes less competitive if it is priced more than \$188 per ton.

Besides the distribution of distillers, a large study is needed in the areas of energy content calculations comparative to corn at variable moisture content level. Variation in energy content is common in distillers having the same moisture content. This is due to the fermentation process used at different ethanol plants. Unlike corn, which has a standard amount of energy content, distillers have variable energy content depending on the ethanol plant. Also, no agency, regulation, or quality standards exist to standardize the energy content of distillers. An organization that establishes testing requirements and standards of distillers should be formed. This would ensure that distillers purchased in the market have the same energy content regardless of where they are purchased.

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