LEAST COST SHIPMENT OF ALFALFA HAY

(*MEDICAGO SATIVA*) IN THE

UNITED STATES

By

SOLOMON K. KARIUKI

Diploma in Horticulture
Jomo Kenyatta University
Juja, Kenya
1991

Bachelor of Science
Oklahoma State University
Stillwater, OK
1995

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
July, 1998

OKLAHOMA STATE UNIVERSITY

LEAST COST SHIPMENT OF ALFALFA HAY

(*MEDICAGO SATIVA*) IN THE

UNITED STATES

Thesis Approved:

Clement E. Ward
____
Thesis Adviser

Brian Adam
____

Francis M. Epplin
____

Wayne B. Powell
____
Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to the people who made this thesis a success. I am extremely thankful to my major advisor, Dr. Clem Ward, for his guidance and patience through the course of this study. I am also thankful to the other committee members, Dr. Francis Epplin and Dr. Brian Adam, for their advisement and instructive comments.

To the faculty and staff of the department of Agricultural Economics, I am eternally grateful for the privilege to have been part of such an outstanding program. You are all wonderful people.

I am financially indebted to Agricultural Makerting Services, U.S. Department of Agriculture through Dr.Clem Ward and Dr. Ray Huhnke for funding the alfalfa project.

To my parents, Kariuki Gachanja, Gathoni Kariuki, Z.G. Wanjau and R.M. Wanjau, thank you for your constant love and prayers. My friend, Wambui Machua, deserved my deepest appreciation for her encouragement, and support.

TABLE OF CONTENTS

Chapter	Page

Chapter Page

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

SAL	Low Quality Alfalfa Hay Supply to Alabama
SWY	Low Quality Alfalfa Hay Supply to Wyomings
DAL	Low Quality Alfalfa Hay Demand from Alabama
DWY	Low Quality Alfalfa Hay Demand from Wyomings
SSAL	High Quality Alfalfa Hay Supply to Alabama
SSWY	High Quality Alfalfa Hay Supply to Wyomings
DDAL	High Quality Alfalfa Hay Demand from Alabama
DDWY	High Quality Alfalfa Hay Demand from Wyomings

CHAPTER I

INTRODUCTION

Alfalfa hay in the United States is an important feed input in the livestock industry. According to Wheaton and Ross[1], alfalfa can supply all protein and energy needed for most beef, is digested twice as fast as most hays, and has the cheapest cost of production among all perennial forages. Wheaton and Ross also argue that a ton of alfalfa has as much protein as 2/3 tons of soybeans and that in times of low rainfall, alfalfa produces more quality forage than other species.

Alfalfa is produced in almost every state in the country. According to Agricultural Statistics (U.S. Department of Agriculture 1986 to 1996) data, there has been a growing domestic demand for alfalfa hay in the last 10 years especially in the South central and Southeast regions. This, according to Konyar and Knapp (1986) can be associated with increasing numbers of alfalfa hay consuming species, particularly dairy cows which are said to be the major alfalfa consumers. Konyar and Knapp (1986) contend that alfalfa is a free market crop with no restrictions on entry or exit from the market. They also observe that price is strictly determined by free interplay of demand and supply. Agricultural Statistics (U.S. Department of Agriculture 1996) shows an

[1] The article is not dated.

increase in real prices paid to alfalfa hay growers supporting the growing demand for alfalfa.

The 10 largest alfalfa hay producing states were different from the 10 largest alfalfa hay consuming states (U.S. Department of Agriculture 1996). This is an indication that trade is necessary for meeting demand in deficit states. Skaggs (1992) observed that in the Western states, about 43 percent of the hay is marketed rather than fed on the farm where it was produced. In the rest of the country, however, this rate was only 14 percent (Skaggs 1992).

The amount of alfalfa hay transported and how far from the production point alfalfa hay will be shipped depends on the supply of alfalfa, cost of transport, demand in general, and demand for specific qualities of alfalfa. Price differentials between alfalfa hay markets comprise transportation and handling costs. Transportation is significant in alfalfa hay marketing because no market could function without the movement of alfalfa hay from one location to the other (Hough 1994). The international market for U.S. alfalfa hay is also growing, from 230,000 metrics tons exported to Japan in 1989, to 577,000 metric tons in 1995 (Ford 1996). Kallenbach (1996) observes that, increased demand from Japan is a major factor contributing to the rise in exports in the last seven years. Kallenbach (1996) argues that since Japan places a strict quota on beef and dairy imports to preserve their livestock industry, demand for forages cannot be met internally due to the small size of Japan's crop land.

The general objective of this research is to determine the out-of-state potential for Oklahoma alfalfa hay and, more specifically, to determine the least cost flow of alfalfa hay from production to consumption regions. A mail survey was one of the instruments used to elicit information about consumption in the U.S. and transportation costs. The survey was sent to 150 animal scientists and agronomists to determine how much alfalfa hay is fed to specific animal species. These survey results were used to estimate the daily consumption for individual species. Quantity and quality of alfalfa hay produced and number of animals by species and state in 1995 were collected.

Linear Programming (LP), an algorithm in General Algebraic Modeling System (GAMS) software, was used to compute minimum transportation costs for shipping alfalfa hay from production to consumption regions (Brooke et al.1992). Sensitivity analysis was used to determine changes in least cost shipping patterns with alfalfa supply and demand changes, quality differences and transportation cost changes, as harvesting technology changed.

Problem Statement

Alfalfa hay is an important feed input for milk production. Skaggs and Snyder (1992) contend that, though it is often considered a low-value crop, the annual value of U.S. alfalfa production in the late 1980s was approximately equal to that of wheat. Yet relatively few resources are dedicated to related research. Increased production of alfalfa hay, changes in numbers of alfalfa hay consuming animals and technological changes have broadened the market for alfalfa hay. Quality of alfalfa hay produced in a given state has also impacted the demand and flow patterns a great deal. Hobbs et al. (1987) argue that quality and protein levels impact prices accordingly and hence the quantity of alfalfa hay demanded. According to Skaggs (1992), 43% of alfalfa hay produced in major Western states was marketed out-of-state.

Increasing domestic and international demand for alfalfa hay suggests increased market potential for Oklahoma alfalfa growers. However, high transportation costs may outweigh the increased market potential. Most alfalfa hay is consumed domestically and not hauled great distances due to high costs of transportation. Oklahoma alfalfa hay growers frequently ask the Oklahoma State University agricultural economics extension staff about the potential to market hay to Japan, Florida or other distant markets.

Changes in shipping costs, alfalfa demand in the U.S., and increased international demand may have an effect on the least cost movements (both destination and quantity shipped) of alfalfa hay. Changes in harvesting technology in the last 20 years has gone from the traditional small rectangular bales, to large round bales to large square bales. This has increased labor efficiency and decreased shipping costs. These bale shapes and sizes determine how much alfalfa hay can be shipped economically from production to consumption points. Over time, supply, demand, and harvesting technology changes may have created opportunities for Oklahoma alfalfa hay growers to market hay over longer distances.

General Objective

The overall objective was to determine the existing and potential domestic and international market for Oklahoma-grown alfalfa hay.

Specific Objectives

Specific objectives were to determine:

1. The least cost movement of alfalfa hay from production to consumption regions and

2. The effect changes in supply, demand, improved harvesting technology and quality differences have on the flow patterns of alfalfa hay.

Organization of the Thesis

This thesis is presented in six chapters. The literature review in the second chapter provides a background of models and techniques used in the study. This chapter also briefly reviews related studies.

Chapter three describes the procedure for modeling. It describes the steps required to complete the results from data collection to data analysis. Chapter four is a conceptual framework; this is the integral component of framing the research problem.

Chapter five is the results of the model. It summarizes the solutions for the base model and the effects of various shocks. Chapter six is a summary and a conclusion of the results. It explains the accomplishment of the objectives stated in chapter one.

CHAPTER II

LITERATURE REVIEW

Several published studies dealing with interregional markets, alfalfa, and transportation were found. The articles selected were based on their relevance to the underlying objectives. A summary of the relationship of these studies and our study is presented in subtopics.

Importance of alfalfa hay

Alfalfa hay is an important feed for livestock production in the United States. In 1986, Konyar and Knapp conducted a study on "Demand for Alfalfa Hay in California". They emphasized the importance of alfalfa hay to livestock production. They outline why farmers would demand more alfalfa than any other livestock feed. The authors tell us that alfalfa is unique in mineral and vitamin components as opposed to other forages. For this reason, just as in Hobbs et al. (1987), alfalfa hay prices are said be inelastic (i.e, a given change in alfalfa hay price results in a small percentage change in the quantity demanded). This idea is supported by Hobbs et al. (1987) who noted that some Kentucky horse farmers have purchased alfalfa hay from as far away as Washington state.

Konyar and Knapp (1986) based their calculations on1982 data. They estimated that 41 percent of alfalfa hay consumption in California was by dairy cows, 18 percent by non-dairy animals, 7 percent by beef cattle, and 24 percent by horses. These, plus fed cattle and sheep are the components of demand to be considered in the transportation model. Actual alfalfa consumption in 1986 was estimated as alfalfa production plus net imports minus change in carry over stocks (Konyar and Knapp 1986). The authors estimated alfalfa stocks by assuming that alfalfa stocks were the same fraction of total stocks as alfalfa production was of total hay for the preceding years. Their study is confined to California which limits its usefulness as a national study and as the author says, "California apparently represents a small part of the market". The study also does not include a transportation component among counties they considered.

Role of Transportation

Location advantages or disadvantages of shippers in various supply regions do not usually pass intact to raw material suppliers. Differences in processing or manufacturing costs may either offset or enhance the effects of location. Bressler and King (1970) note that the usefulness of a multi-regional transportation model is increased when combined with site analysis. Information from transportation models can be used in margin studies. Differences between prices paid by farmers and/or prices received by farmers are partially explained by location of their best source of supplies. The transportation model effectively isolates the contribution of transfer cost to farm-to-consumer margins for various markets.

Modes of Transportation

Different modes of transportation such as rail, truck, barge and planes can be used to transport alfalfa hay. The choice of the most efficient methods depends on the availability of resources and infrastructure. Most of the animal scientists and agronomists surveyed contend that the cheapest means of shipping alfalfa hay is by truck.

Buzby (1986) observes that flatbed trailers pulled by diesel truck tractors get good diesel mileage while hauling hay. In this type of transportation, hay is often covered by tarp to protect it from moisture and road dirt. In the same study, Buzby (1986) argues that back hauls are common in alfalfa hay transportation. She gives an example of a truck hauling cattle from Texas to Oklahoma may ship alfalfa hay to Texas on its way back at a cheaper cost.

Hough (1994), examining logistics of the U.S. wheat industry, observed that rail, truck, and barge transport modes each have different cost structures that gives each mode advantages in certain markets depending on the length of haul. She suggests that trucks are generally the preferred mode over shorter distances, railroads are more efficient than trucks for longer distances while the barge mode has the lowest per unit cost for even longer distances. The review portrays how several modes of transport can be used to ship the same commodity economically. For alfalfa, truck transport is the preferred mode.

Since alfalfa is more bulky than wheat, it seems economical to use the barge mode. However, barge transport would only be applicable for alfalfa in limited regions. Also the agronomist survey response indicated that they preferred truck more than any other mode of transport. Because of these reasons the alfalfa transportation model will be based on truck freight rates.

Tomek and Robinson (1990) suggest that the best means of transporting an agricultural commodity plays a big role in determining the least cost transportation method. They argue that transport cost is the most important single variable determining spatial price relationships. In addition, average transportation rate, or transfer cost, can also be determined by a fixed charge that is independent of the distance traveled (usually associated with loading and off loading) and a variable charge related to the distance over which the commodity is moved. The authors point out that transportation cost per mile often declines as the distance traveled increases; thus the cost of moving commodities between two points is not necessarily a linear function of the distance. Supporting Bressler and King (1970), Tomek and Robinson (1990) observed that the total transport cost increases with distance and consequently the cost per mile of product moved increases, but often at a declining rate.

As in the Hough (1994) study, Tomek and Robinson (1990) note that trucking rates have become competitive relative to barge and railroad but truck rates still differ between locations that are approximately the same distance apart depending on the availability of back hauls and the presence or absence of alternative methods of transporting products. The authors back this up when they point out that interregional price differences presumably are based on the least cost method of moving commodities between points. At the same time the authors note that it may not be possible for every handler or shipper to use the least cost system especially where new handling methods are being introduced.

International Market Potential

The international market for alfalfa hay is growing in the US. According to Kallenbach (1996) exports from the southwestern U.S. totaled 161 thousand tons, of which 65% was from California and the other 35% was shared among Arizona, Nevada and Utah.

The major international market for alfalfa hay is the Pacific Rim. This is advantageous to the southwestern states due to its location in relation to the rest of alfalfa hay producing states in the U.S. However, Mexico is a potential market for most of the mid west and southern alfalfa hay producing states. With its expanding dairy industry, selected states could capitalize on this Mexican market potential.

There are several indicators of Mexico's market potential for US alfalfa hay. A questionnaire sent to Griselda Nannies, co-operative union representative, reveals that 20-25% of their cooperative members' alfalfa purchases come from outside their area. She also indicated that they feed about 11 lbs of alfalfa hay per dairy cow per day. Nicholson (1995) observes that prior to 1992, foreign investment in agriculture was heavily restricted in Mexico. However, since NAFTA came into effect in 1994, US dairy investors have greater access to Mexican markets.

Transportation Models

The least cost alfalfa hay flow pattern model is designed to minimize the cost of transportation subject to shipping rates, supply, and demand. The solution of the model provides optimal quantities a particular state can supply to other states. The multi-quality model tells us the amount of low and high quality alfalfa hay a given state can supply to other states. Several sensitivity analyses of the model show us the effect of various shocks to the system. Buzby (1987) argues that although in many transportation models supply equals demand, the supply of some models exceeds demand. She suggests that in such a situation, the imbalance should be corrected using a fictitious sink or dummy destination to absorb the excess supply. However, in this model (least cost alfalfa hay flow pattern), the restrictions will be set in such a way that quantity demanded is less than or equal to quantity supplied.

In 1981, Meyer designed a transshipment model of the U.S. swine-pork industry. The problem he investigated was that in spite of the locational advantages Oklahoma's swine-pork industry enjoys, there was a steady downward trend in the number of hogs produced between 1970 and 1980. In Meyer's hog transshipment model, demand is represented by a unique log- linear function for each region. Reactive programing is used only for the purpose of computing spatial equilibrium demand quantities to be inserted as a constraint in the transshipment model. Meyer (1981) constructed the transshipment model to solve for the least cost live hog production, live hog shipment, and pork shipment patterns to fulfill demands. It contain rows and columns which represent different activities for the 28 geographical regions. Meyer used 28 consumption regions; 20 variable production regions and 8 fixed production regions. Williams, Meyer, and Bullock (1983), developed an integrated programming model using two common mathematical programming techniques. This integrated programming model involved sequential employment of reactive programming and linear programming.

Reactive programing makes it possible to obtain a solution for a spatial equilibrium problem by maximizing net returns at each shipping point. Each supply point is considered a shipper and by evaluating the demand at each of the outlets, a set of gross prices is established. From these gross prices, the appropriate transfer costs are deducted to obtain a set of net prices. Supplies are allocated to the outlets that offer the highest net prices. Given the conditions of perfect competition, the equilibrium solution is such that the net revenue to each shipper at the multiple supply points is maximized. However, the least cost transport model will assume constant prices at all supply points and therefore will only minimize the cost of transportation to come up with the most efficient pattern of alfalfa hay movement.

Alfalfa Hay Quality

Quality is as important as quantity in determining how much alfalfa hay will be shipped from one state to another. This study considers only low and high quality alfalfa hay. The assumption is that high quality hay goes to dairy cattle while low quality alfalfa goes to meet other demand by hay consuming species.

However, different studies on alfalfa have used different classifications of quality.

Konyar and Knapp (1986) point out that alfalfa hay quality is measured by its nutrient composition of high energy, protein, minerals, and vitamins. This classification is the same as for Hobbs et al. (1987) after their laboratory quality analysis.

Buzby (1986) contends that producers cannot control alfalfa hay quality; however, the ability to control quality depends on location. In most of the Western United States, alfalfa is irrigated which helps control levels of water at different stages of growth. Producers in other parts of the country where rainfall is the primary source of water, cannot control rainfall, so quality depends on weather.

CHAPTER III

CONCEPTUAL FRAMEWORK

This study can be conceptualized on the basis of spatial equilibrium theory. As a free market crop, the levels of demand and supply of alfalfa hay is a fuction of prevailing prices, number of alfalfa hay consuming animal species and cost of transportation.

The amount of alfalfa hay produced in State "A" (figure 3.1) can be obtained directly from a secondary data source. With known costs of transportation and levels of demand at point "B", we can determine how much alfalfa hay we can ship at the lowest opportunity cost.

The three-panel diagram in figure 3.1 explains the basic hypothetical behavior of the alfalfa hay market at zero transfer cost.

The intersection of supply and demand curves in the central graph (states A and B combined) gives the amount of alfalfa hay (OQ) that state A would be willing to trade with state B after its domestic demands are met; it may also be referred to as the inter-regional equilibrium quantity of alfalfa hay shipped from production to consumption states. This model assumes that the producing state has the same production and consuming location.

Figure 3.1: Hypothetical Market Between State A (Supply) and State B (Demand)

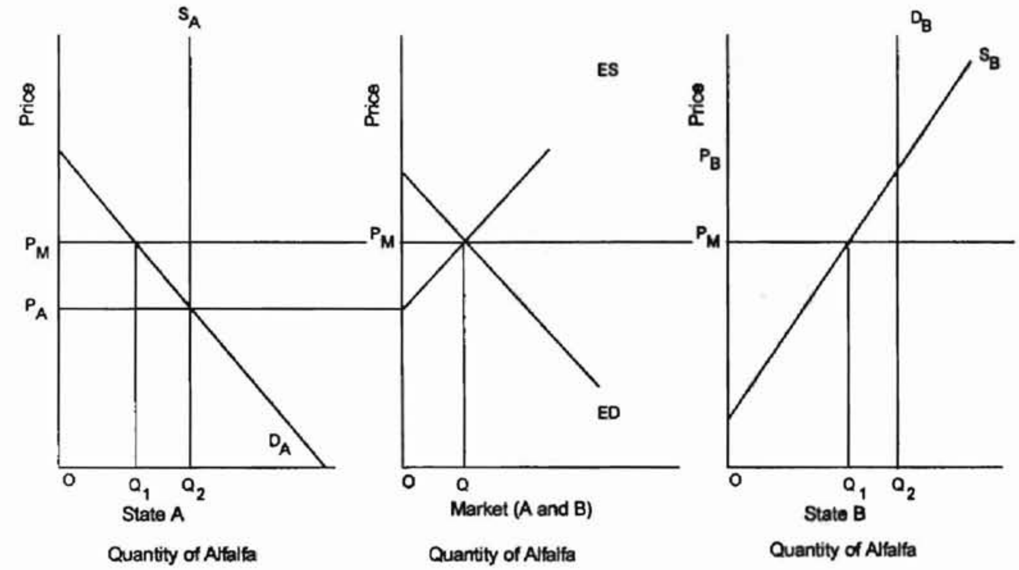
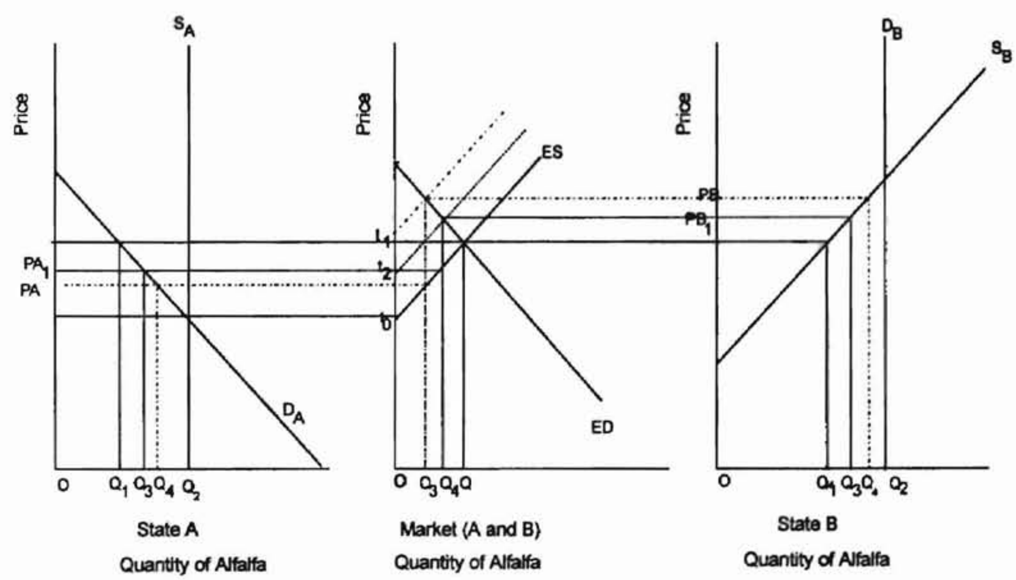


Figure 3.2: Hypothetical Effect of Improved Technology on Alfalfa Market



The introduction of a transfer cost limits the amount that can be shipped from regions A to B. This idea is represented in figure 3.2.

Introducing a transfer cost t_1 in the "market" component of the model decreases the quantity traded from OQ to OQ_3. This is just a theory of the firm argument, where an increase in marginal cost of tranportation causes a decrease in the marginal physical product transported. The quantity supplied by state A is fixed so it will not be affected by the introduction of a transfer cost, however, quantity demanded domestically increases from OQ_1 to OQ_4. In state B, domestic supply increases from OQ_1 to OQ_4 because the opportunity cost of importing exceeds that of local production. This is the same amount state A would have been shipping to state B in the absence of a transfer cost.

Gain in efficiency from improved technology is represented as a reduction in transportation cost, transfer cost from t_1 to t_2. As a result, quantity available in the market for trade increases from OQ_3 to OQ_4. This reduction of transportation cost is also responsible for a decrease in the quantity demanded domestically from OQ_4 to OQ_3 since as it gets cheaper to ship hay, the producers prefer the lucrative inter-state market which leaves the local consumer at a disadvantage. Alfalfa hay producers in state B decrease their production from OQ_4 to OQ_3 which is the level of decrease in state A's domestic consumption. Also, it's cheaper for state B to import alfalfa than buy from local producers. Effects of supply and demand shocks are hypothesized in figure 3.3 and 3.4 respectively.

Figure 3.3: Effect of an Increase in Supply in State A

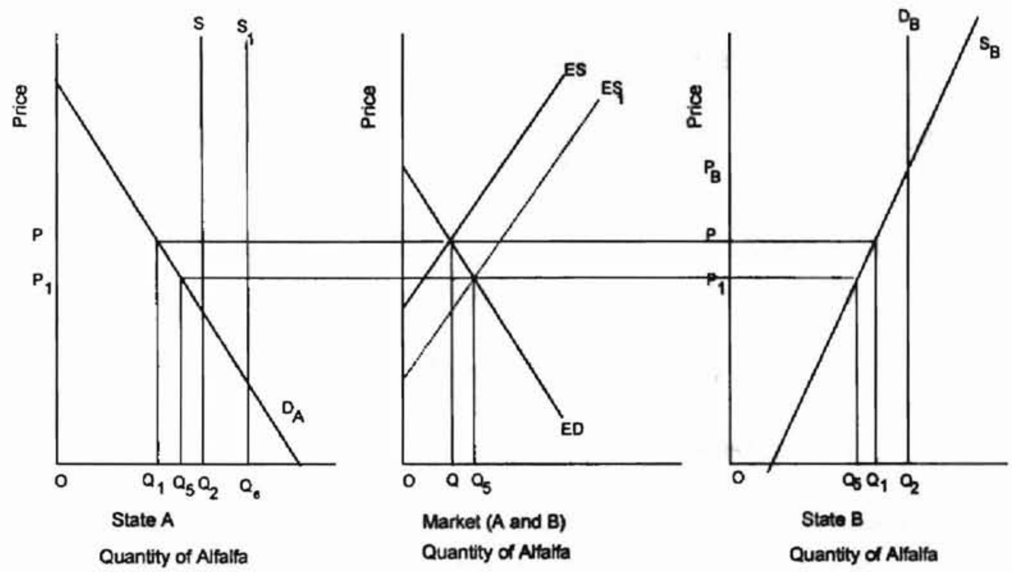
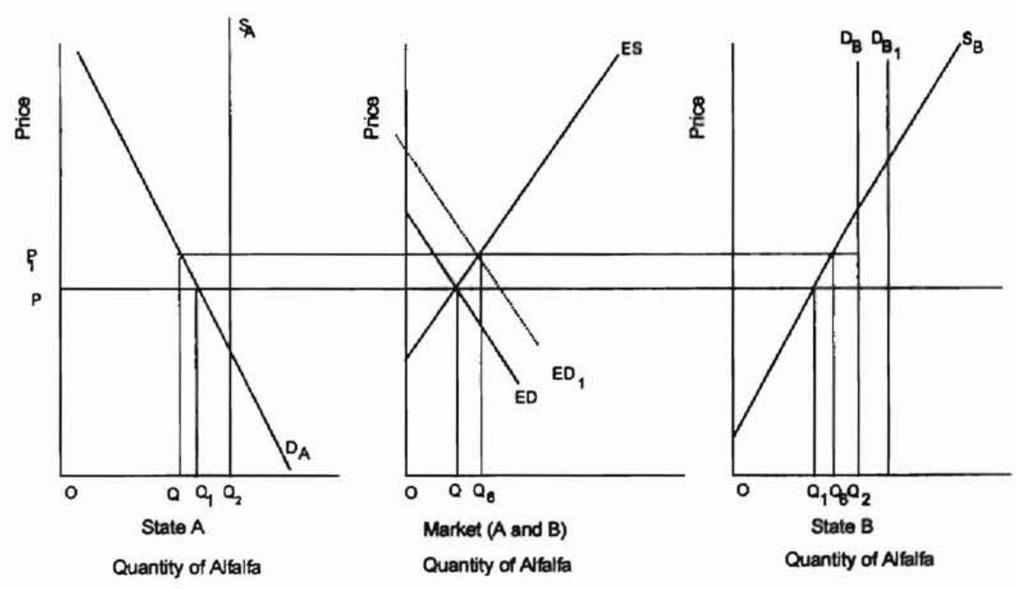


Figure 3.4: Effect of an Increase in Demand in State B



In figure 3.3, as supply increases from S to S_1 in state A , the excess supply market curve shifts from ES to ES_1 in the market. Consequently, quantity traded increase from OQ to OQ_5 is the same as the amount as the increase in state A's excess supply (OQ_2 - OQ_5).

Hypothetically, market prices for alfalfa hay are higher in state A but lower in state B. If state B was to produce its own alfalfa hay, the opportunity cost (shadow price) would be the difference between OP_B and OP. By engaging in trade with state A, livestock producers will pay a lower market price (OP) for alfalfa hay. After supply in state A increases, this market price drops to OP_1. This causes the domestic producers in B to decrease their production further from OQ_1 to OQ_5 which is the same as an increase from OQ to OQ_5 in the market.

Increase in demand in state B from DB to DB_1 causes the quantity traded to increase from OQ to OQ_6. This causes the market demand to shift from ED to ED_1. Quantity supplied to state B from the market increases by (OQ_6-OQ_1). In state A, quantity supplied domestically does not change, however, quantity demanded decreases from OQ_1 to OQ_6. The resultant excess production is the amount shipped to state B.

These three-panel diagrams give the basis of the model design since it is based on surplus and deficit in different states combined with the responses of the survey of animal scientists and agronomists concerning where they sold their alfalfa hay. This information helps us to formulate a hypothesis for testing. Appendix table B3.1 representing different production and consumption levels can be used to hypothesize the flow of alfalfa hay.

The transportation model used here is an unlimited network problem. With known sources and destinations of alfalfa hay, it assumes that alfalfa hay transportation can follow any pattern. Unlike Meyer's (1981) swine-pork industry study, alfalfa hay does not have a processing phase. Therefore, we used linear programing (LP) to solve the problem.

For the model solution to be feasible, we have to impose a restriction that the total supply is greater than or equal to quantity demanded. This is illustrated in a single quality model equation (3.1). The objective function is to minimize cost of transportation Z with the condition that quantity shipped from one state to another state is less than or equal to the amount available in the source state.

$$\begin{aligned} & MIN\ Z = \sum_{i=1}^{48} \sum_{j=1}^{48} C_{ij} X_{ij} \\ & s.t. \sum_{i=1}^{48} X_{ij} \le S_i \text{ for all } i \\ & \sum_{i=1}^{48} X_{ij} \ge D_j \text{ for all } j \end{aligned} \tag{3.1}$$

where:

C_{ij} = Cost of transportation from origin I to destination j,

X_{ij} = Quantity transported from I to j,

S_i = Quantity available in region I,

D_j = Quantity demanded in region j, and

Z = Total transportation cost.

If the total supply is greater than the demand, the constraint will not be violated.

However, if the total demand is greater than the total supply, then the model will be infeasible.

The multi-quality model was set up in such a way that we could have three combinations of supply and demand as follows:

(1) High quality alfalfa hay from source *t* to satisfy the dairy cattle demand in destination *n* using $1.00 per mile shipping rate for 22 tons transported.

(2) High quality alfalfa hay surplus from source *t* to satisfy non-dairy cattle demand in destination *j* and was also shipped at the $1.00 per mile rate.

(3) Low quality alfalfa hay from source *i* to satisfy the non-dairy demand in *j*. This was shipped at a rate of $1.65 per mile for 22 tons hauled just like in the single quality model.

Equation 3.2 represents the objective function for the multi-quality model. After all the dairy demand has been met, the excess high quality is assumed to be fed to non-dairy species. All low quality alfalfa is fed to non-dairy species.

$$\begin{gathered} Min\ Z_1 = \sum_{t=1}^{48}\sum_{n=1}^{48} C_{tn}X_{tn} \ + \ Min\ Z_2 = \sum_{t=1}^{48}\sum_{j=1}^{48} C_{tj}X_{tj} \\ \text{s.}t.\ \sum_{t=1}^{48} X_{tn} \le S_t \text{ for all } t;\ \sum_{t=1}^{48} X_{tj} < S_t \text{ for all } t;\ \sum_{t=1}^{48} X_{tn} \ge D_n \text{ for all } n; \\ \sum_{t=1}^{48} X_{tj} \ge D_j \text{ for all } n. \end{gathered} \tag{3.2}$$

where:

C_{tn} = Cost of transportation from origin *t* to destination *n* in U.S. dollars,

X_{tn} = Quantities transported from *t* to *n* (per 22 tons),

S_t = Quantity available in region *t* in thousand tons,

D_n = Quantity demanded in region n in thousand tons, and

Z_1 = Total transportation cost in U.S. dollars.

C_{tj} = Cost of transportation from origin t to destination j,

X_{tj} = Quantities transported from t to j,

S_t = Quantity available in region t,

D_j = Quantity demanded in region n, and

Z_2 = Total cost of transportation.

CHAPTER IV

METHODS AND PROCEDURE

Procedure

This study is part of a larger project that is examining the market potential for Oklahoma's alfalfa. Buzby (1986) conducted a related study that was also designed to determine the least cost transportation of alfalfa. While our study assumes 48 production and consumption states, her study concentrated only on ten alfalfa producing states around Kentucky. Generally, she was examining Kentucky's demand and related interstate flows for alfalfa hay. Buzby assumed homogeneity of alfalfa quality whereas in this study, alfalfa quality was one of the major variables.

Since alfalfa hay consumption by animal species varies widely, consuming species that will be considered include: dairy cattle, fed cattle, beef cattle, horses, and sheep. These constitute the demand component. Due to lack of data on marketing and usage of alfalfa hay, surveys of animal scientists and agronomists at Land-Grant universities were used to elicit information. One hundred and fifty questionnaires were sent to animal scientists and agronomists in all 48 states. The information sought was: alfalfa hay shipping rates, quantity of alfalfa hay fed to specific animal species per day during the winter (non-grazing) and summer (grazing) months, preferred bale type, and whether they export or import their alfalfa hay from or to their state. The multi-quality model was restricted to 1995, the latest year for which all data were available.

Demand and supply of alfalfa are the key factors in terms of transportation needs. 1995 production data from every state was obtained. Total alfalfa consumption for every state was determined based on the number of sheep, horses, dairy cows, beef cows and fed cattle in each state and the estimated daily alfalfa consumption by species. Specific demand and supply points in each state were chosen and distances between all points were calculated. Shipping costs were computed for each production and consumption region pair. The resulting shipping cost matrix was incorporated into a linear programming framework to develop a transshipment model for solving the least cost flow of alfalfa hay.

Data and Sources

Quantities of alfalfa hay produced by specific states in 1995 were used as the supply component for the base model. Supply qualities for the multi-commodity model were obtained from a combination of primary and secondary data. Production from each state was allocated between low and high qualities as follows: 33% to high quality and 67% to low quality. Agronomists from 16 states provided an estimate of the ratio of high quality to low quality alfalfa hay produced. The average percentage from all responses was used.

In the base model the demand component is made up of all alfalfa hay consuming species. These are: (1) dairy cows, (2) beef cows, (3) fed cattle, (4) sheep, and (5) horses.

Number of animals except for horses, was obtained from Agricultural Statistics (U.S. Department of Agriculture 1996). Horse numbers were obtained from two sources: (1) thoroughbred data from The Jockey Club and (2) Quarter horses from the American Quarter Horse Association. These data are summarized in appendix B3.1.

For the multi-commodity model, dairy cattle was the only species considered for the high quality demand component. While other species (i.e. sheep, fed cattle, beef cattle, and horses) constituted the low quality demand. In the Hobbs et al. (1987) model, the chemical composition of alfalfa hay was analyzed to distinguish low and high quality. However, in the transportation model we assumed, high quality alfalfa hay was equal to or greater than 20 percent Crude Protein (CP) or 150 Relative Feed Value (RFV) based on a previous survey of dairymen (Ward, Huhnke, and Cuperus 1995). Hobbs et al. also used different consumption rates and confined their study to the state of Kentucky as opposed to the 48 states used in this least cost transportation model. Levels of high quality alfalfa hay were obtained by averaging the mid points for answers to question 12 (appendix A1) in the e-mail surveys. An average of 33 percent high quality alfalfa hay was obtained which was what we used to obtain the amounts of high quality alfalfa hay.

Estimated daily alfalfa hay consumption by different animal species was obtained from the survey of animal scientists. To estimate low quality alfalfa consumption in a state for a specific animal species (other than dairy cattle) per year, the average daily consumption rate for alfalfa is multiplied by total number of animals multiplied by 365 days. These are then summed to obtain the low quality demand component. Dairy cattle annual consumption estimate was obtained using the average daily alfalfa consumption, multiplied by total number of dairy cattle in that state, multiplied by 365 days. Data for alfalfa exports to Japan were obtained from Ford (1996).

Cost of Transportation

From the U.S. Bureau of Census density maps, specific locations of alfalfa hay production and demand in given states were identified. Selection of these locations was based on the concentration of alfalfa growing regions and various consuming species within the given state.

Automap Road Atlas Software (Microsoft Corporation 1995) was used to compute distances between supplying and demanding states, based on identified source and destination points. Appendix table B4.2 represents the mileage among all combination of states. Rows represent the supply points while columns represent the demand points. It would be worth noting that the distance from a supply point in "A" to a demand point in state "B" is different from the distance from supply point in state "B" to a demand point in state "A" in most cases. This is because for most states alfalfa hay consuming points are different from alfalfa hay producing points.

Transportation rates and truck sizes were obtained from the agronomist survey. For the single quality base model, $1.65 per mile for a 44,000 pound truck load was used. A $1.00 per mile rate was used in the advanced technology model. The $1.00 per mile per truck rate was used to proxy handling efficiency as a result of improved technology. High quality alfalfa hay fed to dairy cattle is more likely to be harvested in large bale sizes and have a higher handling efficiency than low quality fed to other species. For this reason we used the $1.00 per mile per truck rate. An average of $1.65 per mile per truck was computed as a shipping rate for the base model.

If transportation costs between all combinations (supply and demand) are defined as t_{ij} and trade flows as n_{ij}, then the total transportation cost for all possible trade flows can be expressed as in equations 4.1 and 4.2. Each separate region is a supply region; i = 1, 2, 3, ..., n and demand region; j = 1, 2, 3, ..., n, respectively. With price assumed to be a fixed variable, each region has known quantity demanded and supplied.

$$t_{ij} = r \times d_{ij} \tag{4.1}$$

$$TC = \Sigma\Sigma t_{ij} n_{ij} \tag{4.2}$$

Where:

t = transportation cost for a 22 ton truck load,

r = rate of shipping per mile for 22 ton truck load,

d = distance between i and j (miles),

TC = total transportation cost ($), and

n = quantity of alfalfa hay (thousand tons) shipped from source i to destination j.

California is the port of exit for most of the United States' export to the Pacific Rim. To compute the cost of shipping alfalfa hay to Japan from any state, we established the distance from California to Japan, and then added it to the distance from every state to change) was tested by using lower shipping rates *r* as a proxy for handling and transportation efficiency. Sensitivity to an increase in Texas demand (due to a projected expansion of livestock industry) and changes in Oklahoma supply were explored. Effects of including the international market on the optimal flow pattern was also determined.

California. Ocean rate shipping cost of $55.00 per ton were added to shipping cost of a particular state to California.

Dairy production data for Mexico were not directly available. Milk production levels obtained from Nicholson (1995) provided the basis for estimating dairy cow numbers per state in Mexico. This was done by dividing total annual milk production in each state by annual milk production per cow averaged across different dairy breeds.

Daily alfalfa hay consumption was obtained from the co-operative questionnaire. This and estimated dairy cow numbers were used to compute annual alfalfa consumption, for the demand component of the model. The supply component was obtained from alfalfa production levels for each state in the US.

The cost of shipping alfalfa hay was computed by adding a fixed amount per ton after entering Mexico at the selected ports of entry to the cost of shipping alfalfa to the two ports of entry from the production location in the U.S. For this model two ports of entry were considered; El Paso and Laredo, Texas. Laredo and El Paso in Texas would serve eastern and western states, respectively. We also picked two demand points in Mexico; Toreon and Guadrajala, each of which were combined with each port one at a time. The two demand points were chosen both because of their proximity to the US and the size of their dairy industry. Shipping costs to Guadrajala from the ports of entry were $55 per ton; and to Torreon $25 per ton. This left us with four models to solve.

A linear program solver in GAMS determined the shipping pattern transportation plan that minimizes the cost of shipping to meet demand at all destinations. Various sensitivities of the model were also studied. Effect of compressing bales (technological

CHAPTER V

RESULTS

The objective function of the model is to minimize the cost of transportation. To limit the scope of the model the following assumptions are made:

1. There is a specific supply point in each region (state) and a specific demand point in each region (state),

2. Supply is fixed,

3. The two points (supply and demand) are separated by a known transfer cost,

4. Transfer cost is the cost of shipping hay,

5. There is no storage cost considered, and

6. Truck size was homogenous in all states.

Some of these assumptions tend to limit the model from representing real world conditions. To express the importance and inadequacies of each of them, the six assumptions will be discussed independently.

By assuming that there is a specific supply point *i* in one state and a specific demand point *j* in another state, makes it convenient in calculating the distance from *i* to *j*. Without this assumption we would have to calculate the distance between all supply and loading points within a state, prior to calculating mileage for interstate shipments.

This would be a very complex and time consuming exercise.

The second assumption is that supply at producer points and demand at consumer points are inelastic. The model takes into account only the cost of transportation, ignoring costs of production which is essential for price determination. Price is a function of supply and demand and therefore by fixing quantities supplied and demanded by a given state keeps the level of prices constant.

Another assumption is that cost of storage is not considered. According to Buzby (1986), hay is generally not stored for over one year since returns from storage cannot cover the costs due to storage and product deterioration. Within the same assumption, alfalfa hay produced in one season does carry over to the next. This assumption is valid until better alfalfa hay storage techniques are devised.

Homogeneity of truck size for different states is another assumption that was made. This makes calculations of shipping cost convenient since using different truck sizes for different states would complicate the model. We therefore assumed that a truck load of alfalfa hay is 22 tons.

The cost of shipping from the farm to the collection centers was assumed negligible. Shipping points were assumed to be the production points in a given state, making the cost of shipping to the "production" point equal to zero.

Single Quality Model Results

The results of the transshipment model are summarized in Appendixes, B5.1 to B5.13. Single quality alfalfa hay shipped at $1.65 with no international component is the base model. In all cases, the results represents the optimal flow pattern (i.e., the maximum amount of alfalfa hay that would be shipped to a given destination at a given shipping rate). As illustrated, in the 1995 alfalfa hay production and animal species population table in appendix B3.1 and mileage table in appendix B4.1, the flow pattern is a function of demand, distance, supply and shipping rates.

From the base model in appendix table B5.1, it can be learned that some states meet the demand of other states even before they cleared their own market. For example Oklahoma sends all its 1.444 million tons to Texas and imports from Nebraska and Kansas to meet its demand. Some states, for example, South Dakota skipped closer demand states to supply longer distance markets.

According to the animal scientist and agronomist survey responses (figure 5.1), the general movement of alfalfa hay is different from what the study revealed an indication of lack of information in the alfalfa market. Specific movement for some states un particular, differ sharply. According to survey responses, there are sevral cases where there is a west-east and south-north flow as opposed to an east-west and north-south flow of alfalfa hay revealed by the study. Part of the reason for this is that whereas the model gave us the least cost destination of alfalfa hay

Figure 5.1: Alfalfa Hay Imported into a State from other States Based on Survey Responses

Figure 5.2: Least-Cost Alfalfa Hay Movement, Ten Leading Alfa Production States, 1995 (Assume Domestic Movement, $1.65/ton/mile Transportation Rate) (1,000 Tons)

subject to shipping cost, the survey flow pattern is based on perception and knowledge.

From figure 5.2 (Base[2] model) it can be observed that there is a north to south and west/mid-west to eastern United States general movement of alfalfa hay. For, example states such as Michigan, although supplying alfalfa to itself, most of its supply goes to such places as Indiana, Tennesee, and South Carolina.

The base model results indicate that Oklahoma, a deficit state received its supply from Kansas. Oklahoma shipped all its production to Texas. It would seem logical for Oklahoma, as a deficit state, to meet its demand before shipping its supply anywhere else. Part of the reason is because there are no border restrictions and supply points are different from demand points in some states. If the Kansas production point is closer to Oklahoma's demand point than Oklahoma's own supply point, then the model finds it feasible for Oklahoma to get its supply from Kansas.

Texas is the number one demand state. It has favorable conditions for raising livestock and is also big in area. The model solution indicates that it should get its supply from Oklahoma, Kansas, Nebraska, Missouri, New Mexico and should also supply some to itself. It is interesting to see that a state like Iowa skipped other deficit states such as Kansas and Oklahoma to supply Texas. Visually, it would seem logical for Iowa to meet demand for the closest states and for Texas to exhaust the supply of the neighboring states. However, the transportation cost minimization model found it more feasible for

---

[2] Domestic movement at $1.65/mile rate

Iowa to supply Texas. Shadow prices for other states other than Oklahoma reveal that the opportunity cost of Iowa supplying Kansas is an extra $9.00 per ton as opposed to zero for Texas. In other words for Iowa to supply alfalfa hay to Kansas to enter into the basis, transportation cost between these two states would have to decrease by anextra $9.00 per ton. For a supply activity to be in the basis, the opportunity cost has to be zero.

Although a big supply state, California was also found to be a big demand destination. The model indicates that it should get its supply from Oregon, itself, and Nevada, in that order.

The introduction of an international component in the model as in appendix table B5.6 indicates that all 1.9 million tons of alfalfa hay supplied to Japan should come from California. This is no wonder because California acts as the gateway to most of the Japanese imports. For Oklahoma farmers to export their hay to Japan, they will incur higher shipping costs than California and its neighboring states. As appendix table B5.13 indicates, the shadow price for Oklahoma shipping to Japan is an extra $93.00 per ton. In this context, unless with subsidized transportation costs, Oklahoma farmers should not export their hay to Japan.

Increasing Oklahoma's shipment by 20 percent (appendix table B5.3), the flow pattern is shocked causing a substantial change in quantities and destinations of alfalfa hay. The increased Oklahoma shipment is all sent to Texas.

Among the top ten Producing states, the model indicates that Iowa should decrease its shipment to Arkansas, from 7.9 million tons to 2.2 million tons. As a result, Iowa's shipment to Missouri increases from 1.5 million tons to 2 million tons. The rest of Arkansas' demand is left to be met by Wisconsin. Wisconsin increases its shipments to Tennessee from 178,000 tons to 939,000 tons, and reduces its shipment to Louisiana from 623,000 tons to 493,000 tons. The 637,000 tons Mississippi was getting was getting from Wisconsin now comes from Illinois. South Dakota decreases its shipment to Kansas from 378,000 tons to 89,000 tons. This Kansas deficit is offset by Nebraska which increases its shipment to Kansas from 702,000 tons to 991,000 tons. Other top ten producing states are not affected by the shock.

As illustrated in the appendix table B5.4, increasing Texas demand by 20 percent has no direct effect on Oklahoma because Oklahoma has only Texas as the recipient of its shipment. However, this shock causes a general increase by one unit in Oklahoma's shadow prices to all other states. This extra unit in the opportunity cost for Oklahoma shipments can be avoided by a double shock to the model. By using both the supply and demand shocks, Oklahoma's shadow prices are the same as those of the base model and its shipment increase goes to fulfill the demand increase in Texas. With this demand shock, all the top ten producing states increased their shipment except for Michigan to Connecticut which decreases by a mere 7 percent.

Multi-Quality Model

As indicated in appendix table B5.1 of the single quality model, California meets the international demand all by itself. According to Ford (1996), 90 percent of alfalfa hay shipped to Japan is for dairy. Therefore, in building the multi-quality model, we considered all hay shipped to Japan as high quality alfalfa. According to the Agricultural

Statistics (U.S. Deparment of Agriculture 1996), California is a big dairy producing state. In the multi-quality model where dairy quality alfalfa was determined to be 33 percent of total production, California no longer has enough for itself and for export. Therefore, Utah, Idaho, Nevada and Oregon supplement California's shipment to Japan. California

Figure 5.3: Least Cost Movement Multi-quality. Ten Leading Alfalfa Hay Production States. 1995 (1,000 tons)

Figure 5.4: Least Cost Movement Multi-quality. Ten Leading Alfalfa Hay Consumption States. 1995 (1,000 tons)

meets the rest of its demand for dairy quality alfalfa from Idaho while other species' demand are met by Nevada and Oregon.

The single and multi-quality model solutions are different in the sense that, the multi-quality model (appendix tables B5.7 through B5.10) provides a possibility of shipping alfalfa hay for a longer haul than the single quality model. There is also a noticeable difference in the general movement of alfalfa. The multi-quality's high quality alfalfa (appendix table B5.8), goes to dairy concentrated states irrespective of the distance. Dairy quality alfalfa is harvested frequently in larger bales which have higher handling efficiency. This efficiency is proxied by lower shipping costs.

This makes it possible for dairy quality alfalfa to be transported longer distances than non-dairy quality alfalfa. Figure 5.3 summarizes the solution for the multi-quality model.

This makes it possible for dairy quality alfalfa to be transported longer distances than non-dairy quality alfalfa. Figures 5.3 and 5.4 summarizes the solution for the multi-quality model. Figure 5.3 represents the ten leading alfalfa hay production states while figure 5.4 represents the ten leading alfalfa consumption states. According to figure 5.4, Nebraska retains only 3 percent of its high quality alfalfa while the rest is shipped out of state. On the other hand, it utilizes 54 percent (2.57 million tons) of its low quality alfalfa and markets only 15 percent out of state; 673,000 to Texas and 65,000 to Kansas. This is an indication that although Nebraska, as an example, can ship its low quality hay out of state, it ends up in neighboring states where the distance covered is not as great as to Florida, Virginia and Kentucky, some of its high quality alfalfa destinations.

The model also indicates that whereas Oklahoma exports all its high quality alfalfa hay, it retains 1.01 million tons for its domestic use. It ships 374, 000 tons of dairy quality to Texas. This is yet more proof that markets for non-dairy quality alfalfa hay are more localized than for dairy quality alfalfa. It would be feasible for a state to sell its dairy quality hay production out of state than non-dairy quality alfalfa because it's cheaper to transport and also raises more revenue.

Other top ten alfalfa hay producing states and where they send their hay is as follows: South Dakota to Wisconsin, Delaware, Illinois and Iowa to meet dairy demand. Iowa to Wisconsin for dairy and part of its dairy quality alfalfa production to Texas for non-dairy. Its low quality alfalfa hay is used locally. Wisconsin supplies dairy quality hay to Michigan, Connecticut, New York, Indiana, Delaware and uses some locally. Seven percent of its dairy quality alfalfa is demanded in Louisiana for non-dairy species. Its low quality alfalfa production goes to Missouri, and Arkansas.

Except for the 4 percent of California's shipment (331,000 tons) that goes to meet New Mexico's dairy demand, the rest of its production is either used in the state or exported to Japan. California meets its non-dairy quality demand from itself, Nevada and Oregon and shipment for its dairy from itself, Idaho, Utah, and Oregon. Idaho sends some of its high and low quality alfalfa to Wyoming and exports the rest of its high quality to Japan. Some of its high quality alfalfa is used in Wyoming by other species. Montana retains all its production and uses some of its high quality alfalfa for non-dairy demand.

Effects of 20% increases in Oklahoma's alfalfa shipment and 20% increase in

Texas demand also changes the schedule of the flow pattern. The solution is summarized and presented in appendix tables B5.10 through B5.12. Other sensitivity analyses determined in the single quality model did not apply in the multi-quality model. The $1.00 per ton per mile shipping rate used in the single quality model to proxy effects of improved technology is the same rate used for shipping dairy quality alfalfa. Therefore it was not possible to show the effect of improved technology in the multi-quality model.

International Models

Since 90% of alfalfa hay exported from United States to Japan is dairy quality, Japan was considered as part the destination of alfalfa hay and not as a sensitivity analysis.

To determine the most beneficial model for Oklahoma hay growers, shadow prices for Oklahoma to all states and Japan were considered. The higher the shadow price the more costly it would be for Oklahoma to ship alfalfa hay to a state. The dairy quality alfalfa with 20% increase in Oklahoma supply in the multi-quality model had the lowest spatial shadow price.

For Mexico models, there was a substantial change in the amount and destination of alfalfa hay from having Japan as the only international market for same states. Specifically the following are resulting flow patterns.

Torreon through El Paso

Arizona and New Mexico were the sole exporters of alfalfa hay to Torreon with 18 and 181 thousand tons, respectively. No alfalfa hay from Oklahoma was shipped to

Torreon under the model results. Other results included: California increased the shipment to itself from 550 to 1436 thousand tons. Amounts from Utah were increased from 358 to 376 thousand tons and California no longer demanded from Nevada and Oregon. Missouri alfalfa hay found a new market in Florida with a shipment of 180 thousands tons. Idaho increased its demand from Montana from 409 to 427 thousand tons but decreased demand from Utah from 135 to 117 thousand tons. Kansas shifted its 200 thousand tons demand from itself to Colorado. Kentucky now gets 180 thousands tons from Missouri causing to limit its demand from Nebraska from 408 to 228 thousands tons.

Oklahoma increased it's total shipment from 433 to 454 thousand tons. Kansas shipment to Oklahoma also increases from 43 to 222 thousand tons. Other noticeable effects are the change in players in the Japanese market. Japanese demand formerly was dominated by California, now Nevada and Oregon can ship 324 and 580 thousand tons respectively.

To Torreon through Laredo

In this model, New Mexico was the sole supplier of the 209 thousands tons demanded by the said Mexican state. Oklahoma received 243 thousand tons from Kansas but supplied 433 thousand tons to Texas.

To Guadrajala through El Paso

The changes in this model were slightly different from the first two, however, the differences were insignificant. There was no apparent changes in Oklahoma alfalfa hay market. The demand in Guadrajala was met by Arizona and New Mexico with 18 and 270 thousand tons respectively.

To Guadrajala through Laredo

As observed in the model for Torreon through Laredo, New Mexico was the sole supplier of alfalfa to Guadrajala. One of the most noticeable differences between this model and the first two is that California alfalfa hay demand was not affected by inclusion of Mexico as the second international market. Oklahoma's market response was no different from that in the previous two models.

Changes in the original international model after including Mexico are summarized in tables 5.1 through 5.4.

Table 5.1: Effect of Mexico on the Higher Quality Alfalfa Hay International Model: To Torreon through El Paso.

Shipments to	Shipments from	Base[a]	After[b]	Change
		(1,000 tons)		
California	Arizona	5501	436	-886
California	Utah	358	376	-18
Idaho	Montana	409	427	-18
Idaho	Utah	135	117	18
Kansas	Colorado	0	200	-200
Kentucky	Missouri	0	180	-180
Kentucky	Nebraska	408	228	180
Minnesota	Montana	357[c]	339	-180
Missouri	Missouri	0	180	18
Montana	Missouri	163	343	-180
New Mexico	Arizona	90	72	180
New Mexico	California	331	349	18
Ohio	Vermont	0	39	-18
Oklahoma	Wisconsin	0	22	-39
Kansas	Oklahoma	243	222	-22
Oklahoma	Oklahoma	0	21	21
Texas	Colorado	778[d]	578	-21
Texas	Kansas	234[e]	455[e]	200
Texas	Oklahoma	433	412	221
Japan	California	1189	285	21
Japan	Nevada	0	324	904
Japan	Oregon	0	580	-580
Torreon	New Mexico	0	191	-191
Total Change				-1693

[a] Quantities with Japan as the only international alfalfa hay market.

[b] Quantities after including Mexico in international alfalfa hay market.

[c] Includes 18, 000 tons for non-dairy demand.

[d] All is for non-dairy demand.

[e] All is for non-dairy demand.

Table 5.2: Effect of Mexico on the Higher Quality Alfalfa Hay International Model: To Torreon through Laredo.

Shipments to	Shipments from	Base[a]	After[b]	Change
		(1,000 tons)		
California	Arizona	550	1454	-904
California	Utah	358	358	0
Idaho	Montana	409	409	0
Idaho	Utah	135	135	0
Kansas	Colorado	0	0	0
Kentucky	Missouri	0	0	0
Kentucky	Nebraska	408	408	0
Minnesota	Montana	357[c]	38	319
Missouri	Missouri	0	0	0
Montana	Missouri	163	0	163
New Mexico	Arizona	90	90	0
New Mexico	California	331	331	0
Ohio	Vermont	0	0	0
Oklahoma	Wisconsin	0	0	0
Kansas	Oklahoma	243	243	0
Oklahoma	Oklahoma	0	0	0
Texas	Colorado	778	578[10]	200
Texas	Kansas	234[d]	455[d]	-221
Texas	Oklahoma	433	433	0
Japan	California	1189	285	904
Japan	Nevada	0	324	324
Japan	Oregon	0	580	-580
Torreon	New Mexico	0	209	-209
Total Change				-600

[a] Quantities with Japan as the only international alfalfa hay market.

[b] Quantities after including Mexico in international alfalfa hay market.

[c] Includes 18, 000 tons for non-dairy demand.

[d] Includes 51,000 tons for non-dairy demand.

Table 5.3: Effect of Mexico on the Higher Quality Alfalfa Hay International Model To Guadlajara through El Paso.

Shipments to	Shipments from	Base[a]	After[b]	Change
		(1,000 tons)		
California	Arizona	550	0	550
California	Utah	358	376	-18
Idaho	Montana	409	327	82
Idaho	Utah	135	117	18
Kansas	Colorado	0	200	-200
Kentucky	Missouri	0	0	0
Kentucky	Nebraska	408	408	0
Minnesota	Montana	357[c]	38	319
Missouri	Missouri	0	0	0
Montana	Missouri	163	0	163
New Mexico	Arizona	90	72	18
New Mexico	California	331	349	-18
Ohio	Vermont	0	0	0
Oklahoma	Wisconsin	0	0	0
Kansas	Oklahoma	243	243	0
Oklahoma	Oklahoma	0	0	0
Texas	Colorado	778[d]	578	759
Texas	Kansas	455[e]	434	21
Texas	Oklahoma	433	433	0
Japan	California	1189	609	580
Japan	Nevada	0	0	0
Japan	Oregon	0	580	-580
Guadlajara	New Mexico	0	270	-270
Total Change				1429

[a] Quantities with Japan as the only international alfalfa hay market.

[b] Quantities after including Mexico in international alfalfa hay market.

[c] Includes 18, 000 tons for non-dairy demand.

[d] Includes 559,000 tons for non-dairy demand.

Table 5.4: Effect of Mexico on the Higher Quality Alfalfa Hay International Model: To Guadlajara through Laredo.

Shipments to	Shipments from	Base[a]	After[b]	Change
		(1,000 tons)		
California	Arizona	550	0	550
California	Utah	358	358	0
Idaho	Montana	409	409	0
Idaho	Utah	135	135	0
Kansas	Colorado	0	200	-200
Kentucky	Missouri	0	0	0
Kentucky	Nebraska	408	408	0
Minnesota	Montana	357[c]	0	357
Missouri	Missouri	0	0	0
Montana	Missouri	163	0	163
New Mexico	Arizona	90	90	0
New Mexico	California	331	331	0
Ohio	Vermont	0	0	0
Oklahoma	Wisconsin	0	0	0
Kansas	Oklahoma	243	243	0
Oklahoma	Oklahoma	0	0	0
Texas	Colorado	778	678[d]	100
Texas	Kansas	455	434	21
Texas	Oklahoma	433	433	0
Japan	California	1189	1189	0
Japan	Nevada	0	0	0
Japan	Oregon	0	0	0
Guadlajara	New Mexico	0	288	-288
Total Change				708

[a] Quantities with Japan as the only international alfalfa hay market.

[b] Quantities after including Mexico in international alfalfa hay market.

[c] Includes 18, 000 tons for non-dairy demand.

[d]Includes 51,000 tons for non-dairy demand.

Chapter VI

SUMMARY AND CONCLUSION

In determining the least cost flow pattern for low and high quality alfalfa hay, part of the data used was secondary while surveys were used to elicit the rest of the data.

Supply, demand and cost of transportation were determined to provide the parameters for the models. In the single quality model, supply from a state represents the exact amount produced in 1995 and demand is the total consumption based on the number of alfalfa hay consuming animals. Shipping rates are from the survey of agronomists.

In the multi-quality model, of alfalfa hay produced, 33 percent was estimated to be dairy quality and 67 percent was of lower quality based on a survey of agronomists. The dairy demand was based on the number of dairy cows and estimated alfalfa consumption per day. Demand by other species was based on total number of other alfalfa hay consuming livestock and estimated alfalfa consumption per day. A $1.00 per mile transportation rate was used for transporting high quality alfalfa hay and $1.65 per mile rate was used for shipping non-dairy quality alfalfa.

The objective function of the study was to minimize the cost of transportation from production locations to consumption locations. Oklahoma is an alfalfa hay deficit state. The optimal flow pattern did not indicate that Oklahoma could ship its hay to Japan and Florida. However, a drop in Oklahoma's shadow prices to Florida from $51.00 to $31.00 per ton per mile assuming larger bale sizes indicates that compressing alfalfa hay to increase shipping and handling efficiency will help Oklahoma exploit long distance markets. Growers can exploit this situation and produce a higher percentage of high quality alfalfa which can make them competitive for such markets as Florida. Otherwise they might not cover the cost of shipping.

The whole 20 percent increase in Oklahoma's shipment goes to Texas. This is an indication that Texas livestock producers get their hay from Kansas and other long distance sources because Oklahoma does not have enough. Therefore even though Oklahoma might not have a great potential in longer distance markets, it could still be advisable for Oklahoma hay producers to investment more in the alfalfa hay industry to exploit this Texas market as long as production costs are covered.

For the Mexico models, except in model two (to Torreon through Laredo) where Oklahoma increased its shipments, there is no apparent significant advantage to the Oklahoma alfalfa hay market due to inclusion of Mexico in the model. New Mexico is the dominant supplier to both Torreon and Guadrajala due to a combination of its location and excess shipment of high quality alfalfa hay.

REFERENCES

Bressler, R.G. Jr., and R.A. King. "Market Prices and Inter-Regional Trade." Multi-region Models: Production and Consumption Fixed. New York: John Wiley and Sons, Inc., 1970, pp. 93-107.

Brooke.A, A. Drud and A. Meeras. GAMS BDM-LP Version. Development Research Department, World Bank, Washington D.C (1992).

Buzby, J.C. "A Spatial Analysis of Alfalfa Hay Transportation In the Central States." Unpublished M.S. thesis, University of Kentucky, 1986.

Ford W.P., "Forage Exports From The Western United States to the Pacific Rim." 27th National Alfalfa Symposium Report. San Diego, California: 1996, pp. 73-80.

Hobbs, K.J., Jean C. Buzby, Joe T. Davis, Barry W. Bobst. "Alfalfa Demand Estimates Using Feed-Mix Model for Dairy, Horses, and Beef Industries". Universtity of Kentucky, Lexington Kentucky. Agricultural Economics Research Report 47 October 1987, pp. 5-25.

Hough, J.A., "Pricing of Transportation Services." Logistics of the U.S. Wheat Industry. Kansas City Kansas: Upper Grain Transportation Institute Publication No. 100, (October 1994): pp. 21-30.

Kallenbach, R.L., "The Size, Scope and Impact Of Hay Exports From The South West United States". 27th National Alfalfa Symposium Report. San Diego, California:1996, pp. 69-71.

Konyar, K. and K. Knapp, Demand for Alfalfa Hay in California. University of California at Riverside: Gianini Foundation Research Report No. 333, May 1986, pp. 4-20.

Meyer, S.R., Transshipment Model of the U.S. Swine-Pork Industry. Oklahoma Experiment Station Research Report, May 1981.

Microsoft Corporation. Automap Road Atlas - Version 4.0. New York: 1995.

Nicholson, Charles F., Mexico's Dairy Sector in the 1990s: A Descriptive Analysis. Department of Agriculture, Resource, and Managerial Economics, Cornell University, November 1995.

Skaggs, R. and Donald L. Snyder., "A Comparison of Selected Methods of Forecasting Monthly Alfalfa Hay Prices." New Mexico State University, 1992.

Skaggs, R. Results of a Survey of New Mexico Alfalfa Hay Producers, End-Users, and Brokers/Dealers. New Mexico State University, Agricultural Experimental Station Bulletin 765, November 1992.

Tomek, W. G. and Kenneth L. Robinson. Agricultural Product Prices. Ithaca, New York: Cornell University Press, 1990, pp 142-146.

U.S. Bureau of Census. 1992 Census of Agriculture. Economics and Statistics Administration, Government Printing Office, 1995.

U.S. Department of Agriculture: Agricultural Statistics. Washington D.C.: U.S. Government Printing Office, 1986, 1988, and 1995.

Wheaton.H., and J. Ross. "Alfalfa for Beef Cows". Woodland, California: Certified Alfalfa Seed Council, Inc. University of Missouri-Columbia, (Not dated).

William, J.E., and S. Meyer, and J.B. Bullock. "Interregional Competition in the U.S. Swine-Pork Industry." Southern Journal of Agricultural Economics July 1983:145-152.

Ward, Clement., Raymond L. Huhnke, and Gerrit W. Cuperus. 1995. Alfalfa Hay preferences by Oklahoma and Texas Dairy Producers. Oklahoma State University, Extension Circular E-936.

APPENDIX

APPENDIX A

A1: Animal Scientist, Agronomist and Exporters Surveys

1. How many pounds of **alfalfa hay** are **fed per head per day on average during the winter months** by producers in your state?

Lbs. Fed/Head/Day

	Small Operation	Large Operation
Dairy cows		
Beef cows		
Fed cattle		
Horses		
Sheep		

2. How many pounds of **alfalfa hay** are **fed per head per day on average during the summer months** by producers in your state? (Exclude grazed alfalfa.)

Lbs. Fed\Head\Day

	Small Operation	Large Operation
Dairy cows		
Beef cows		
Fed cattle		
Horses		
Sheep		

3. Is alfalfa hay **imported** into your state from other states?. Yes ☐ No ☐
If yes, identify the primary sources (i.e. states) based on total quantity imported. List of States____

____

4. Is alfalfa hay **exported** from your state **to other states?** Yes ☐ No ☐
If yes, identify the primary markets (i.e. states) based on total quantity exported. List of States____

____

5. Is alfalfa hay **exported** from your state to other countries? Yes ☐ No ☐
If yes, identify the primary markets (i.e. countries) based on total quantity exported.
List of Countries ____

____

6. Is alfalfa hay **imported** into your state from other states?. Yes ☐ No ☐
If yes, identify the primary sources (i.e. states) based on total quantity imported. List of States____

____

7. Is alfalfa hay **exported** from your state **to other states?** Yes ☐ No ☐
If yes, identify the primary markets (i.e. states) based on total quantity exported. List of States____

____

8. Is alfalfa hay **exported** from your state to other countries? Yes ☐ No ☐
If yes, identify the primary markets (i.e. countries) based on total quantity exported.
List of Countries ____

____

9. What are your transportation costs for shipping ocean containers overseas? Please indicate volume of each size of container and any differences in cost depending on package type.

Mode	Package type	Container volume	cost per unit distance
Ocean container	________	____________	________
Ocean container	________	____________	________

10. What is the load limit for transporting alfalfa in your state?
___40,000 lbs. (20 tons) _50,000 lbs. (25 tons)
___44,000 lbs. (22 tons) _58,000 lbs. (29 tons)
___48,000 lbs. (24 tons) ______Other (Please specify)______

11. What is the common trucking rate for transporting alfalfa hay in your state?

$______per loaded mile for ________Package type/size (units)

or

$______per______________for_____package type/size.(units)

12. What percentage of your Alfalfa hay is fed to dairy cows?

Appendix B

Appendix B3.1: 1995 Alfalfa Hay Production data and number of Alfalfa hay consuming animals.

State	Alfalfa Prod. ('000 Tons)	Dairy Cows ('000 Head)	Beef Cows ('000 Head)	Fed Cattle ('000 Head)	Sheep ('000 Head)	Horses ('000 Heads)	Alfalfa Cons. Dairy '000 tons	Alfalfa Cons. Other sp. '000 to	Total Cons. '000 tons	Difference '000 tons
AL	0	36	904	17	5	39	89	639	728	-728
AZ	1287	116	239	443	70	49	287	365	652	635
AR	63	61	969	27	0	54	151	700	851	-788
CA	6900	1250	840	844	430	170	3093	1119	4212	2688
CO	3060	83	817	2089	210	92	205	1328	1534	1526
CT	32	32	8	0	5	4	79	11	90	-58
DE	15	10	3	0	0	1	25	3	28	-13
FL	0	170	1130	0	0	64	421	808	1229	-1229
GA	0	102	708	32	0	44	252	520	773	-773
ID	4510	220	500	570	194	59	544	621	1165	3345
IL	2480	165	505	591	55	52	408	583	991	1489
IN	1280	145	325	422	55	45	359	405	764	516
IA	4860	250	1060	1920	155	70	619	1394	2013	2847
KS	3230	81	1509	4304	87	87	200	2407	2608	622
KY	1170	165	1165	84	17	57	408	853	1261	-91
LA	0	79	531	11	10	67	196	427	623	-623
ME	30	39	18	0	8	3	97	17	114	-84
MD	237	91	69	42	14	13	225	77	302	-65
MA	48	28	9	0	8	4	69	13	82	-34
MI	4305	333	132	443	49	42	824	282	1106	3199
MN	4988	600	420	654	110	43	1485	552	2037	2951
MS	0	57	683	8	0	38	141	490	631	-631
MO	1260	195	2105	148	53	80	483	1521	2004	-744
MT	4000	21	1559	211	367	85	52	1282	1334	2666
NE	4725	75	1885	4093	70	76	186	2570	2756	1969
NV	1080	23	242	53	61	20	57	214	271	809
NH	27	19	5	0	5	2	47	6	53	-26
NJ	105	23	13	8	11	9	57	25	82	23
NM	1325	170	560	327	210	60	421	593	1014	311
NY	1690	710	70	53	44	28	1757	106	1863	-173
NC	62	89	481	32	11	36	220	366	586	-524
ND	3080	65	945	211	79	37	161	744	905	2175
OH	2660	293	337	475	107	51	725	452	1177	1483
OK	1444	98	1952	802	60	189	243	1744	1986	-542
OR	1935	100	610	211	200	50	247	576	823	1112
PA	2262	639	171	169	74	34	1581	222	1803	459
RI	4	2	1	0	0	1	5	2	7	-3
SC	0	28	242	15	0	16	69	180	249	-249
SD	6500	120	1660	717	355	63	297	1473	1770	4730
TN	180	130	1130	57	6	38	322	798	1119	-939
TX	576	400	6000	5022	1100	457	990	6261	7251	-6675
UT	2344	85	345	127	310	68	210	430	640	1704
VT	200	157	15	0	14	2	389	16	405	-205
VA	462	129	721	84	65	23	319	540	859	-397
WA	2550	263	317	329	35	54	651	377	1028	1522
WV	120	22	238	21	43	9	54	184	238	-118
WI	5980	1500	190	317	53	30	3712	268	3980	2000
WY	1914	6	734	211	460	52	15	735	750	1164
U.S.	84980	9487	35156	26229	5300	2672	23477	0	58859	26121

Appendix B4.1: Distance between all production and consumption locations.

	AL-Arab	AZ-Chandler	AR-Conway	CA-Modesto	CO-Grover	CT-Manches	DE-Maliford	FL-Holopaw	GA-Sparta	ID-Twin Fall	IL-Stokton
AL-Decateu	59	688	355	2243	1308	1079	853	671	316	1937	683
AZ-Buckey	1726	1056	1321	684	997	2614	2438	2227	2008	870	1732
AR-Horsesh	342	435	102	1991	1046	1292	1089	939	602	1675	594
CA-Holtvill	1965	1258	1522	564	1182	2816	2695	2361	2142	867	1977
CO-Anton	1231	665	880	1267	137	1857	1677	1814	1435	799	861
CT-Manche	1055	1640	1380	3033	1868	0	316	1263	1002	2497	1072
DE-Newcas	811	1425	1135	2887	1723	255	63	1003	725	2351	940
FL-Lakelan	622	1266	976	2875	1897	1259	1035	73	440	2525	1262
GA-Carters	134	857	524	2412	1400	1012	787	529	150	2029	775
ID-Idaho fa	1872	1349	1563	829	618	2399	2292	2455	2076	160	1403
IL-Freeport	431	866	668	2055	891	1050	962	1276	897	1519	22
IN-Southbe	586	914	705	2197	1032	828	757	1153	774	1661	236
IA-West Un	855	794	710	1970	805	1214	1125	1437	1058	1434	142
KS-Salina	881	310	524	1598	478	1503	1327	1464	1085	1136	622
KY-Versaill	356	879	573	2372	1208	818	628	878	459	1837	504
LA-Arcadia	483	393	227	1950	1176	1503	1277	903	660	1834	868
ME-Bangor	1374	1959	1698	3256	2091	324	643	1582	1320	2720	1295
MD-Thurm	717	1330	1041	2791	1627	363	172	956	663	2256	831
Ma-Worcest	1108	1742	1432	3085	1921	58	368	1316	1054	2550	1125
MI-Lakevie	744	1046	837	2329	1165	821	790	1308	888	1793	369
MN-Melros	1115	956	898	1901	845	1312	1358	1627	1318	1046	1197
MS-Forest	270	605	348	2161	1369	1290	1064	1369	447	1998	802
MO-King C	790	498	463	1777	612	1398	1186	1373	994	1241	402
MT-Belgrad	1894	1448	1566	1041	702	2342	2253	2476	2098	372	1249
NE-Norfolk	1009	566	682	1640	476	1477	1370	1592	1213	1104	460
NV-Yeringt	2324	1611	1855	213	1070	2851	2764	2907	2528	488	1855
NH-Manche	1182	1766	1506	3120	1956	131	441	1389	1128	2584	1160
NJ-Glassbor	843	1457	1135	2929	1765	241	95	1035	757	2394	969
NM-Artesia	1217	540	833	1290	687	2126	1944	1637	1394	1100	1329
NY-Rome	1038	1505	1286	2861	1696	233	377	1298	984	2325	900
NC-Lexingt	444	1121	789	2677	1613	701	468	628	287	2241	885
ND-Dickins	1539	1137	1267	1473	607	1871	1782	2122	1743	804	858
OH-Massill	657	1092	873	2503	1339	568	446	1036	694	1968	543
OK-Chikash	752	54	347	1572	719	1646	1469	1341	1012	1357	848
OR-Adel	2330	1807	2021	490	1075	2857	2750	2912	2533	487	1860
PA-Shippe	723	1319	1035	2772	1608	342	195	996	669	2237	812
RI-Warwick	1115	1712	1439	3104	1940	81	378	1318	1061	2568	1144
SC-Rockvill	414	1215	882	2771	1760	902	654	450	246	2389	1076
SD-Gregory	1176	704	848	1562	452	1636	1529	1758	1379	978	575
TN-Cumber	222	681	349	2237	1181	1056	866	808	429	1810	556
TX-Longvie	597	282	262	1838	1064	1594	1368	1017	774	1641	916
UT -Smithfi	1797	1274	1488	801	542	2324	2236	2379	2000	199	1328
VT-Rutland	1152	1682	1464	3038	1874	168	441	1377	1098	2502	1078
VA-Harriso	577	1234	846	2790	1614	481	256	865	523	2243	825
WA-Addy	2338	1853	2010	996	1146	2786	2697	2920	2542	575	1693
WV-Richwo	522	1153	873	2646	1482	630	408	828	486	2111	730
WI-Janesvil	708	880	683	2101	937	1047	958	1291	912	1565	77
WY-Sherida	1652	1164	1324	1221	419	2090	2014	2234	1855	552	1006

Appendix B4.1 Continued

	IN-Southben	IA- Oelwein	KS-Wichita	KY-Columbia	LA-Kentwood	ME-Old city	MD-Fredrick	MA-Greenfiel	MI-Grand Ra	MN-Little fa	MS-Magnolia	MO-Mansfield	MT-White Sup	NE-Beatrice
AL-Decateu	553	788	789	257	707	1523	720	1132	663	1082	399	439	1868	858
AZ-Buckey	1888	1647	1087	1826	1561	2995	2284	2660	1972	1798	1577	1373	1221	1268
AR-Horsesh	637	637	489	442	408	1736	948	1345	721	937	393	184	1606	596
CA-Holtvill	2089	1892	1288	2044	1695	3197	2485	2861	2173	1983	1711	1574	1266	1469
CO-Anton	1021	776	446	1139	1264	2114	1523	1866	1105	867	1250	757	793	395
CT-Manche	828	1219	1525	914	1481	449	380	70	824	1446	1413	1286	2218	1476
DE-Newcast	690	1073	1310	686	1177	706	117	316	728	1313	1169	1071	2199	1298
FL-Lakelan	1126	1377	1459	775	770	1721	940	1331	1235	1670	700	1105	2457	1447
GA-Carters	630	880	963	279	796	1456	653	1065	738	1174	471	608	1960	950
ID-Idaho fa	1563	1282	1130	1780	1948	2656	2138	2408	1647	1100	1934	1402	310	1010
IL-Freeport	214	143	663	559	910	1307	807	1060	299	436	895	737	1275	498
IN-Southbe	0	383	777	400	910	1098	603	846	114	610	895	560	1544	640
IA-WestUni	378	33	578	733	987	1470	971	1223	462	312	972	544	1130	413
KS-Salina	755	537	91	789	909	1848	1173	1549	839	648	849	408	1144	148
KY-Versaill	323	622	771	109	726	1261	474	871	421	877	694	509	1736	758
LA-Arcadia	896	886	610	662	254	1946	1144	1556	980	1120	240	419	1842	787
ME-Bangor	1062	1442	1844	1232	1474	128	699	308	995	1467	1477	1605	2329	1699
MD-Thurm	587	977	1215	591	1083	807	21	416	619	1204	1075	976	2090	1184
Ma-Worcest	881	1271	1578	966	1421	392	432	59	843	1498	1466	1339	2384	1529
MI-Lakevie	162	515	909	559	1042	1025	636	778	48	527	1027	692	1669	772
MN-Melros	610	325	740	955	1266	1520	1203	1281	531	50	1251	756	888	685
MS-Forest	808	852	782	528	148	1733	931	1343	892	1169	133	455	1882	874
MO-King C	562	317	282	698	847	1655	1032	1407	646	503	833	320	1173	162
MT-Belgrad	1506	1134	1228	1802	1951	2373	2099	2177	1431	927	1937	1424	106	1059
NE-Norfolk	641	353	346	917	1067	1733	1215	1486	725	402	1052	539	902	172
NV-Yeringt	2015	1770	1582	2232	2142	3108	2609	2860	2099	1748	2149	1854	958	1462
NH-Manche	925	1306	1651	1040	1522	352	506	99	859	1440	1539	1412	2301	1563
NJ-Glassbor	725	1115	1342	718	1177	685	149	294	757	1342	1201	1103	2228	1329
NM-Artesia	1400	1244	664	1296	966	2507	1826	2172	1484	1429	1912	885	1279	840
NY-Rome	666	1046	1390	833	1548	540	362	189	600	1274	1395	1151	2159	1304
NC-Lexingt	662	1007	1175	415	888	1103	352	775	729	1258	762	821	2121	1163
ND-Dickins	1035	750	917	1379	1652	1902	1628	1706	975	456	1637	1124	460	788
OH-Masaill	299	689	977	420	1404	960	292	615	331	917	995	738	1802	947
OK-Chikash	919	764	209	852	698	2090	1315	1692	1004	949	678	404	1365	445
OR-Adel	2021	1776	1587	2237	2309	3113	2595	2866	2105	1740	2316	1859	852	1467
PA-Shippe	568	958	1204	581	1518	785	62	395	621	1185	1080	965	2125	1191
RI-Warwick	900	1290	1597	973	1209	420	439	120	897	1517	1481	1358	2403	1547
SC-Rockvill	891	1193	1323	562	943	1370	599	980	975	1451	788	969	2320	1310
SD-Gregory	800	457	485	1083	1233	1892	1374	1645	884	436	1218	705	734	331
TN-Cumber	461	661	744	178	485	1500	712	1109	563	955	470	389	1741	731
TX-Longvie	954	924	498	720	345	2037	1234	1647	1038	1109	353	453	1731	681
UT -Smithfi	1488	1243	1054	1704	1828	2580	2082	2333	1572	1243	1858	1327	452	934
VT-Rutland	843	1224	1567	1010	1740	361	476	98	777	1339	1509	1328	2201	1481
VA-Harriso	581	961	1177	486	1010	925	122	535	613	1198	935	915	2159	1164
WA-Addy	1950	1578	1633	2246	2395	2725	2543	2671	1867	1371	2381	1868	452	1503
WV-Richwo	507	852	1045	374	1089	1073	286	683	574	1103	879	783	1989	1032
WI-Janesvill	211	175	709	555	924	1303	804	1056	295	403	909	526	1288	544
WY-Sherida	1254	891	945	1559	1709	2346	1860	2099	1338	832	1694	1181	291	776

Appendix B4.1 Continued

	NV-Fallon	NH-Mancheste	NJ-Glassboro	NM-Rincon	NY-Rome	NC-Butner	ND-Linton	OH-Wardswo	OK-Paulsvalle	OR-Garibaldi	PA-Coatesville	RI-Warwick
AL-Decateu	2236	1205	867	1366	1037	560	1382	616	688	2569	847	1138
AZ-Buckey	770	2740	2431	431	2479	2202	1569	2058	1056	1355	2392	2686
AR-Horsesh	1968	1418	1096	1142	1193	818	1120	773	435	2307	1061	1352
CA-Holtvill	650	2942	2633	565	2680	2420	1672	2259	1258	1235	2593	2887
CO-Anton	1098	1945	1670	688	1685	1558	637	1277	665	1432	1631	1929
CT-Manche	2796	131	240	2334	232	659	1760	556	1640	3129	266	81
DE-Newcas	2650	381	34	2119	321	356	1627	424	1425	2984	42	314
FL-Lakelan	2824	1385	1049	1808	1325	689	1970	1074	1266	3158	1026	1332
GA-Carters	2328	1138	800	1516	995	424	1474	646	857	2661	781	1072
ID-Idaho fa	592	2487	2296	1032	2227	2199	808	1847	1349	793	2238	2471
IL-Freeport	2427	1138	947	1470	878	932	750	498	866	2887	889	1118
IN-Southbe	1960	925	725	1608	665	731	924	276	914	2293	667	899
IA-West Un	1733	1301	1111	1385	1042	1104	621	662	794	1953	1053	1285
KS-Salina	1435	1629	1320	845	1368	1208	622	947	310	1768	1281	1575
KY-Versaill	2136	944	622	1573	731	463	1191	311	879	2469	586	877
LA-Arcadia	1927	1629	1290	960	1443	946	1312	1022	393	2466	1271	1349
ME-Bangor	3019	227	560	2653	467	656	1773	875	1959	3169	585	295
MD-Thurm	2554	498	159	2025	346	310	1518	324	1330	2888	108	423
Ma-Worcest	2849	74	292	2387	251	616	1812	609	1742	3182	319	61
MI-Lakevie	2092	856	775	1740	597	816	841	326	1046	2426	717	895
MN-Melros	1664	1360	1343	1455	1274	1328	316	894	956	1729	1297	1386
MS-Forest	2138	1416	1077	1171	1272	733	1443	888	605	2630	1058	1116
MO-King C	1540	1486	1179	1067	1226	1117	686	806	498	1874	1140	1470
MT-Belgrad	804	2312	2239	1244	2170	2185	635	1790	1448	834	2181	2413
NE-Norfolk	1403	1564	1373	1101	1305	1328	440	924	566	1737	1315	1548
NV-Yeringt	67	2939	2748	1106	2679	2651	1457	2299	1611	686	2690	2923
NH-Manche	2883	0	365	2460	268	935	1746	682	1766	3217	393	117
NJ-Glassbor	2693	367	0	2151	321	388	1656	453	1457	3026	55	295
NM-Artesia	1273	2252	1943	215	1990	1672	1192	1570	540	1732	1904	2198
NY-Rome	2624	268	321	2199	0	731	1588	426	1505	2957	298	306
NC-Lexingt	2540	827	483	1800	704	98	1572	462	1121	2874	460	757
ND-Dickins	1236	1841	1768	1276	1699	1753	165	1319	1137	1301	1710	1942
OH-Massill	2267	694	433	1786	443	508	1230	23	1092	2600	379	639
OK-Chikash	1549	1772	1463	723	1510	1228	959	1090	54	1989	1424	1717
OR-Adel	307	2944	2753	1367	2685	2656	1449	2304	1807	454	2695	2928
PA-Shippe	2535	468	164	2013	324	349	1499	305	1319	2869	110	401
RI-Warwick	2867	117	295	2406	306	671	1831	628	1712	3201	326	0
SC-Rockvill	2688	1053	698	1833	961	338	1765	723	1215	3021	675	981
SD-Gregory	1325	1723	1532	1113	1463	1487	268	1083	704	1558	1474	1707
TN-Cumber	2109	1182	860	1360	958	594	1255	537	681	2442	825	1122
TX-Longvie	1815	1720	1381	848	1500	1059	1249	1080	282	2274	1362	1653
UT -Smithfi	564	2411	2220	916	2152	2123	951	1771	1274	831	2162	2395
VT-Rutland	2801	120	361	2376	185	730	1646	603	1682	3135	371	204
VA-Harriso	2542	607	269	1913	464	223	1512	327	1234	2875	250	541
WA-Addy	834	2665	2683	1601	2614	2629	1079	2234	1853	508	2625	2857
WV-Richwo	2633	756	421	1847	580	284	1417	287	1153	2743	398	689
WI-Janesvil	1864	1134	943	1517	874	928	717	512	880	2129	897	895
WY-Sherida	984	2177	1986	1072	1917	1943	511	1537	1164	1114	1928	2161

Appendix B4.1

	SC-Newberry	SD-Parkston	TN-Waynesbo	TX-Winnsboro	UT-Smithfield	VT-Albany	VA-Altavista	WA-Blaine	WV-Martinsbu	WI-Monroe	WY-Afton
AL-Decateu	403	1080	93	564	1764	1286	561	2641	691	686	1763
AZ-Buckey	2083	1461	1667	1212	811	2742	2184	1587	2266	1748	907
AR-Horsesh	699	819	243	336	1503	1457	800	2355	927	618	1502
CA-Holtvill	2242	1646	1845	1346	840	2943	2402	1467	2467	1993	936
CO-Anton	1478	530	1097	888	627	1915	1509	1504	1505	877	626
CT-Manche	868	1574	1114	1589	2325	259	599	3097	390	1071	2324
DE-Newcas	601	1428	870	1345	2179	488	315	2965	160	939	2178
FL-Lakelan	531	1669	751	1069	2353	1502	748	3229	965	1266	2352
GA-Carters	238	1260	240	742	1856	1228	455	2733	624	778	1856
ID-Idaho fa	2119	895	2208	1517	143	2457	2174	865	2120	1396	117
IL-Freeport	883	527	613	910	1347	1109	877	2024	790	25	1346
IN-Southbe	712	738	542	949	1489	900	676	2262	592	235	1620
IA-West Un	1054	382	767	892	1262	1272	1049	1879	953	150	1261
KS-Salina	1128	383	752	533	964	1631	1183	1840	1155	638	963
KY-Versaill	400	977	312	782	1664	995	439	2491	456	503	1664
LA-Arcadia	760	1010	460	185	1662	1709	977	2538	1115	892	1661
ME-Bangor	1186	1797	1433	1908	2548	256	918	2936	709	1294	2547
MD-Thurm	529	1332	776	1251	2083	570	244	2856	65	830	2082
Ma-Worcest	920	1626	1167	1690	2377	234	652	2960	443	1124	2377
MI-Lakevie	830	870	700	1081	1621	827	741	2179	618	399	1620
MN-Melros	1460	304	1004	1054	923	1321	1273	1750	1186	413	1113
MS-Forest	1033	1096	271	408	1825	1496	1088	2633	902	817	1825
MO-King C	1037	385	661	600	1069	1456	1092	1945	1014	418	1068
MT-Belgrad	2141	780	1522	1671	355	2174	2130	759	2081	1247	300
NE-Norfolk	1256	128	880	789	932	1535	1273	1651	1198	478	931
NV-Yeringt	2571	1459	2161	1756	639	2909	2626	918	2572	1871	735
NH-Manche	994	1661	1240	1715	2412	184	725	2909	516	1159	2411
NJ-Glassbor	633	1470	902	1377	2221	467	347	2994	192	968	2221
NM-Artesia	1494	1050	1627	598	977	2254	1654	1804	1782	1344	1097
NY-Rome	850	1401	1026	1495	2153	266	582	2790	372	899	2152
NC-Lexingt	153	1385	510	998	2069	928	129	2876	334	884	2068
ND-Dickins	1702	482	1459	1404	787	1703	1697	1227	1610	838	686
OH-Massill	560	1044	613	1083	1795	706	413	2568	274	542	1795
OK-Chikash	1109	680	653	277	1185	1774	1210	2061	1297	864	1184
OR-Adel	2577	1464	2200	1922	626	2915	2632	654	2578	1876	737
PA-Shippe	535	1313	782	1256	2064	557	266	2837	57	811	2063
RI-Warwick	927	1645	1174	1648	2396	296	659	3021	450	1143	2395
SC-Rockvill	181	1533	616	1070	2217	1150	397	3093	619	1077	2216
SD-Gregory	1422	93	1046	927	854	1694	1432	1483	1356	605	805
TN-Cumber	479	953	97	558	1638	1221	576	2467	703	559	1637
TX-Longvie	874	972	521	76	1550	1763	1079	2427	1206	940	1549
UT -Smithfi	2044	931	1743	1497	0	2382	2099	903	2072	1343	125
VT-Rutland	964	1579	1211	1673	2330	117	695	2809	486	1077	2329
VA-Harriso	389	1316	636	1111	2071	677	121	2850	94	824	2070
WA-Addy	2585	895	2276	2115	712	2527	2574	330	2525	1691	680
WV-Richwo	352	1207	580	1055	1938	847	182	2722	246	729	1938
WI-Janesvil	877	547	627	925	1393	1105	873	2055	786	35	1392
WY-Sherida	1899	538	1128	1387	518	2148	1887	1040	1812	1005	406

Appendix B5.1: Base model Single Quality; Optimal Shipping Pattern From Production To Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		752														
SAR			63													
SCA				1468												
SCO					1532									1528		
SCT						32										
SDE							15									
SFL																
SGA																
SID										1165						
SIL	728		788								991					
SIN								688				501			91	
SIA													2013			
SKS																
SKY															1170	
SLA																
SME																
SMD																
SMA																
SMI									773			263				
SMN																
SMS																
SMO																
SMT																
SNE														702		
SNV				1080												
SNH																
SNJ						23	4									
SNM																
SNY																
SNC								62								
SND																
SOH								479								
SOK																
SOR				1664												
SPA						35	13									
SRI																
SSC																
SSD														378		
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI								649								623
SWY																

Appendix B5.1

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													526			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA							1436									
SKS																
SKY																
SLA																
SME	30															
SMD		237														
SMA			19								26					
SMI	84		63	1106										173		
SMN					2037											
SMS								1205								
SMO																
SMT								400								
SNE									2756							
SNV																
SNH											27					
SNJ												82				
SNM													488			
SNY														1690		
SNC																
SND																905
SOH															478	
SOK																
SOR										271						
SPA		65													108	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI						631	568									
SWY								934								

Appendix B5.1

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL								761								
SIN																
SIA									623							
SKS		719							2511							
SKY																
SLA																
SME																
SMD																
SMA					3											
SMI											205					
SMN																
SMS																
SMO									1260							
SMT																
SNE		1267														
SNV																
SNH																
SNJ				33												
SNM									837							
SNY				47												
SNC																
SND																
SOH	1177					249						277				
SOK									1444							
SOR																
SPA				1803										238		
SRI					4											
SSC																
SSD							1770									
STN								180								
STX									576							
SUT										640						750
SVT											200					
SVA												462				
SWA			823										1028			
SWV												225				
SWI								901				120			3980	
SWY																

Appendix B5.2:Technology Shock, Single Quality; Optimal Shipping Pattern From Production To Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		752														
SAR			63													
SCA				1468												
SCO					1532											
SCT						32										
SDE							15									
SFL																
SGA																
SID																
SIL	728		568								991					
SIN								425				764			91	
SIA			220										2013			
SKS														639		
SKY															1170	
SLA																
SME																
SMD																
SMA																
SMI								14	773			263				
SMN																
SMS																
SMO																
SMT																
SNE														1969		
SNV				1080												
SNH																
SNJ						23										
SNM																
SNY																
SNC								60								
SND																
SOH								790								
SOK																
SOR				1664												
SPA						35	13									
SRI																
SSC																
SSD																
STN																
STX																
SUT										1165						
SVT																
SVA																
SWA																
SWV																
SWI								649								623
SWY																

Appendix B5.2

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													526			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL						193										
SIN																
SIA							2004									
SKS																
SKY																
SLA																
SME	30															
SMD		237													127	
SMA			19								26					
SMI	84		63	1106										173		
SMN					2037											
SMS																
SMO																
SMT								400								
SNE									2756							
SNV																
SNH											27					
SNJ												82				
SNM													488			
SNY														1690		
SNC															62	
SND																905
SOH															416	
SOK																
SOR										271						
SPA		65													108	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI						438	1911									
SWY								934								

Appendix B5.2

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR																
SCA																
SCO									1528							
SCT																
SDE																
SFL																
SGA																
SID																750
SIL								544								
SIN																
SIA																
SKS		164							2427							
SKY																
SLA																
SME																
SMD																
SMA					3											
SMI						249					205					
SMN																
SMS																
SMO									1260							
SMT																
SNE									34							
SNV																
SNH																
SNJ																
SNM									837							
SNY											220					
SNC																
SND																
SOH	1177											277				
SOK		1444														
SOR																
SPA				1803										238		
SRI					4											
SSC																
SSD		378					1770									
STN								180								
STX									576							
SUT										640						752
SVT											200					
SVA												462				
SWA			823										1028			
SWV												120				
SWI								357							3980	
SWY																

Appendix B5.3: 20% Increase in Oklahoma Production; Optimal Shipping Pattern from Production To Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		752														
SAR			63													
SCA				1468												
SCO					1532									1528		
SCT						32										
SDE							15									
SFL																
SGA																
SID										1165						
SIL	728										991					130
SIN								688				501			91	
SIA			220										2013			
SKS																
SKY															1170	
SLA																
SME																
SMD																
SMA																
SMI									773			263				
SMN																
SMS																
SMO																
SMT																
SNE														991		
SNV				1080												
SNH																
SNJ						23	13									
SNM																
SNY																
SNC								62								
SND																
SOH								479								
SOK																
SOR				1664												
SPA						35	13									
SRI																
SSC																
SSD														89		
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI			568					649								493
SWY																

Appendix B5.3

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													526			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA							2004									
SKS																
SKY																
SLA																
SME	30															
SMD		237													127	
SMA			19								26					
SMI	84		63	1106										173		
SMN					2037											
SMS								1205								
SMO																
SMT								400								
SNE									2756							
SNV																
SNH											27					
SNJ												82				
SNM													488			
SNY														1690		
SNC																
SND																905
SOH															478	
SOK																
SOR										271						
SPA		65													108	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV															120	
SWI						631	568									
SWY								934								

Appendix B5.3

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL								761								
SIN																
SIA									623							
SKS		1008							2222							
SKY																
SLA																
SME																
SMD																
SMA					3											
SMI											205					
SMN																
SMS																
SMO									1260							
SMT																
SNE		978														
SNV																
SNH																
SNJ				33												
SNM									837							
SNY				47												
SNC																
SND																
SOH	1177					249						277				
SOK									1733							
SOR																
SPA				1803										238		
SRI					4											
SSC																
SSD		17					1770									
STN								180								
STX									576							
SUT										640						750
SVT											200					
SVA												462				
SWA			823										1028			
SWV												120				
SWI								939							3980	
SWY																

Appendix B5.4: 20 % Increase In Texas Demand; Optimal Shipping Pattern From Production To Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		752														
SAR			63													
SCA				1468												
SCO					1532									796		
SCT						32										
SDE							15									
SFL																
SGA																
SID										1165						
SIL	728		788								991					
SIN								669				520			91	
SIA													2013			
SKS																
SKY															1170	
SLA																
SME																
SMD																
SMA						19										
SMI									773			244				
SMN																
SMS																
SMO																
SMT																
SNE																
SNV				1080												
SNH																
SNJ						10	13									
SNM																
SNY																
SNC								62								
SND																
SOH								498								
SOK																
SOR				1664												
SPA						29	13									
SRI																
SSC																
SSD														1812		
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI								649								623
SWY																

Appendix B5.4

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													526			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA							1436									
SKS																
SKY																
SLA																
SME	30															
SMD		110													127	
SMA											26					
SMI	84		82	1106										173		
SMN					2037											
SMS								1205								
SMO																
SMT								400								
SNE									2756							
SNV																
SNH											27					
SNJ												82				
SNM													488			
SNY														1690		
SNC																
SND																905
SOH															339	
SOK																
SOR										271						
SPA		192													108	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV															120	
SWI						631	568									
SWY								934								

Appendix B5.4

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL								761								
SIN																
SIA									623							
SKS		719							2511							
SKY																
SLA																
SME																
SMD																
SMA					3											
SMI											205					
SMN																
SMS																
SMO									1260							
SMT																
SNE		1969														
SNV																
SNH																
SNJ				33												
SNM									837							
SNY				47												
SNC																
SND																
SOH	1177					249						397				
SOK									1444							
SOR																
SPA				1803										238		
SRI					4											
SSC																
SSD		17					1770									
STN								180								
STX									576							
SUT										640						750
SVT											200					
SVA												462				
SWA			823										1028			
SWV												225				
SWI								901				120			3980	
SWY																

Appendix B5.5: 20% Increase in Texas Demand and Oklahoma Production Optimal Shipping Pattern from Production to Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		752														
SAR			63													
SCA				1468												
SCO					1532									1085		
SCT						32										
SDE							15									
SFL																
SGA																
SID										1165						
SIL	728		788								991					
SIN								688				520			91	
SIA						19							2013			
SKS																
SKY															1170	
SLA																
SME																
SMD																
SMA																
SMI									773			244				
SMN																
SMS																
SMO																
SMT																
SNE																
SNV				1080												
SNH																
SNJ						10	13									
SNM																
SNY																
SNC								62								
SND																
SOH								479								
SOK																
SOR				1664												
SPA						29										
SRI																
SSC																
SSD								1523						1523		
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI								649								623
SWY																

Appendix B5.5

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													526			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA							1436									
SKS																
SKY																
SLA																
SME	30															
SMD		110													127	
SMA											26					
SMI	84		82	1106										173		
SMN					2037											
SMS																
SMO																
SMT								400								
SNE									2756							
SNV																
SNH											27					
SNJ												82				
SNM													488			
SNY														1690		
SNC																
SND																905
SOH															459	
SOK																
SOR										271						
SPA		192														
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV															120	
SWI						631	568									
SWY								934								

Appendix B5.5

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL								761								
SIN																
SIA									623							
SKS									3230							
SKY																
SLA																
SME																
SMD																
SMA					3											
SMI											205					
SMN																
SMS																
SMO									1260							
SMT																
SNE		1969														
SNV																
SNH																
SNJ																
SNM									837							
SNY																
SNC																
SND																
SOH	1177					249						277				
SOK									1733							
SOR																
SPA				1803										238		
SRI					4											
SSC																
SSD		17					1770									
STN								180								
STX									576							
SUT										640						750
SVT											200					
SVA												462				
SWA			823										1028			
SWV												120				
SWI								178							3980	
SWY																

Appendix B5.6: International Component; Optimal Shipping Pattern From Production To Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		717														
SAR			105													
SCA				1009												
SCO					1465									678		
SCT						57										
SDE							21									
SFL																
SGA																
SID										997						
SIL	735										1304					
SIN								7				947			466	
SIA			220										2147			
SKS																
SKY									10						806	
SLA																
SME																
SMD																
SMA						58										
SMI									802			263				
SMN																
SMS																
SMO																
SMT																
SNE														1566		
SNV				984												
SNH																
SNJ							4									
SNM																
SNY																
SNC								60								
SND																
SOH								549								
SOK																
SOR				1603												
SPA																
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI			568					649								697
SWY																

Appendix B5.6

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													461			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA							2004									
SKS																
SKY																
SLA																
SME	54															
SMD		248													127	
SMA			19								13					
SMI				1165										173		
SMN					2634											
SMS																
SMO																
SMT								1205								
SNE									2969							
SNV																
SNH											59					
SNJ												109				
SNM													313			
SNY			97											2272		
SNC																
SND																951
SOH															106	
SOK																
SOR										329						
SPA		108													489	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT	80															
SVA																
SWA																
SWV															120	
SWI						679	1911									
SWY																

Appendix B5.8

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY	Japan
SAL																	
SAK																	
SAZ																	
SAR																	
SCA																	1189
SCO																	
SCT																	
SDE																	
SFL																	
SGA																	
SID																	
SIL								544									
SIN																	
SIA																	
SKS									3510								
SKY																	
SLA									32								
SME																	
SMD																	
SMA					3												
SMI																	
SMN																	
SMS																	
SMO									1260								
SMT																	
SNE		362							34								
SNV																	
SNH																	
SNJ				33													
SNM									887								
SNY				47							220						
SNC																	
SND																	
SOH	1349					313						384					
SOK		1505															
SOR																	
SPA				1827										264			
SRI					9												
SSC																	
SSD							1718										
STN								300									
STX									640								
SUT										582						752	
SVT											208						
SVA												264					
SWA			802										962				
SWV												225					
SWI								357							4468		
SWY																	

Appendix B5.7: Multi-Quality Base Model Solution: Optimal Shipping Pattern From Production To Consumption Regions (low Quality to non-Dairy Demand)

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		365														
SAR																
SCA																
SCO					1328									814		
SCT						11										
SDE							3									
SFL																
SGA																
SID										621						
SIL	639										583					
SIN												405				
SIA													1394			
SKS														1593		
SKY															819	
SLA																
SME																
SMD								89								
SMA																
SMI																
SMN																
SMS																
SMO																
SMT																
SNE														65		
SNV				756												
SNH																
SNJ																
SNM																
SNY																
SNC								43								
SND															34	
SOH								25	520							
SOK																
SOR				363												
SPA								651								
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI			700													427
SWY																

Appendix B5.7

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													515			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA																
SKS																
SKY																
SLA																
SME	17															
SMD		77														
SMA			13													
SMI				282												
SMN					552											
SMS																
SMO																
SMT								1264								
SNE									2570							
SNV																
SNH											6					
SNJ												25				
SNM													78			
SNY														106		
SNC																
SND																744
SOH																
SOK																
SOR										214						
SPA															366	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI						490	1521									
SWY																

Appendix B5.7

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR									44							
SCA																
SCO																
SCT																
SDE				8												
SFL																
SGA																
SID																
SIL									514							
SIN								491								
SIA									668							
SKS		733														
SKY																
SLA																
SME																
SMD																
SMA																
SMI																
SMN																
SMS																
SMO									882							
SMT																
SNE									5							
SNV																
SNH																
SNJ				49												
SNM									850							
SNY																
SNC																
SND																
SOH	452					96		181								
SOK		1011														
SOR			576													
SPA				165								217		184		
SRI					2											
SSC																
SSD							1473									
STN								126								
STX									403							
SUT										430						735
SVT											16					
SVA												323				
SWA													377			
SWV						84										
SWI									58						268	
SWY																

Appendix B5.8: Multi-Quality Base Model, high quality to dairy and non-dairy demand.

	DDAL	DDAZ	DDAR	DDCA	DDCO	DDCT	DDDE	DDFL	DDGA	DDID	DDIL	DDIN	DDIA	DDKS	DDKY	DDLA	DDME
SSAL																	
SSAK																	
SSAZ		287															
SSAR								19									
SSCA				550													
SSCO																	
SSCT						10											
SSDE																	
SSFL																	
SSGA																	
SSID				1281													
SSIL	89																
SSIN																	
SSIA																	
SSKS			151											200			
SSKY																	
SSLA																	
SSME																	9
SSMD																	
SSMA																	
SSMI																	
SSMN						54											
SSMS																	
SSMO									198								
SSMT										409							88
SSNE								402							408		
SSNV				324													
SSNH																	
SSNJ																	
SSNM																23	
SSNY																	
SSNC																	
SSND																	
SSOH																	
SSOK																	
SSOR				580													
SSPA																	
SSRI						1											
SSSC																	
SSSD											408		619				
SSTN									54								
SSTX																173	
SSUT				358						135							
SSVT																	
SSVA																	
SSWA																	
SSWV																	
SSWI							25					359					
SSWY					205												
SSJAP																	

Appendix B5.8

	DDMD	DDMA	DDMI	DDMN	DDMS	DDMO	DDMT	DDNE	DDNV	DDNH	DDNJ	DDNM	DDNY	DDNC	DND	DDOH
SSAL																
SSAK																
SSAZ												90				
SSAR																
SSCA												331				
SSCO						140										
SSCT																
SSDE											4					
SSFL																
SSGA																
SSID									57							
SSIL																341
SSIN																384
SSIA																
SSKS					141											
SSKY														201		
SSLA																
SSME																
SSMD																
SSMA																
SSMI		41											1250			
SSMN		7	824	611												
SSMS																
SSMO						180										
SSMT				339			52								161	
SSNE	196					163		186								
SSNV																
SSNH										8						
SSNJ											31					
SSNM																
SSNY													507			
SSNC														19		
SSND				535												
SSOH																
SSOK																
SSOR																
SSPA																
SSRI																
SSSC																
SSSD	29															
SSTN																
SSTX																
SSUT																
SSVT		21								39						
SSVA																
SSWA																
SSWV																
SSWI											22					
SSWY																
SSJAP																

Appendix B5.8

	DDOK	DDOR	DDPA	DDRI	DDSC	DDSD	DDTN	DDTX	DDUT	DDVT	DDVA	DDWA	DDWV	DDWI	DDWY	DDJP	DMT	DTX
SSAL																		
SSAK																		
SSAZ																		
SSAR																		
SSCA																1189		
SSCO																		778
SSCT																		
SSDE																		
SSFL																		
SSGA																		
SSID															15			
SSIL														314				
SSIN																		
SSIA														1458				
SSKS	243							183										51
SSKY					69						82							
SSLA																		
SSME																		
SSMD			71															
SSMA																		
SSMI																		
SSMN																		
SSMS																		
SSMO																		
SSMT		133															18	
SSNE											62							
SSNV																		
SSNH																		
SSNJ																		
SSNM								374										
SSNY																		
SSNC																		
SSND										389								
SSOH			798															
SSOK								433										
SSOR																		
SSPA			679															
SSRI																		
SSSC																		
SSSD						297							54	543				
SSTN																		
SSTX																		
SSUT									210									
SSVT																		
SSVA											139							
SSWA		114										651						
SSWV											36							
SSWI			33	5										1350				
SSWY							322							47				
SSJAP																		

Appendix B5.9: 20% Increase in Oklahoma Production, Multi-Quality Model; Optimal Shipping Pattern from Production to Consumption Regions (low Quality to non-dairy Demand)

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		365														
SAR																
SCA																
SCO					1328									814		
SCT						11										
SDE							3									
SFL																
SGA																
SID										621						
SIL	639		514								583					
SIN												405				
SIA													1394			
SKS														1593		
SKY															819	
SLA																
SME																
SMD								89								
SMA																
SMI																
SMN																
SMS																
SMO																
SMT																
SNE																
SNV				756												
SNH																
SNJ																
SNM																
SNY																
SNC								43								
SND																
SOH								25	520						34	
SOK																
SOR				363												
SPA								651								
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI			186													
SWY																421

Appendix B5.9

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND	DOH
SAL																	
SAK																	
SAZ													515				
SAR																	
SCA																	
SCO																	
SCT																	
SDE																	
SFL																	
SGA																	
SID																	
SIL																	
SIN																	
SIA																	
SKS																	
SKY																	
SLA																	
SME	17																
SMD																	
SMA			13														
SMI				282													
SMN					552												
SMS																	
SMO																	
SMT								1264									
SNE									2570								
SNV																	
SNH											6						
SNJ												25					
SNM													78				
SNY														106			
SNC																	
SND																744	
SOH																	452
SOK																	
SOR										214							
SPA		77													366		
SRI																	
SSC																	
SSD																	
STN																	
STX																	
SUT																	
SVT																	
SVA																	
SWA																	
SWV																	
SWI						490	1521										
SWY																	

Appendix B5.9

	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL															
SAK															
SAZ															
SAR								44							
SCA															
SCO															
SCT															
SDE			8												
SFL															
SGA															
SID															
SIL															
SIN							491								
SIA								2008							
SKS	668														
SKY															
SLA															
SME															
SMD															
SMA															
SMI															
SMN															
SMS															
SMO								882							
SMT															
SNE	738														
SNV															
SNH															
SNJ			49												
SNM								850							
SNY															
SNC					96										
SND															
SOH							181								
SOK	338							823							
SOR		576													
SPA			165								217		184		
SRI				2											
SSC															
SSD						1473									
STN							126								
STX								403							735
SUT									430						
SVT										16					
SVA											323				
SWA												377			
SWV					84										
SWI								283						268	
SWY															

Appendix 5.10: Multi-Quality Model: 20% increase in Oklahoma supply high quality to dairy and non-dairy demand.

	DDAL	DDAZ	DDAR	DDCA	DDCO	DDCT	DDDE	DDFL	DDGA	DDID	DDIL	DDIN	DDIA	DDKS	DDKY	DDLA	DDME
SSAL																	
SSAK																	
SSAZ		287															
SSAR								19									
SSCA				851													
SSCO																	
SSCT						10											
SSDE																	
SSFL																	
SSGA																	
SSID				1338													
SSIL	89																
SSIN																	
SSIA																	
SSKS			151											200			
SSKY																	
SSLA																	
SSME																	9
SSMD																	
SSMA						14											
SSMI						54											
SSMN																	
SSMS																	
SSMO									252								
SSMT										409							38
SSNE								348							408		
SSNV				324													
SSNH																	
SSNJ																	
SSNM																23	
SSNY																	
SSNC																	
SSND																	50
SSOH																	
SSOK																	
SSOR				580													
SSPA																	
SSRI						1											
SSSC																	
SSSD											408		619	200			
SSTN								54	59								
SSTX																173	
SSUT										135							
SSVT																	
SSVA																	
SSWA																	
SSWV																	
SSWI						25						359					
SSWY					205												
SSJAP																	

Appendix B5.10

	DDMD	DDMA	DDMI	DDMN	DDMS	DDMO	DDMT	DDNE	DDNV	DDNH	DDNJ	DDNM	DDNY	DDNC	DDND	DDOH
SSAL																
SSAK																
SSAZ												90				
SSAR																
SSCA												331				
SSCO						140										
SSCT																
SSDE											4					
SSFL																
SSGA																
SSID											17					
SSIL																341
SSIN																384
SSIA																
SSKS					141											
SSKY														200		
SSLA																
SSME																
SSMD																
SSMA										16						
SSMI		41											1199			
SSMN		7	824	611												
SSMS																
SSMO						126										
SSMT							52									
SSNE	196					217		186								
SSNV																
SSNH										8						
SSNJ											31					
SSNM																
SSNY													507			
SSNC														19		
SSND				423												
SSOH																
SSOK																
SSOR																
SSPA																
SSRI																
SSSC																
SSSD	29															
SSTN																
SSTX																
SSUT									57							
SSVT		21								39						
SSVA																
SSWA																
SSWV																
SSWI											22					
SSWY																
SSJAP																

Appendix B5.10

	DDOK	DDOR	DDPA	DDRI	DDSC	DDSD	DDTN	DDTX	DDUT	DDVT	DDVA	DDWA	DDWV	DDWI	DDWY	DDJP	DMT	DTX	DWY
SSAL																			
SSAK																			
SSAZ																			
SSAR																			
SSCA																888			
SSCO																		778	
SSCT																			
SSDE																			
SSFL																			
SSGA																			
SSID															15				
SSIL														314					
SSIN																			
SSIA														1458					
SSKS	243							44										190	
SSKY					69						82								
SSLA																			
SSME																			
SSMD			71																
SSMA																			
SSMI																			
SSMN																			
SSMS																			
SSMO																			
SSMT		133								389							18		
SSNE											62								
SSNV																			
SSNH																			
SSNJ																			
SSNM								374											
SSNY																			
SSNC																			
SSND																			
SSOH			798																
SSOK								572										329	
SSOR																			
SSPA			679																
SSRI																			
SSSC																			
SSSD						297								597					
SSTN																			
SSTX																			
SSUT									210							301			
SSVT																			
SSVA											139								
SSWA		114										651							
SSWV											36								
SSWI			33	5									54	1296					
SSWY							322							47					
SSJAP																			

Appendix B5.11: 20% Increase in Texas Demand, Multi-Quality Model, Optimal Shipping Pattern from Production to Consumption Regions

	DAL	DAZ	DAR	DCA	DCO	DCT	DDE	DFL	DGA	DID	DIL	DIN	DIA	DKS	DKY	DLA
SAL																
SAK																
SAZ		365														
SAR																
SCA																
SCO					1328									814		
SCT						11										
SDE							3									
SFL																
SGA																
SID										621						
SIL	639										583					
SIN												405				
SIA													1394			
SKS														955		
SKY															819	
SLA																
SME																
SMD								89								
SMA																
SMI																
SMN																
SMS																
SMO																
SMT																
SNE																
SNV				756												
SNH																
SNJ																
SNM																
SNY																
SNC								43								
SND																
SOH								25	520						34	
SOK																
SOR				363												
SPA								651								
SRI																
SSC																
SSD														1346		
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI			700													427
SWY																

Appendix B5.11

	DME	DMD	DMA	DMI	DMN	DMS	DMO	DMT	DNE	DNV	DNH	DNJ	DNM	DNY	DNC	DND
SAL																
SAK																
SAZ													515			
SAR																
SCA																
SCO																
SCT																
SDE																
SFL																
SGA																
SID																
SIL																
SIN																
SIA																
SKS																
SKY																
SLA																
SME	17															
SMD		77														
SMA			13													
SMI				282												
SMN					552											
SMS																
SMO																
SMT								1264								
SNE									2570							
SNV																
SNH											6					
SNJ												25				
SNM													78			
SNY														106		
SNC																
SND																744
SOH																
SOK																
SOR										214						
SPA		77													366	
SRI																
SSC																
SSD																
STN																
STX																
SUT																
SVT																
SVA																
SWA																
SWV																
SWI						490	1521									
SWY																

Appendix B5.11

	DOH	DOK	DOR	DPA	DRI	DSC	DSD	DTN	DTX	DUT	DVT	DVA	DWA	DWV	DWI	DWY
SAL																
SAK																
SAZ																
SAR									42							
SCA																
SCO																
SCT																
SDE				7												
SFL																
SGA																
SID																
SIL																
SIN									246						268	
SIA								491	2008							
SKS		643							663							
SKY																
SLA																
SME																
SMD																
SMA																
SMI																
SMN																
SMS																
SMO									882							
SMT																
SNE									783							
SNV																
SNH																
SNJ				45												
SNM									858							
SNY																
SNC																
SND																
SOH	452					96		181								
SOK		1101							968							
SOR			576													
SPA				165								217		184		
SRI					2											
SSC																
SSD							1473									
STN								126								
STX									403							735
SUT										430						
SVT											16					
SVA												323				
SWA													377			
SWV						84										
SWI									1048							
SWY																

Appendix B5.12: 20% increase in Texas Demand Multi-Quality, Optimal Shipping Pattern From Production To Consumption Regions. (High Quality to Dairy and non-Dairy Demand)

	DDAL	DDAZ	DDAR	DDCA	DDCO	DDCT	DDDE	DDFL	DDGA	DDID	DDIL	DDIN	DDIA	DDKS	DDKY	DDLA	DDME
SSAL																	
SSAK																	
SSAZ		287															
SSAR								19									
SSCA				550													
SSCO														200			
SSCT						10											
SSDE																	
SSFL																	
SSGA																	
SSID				1281													
SSIL	89																
SSIN																	
SSIA																	
SSKS			151														
SSKY																	
SSLA																	
SSME																	9
SSMD																	
SSMA						14											
SSMI																	
SSMN						54											
SSMS																	
SSMO									252						126		
SSMT										409							88
SSNE								348							282		
SSNV				324													
SSNH																	
SSNJ																	
SSNM																23	
SSNY																	
SSNC																	
SSND																	
SSOH																	
SSOK																	
SSOR				580													
SSPA																	
SSRI						1											
SSSC																	
SSSD											408		619				
SSTN								54									
SSTX																173	
SSUT				358						135							
SSVT																	
SSVA																	
SSWA																	
SSWV																	
SSWI							25					359					
SSWY					205												
SSJAP																	

Appendix B5.12

	DDMD	DDMA	DDMI	DDMN	DDMS	DDMO	DDMT	DDNE	DDNV	DDNH	DDNJ	DDNM	DDNY	DDNC	DDND	DDOH
SSAL																
SSAK																
SSAZ												90				
SSAR																
SSCA												331				
SSCO						140										
SSCT																
SSDE											4					
SSFL																
SSGA																
SSID									57							
SSIL																341
SSIN																384
SSIA																
SSKS					141											
SSKY														201		
SSLA																
SSME																
SSMD																
SSMA																
SSMI		41											1250			
SSMN		7	824	611												
SSMS																
SSMO																
SSMT							52								161	
SSNE	196					343		186								
SSNV																
SSNH										8						
SSNJ											31					
SSNM																
SSNY													507			
SSNC														19		
SSND				874												
SSOH																
SSOK																
SSOR																
SSPA																
SSRI																
SSSC																
SSSD	29															
SSTN																
SSTX																
SSUT																
SSVT		21								39						
SSVA																
SSWA																
SSWV																
SSWI											22					
SSWY																
SSJAP																

Appendix B5.12

	DDOK	DDOR	DDPA	DDRI	DDSC	DDSD	DDTN	DDTX	DDUT	DDVT	DDVA	DDWA	DDWV	DDWI	DDWY	DDJP	MT	TX
SSAL																		
SSAK																		
SSAZ																		
SSAR																		
SSCA																1869		
SSCO								147										631
SSCT																		
SSDE																		
SSFL																		
SSGA																		
SSID															15			
SSIL														314				
SSIN																		
SSIA														1458				
SSKS								477										
SSKY					69						82							
SSLA																		
SSME																		
SSMD			71															
SSMA																		
SSMI																		
SSMN																		
SSMS																		
SSMO																		
SSMT		133								339							18	
SSNE											62							
SSNV																		
SSNH																		
SSNJ																		
SSNM																		
SSNY																		
SSNC																		
SSND										50								
SSOH			798															
SSOK	243							374										
SSOR																		
SSPA			679															
SSRI																		
SSSC																		
SSSD						297		190						597				
SSTN																		
SSTX																		
SSUT									210									
SSVT																		
SSVA											139							
SSWA		114										651						
SSWV											36							
SSWI			33	5										1296				
SSWY							322						54	47				
SSJAP																		

Appedix B5.13 :Shadow prices for Oklahoma's shipment in various models.

Single Quality Model:

STATE	Base Model	20% OK supply increase	20% Texas demand increase	Advancement in Technology	International Component	Increase in Supply and Demand (20%)	Demand shock:low quality to non-dairy	Demand shock:high quality to dairy	Demand shock:High quality to non-dairy
Alabama	67	67	67	41	68	67	71	18	58
Arizona	107	107	107	65	107	107	107	75	87
Arkansas	19	19	19	11	20	19	23	7	21
California	124	124	125	75	121	125	129	86	91
Colorado	89	89	90	54	89	90	89	61	76
Connecticut	113	113	114	69	137	114	171	31	131
Delaware	111	111	112	68	113	112	145	27	110
Florida	51	51	52	31	49	52	71	11	39
Georgia	57	57	58	335	54	58	72	13	50
Idaho	138	138	139	82	135	139	138	104	106
Illinois	105	105	105	64	106	105	109	42	92
Indiana	105	105	106	64	103	106	112	36	93
Iowa	101	101	101	61	100	101	101	44	87
Kansas	28	28	29	17	28	29	28	17	30
Kentucky	70	70	71	43	68	71	80	19	63
Louisiana	27	27	27	16	28	27	31	6	19
Maine	128	128	129	78	147	129	195	41	141
Maryland	110	110	111	67	108	111	139	27	108
Massachusetts	117	117	118	71	141	118	171	34	129
Michigan	119	119	102	73	116	120	119	36	98
Minnesota	115	115	116	70	112	116	115	55	96
Mississippi	27	27	27	16	28	27	31	5	19
Missouri	35	35	35	22	36	35	39	16	36
Montana	128	128	129	78	139	129	142	110	110
Nebraska	58	58	58	36	58	58	58	35	54
Nevada	136	136	137	83	133	137	141	96	104
New Hampshire	121	121	122	74	145	122	81	36	137
New Jersey	118	118	119	72	120	119	151	27	116
New Mexico	62	62	62	38	62	62	62	47	49
New York	116	116	117	71	141	117	161	34	125
North Carolina	82	82	83	50	80	83	111	19	83
North Dakota	108	108	109	66	105	109	108	69	88
Ohio	108	108	109	66	106	109	128	30	104
Oklahoma	0	0	0	0	0	0	0	0	7
Oregon	159	159	160	97	156	160	163	107	113
Pennsylvania	115	115	116	70	113	116	144	28	110
Rhode Island	118	118	119	72	142	119	177	41	134
South Carolina	69	69	70	42	67	70	89	17	65
South Dakota	92	92	93	56	89	93	92	56	80
Tennessee	46	46	46	28	47	46	51	26	40
Texas	0	0	0	0	0	0	0	0	0
Utah	137	137	138	83	134	138	137	105	110
Vermont	119	119	120	73	141	120	172	36	128
Virginia	88	88	89	53	86	89	116	19	88
Washington	178	178	179	108	175	179	178	118	125
West Virginia	109	109	110	66	107	110	138	27	108
Wisconsin	106	106	106	64	107	106	110	41	93
Wyoming	128	128	129	78	125	129	128	101	101
Japan	DNA	DNA	DNA	DNA	93	DNA	DNA	89	DNA
Total	4464	4464	4480	3017	4685	4498	5124	2125	4052

Appendix B5.13: Multi-QualityModel

STATE	Base:low quality to non-dairy demand	Base:High quality to dairy demand	Base: High quality to non-dairy	Supply shock: low quality to non-dairy	Supply shock: High quality to dairy	Supply shock: High quality to non-dairy
Alabama	71	13	58	69	18	56
Arizona	107	89	87	107	73	87
Arkansas	23	4	21	21	7	19
California	129	80	91	127	85	89
Colorado	89	56	78	89	61	76
Connecticut	171	29	131	169	31	129
Delaware	145	22	110	143	27	108
Florida	71	6	39	69	11	37
Georgia	72	9	50	70	13	48
Idaho	138	98	106	136	102	104
Illinois	109	37	92	107	42	90
Indiana	112	31	93	110	36	91
Iowa	101	39	87	101	44	87
Kansas	28	17	30	28	17	29
Kentucky	80	15	63	78	19	61
Louisiana	31	2	19	29	6	17
Maine	195	40	141	193	41	139
Maryland	139	22	108	137	27	106
Massachusetts	171	32	129	169	34	127
Michigan	119	34	98	117	36	96
Minnesota	115	35	96	113	55	94
Mississippi	31	54	19	29	5	17
Missouri	39	4	36	37	16	34
Montana	142	12	110	140	108	108
Nebraska	58	110	54	58	35	54
Nevada	141	30	104	139	94	102
New Hampshire	181	90	137	179	36	135
New Jersey	151	35	116	149	27	114
New Mexico	62	23	49	62	46	49
New York	161	42	125	159	34	123
North Carolina	111	32	83	109	19	81
North Dakota	108	15	88	106	69	86
Ohio	128	68	104	126	30	102
Oklahoma	0	0	7	0	0	7
Oregon	163	105	113	161	105	110
Pennsylvania	144	23	110	142	28	108
Rhode Island	177	37	134	175	41	132
South Carolina	89	12	64	87	17	63
South Dakota	92	52	80	90	56	78
Tennessee	51	22	40	49	26	38
Texas	0	0	0	0	0	0
Utah	137	99	110	135	103	108
Vermont	172	35	128	170	36	126
Virginia	116	15	88	114	19	86
Washington	178	117	125	176	117	123
West Virginia	138	22	108	136	27	106
Wisconsin	110	37	93	108	41	91
Wyoming	128	95	101	126	99	99
Japan	DN	83	DNA	DNA	DNA	DNA
Total	5224	1959	4051	5144	2019	3970

VITA

Solomon Kioni Kariuki

Candidate for the Degree of

Master of Science

Thesis: LEAST COST SHIPMENT OF ALFALFA HAY (*MEDICAGO SATIVA*) IN THE UNITED STATES

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Kimahuri Village, Nyeri District, Kenya. Sixth born son of Mr.Kariuki Gachanja and Mrs. Gathoni Kariuki.

Education: Graduated from Kirangari High School, Kabete, Kenya, in December 1987; received a diploma in Horticulture from Jomo Kenyatta University, Juja, Kenya in May, 1991; received a Bachelor of Science Degree in Agricultural Economics from Oklahoma State University in May, 1995; Completed the requirements of Masters of Science degree from Oklahoma State University in July, 1998.

Professional Experience: Research Assistant, Department of Agricultural Economics, Oklahoma State University, May, 1995 to May, 1996; Student Research Assistant, Department of Agricultural Economics, Oklahoma State University, May, 1996 to July, 1998.