Optimum Organization and Operation of Oklahoma Country Grain Elevators with Sideline Activities

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Oklahoma country elevators traditionally have served in facilitating grain assembly by receiving grain from farmers for subsequent delivery for milling, export or terminal storage. In addition to their assembly function, country elevators perform many related functions such as storing, grading, and blending grains.

Government programs of the 1950's created incentives for the expansion of grain storage capacity through occupancy contracts, accelerated ammortization, and storage and handling agreements.[1] The increase in demand for storage of Commodity Credit Corporation (CCC) stocks apparently created an incentive for expansion of storage space, both through existing firms adding additional facilities and through new firms entering the industry. Schnake and others found that from 1957 to 1962, a period during which average yearly CCC stocks of wheat in Oklahoma increased by nearly 25 million bushels to 100 million bushels, the total number of firms increased by 28 percent with some trend toward diversification.[2] Relative to annual production, much of the storage capacity was excess capacity for years of low CCC stocks.

The incentive for expansion of storage space changed during the 1960's. During the period 1962 to 1967, the total number of firms in the industry declined by 23 percent as CCC inventories declined from about 100 million to 6 million bushels.[3] As storage income fell, country elevators found it necessary to expand the scope of their activities to include merchandising farm inputs related to grain and livestock production such as feed, seed, fertilizer, and petroleum or to exit from the industry. An increase in the demand for farm inputs, especially fertilizer, was an important factor which permitted the expansion of sideline activities.

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OBJECTIVES

The objectives of the study were to investigate: (1) the relative profitability of providing different products and services with facilities typical of those owned by grain elevator firms in Northwestern Oklahoma, (2) the effects of different market conditions on elevator profits, and (3) the effects of variability in grain-handling and storage volumes on elevator profits.

Since firms are characterized by considerable excess capacity but have a number of years of useful life remaining, attention will be focused on the problem of how to best utilize existing facilities. This problem is first analyzed under assumptions of certainty. Then, since grain-handling and storage volumes are subject to a high degree of variability due to factors largely beyond the control of management an attempt is made to analyze the effects of such variation on the profitability of elevator operations.

PROCEDURES

Several models of typical country grain elevator firms were constructed on the basis of knowledge of the nature of country grain elevator operations and of the types of facilities available and being used in the major wheat producing area of northwestern Oklahoma. The specific area of the state includes 19 counties as shown in Figure 1. Available secondary data were supplemented with information obtained by direct inquiry to necessary sources and used to formulate models

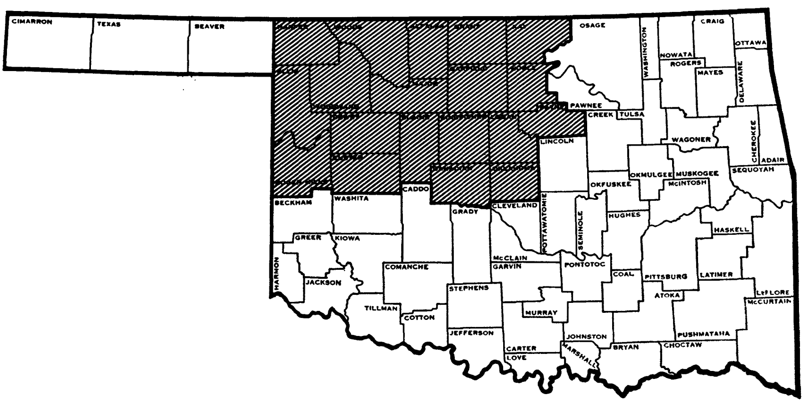

Figure 1. Nineteen County Study Area in Northwest and North Central Oklahoma.

soluble by linear programming algorithms. The Monte Carlo procedure was used to study the effects of variability in the volumes of grain handled and stored on the operating profitability of these facilities.

THE MODEL

The basic model used in this analysis is constructed within the framework of the deterministic linear programming model of the firm. Fixed factors of the model are the basic technology and operating environment of the firm, storage and operating capacities, and the labor force including the manager, assistant manager, and the bookkeeper. Variable factors include product ingredients, power, maintenance and repair, and overtime labor.

The model consists of five separate departments including (1) wheat handling, (2) custom seed cleaning and treating, (3) bag and bulk fertilizer merchandising and bulk blending, (4) protein supplement sales and custom feed grinding, mixing, and delivery, and (5) petroleum sales and delivery. The planning period of the model is one year and is divided into eleven periods ranging from two to twelve weeks in length as listed in Table 1. It was necessary to partition the year in this manner in order to make the model reflect highly seasonal operations in several departments.

Table 1. Critical Periods for Departmental Operations.

Pd. No.	Approximate Length	Time Interval	Department[1]
1	4 weeks	Jan. 1 - Jan. 31	5
2	12 weeks	Feb. 1 - April 30	3, 5
3	6 weeks	May 1 - June 15	4, 5
4	2 weeks	June 16 - June 30	1, 4, 5
5	4 weeks	July 1 - July 31	4, 5
6	4 weeks	Aug. 1 - Aug. 31	3, 4, 5
7	2 weeks	Sept. 1 - Sept. 15	2, 3, 4, 5
8	4 weeks	Sept. 16 - Oct. 15	2, 3, 4, 5
9	2 weeks	Oct. 16 - Oct. 31	2, 3, 4, 5, 6
10	2 weeks	Nov. 1 - Nov. 15	5, 6
11	6 weeks	Nov. 16 - Dec. 31	5

[1] Departmental Codes are:
1 — Wheat, barley, and oats
2 — seed
3 — fertilizer
4 — petroleum
5 — feed
6 — grain sorghum

Fixed Factors

The basic equipment of the firm is listed in Appendix Tables I through IV· Included are operating capacities, horsepower ratings, and replacement costs. In addition to the listed equipment, the model assumes 1,000,000 bushels of upright grain storage capacity, 500 tons of warehouse storage capacity, 720 tons of bulk fertilizer storage capacity, 60 thousand gallons of petroleum storage capacity, and a truck loading spout. A flatbed truck with grain body, a bulk feed truck, and two petroleum delivery trucks are also owned and operated by the firm.

A manager, assistant manager, bookkeeper, and a 15 man labor force are assumed to be required to operate the firm during the harvest season. The grain receiving and loading crew consists of 12 men. The other three men are in petroleum and feed operations. The manager is assumed to perform only administrative duties and is not a part of the effective labor force. The assistant manager, on the other hand, supervises the labor force while working with them, and, hence, is available to satisfy labor requirements. The manager, assistant manager, and bookkeeper are salaried whereas the labor force is paid an hourly wage.

Variable Factors

Variable factors in the model include product ingredients, power, maintenance and repair, and overtime use of a part of the labor force. It is assumed that 12 men can work up to 48 hours per week overtime during the two week harvest season at one and one-half times the hourly wage of $1.65. This is the average wage reported by Roland Smith in a 1968 study of Oklahoma Custom Seed Cleaning Operations.[4]

The major chemical product ingredients are a phostoxin-carbon tetrachloride mix used for fumigation of stored grain and fungicides used for treating seed. Actual cost figures were used for these chemicals.

A formula presented by Streeter, Kelley, and Manuel[5] was used to estimate power requirements in kilowatt hours (KWH) for performing various operations. The formula is

$$KWH = (HP)\ (.8)$$

where HP refers to rated horsepower of the electric motor used. Estimated KWH requirements per unit of operation were obtained by dividing total KWH requirements of operating equipment by capacity per hour. Unit power requirements for operating equipment in the grain elevator, custom seed cleaning and treating plant, bulk fertilizer blending plant, and custom feed mill are shown in Appendix Tables V through VIII. Other power requirements are not significant.

Depreciation costs conventionally are assumed to be a function of time. In this case they are fixed because they do not vary with output. However, moving equipment in an elevator such as legs, dust fans, and belts, as well as non-moving equipment such as distributors and spouts, has also been found to deteriorate because of use.[6] Therefore, depreciation may be a function of use as well as time, and use depreciation would be a variable cost. Use depreciation was assumed in this study, and estimated maintenance and repair costs were used as a measure of the use depreciation.

Maintenance and repair costs were estimated in different ways for different equipment. Maintenance and repair costs for elevator equipment were adapted from Marketing Research Report 676 and are based on actual costs incurred in a sample of elevators in the Hard Winter Wheat Area.[7] These costs were inflated to make them representative of current price levels. Unit maintenance and repair costs for individual pieces of equipment were obtained by dividing inflated actual costs by observed use levels. Unit costs for individual items of equipment were then aggregated to obtain an estimate of maintenance and repair costs for performing the various operations.

Rule of thumb figures were used to estimate maintenance and repair costs for the custom seed cleaning plant and the custom feed mill. Seed cleaning plant costs were estimated by Smith[8] to be .75 percent of replacement cost per year based on an operating standard of 42,228 bushels cleaned per year. Feed mill costs are based on the findings of Vosloh[9] and Austin and Nelson.[10]

Vosloh used 7 percent of replacement costs per year for firms operating at capacity while Austin and Nelson assumed annual maintenance and repair costs to be 5 percent for plants operating at capacity. Six percent was used as the appropriate figure for this study for capacity operation. However, since it was estimated that most custom mills operated at about 25 percent of capacity, an annual figure of 1.5 percent of replacment costs was divided by an operating standard of 1,950 tons per year to obtain estimates of unit maintenance and repair costs.

Maintenance and repair costs for the bulk fertilizer plant consisted of payloader operating costs and upkeep of fertilizer plant equipment. Payloader operating costs were estimated from a study by Bowers.[11] Operating costs per hour were divided by loading capacity per hour to determine unit operation costs for the payloader. Fertilizer plant equipment upkeep costs were estimated from a study of actual costs in typical plants.[12] Average costs per ton based on an annual volume of 4,000 tons were estimated from these data. Unit maintenance and repair costs for grain elevator equipment and bulk fertilizer blending plant equipment are listed in Tables IX and X in the Appendix.

Truck operating costs for feed and petroleum delivery were based on a standard figure of $.073 per mile obtained from a truck rental agency.[13] This figure was based on a 2-axle truck driven 30,000 miles per year. No maintenance and repair costs were assumed to be associated with warehouse storage and handling of feeds and fertilizers and storage and handling of petroleum.

Gross Margins

Gross margins representative of normal charges made by firms in the area for similar products and services were specified. These basic gross margins applied to each variant of all models estimated and are listed in Table 2. All margins assume a cash sale and are adjusted to account for losses due to shrinkage and waste.

Maximum Adjustments

The basic linear programming model was first run under the assumption of unlimited markets. This run specified how much of each product should be sold to maximize returns to the firm given unlimited markets at the charges and set an upper limit on potential sales and returns. From the upper limits established, excess capacity of the firm as organized for this study can be estimated.

The sales volumes which would maximize profits were higher than realistic market limits would allow. Grain volume was 16,918,230 bushels,

Table 2. Gross Margins for Products and Services of the Model Firm.

Product or Service	Charge Per Unit
Grain	
Handling margin, all grain	$ .06/bu.
Storage charge	
Wheat, barley, grain sorghum	$ .0108/bu./mo.
Oats	$ .008/bu./mo.
Seed	
Cleaning charge	$ 7.80/100 bu.
Treating charge	$ 6.00/100 bu.
Fertilizer	
Margin, all fertilizer	$ 8.00/ton
Blending charge	$ 5.00/ton
Petroleum sale and delivery	$ 4.00/100 gal.
Feed	
Protein supplement	$10.00/ton
Molasses	$15.00/ton
Grinding and mixing	$ 4.00/ton
Bagging	$ 1.50/ton
Delivery	$ 3.00/ton

fertilizer volume was 8,639.82 tons, petroleum products volume was 1,079,784 gallons, and feed volume was 18,912.05 tons (Table 3). Storage capacities in each operating department would be used at full capacity at these sales volumes. Feed mill operating capacity and grain loading capacity were also utilized at full capacity. Labor was used at capacity during the first half of September and the last half of October and was utilized at near capacity the year round. The grain department operated 16 hours per day during the wheat harvest season between June 16 and June 30. In addition to normal operation, the equivalent of a 13-man crew (12 men plus assistant manager) working 8 hours per day overtime was required. Overtime labor was allowed in this model only during the wheat harvest season and for the equivalent of a 13-man grain receiving and loading crew.

In the grain department, 1,000,000 bushels of wheat were stored. It was more profitable in this model for the firm to keep its storage space filled to capacity during the entire year than to ship grain out of storage before harvest and place new grain into storage at harvest, regardless of whether the new grain remained in storage or was shipped out before the end of the year. About one-half of the wheat shipped was by truck and about one-half was by hoppercar. No wheat was shipped by boxcar. If the effective transportation rates for shipping by boxcar,

Table 3. Profit Maximizing Sales Volumes of Products and Services for the Firm with Unlimited Markets.

Product or Service	Sales Volume
Grain	
Received and shipped at harvest	
Shipped by hoppercar	709,304 bu.
Shipped by truck	684,524 bu.
Received and shipped, non-harvest period	
Shipped by hoppercar	6,652,225 bu.
Shipped by truck	7,872,177 bu.
Storage	1,000,000 bu.
Fertilizer sales — bulk blended	
Spring	4,320 tons
Fall	4,320 tons
Petroleum sales and delivery	1,079,784 gals.
Feed sales and delivery	
Winter	
Protein supplement sales	6,420 tons
Bulk feed sales — custom ground and mixed, imported grains and molasses	4,730 tons
Bulk feed sales delivery	670 tons
Summer	
Protein supplement sales	3,852 tons
Bulk feed sales — custom ground and mixed, imported grains and molasses	2,838 tons
Bulk feed sales delivery	402 tons

hoppercar, and truck were equal, the order of preference to minimize costs under unlimited markets would be truck, hoppercar, and boxcar shipment in that order.

ANALYSIS OF THE FIRM OPERATION LEVELS

Normal Years with Standard Sideline Sales Volumes

Standard sales volumes were specified for all major products and services of the firm and are included in Table XI in the Appendix. Generally, the volumes reflected typical levels of sideline activities for a firm of this size as obtained from research studies and interviews with managers and other personnel in Oklahoma. Except for petroleum products, the volumes were significantly lower than the volumes reported in Table 3.

A normal year was defined as one which included the full range of market prices relative to support prices and the related storage decisions of producers. For normal years, it was assumed that 90 percent of the wheat crop would be received at harvest and an equivalent of 10 percent of the crop would be received at a constant rate outside the harvest season. All wheat received outside the harvest season would be shipped directly and would not enter storage. A given percentage of the grain received at harvest would be put into storage and the remainder shipped immediately without entering storage. Grain put into storage would be sold out at a constant rate between the end of the current harvest and the beginning of the next harvest, making the effective storage interval about 6 months in length. The model permitted no wheat to be stored continuously. Runs were made assuming that 0, 25, 50, 75, and 100 percent of the wheat received at harvest would enter storage.

Effects of Alternative Wheat Storage Levels

Table 4 lists gross returns to the hypothetical firm at the three grain-handling volumes in normal years with different percentages of the grain received at harvest entering storage. Gross returns to the firm ranged from $133,343 with no grain entering storage to $152,868 with 450,000 bushels or all grain received at harvest entering storage at the low grain-handling volume. Fixed costs would not be covered at any storage level for the low handling volume. Gross returns to the firm ranged from $163,068 to $202,153 at the medium grain-handling volume and from $191,242 to $233,458 at the high grain-handling volume. At the high volume, gross returns to the firm reached a maximum at complete utilization of grain storage capacity. Since this capacity was not sufficient

Table 4. **Gross Returns to the Firm in Normal Years with Different Percentages of the Grain Received at Harvest Entering Storage at Alternative Grain-Handling Volumes.**

Percent of grain received at harvest entering storage	Gross returns at handling volumes of[1]		
	500,000 bu.	1,000,000 bu.	1,500,000 bu.
0	$133,343	$163,068	$191,242
25	$138,231	$172,852	$206,127
50	$143,110	$182,623	$220,793
75[2]	$147,989	$192,395	$233,458
Capacity	$152,868	$202,153	$233,458

[1] Fixed costs total $166,484.
[2] 75 or as much as capacity will permit.

to allow 75 percent of the grain received at harvest to enter storage, grain which could not enter storage was assumed to be shipped directly.

The importance volume stored had on gross returns was indicated by the fact that gross returns for the model with a handling volume of 1,000,000 bushels and 675,000 bushels placed in storage at harvest were higher than the model with a handling volume of 1,500,000 bushels but with no grain entering storage. For alternative percentage storage levels, the indicated ranges in gross returns were $19,525 (all at net losses) at the low grain-handling volume, $39,085 at the medium handling volume, and $42,216 at the high grain-handling volume. An average storage interval longer than six months would accentuate these differences.

No overtime operation was required at the low and medium grain-handling volumes. At the high grain-handling volume, overtime operations of 46 hours were required if no grain received at harvest entered storage and 40 hours were required if at least 25 percent of the grain received at harvest entered storage. Harvest season labor would be a limiting factor in the 46-hour overtime case and grain receiving capacity would be a limiting factor in the 40-hour case. If no more than 25 percent of the grain received at harvest enters storage, the third elevator leg must be used in loading in order to be able to load the required amount of grain at the high grain-handling volume. It is assumed that this leg is set up to load boxcars or hoppercars.

ANALYSIS OF FIRM ACTIVITIES

Normal Years With 50 Percent of Grain Entering Storage

The level of 50 percent of grain receipts at harvest entering storage was selected for detailed analysis of the firm's activities. The three handling volumes of 500,000 bushels, 1,000,000 bushels and 1,500,000 bushels were also assumed. The highest volume required the firm to remain open for business during the harvest season for approximately an extra 40 hours. About 515 hours of overtime labor was required.

The modes of shipment would be sensitive to either rates or manager preferences. The labor and loading time requirements were less for hoppercar than for boxcar shipments, but with a crew hired, returns would be higher for boxcar shipments unless a better use could be found for the labor. A rate differential in favor of any mode of transport would result in that mode being most profitable.

With equal rates, the situation indicated that all grain received and shipped out at harvest was shipped by truck at a handling volume of 500,000 bushels. At a handling volume of 1,000,000 bushels, 24 percent was shipped by boxcar and 76 percent by truck; at a handling volume of 1,500,000 bushels, 29 percent was shipped by boxcar and 71 percent by truck. The 10 percent of each crop which was received and shipped outside the harvest season was shipped by truck.

Table 5 lists availability and utilization of resources for the sideline departments. A maximum of 206 tons of warehouse storage capacity was required to handle protein supplement and bagged fertilizer inventories, assuming that sales of feed and fertilizer occurred at constant rates between September 16 and October 31 and that the order interval was two weeks in length. A considerable amount of slack was available to take care of brief periods of much higher than usual feed or bag fertilizer sales. An even greater amount of excess capacity existed with respect to warehouse storage during other periods of the year.

Excess bulk fertilizer storage capacity also existed. Assuming that bulk fertilizer sales occurred at a constant rate between February 1 and April 30, bulk fertilizer storage capacity of 167 tons was required to support an order interval of two weeks. Excess capacity was much less during the fall sales period (August 1 to October 31) with 500 tons of storage capacity required to support sales at a constant rate with an order interval of two weeks. If sales were bunched into short periods in the fall, either larger bin capacity or a shorter order interval would have been required.

A problem could exist in the model with respect to petroleum storage capacity. Capacity of 60,000 gallons and a two-week order interval were assumed. For sales occurring at a constant rate between February 1 and October 31, only 4,433 gallons of storage capacity were unused. This may not be enough reserve capacity for an actual operation. Sales probably would be more heavily concentrated in some parts of the February 1 through October 31 period, such as during wheat harvest and during wheat planting in the fall, than in others, and reserve banks for both gasoline and diesel fuel would be needed.

Table 5. Availability and Utilization of Factors in Sideline Activities with Standard Sales Volumes for Products and Services.

Factor and unit	Factor Availability	Factor Utilization	Percentage Utilization
Warehouse storage capacity (tons)			
Period 1	500	81	16.2
Period 2	500	122	24.4
Period 3	500	20	4.0
Period 4	500	20	4.0
Period 5	500	20	4.0
Period 6	500	145	29.0
Period 7	500	145	29.0
Period 8	500	206	41.2
Period 9	500	206	41.2
Period 10	500	81	16.2
Period 11	500	81	16.2
Bulk fertilizer storage capacity (tons)			
Spring	720	167	23.2
Fall	720	500	69.4
Petroleum storage capacity (gal)	60,000	55,567	92.6
Seed cleaning capacity (hrs)	384	169	44.0
Bulk fertilizer handling capacity (hrs)			
Spring	576	50	8.7
Fall	576	150	26.0
Petroleum delivery capacity (gal)	1,464,000	1,000,000	68.3
Feed milling capacity (tons)			
Winter	5,400	1,560	28.9
Summer	3,240	390	12.0
Bulk feed delivery capacity (tons)			
Winter	3,600	998	27.7
Summer	2,160	249	11.5
Bag feed delivery capacity (tons)			
Winter	2,469	253	10.2
Summer	1,481	59	4.0

Seed cleaning capacity of 169 hours was required in the model to handle a seed cleaning volume of 42,228 bushels. If the firm operated 8 hours per day and six days per week during the September 1 through October 31 period, 384 hours would be available. On this basis 44 percent of the total capacity was utilized. However, it should be noted that the seed cleaning plant might be required to remain open more than eight hours per day on some days during the September 1 through October 31 period which would require that overtime labor be hired.

Considerable excess capacity also existed in bulk fertilizer handling capacity. Assuming that the bulk fertilizer plant remained open eight hours per day during both the spring (February 1 through April 30) and the fall (August 1 through October 31) periods, only nine percent of the spring handling capacity and 26 percent of the fall capacity would be utilized.

About 46 percent more petroleum delivery capacity was available than was required. This is based on the assumption that two trucks were available for delivery eight hours per day six days per week during the February 1 through October 31 period. It was also assumed that petroleum was delivered in 300-gallon lots with four lots delivered per 25-mile round trip. If fewer gallons of petroleum were delivered per mile and per unit of driving time, excess delivery capacity would be overstated.

Feed milling capacity in the model was 5,400 tons in the winter and 3,240 tons in the summer. This capacity is based on the assumption that the feed mill is open eight hours per day six days per week the year around. Utilization in the model was estimated at 1,500 tons or 29 percent of capacity in the winter and at 390 tons or 12 percent in the summer.

A bulk feed truck and a flatbed truck with grain body were assumed to be available eight hours per day six days per week the year around for feed delivery in 3.5-ton lots with an average delivery round trip of 25 miles. Based on these facilities, utilization of bulk feed delivery capacity was estimated at 12 percent in the winter and 28 percent in the summer. Utilization of bag feed delivery capacity was estimated at 10 percent in the winter and 4 percent in the summer.

Table 6 lists availability and utilization of the factors in the models which were not used solely in sideline departments at the three grain-handling volumes in normal years. Considerable excess capacity existed in grain storage. At a handling volume of 500,000 bushels, only 240,000 bushels of storage capacity were required. About 465,000 bushels of storage capacity were required for the handling volume of 1,000,000 bushels, but only 690,000 bushels of storage capacity were required for the handling volume of 1,500,000 bushels. Assuming a bin capacity of 20,000 bushels and that one bin must be kept empty to facilitate turning the wheat, 260,000 bushels, 485,000 bushels, and 710,000 bushels of grain storage capacity, respectively, were required at the three grain-handling volumes during July. If oats, barley, and grain sorghum were stored, three additional storage bins would be necessary. With one additional bin required for turning, the maximum July grain storage capacity requirements at the three grain-handling volumes would increase to 340,000 bushels, 565,000 bushels and 790,000 bushels, respectively. Storage capacity requirements in other months would be lower than in July.

At two minutes per transaction, bookkeeping times of 13,730 minutes, 14,338 minutes and 14,945 minutes were estimated as required for grain-handling volumes of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels, respectively. Hence, between 11 and 12 percent of a bookkeeper's time (based on a 40-hour week) was required to perform the

Table 6. Availability and Utilization of Factors in the Grain Department, Normal Years with 50 Percent of the Grain Received at Harvest Entering Storage at Alternative Grain-Handling Volumes.

Factor and Unit	Factor Availability	Factor Utilization at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Grain storage capacity (bu)				
Period 1	1,000,000	127,863	235,472	343,081
Period 2	1,000,000	104,889	192,994	281,099
Period 3	1,000,000	36,157	65,413	94,669
Period 4	1,000,000	239,035	464,035	689,035
Period 5	980,000[1]	238,339	463,339	688,339
Period 6	1,000,000	217,368	422,803	628,238
Period 7	1,000,000	196,398	382,268	568,139
Period 8	1,000,000	185,911	361,999	538,068
Period 9	1,000,000	164,970	321,493	478,016
Period 10	1,000,000	153,494	300,234	446,974
Period 11	980,000[1]	142,001	278,958	415,914
Grain receiving capacity at harvest (trucks)	6,019	2,879	5,692	[2]
Car loading capacity at harvest (min)	11,520		2,986	[2]
Truck loading capacity (min)				
Before harvest	63,360	2,716	4,929	7,142
At harvest	5,760	3,809	5,760	[2]
After harvest	69,120	2,908	5,322	7,737
Bookkeeping time (man min)	124,800	13,730	14,338	14,945
Labor (man min)				
Period 1	184,320	16,967	17,649	18,331
Period 2	552,960	106,081	108,104	110,126
Period 3	276,480	33,668	34,667	35,665
Period 4	92,160	42,139	75,475	[2]
Period 5	184,320	23,262	24,717	26,173
Period 6	184,320	30,477	31,179	31,880
Period 7	92,160	22,607	22,956	23,305
Period 8	184,320	55,457	56,153	56,849
Period 9	92,160	27,786	28,132	28,479
Period 10	92,160	8,545	8,891	9,236
Period 11	276,480	25,454	26,485	27,515
Overtime labor in period 4	74,880			30,917

[1] Assumes one bin must be kept empty for turning grain.
[2] Number not computed because of forced overtime operation.

bookkeeping activities. It does not appear that a full time bookkeper could be justified in this model if one were available on a part-time basis unless the bookkeeper also dod a considerable amount of secretarial or other work.

During the wheat harvest, the total labor force (assistant manager, a 12-man grain receiving and loading crew, and three men in other operations) was utilized at 46 percent of capacity at a grain handling volume of 500,000 bushels and 82 percent of capacity at a grain handling volume of 1,000,000 bushels. Because of limited grain receiving capacity, the firm remained open 40 hours more than the usual 48 hours per week during the harvest season at a handling volume of 1,500,000 bushels. This required the hiring of a 12-man grain receiving and loading crew for a total of 515 hours of overtime work. The overtime was required even though labor might not be fully utilized during normal operating hours. This estimate probably should be interpreted as a lower limit on the hours of overtime because the firm generally would not operate at capacity eight hours per day during the harvest season. However, a smaller crew might be hired during some of the additional operating time.

Assuming a 48-hour week, the total labor was utilized at about 10 to 30 percent of capacity during the non-harvest periods of the year. The estimates may be somewhat low because they did not allow time for changing jobs. However, they do serve to point out the large amount of slack time which would exist in this type of organization.

Grain receiving capacity at wheat harvest was utilized at 48 percent of capacity at the low grain-handling volume and 95 percent of capacity at the medium grain-handling volume for minimum cost operations of the model firm. As previously mentioned, the high volume of grain could not be received unless the firm remained open more than eight hours per day on some days during the harvest season.

The estimated utilization percentages would be significantly higher if wheat receipts were highly concentrated during a few days of the harvest season. Bouland[14] found that in the Hard Winter Wheat area of the Central Great Plains, 90 to 99 percent of the wheat arriving at the elevator during the harvest season usually arrived during a two-week interval as assumed in this study. About 22 percent of the crop was harvested in a single day and 50 percent or more delivered to the elevator in three to four days. During large crop years, the peak harvest and delivery period was shorter than usual.

In this model, 90 percent of the wheat was assumed to be received at harvest. If, in addition, 22 percent were received in a single day, the low handling volume would require nearly 10 hours of operation to receive 99,000 bushels, the medium handling volume would require 20 hours of operation to receive 198,000 bushels and the high grain-handling volume would require 30 hours of operation to receive 297,000 bushels. Obviously, the elevator could not receive the high volume of grain on a single day unless average load size received were considerably larger than the assumed load size of 160 bushels.

No car loading capacity was utilized at the low grain-handling volume in the least cost solution. All grain was shipped by truck. Truck loading capacity at wheat harvest was utilized at the level of 3,809 minutes or 66 percent of capacity.

At the medium grain-handling volume, truck loading capacity at wheat harvest was not adequate to allow all grain shipped at harvest to be shipped by truck if the firm operated 48 hours per week and if only one leg were set up to load trucks. Hence, an estimated 109,076 bushels were shipped by boxcar requiring 2,986 minutes or 26 percent of the available car loading time, based on two legs set up to load cars. In this solution, no wheat was shipped by rail outside the harvest season.

Since limited grain receiving capacity at the high grain-handling volume required at least 46 hours of overtime operation, both truck and car loading capacities at harvest would be increased. However, relatively more wheat, a total of 192,765 bushels, was estimated to be shipped by boxcar. As in the case of the medium handling volume, neither truck loading capacity nor car loading capacity was fully utilized outside the harvest season. No grain was shipped by rail outside the harvest season in the least cost solution.

It should be noted that one-half the grain received at harvest was assumed to be shipped directly without entering storage. A bottleneck could develop if transportation were not available in a sufficient quantity to allow loading as grain is received, even allowing for one-half the grain to enter storage. If adequate transportation were not available, some grain to be shipped might first enter storage and then be removed, thus considerably increasing maintenance and repair and power costs.

Insight into the most profitable operation of the firm can also be gained by studying the values of additional market units for various products and services at the assumed three grain-handling volumes in normal years in which 50 percent of the grain received at harvest entered storage as shown in Table 7. Receiving and shipping an additional 1,000 bushels of grain at a constant rate during the harvest season would increase returns to the firm by $56.08 to $59.54 at all three grain-handling volumes. Receiving and placing an additional 1,000 bushels of grain into storage at harvest and shipping it at a constant rate outside the harvest season would increase returns to the firm by $102.91 at the low and medium grain-handling volumes and by $99.53 at the high grain-handling volume.

The values of additional market units of sideline products and services were in accordance with their margins less power and maintenance and repair costs. For example, cleaning and treating an additional 100 bushels of seed would increase returns by $9.31, selling another ton of bulk-blended fertilizer would increase returns by $10.04, selling another 300-gallon lot of petroleum would increase returns by $10.18, and selling and delivering another ton of custom ground and mixed molasses feed from grain shipped into the area would increase returns by $12.52. Values of additional market units for sideline products and

Table 7. Value to the Firm of Additional Market Units of Products and Services in Normal Years with 50 Percent of the Grain Received at Harvest Entering Storage at Alternative Grain-Handling Volumes

Product or Service	Value of Additional Market Unit at Handling Volume of		
	500,000 Bu	1,000,00 Bu.	1,500,000 Bu.
Grain			
Receive at harvest and ship directly	$ 59.54/1,000 bu.	$ 59.46/1,000 bu.	$56.08/1,000 bu.
Receive outside the harvest season and ship directly	$ 59.54/1,000 bu.	$ 59.54/1,000 bu.	$59.54/1,000 bu.
Receive at harvest, store, and ship later	$102.91/1,000 bu.	$102.91/1,000 bu.	$99.53/1,000 bu.
Clean and treat seed	$ 9.31/100 bu.	$ 9.31/100 bu.	$ 9.31/100 bu.
Sell bulk blended fertilizer	$ 10.04/ton	$ 10.04/ton	$10.04/ton
Petroleum sale and delivery	$ 10.18/300 gal.	$ 10.18/300 gal.	$10.18/300 gal.
Deliver custom ground and mixed molasses feed from grain shipped into the area	$ 12.52/ton	$ 12.52/ton	$12.52/ton

services were the same for the low and medium grain-handling volumes. At the high grain-handling volume, additional market units of custom ground and mixed feed sales from farmer-delivered grain in the summer and from all grain banking operations had slightly lower values. The values of additional market units of products and services in each sideline department are listed in Table XII in the Appendix.

Effects of Large Demand for Wheat Storage

For this analysis, the firm was assumed to be operating with standard sales volumes for products and services in sideline departments, under alternative handling volumes, and under relatively low market prices which approximate the support prices. With a market price of wheat approximately the same as the support price, there is little or no chance of loss and a positive chance of gain from price changes of wheat under loan. Consequently, there is an economic incentive for farmers to place the wheat under loan when the market price is low relative to the support price. The result would be a greater demand for storage in terms of both the storage of a larger quantity and the storage for a longer period of time.

Gross returns to the firm with low market prices were estimated at $172,776, $241,971 and $276,215, respectively, for the three grain-handling volumes. These returns were substantially higher than those for similar handling volumes in normal years, regardless of the percentages of grain entering storage. The higher returns reflected the higher utilization of storage capacity, and the longer storage intervals.

At the low grain-handling volume and least cost operation with the labor force hired, both the 50,000 bushels of grain received and shipped at a constant rate from May 1 through June 15 and the 450,000 bushels shipped out of storage at a constant rate during the same period were shipped by truck. At the medium grain-handling volume, 96,960 bushels received were shipped by truck and 3,040 bushels received were shipped by boxcar during the May 1 through June 15 period. About 900,000 bushels were shipped out of storage by truck during the same period. At the high volume, 383,340 bushels received were shipped by truck at harvest because there was not sufficient storage capacity to store all the grain received during this period. During the May 1 through June 15 period, 30,300 bushels of the grain received were shipped by truck, 966,-660 bushels were shipped out of storage by truck. A rate differential in favor of any mode of transportation would have caused that mode to be used up to the limit of loading capacity for it.

The capacity utilizations of factors used solely in sideline departments were identical in this analysis to those for normal years. Capacity utilizations of factors not used solely in sideline departments at the three grain-handling volumes are listed in Table 8. At the low volume, considerable excess capacity existed with respect to grain storage capacity. However, since some wheat, barley, oats, and grain sorghum may be stored in grain banking operations and since different qualities of different grains would be kept in separate bins, considerably more grain storage capacity could be required. At the medium and high grain-handling volumes, grain storage capacity was fully utilized and would not have been adequate if the foregoing factors were important.

Capacity utilization of other factors at each grain-handling volume in this analysis was similar to the results for normal years. During May 1 through June 15 period, prior to harvest, the assistant manager and 15-man work force was utilized at 16 percent of capacity at the low grain-handling volume, at 20 percent of capacity at the medium volume, and at 23 percent of capacity at the high grain-handling volume. Harvest season labor utilization was 42 percent and 71 percent of capacity, respectively, at the low and medium grain-handling volumes.

Grain receiving capacity during the May 1 through June 15 pre-harvest period was utilized at 1.7 percent of capacity at the low grain-handling volume, 3.5 percent at the medium volume, and 5.2 percent of capacity at the high grain-handling volume. Grain receiving capacity during the wheat harvest was utilized at levels similar to those in normal years.

Table 8. Availability and Utilization of Factors in the Grain Department, Years with Low Prices at Harvest and Alternative Grain-Handling Volumes.

Factor and Unit	Availability	Factor Utilization at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Grain storage capacity (bu)				
Period 1	1,000,000	470,255	920,255	986,915
Period 2	1,000,000	466,785	916,785	983,445
Period 3	1,000,000	456,901	906,901	973,561
Period 4	1,000,000	464,035	914,035	980,695
Period 5	980,000[1]	463,339	913,339	980,000
Period 6	1,000,000	461,933	911,933	978,593
Period 7	1,000,000	460,537	910,527	977,187
Period 8	1,000,000	459,824	909,824	976,485
Period 9	1,000,000	458,447	908,447	975,108
Period 10	1,000,000	456,755	906,755	937,415
Period 11	980,000[1]	455,045	905,045	971,705
Grain receiving capacity (trucks)				
Before harvest	18,058	312	625	938
At harvest	6,019	2,879	5,692	[2]
Car loading capacity (min)				
Before harvest	31,283		83	3,277
At harvest	11,520			[2]
Truck loading capacity (min)				
Before harvest	17,280	8,917		
at harvest	5,760	23	23	[2]
Bookkeeping time (man min.)	124,800	13,622	14,122	14,622
Labor (man min.)				
Period 1	184,320	16,375	16,465	16,478
Period 2	552,960	104,328	104,598	104,638
Period 3	276,480	44,143	55,688	63,471
Period 4	92,160	38,353	65,267	[2]
Period 5	184,320	23,396	24,986	25,222
Period 6	184,320	29,865	29,955	29,969
Period 7	92,160	22,302	22,347	22,354
Period 8	184,320	54,851	54,941	54,955
Period 9	92,160	27,484	27,529	27,536
Period 10	92,160	8,245	8,290	8,297
Period 11	276,480	24,589	24,694	27,714
Overtime labor in period 4 (man min.)	74,880			30,917

[1] Assumes one bin must be kept empty for turning.
[2] Number not computed because of forced overtime operation.

As in the case of normal years in which at least 25 percent of the grain received at harvest entered storage, the least cost results indicated primary use of truck transportation at low grain-handling volumes. As the grain-handling volume increased, truck loading capacity became fully utilized and car loading capacity was employed.

Table 9 lists values of additional market units of various grain services at the three grain-handling volumes in years with low prices at harvest. Receiving and shipping 1,000 bushels at harvest would increase returns to the firm by $59.54 at the low and medium grain-handling

Table 9. Value to the Firm of Additional Market Units of Grain Services in Years with Low Prices at Harvest at Alternative Grain-Handling Volumes.

Product or Service	Value of Additional Market Unit at Handling Volumes of 500,000 Bu.	1,000,000 Bu.	1,500,000 Bu.
	per 1,000 bu.		
Receive grain at harvest and ship directly	$ 59.54	$ 59.54	$ 56.13
Receive grain before harvest and ship directly	$ 59.54	$ 59.46	$ 59.46
Receive grain at harvest, store, and ship out before the next harvest	$147.15	$147.07	$143.66
Receive grain at harvest, store, and ship out at a constant rate before the next harvest	$102.91	$102.87	$ 99.45

volumes and receiving and shipping an additional 1,000 bushels would increase returns by $56.13 at the high grain-handling volume. Receiving and shipping another 1,000 bushels of grain during the May 1 through June 15 period prior to harvest would increase returns by $59.54 at the low grain handling volume and by $59.46 at the medium and high grain-handling volumes.

Receiving and putting another 1,000 bushels of grain into storage at harvest and shipping it out during the May 1 through June 15 period prior to the next harvest would increase returns to the firm by $147.15 at the low handling volume, by $147.07 at the medium handling volume, and by $143.66 at the high grain-handling volume. Putting 1,000 bushels into storage and shipping it out at a constant rate before the next harvest would increase returns by $102.91 at the low volume, $102.87 at the medium volume, and by $99.45 at the high grain-handling volume. However, it must be noted that no storage capacity was available in the solutions to allow activities requiring grain storage to be increased.

The values of additional market units of sideline products and services were equivalent in this analysis to those for normal years in which at least 25 percent of the grain received at harvest entered storage.

Effects of Small Demand for Wheat Storage

Market prices which are high relative to the level of support prices are indicative of free market conditions. Generally, there is a greater risk of price changes in a free market, and the changes may be either up or down. Also, relatively high market prices tend to be associated with lower levels of storage of wheat under loan or government account. A lower demand for storage would be expected to affect adversely the level of returns to the elevator firm. The expectations were confirmed for the assumption that the firm would receive all grain at harvest with no quantity entering storage. Returns to the firm were estimated at $133,338, $162,813, and $190,668, respectively, at the three grain-handling volumes. During the harvest season the medium grain-handling volume required the hiring of 92 hours of overtime labor and the high grain-handling volume required the hiring of 808 hours of overtime labor.

Because storage was not used, more grain was assumed to be received and shipped at harvest under this price situation than in previous analyses. The limited time of the labor force available for loading wheat resulted in more use of rail transportation facilities.

At the low grain-handling volume it was estimated that 159,076 bushels received at harvest was shipped by boxcar and 340,924 bushels received was shipped by truck. At the medium volume, 633,710 bushels received at harvest was shipped by hoppercar and 366,290 bushels received was shipped by truck; at the high grain-handling volume, 937,461 bushels received at harvest was shipped by hoppercar and 562,539 bushels received was shipped by truck.

The results of the analysis of capacity utilization of factors under the high price situation were similar to those for normal years and for years with low prices at harvest. Capacity utilizations of factors used solely in sideline departments were identical. Since no grain entered storage except that for grain banking operations, the grain receiving functions were altered. Labor during the harvest season was utilized at 58 percent of capacity at the low grain-handling volume and overtime labor was required at the medium and high grain-handling volumes for this model. Grain receiving capacity at harvest was utilized at 53 percent of capacity at the low grain-handling volume and approximately capacity at the medium and high-handling volumes. Truck-loading capacity was fully utilized at each grain handling volume and cars were loaded from two legs in order to handle the high volume of grain. The limited loading capacity at the high handling volume caused rail shipment to be by hoppercar rather than boxcar.

Table 10 lists values of additional market units of various grain services at the three grain-handling volumes in years with high prices at harvest. Receiving and shipping another 1,000 bushels at harvest would increase returns to the firm by $59.46 at the low handling volume and by $55.71 at the medium and high grain-handling volumes. Receiving and shipping 1,000 bushels outside the harvest season would increase returns to the firm by $59.54 at each grain-handling volume. Putting 1,000 bushels of grain into storage at harvest and shipping it out at a constant

Table 10. Value to the Firm of Additional Market Units of Grain Services in Years with High Prices at Harvest at Alternative Grain-Handling Volumes.

Product or Service	Value of Additional Market Unit at Handling Volumes of 500,000 Bu.	1,000,000 Bu.	1,500,000 Bu.
	---- per 1,000 bu. ----		
Receive grain at harvest and ship directly	$ 59.46	$ 55.71	$ 55.71
Receive grain outside harvest season and ship directly	$ 59.54	$ 59.54	$ 59.54
Receive grain at harvest, store, and ship later	$102.91	$100.48	$100.48

rate before the next harvest would increase returns to the firm by $102.91 at the low grain-handling volume and by $100.48 at the medium and high handling volumes.

The values of additional market units of products and services sold during the summer months at the medium and high grain-handling volumes were lower than the corresponding values in normal years because these products and services competed for labor during the harvest season. The sale and delivery of another 300-gallon lot of petroleum during the summer months would increase returns to the firm by $10.08 and sale and delivery of another ton of custom ground and mixed molasses feed during the summer months from grain shipped into the area would increase returns to the firm by $12.01.

A STOCHASTIC ANALYSIS

Two factors largely beyond the control of elevator management have high variability and are important determinants of the firm's profitability. These are grain-handling volume and grain-storage volume. This section contains an analysis of the effects of the two factors on returns to the firm under the assumption that the factors are random variables with specified probability distributions.

The Model and Assumptions

The deterministic linear programming model used in the previous analysis was extended to include random components, and the Monte Carlo procedure was used to derive a solution through the distribution method. Grain-handling volume was assumed to be a normally distributed random variable with a mean of 1,000,000 bushels and a standard deviation of 333,333 bushels. This gave the distribution of grain-handling volumes a coefficient of variation of 33 percent which is one third larger than that of the distribution of wheat production in the 19-county area since 1957.

As in the analysis for normal years, 90 percent of the grain handled was assumed to be received at a constant rate during the harvest season and 10 percent was assumed to be received at a constant rate outside the harvest season. However, the percentage of grain received at harvest which entered storage was assumed to be a normally distributed random variable with a mean of 50 percent and a standard deviation of 10 percent. If a random percentage less than zero were drawn, the percentage entering storage was assumed to be zero, and if a random percentage greater than 100 percent were drawn, the percentage entering storage was assumed to be 100. The maximum effective grain storage capacity was 966,660 bushels because 33,340 bushels of storage capacity were required for grain banking operations. Consequently, not more than 966,660 bushels of grain received at harvest were allowed to be stored. No grain received outside the harvest season was assumed to enter storage.

The Analysis

A random sample of size 40 was obtained from each distribution and used to obtain solutions to each of the 40 resulting deterministic problems. In the samples used, grain-handling volume ranged from a low of 191,000 bushels to a high of 1,707,000 bushels and the percentage of grain received at harvest entering storage ranged from a low of 30 percent to a high of 68 percent. The means were 955,388 bushels and 50.4 percent, and the standard deviations were 350,331 bushels and 10.6 percent, respectively.

Receiving and shipping grain at harvest averaged 428,500 bushels with a standard deviation of 183,300 bushels. Receiving and placing grain into storage at harvest and shipping it out at a constant rate throughout the marketing year averaged 431,300 bushels with a standard deviation of 184,200 bushels. Receiving and shipping grain at a constant rate outside the harvest season averaged 95,550 bushels with a standard deviation of 35,000 bushels.

Returns to the firm averaged $178,861 with a standard deviation of $27,572. Figure 2 shows the distribution of returns in the form of a histogram. Returns less than $133,900 were achieved twice or 5.0 percent of the time, returns between $133,900 and $163,900 were achieved 22.5 percent of the time, returns between $163,900 and $193,900 were achieved 40 percent of the time, returns between $193,900 and $223,900 were achieved 25 percent of the time, and returns greater than $223,900 were

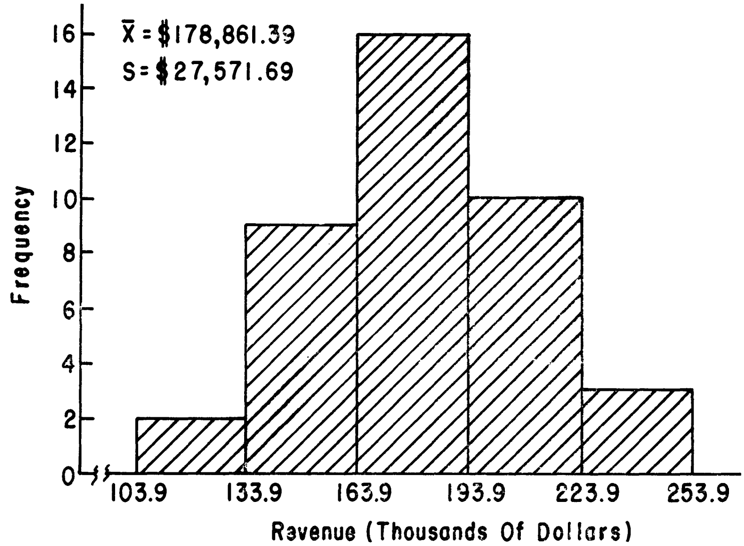

Figure 2. The Distribution of Returns to the Firm Assuming Grain-Handling Volume and the Percentage of Grain Received at Harvest Entering Storage are Random Variables.

achieved 7.5 percent of the time. If the distribution of returns were normal and the sample values valid, returns would be between $160,085 and $197,638 fifty percent of the time and between $123,139 and $234,584 ninety-five percent of the time.

Overtime operation during the harvest season was required 35 percent of the time with maximum overtime operation of 58 hours. When overtime operation was required, the average time was 25 hours. The distribution of hours of overtime operation in 16-hour intervals is shown in the form of a histogram in Figure 3. Truck loading capacity at harvest was utilized at capacity 60 percent of the time, thus requiring some grain received at harvest to be shipped by rail. Standard sales volumes were met for each product and service in each year.

The values of additional market units for grain services did not change greatly with different grain-handling volumes and different percentages of the grain received at harvest entering storage. These values are shown in Table 11. Receiving and shipping an additional 1,000 bushels of grain would increase returns to the firm by an amount between $56.08 and $59.54.

Receiving and placing an additional 1,000 bushels of grain into storage at harvest and shipping it out at a constant rate throughout the

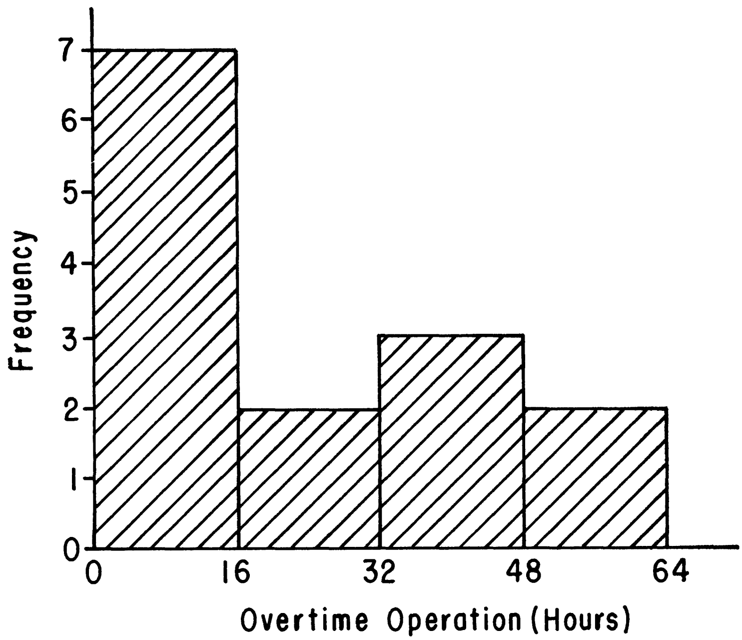

Figure 3. The Distribution of Hours of Overtime Operation When Overtime Operation is Required Assuming Grain-Handling Volume and the Percentage of Grain Received at Harvest Entering Storage are Random Variables.

Table 11. The Values of Additional Market Units for Grain Products and Services Assuming Grain-Handling Volume and the Percentage of Grain Received at Harvest Entering Storage are Random Variables with Specified Probability Distribution.

Product or Service	Value	Relative Frequency
	(per 1,000 bu.)	(percent)
Receive grain at harvest and ship directly	$ 56.08	32.5
	$ 56.13	2.5
	$ 59.46	27.5
	$ 59.54	37.5
Received grain outside harvest season and ship directly	$ 59.54	100.0
Receive grain at harvest, store, and ship later	$ 99.50	2.5
	$ 99.55	32.5
	$102.91	65.0

marketing year would increase returns by an amount between $99.50 and $102.91. This activity would have a value of $99.50 about one-third of the time and a value of $102.91 about two-thirds of the time. The values of additional market units for sideline products and services were similar to those for normal years in which 50 percent of the grain received at harvest enters storage.

SUMMARY

Several variants of a deterministic linear programming model were used to depict a grain elevator firm with sideline activities in Northwestern Oklahoma. The basic model consisted of five separate departments including grain, feed, seed, fertilizer, and petroleum. Fixed factors in the model included the basic technology and operating environment of the firm, storage and operating capacities, management, and the labor force. Variable factors were product ingredients, power, maintenance and repair, and overtime labor. Gross margins representative of normal charges made by firms in the area for typical products and services were specified.

In general, the results are consistent with existing hypotheses that firms are characterized by considerable excess capacity, especially outside the harvest season, and that grain storage is a highly profitable undertaking given excess storage capacity. Profits of grain elevator firms appear to be highly sensitive to grain-handling volume, storage volume, and length of the storage interval. Furthermore, profits tend to be inversely related to wheat prices. A transportation rate differential in favor of any mode tends to make that mode the most profitable.

Operation of all sideline departments appears to be profitable with the sales volumes specified for the model. Profits could be enhanced considerably by attempting to increase sales of selected sideline products and services, perhaps by advertising or non-price concessions. Generally, service-oriented activities tended to be the most profitable in this model.

The effects of different handling volumes, storage volumes, and lengths of the average storage interval in the grain department on profits in conjunction with standard sales volumes for each product and service in each sideline department were estimated. Runs were made assuming grain-handling volumes of 500,000 bushels, 1,000,000 bushels and 1,500,000 bushels for normal years, years with low prices at harvest relative to the support price, and years with high prices at harvest relative to the support price. In addition, the model was run for normal years assuming alternative percentages of volume entering storage.

Normal years were defined as those in which 90 percent of the wheat crop was received at harvest and 10 percent was received outside the

harvest season. The average storage interval was six months. Returns to the firm ranged from a low of $133,343 with no grain entering storage at the low grain-handling volume to a high of $233,458 with storage at capacity at the high grain-handling volume. With fixed costs of $166,484, net returns ranged from a loss of $33,141 in the former case to a profit of $66,974 in the latter case. Gross returns were $143,110, $182,628 and $220,793, respectively, at the three grain-handling volumes with 50 percent of the grain received at harvest entering storage.

A large amount of overtime operation during the harvest season was required at high grain-handling volumes. Overtime operation of 46 hours was required to make enough labor available in the case where no grain entered storage and overtime operation of 40 hours was required to make available enough grain receiving capacity in cases where some grain entered storage. These figures should be considered as lower limits because grain receipts are likely to be more concentrated than were assumed.

Considerable excess capacity was apparent with respect to factors used solely in sideline departments. Seed cleaning capacity, bulk fertilizer handling capacity, feed milling capacity, and petroleum and feed delivery capacity appeared to be more than adequate. However, concentrated demands in the seed plant and bulk fertilizer plant before wheat planting in the fall could require limited amounts of overtime operation and the hiring of overtime labor.

When grain storage capacity was available, receiving wheat at harvest, placing it in storage, and shipping it at a constant rate throughout the marketing year was by far the most profitable grain-handling alternative. Additional units of this activity had values ranging from $99.50 to $102.91 per 1,000 bushels. Receiving and shipping grain directly outside the harvest season was more profitable than receiving and shipping grain at harvest if large amounts of grain were received at harvest. Receiving and shipping an additional 1,000 bushels directly outside the harvest season had a value of $59.54 in each case considered. Receiving and shipping an additional 1,000 bushels directly at harvest had values ranging from $55.71 to $59.54. The profitability of sideline products and services was in accordance with their respective gross margins less variable costs. It was profitable to meet standard demands for each product and service.

Years with low prices at harvest relative to the support price resulted in high returns because more grain tended to be stored and the storage interval tended to be longer. The estimates were based on a storage interval of almost 12 months. Gross returns to the firm were $172,776, $241,971 and $276,215 respectively, at the three grain-handling volumes. With fixed costs of $166,484, small profits would be incurred at the low grain handling volume and large profits would be incurred at the medium and high grain-handling volumes.

If capacity were available, receiving grain at harvest, storing it, and shipping it during the six weeks preceding the next harvest is more than twice as profitable as receiving and shipping grain directly either at harvest or during the six-week period preceding the next harvest. Additional units of this activity had values ranging from $143.66 to $147.15 per 1,000 bushels. Receiving and shipping directly had values ranging from $56.13 to $59.54 per 1,000 bushels.

Years with high prices at harvest relative to the support price resulted in low returns because it was assumed that little grain would enter storage and that the storage interval would be short. Gross returns to the firm were $133,338, $162,813, and $190,668, respectively, at the three grain-handling volumes. Fixed costs of $166,484 would result in losses at the low and medium grain-handling volumes and profits only at the high grain-handling volume. More overtime operation during the harvest season was required at high grain-handling volumes because of labor requirements, primarily in grain receiving and loading. The values of all grain and some sideline products and service requiring harvest season labor tended to be lower at high grain-handling volumes in years with high prices at harvest. Sideline products and services in this category included petroleum sale and delivery and feed sales and delivery. However, feed sales during this period tended to be of limited importance.

The model was extended to include assumptions that grain-handling volume and storage volume were random variables with specified probability distributions and estimates obtained by the Monte Carlo technique. Gross returns to the firm averaged $178,861 with a standard deviation of $27,572. With fixed costs of $166,484, profits would have been incurred 70 percent of the time. If the distribution of returns were normal and the sample values valid, returns would be between $123,139 and $234,584 ninety-five percent of the time. Overtime operation during the harvest season was required 30 percent of the time with a maximum overtime operation of 58 hours. When overtime operation was required, the average was 25 hours. Some grain received by the model firm at harvest was shipped by rail 60 percent of the time. It was profitable for the firm to meet standard sales volumes for each product and service in each year.

FOOTNOTES

[1]Edward M. Corley, "Estimated Effects of Variations in Wheat Production Upon Costs of Country Elevators in Northwest Oklahoma", (unpub. Ph.D. dissertation, Oklahoma State University, 1964), p. 22.

[2]L. D. Schnake, B. L. Sanders, and Barry Bloyd, "Use of a Stochastic Markov Chain Process to Show Dynamic Adjustments in the Structure of Oklahoma Grain Storage Firms to Changes in CCC Storage Levels" (unpub. manuscript, Oklahoma State University, 1968), p. 12.

[3]U. S. Department of Agriculture, **Grain Marketing News,** Consumer and Marketing Service, XVI (Washington, 1968), p. 11.

[4]Roland D. Smith, "An Economic Analysis of Custom Seed Cleaning Operations in Oklahoma" (unpub. M.S. thesis, Oklahoma State University, 1968), p. 56.

[5]Charles L. Streeter, Paul L. Kelley, and Milton L. Manuel, **A Linear Programming Model of A Grain Elevator and Feed Firm,** Kansas State University Agricultural Experiment Station Technical Bulletin 137 (Manhattan, 1965), pp. 32-33.

[6]Heber D. Bouland, **Selecting the Best Capacity of Truck Receiving Facilities for County Grain Elevators,** Marketing Research Report 671, Agricultural Marketing Service (Washington, 1964), p. 30.

[7]Albert H. Graves and Gerald L. Kline, **Loading Boxcars at Country Elevators in the Hard Winter Wheat Area,** Marketing Research Report 676 Agricultural Research Service (Washington, 1964).

[8]Smith, p. 61.

[9]Carl J. Vosloh, Jr., **Costs and Economies of Scale in Feed Manufacturing,** Marketing Research Report 815, Economic Research Service (Washington, 1968), p. 13.

[10]Philip E. Austin and David C. Nelson, **An Economic Analysis of the Costs of Manufacturing Commercial Feed in North Dakota,** North Dakota State University Agricultural Economics Report 47 (Fargo, 1966), p. 19.

[11]Wendell, Bowers, **Costs of Owning and Operating Farm Machinery,** University of Illinois College of Agriculture Extension Bulletin A Eng-867 (Urbana, 1966).

[12]These figures were obtained from Farmland Industries, Enid.

[13]This figure was obtained from Ryder Truck Rentals, Oklahoma City.

[14]Bouland, pp. 9-11.

Appendix Table I.—Operating Capacities, Horsepower Ratings, and Replacement Costs for the Grain Elevator.

Item	Capacity	H.P. Rating	Replacement Cost
	(Bushels per Hour)	(Horsepower)	(Dollars)
Bins			500,000.00
Building			28,334.60
Equipment			130,096.80
6,000 bu. legs—3	18,000	120.0	
Dust fans—3	18,000	9.0	
Distributors—3	18,000	1.5	
Belt conveyors—3	18,000	45.0	
25 bu. auto scales—3	18,000		
Manifold aeration system—9	1,000,000	250.0	
Loadout spouts—2	12,000		
Hot spot system			
50′ x 10′ truck scale			
At harvest (4 men)	10,032		
Outside harvest (2 men)	3,360		
Man lifts—3		4.5	
Car puller		40.0	
Semi dumper		50.0	
Power shovel		10.0	
		Total Cost	658,431.40

Appendix Table II.—Operating Capacities, Horsepower Ratings, and Replacement Costs for the Single Unit Seed Cleaning and Treating Plant.

Item	Capacity	H.P. Rating	Replacement Cost
	(Bushels per Hour)	(Horsepower)	(Dollars)
Building & foundation			13,620.00
Dump pit			1,430.60
Truck hoist		5.0	2,426.00
Receiving elevator leg	900	5.0	3,124.14
Cleaner	250	7.5	4,763.10
Clean elevator leg	800	5.0	2,708.49
Treater	250	5.0	1,535.30
Holding and clean grain bins			1,922.30
Dust systems & walkways	250	5.0	2,848.70
		Total Cost	34,378.63

Appendix Table III.—Operating Capacities, Horsepower Ratings, and Replacement Costs for the Bulk Fertilizer Blending Plant.

Item	Capacity	H.P. Rating	Replacement Cost
	(Tons per Hour)	(Horsepower)	(Dollars)
Building & equipment			19,264.00
18″ x 30′ schuttlebut	25	3.0	
11′ undercar conveyor	25	5.0	
40′ bucket elevator	25	5.0	
Other equipment			12,900.00
1 ton blender	15	10.0	
Discharge system	15	5.0	
1/2 ton loader	30		
		Total Cost	32,164.00

Appendix Table IV.—Operating Capacities, Horsepower Ratings, and Replacement Costs for the Feed Mill (30 Ton).

Item	Capacity	H.P. Rating	Replacement Cost
	(Tons per Hour)	(Horsepower)	(Dollars)
Building			25,000.00
Truck receiving hopper	50		3,800.00
Receiving conveyor	50	5.0	2,000.00
Permanent type hopper magnet—2			710.00
Receiving elevator	50	5.0	2,800.00
Receiving distributor	50		500.00
50 ton grain, meal, or concentrate bin—5			8,000.00
2 ton vertical mixer	11.3647	10.0	2,000.00
Screw conveyor	15	1.0	1,000.00
Bucket elevator—mash	15	5.0	2,500.00
2 way valve and connectors			100.00
Bulk load out distributor	15	.25	250.00
Ton bulk load out bins—4			3,000.00
Grain conveyor to grinder	4	5.0	1,500.00
Hammer mill, fan, etc.	4	50.0	4,500.00
Hammer mill collector and piping	4		1,250.00
6 ton ground grain bins—2			1,400.00
2 ton hopper and dial scale			800.00
Bagging scale—gross type	2		1,500.00
2 ton bagging bin			500.00
Portable type sewing belt and machine	2	1.0	1,900.00
Cold type molasses mixer, pump, meter, etc., feed bin, tank	5	7.5	4,300.00
Alternate custom truck hoist		7.5	2,300.00
		Total Cost	71,610.00

Appendix Table V.—Unit Power Requirements for Operation of Grain Elevator Equipment.

Item	HP	KWH[1] (Total)	Capacity (Bushels Per Hour)	KWH (Per 1,000 Bu.)
6,000 bu. legs—3	120.0	96.0	18,000	5.33333
Dust fans—3	9.0	7.2	18,000	.40000
Belt conveyors—3	45.0	36.0	18,000	2.00000
Aeration system—9	250.0	200.0	1,000,000	.20000

[1] KHW = (HP) (.8).

Appendix Table VI.—Unit Power Requirements for Operation of Single Unit Seed Cleaning and Treating Plant.

Equipment	HP	KWH[1] (Total)	Capacity (Bushels Per Hour)	KWH (Per 100 Bu.)
Receiving leg	5.0	4.0	900	.44444
Cleaner	7.5	6.0	250	2.40000
Clean leg	5.0	4.0	250	1.60000
Treater	1.0	0.8	250	.32000
Dust System	5.0	4.0	250	1.60000

[1] KHW = (HP) (.8).

Appendix Table VII.—Unit Power Requirements for Operation of Bulk Fertilizer Blending Plant.

Equipment	HP	KWH[1] (Total)	Capacity (Tons Per Hour)	KWH (Per Ton)
Shuttlebut	3.0	2.4	25	.09600
Undercar conveyor	5.0	4.0	25	.16000
Bucket elevator	5.0	4.0	25	.16000
Blender, etc.	15.0	12.0	15	.80000

[1] KHW = (HP) (.8).

Appendix_Table_VIII—Unit Power Requirements for Operation of 30 Ton **Feed Mill Equipment.**

Equipment	HP	KWH[1]	Capacity	KWH
		(Total)	(Tons Per Hour)	(Per Ton)
Receiving conveyor	5.0	4.0	50	.08000
Receiving elevator	5.0	4.0	50	.08000
2 ton vertical mixer	10.0	8.0	11.3647	.70393
Screw conveyor	1.0	0.8	15	.05333
Mash elevator	5.0	4.0	15	.26666
Conveyor to grinder	5.0	4.0	4	1.00000
Hammer mill, fan, etc.	50.0	40.0	4	10.00000
Portable sewing machine	1.0	0.8	2	.40000
Molasses mixer & pump	7.5	6.0	5	1.20000

[1] KHW = (HP) (.8).

Appendix Table IX.—Unit Maintenance and Repair Costs for Operation of Grain Elevator Equipment.

Item	Maintenance and Repair[1]
	(Dollars Per 1,000 Bu.)
Legs—3	.11689
Dust fans—3	.00072
Man lifts—3	.00185
Distributors—3	.00951
Semi dumper	
Power shovel	
Belt conveyors—3	.06545
Car puller	
Boxcar	.02751
Hoppercar	.04752
25 bu. auto scales—3	
50′ x 10′ truck scale	.00074
Manifold aeration system—9	
Hotspot system	
Intercom	
Loadout spouts—2	.05528

[1] Based on an annual handling volume of 1,125,000 bushels.

Appendix Table X.—Unit Maintenance and Repair Costs for Operation of Bulk Fertilizer Blending Plant Equipment.

Item	Maintenance and Repair[1]
	(Dollars Per Ton)
Schuttlebut, undercar conveyor, bucket elevator	.06666
Blender, etc.	.06666[2]
Payloader	2.78400

[1] Based on an annual handling volume of 4,000 tons.
[2] Based on an annual blending volume of 2,000 tons.

Appendix Table XI.—Standard Sales Volumes for Products and Services in Sideline Departments.

Product or Service	Standard Sales Volume
Seed	
Clean	10,557.00 bu.
Clean and treat	31,671.00 bu.
Fertilizer	
Sell bulk blended fertilizer in spring	500.00 tons
Sell bulk fertilizer in spring	500.00 tons
Sell bulk blended fertilizer in fall	1,500.00 tons
Sell bulk fertilizer in fall	1,500.00 tons
Sell bag fertilizer in spring	250.00 tons
Sell bag fertilizer in fall	750.00 tons
Petroleum sale and delivery	1,000,000.00 gal.
Feed	
Sell protein supplement in winter	900.00 tons
Sell protein supplement in summer	100.00 tons
Sell bulk custom ground and mixed feed from farmer delivered grain in winter	37.44 tons
Sell bulk custom ground and mixed feed from farmer delivered grain in summer	9.36 tons
Sell bag custom ground and mixed feed from farmer delivered grain in winter	9.36 tons
Sell bag custom ground and mixed feed from farmer delivered grain in summer	2.34 tons
Sell bulk custom ground and mixed molasses feed from farmer delivered grain in winter	12.48 tons
Sell bulk custom ground and mixed molasses feed from farmer delivered grain in summer	3.12 tons
Sell bag custom ground and mixed molasses feed from farmer delivered grain in winter	3.12 tons
Sell bag custom ground and mixed molasses feed from farmer delivered grain in summer	.78 tons
Sell bulk custom ground and mixed feed from grain shipped into the area in winter	56.16 tons
Sell bulk custom ground and mixed feed from grain shipped into the area in summer	14.04 tons
Sell bag custom ground and mixed feed from grain shipped into the area in winter	14.04 tons
Sell bag custom ground and mixed feed from grain shipped into the area in summer	3.51 tons
Sell bulk custom ground and mixed molasses feed from grain shipped into the area in winter	18.72 tons
Sell bulk custom ground and mixed molasses feed from grain shipped into the area in summer	4.68 tons
Sell bag custom ground and mixed molasses feed from grain shipped into the area in winter	4.68 tons
Sell bag custom ground and mixed molasses feed from grain shipped into the area in summer	1.17 tons
Sell bulk custom ground and mixed feed from banked grain in winter	93.60 tons
Sell bulk custom ground and mixed feed from banked grain in summer	23.40 tons
Sell bag custom ground and mixed feed from banked grain in winter	23.40 tons
Sell bag custom ground and mixed feed from banked grain in summer	5.85 tons
Sell bulk custom ground and mixed molasses feed from banked grain in winter	31.20 tons

Appendix Table XI.—(Continued).

Product or Service	Standard Sales Volume
Sell bulk custom ground and mixed molasses feed from banked grain in summer	7.80 tons
Sell bag custom ground and mixed molasses feed from banked grain in winter	7.80 tons
Sell bag custom ground and mixed molasses feed from banked grain in summer	1.95 tons
Deliver bulk custom ground and mixed feed from farmer delivered grain in winter	149.76 tons
Deliver bulk custom ground and mixed feed from farmer delivered grain in summer	37.44 tons
Deliver bag custom ground and mixed feed from farmer delivered grain in winter	37.44 tons
Deliver bag custom ground and mixed feed from farmer delivered grain in summer	9.36 tons
Deliver bulk custom ground and mixed molasses feed from farmer delivered grain in winter	49.92 tons
Deliver bulk custom ground and mixed molasses feed from farmer delivered grain in summer	12.48 tons
Deliver bag custom ground and mixed molasses feed from farmer delivered grain in winter	12.48 tons
Deliver bag custom ground and mixed molasses feed from farmer delivered grain in summer	3.12 tons
Deliver bulk custom ground and mixed feed from grain shipped into the area in winter	224.64 tons
Deliver bulk custom ground and mixed feed from grain shipped into the area in summer	56.16 tons
Deliver bag custom ground and mixed feed from grain shipped into the area in winter	56.16 tons
Deliver bag custom ground and mixed feed from grain shipped into the area in summer	14.04 tons
Deliver bulk custom ground and mixed molasses feed from grain shipped into the area in winter	74.88 tons
Deliver bulk custom ground and mixed molasses feed from grain shipped into the area in summer	18.72 tons
Deliver bag custom ground and mixed molasses feed from grain shipped into the area in winter	18.72 tons
Deliver bag custom ground and mixed molasses feed from grain shipped into the area in summer	4.68 tons
Deliver bulk custom ground and mixed feed from banked grain in winter	374.40 tons
Deliver bulk custom ground and mixed feed from banked grain in summer	93.60 tons
Deliver bag custom ground and mixed feed from banked grain in winter	93.60 tons
Deliver bag custom ground and mixed feed from banked grain in summer	23.40 tons
Deliver bulk custom ground and mixed molasses feed from banked grain in winter	124.80 tons
Deliver bulk custom ground and mixed molasses feed from banked grain in summer	31.20 tons
Deliver bag custom ground and mixed molasses feed from banked grain in winter	31.20 tons
Deliver bag custom ground and mixed molasses feed from banked grain in summer	7.80 tons

Appendix Table XII.—Value to the Firm of Additional Market Units of Products and Services in Sideline Departments in Normal Years in Which 50 Percent of the Grain Received at Harvest Enters Storage at Selected Grain Handling Volumes Under the Assumption of Standard Sales Volumes of Products and Services in Sideline Departments.

Product or Service	Value of Additional Market Units at 500,000 Bu. and 1,000,000 Bu.	Value of Additional Market Units at 1,500,000 Bu.
Seed		
Clean	$ 7.35/100 bu.	$ 7.35/100 bu.
Clean and treat	$ 9.31/100 bu.	$ 9.31/100 bu.
Fertilizer		
Sell bulk blended fertilizer in spring	$10.04/ton	$10.04/ton
Sell bulk fertilizer in spring	$ 5.13/ton	$ 5.13/ton
Sell bulk blended fertilizer in fall	$10.04/ton	$10.04/ton
Sell bulk fertilizer in fall	$ 5.13/ton	$ 5.13/ton
Sell bag fertilizer in spring	$ 8.00/ton	$ 8.00/ton
Sell bag fertilizer in fall	$ 8.00/ton	$ 8.00/ton
Petroleum sale and delivery	$10.18/300 gal.	$10.18/300 gal.
Feed		
Sell protein supplement in winter	$10.00/ton	$10.00/ton
Sell protein supplement in summer	$10.00/ton	$10.00/ton
Sell bulk custom ground and mixed feed from farmer delivered grain in winter	$ 5.41/ton	$ 5.41/ton
Sell bulk custom ground and mixed feed from farmer delivered grain in summer	$ 5.41/ton	$ 5.35/ton
Sell bag custom ground and mixed feed from farmer delivered grain in winter	$ 6.80/ton	$ 6.80/ton
Sell bag custom ground and mixed feed from farmer delivered grain in summer	$ 6.80/ton	$ 6.74/ton
Sell bulk custom ground and mixed molasses feed from farmer delivered grain in winter	$ 6.90/ton	$ 6.90/ton
Sell bulk custom ground and mixed molasses feed from farmer delivered grain in summer	$ 6.90/ton	$ 6.84/ton
Sell bag custom ground and mixed molasses feed from farmer delivered grain in winter	$ 8.29/ton	$ 8.29/ton
Sell bag custom ground and mixed molasses feed from farmer delivered grain in summer	$ 8.29/ton	$ 8.23/ton
Sell bulk custom ground and mixed feed from grain shipped into the area in winter	$ 7.41/ton	$ 7.41/ton

Appendix Table XII.—(Continued).

Product or Service	Value of Additional Market Units at 500,000 Bu. and 1,000,000 Bu.	Value of Additional Market Units at 1,500,000 Bu.
Sell bulk custom ground and mixed feed from grain shipped into the area in summer	$ 7.41/ton	$ 7.41/ton
Sell bag custom ground and mixed feed from grain shipped into the area in winter	$ 8.80/ton	$ 8.80/ton
Sell bag custom ground and mixed feed from grain shipped into the area in summer	$ 8.80/ton	$ 8.80/ton
Sell bulk custom ground and mixed molasses feed from grain shipped into the area in winter	$ 8.65/ton	$ 8.65/ton
Sell bulk custom ground and mixed molasses feed from grain shipped into the area in summer	$ 8.65/ton	$ 8.65/ton
Sell bag custom ground and mixed molasses feed from grain shipped into the area in winter	$10.04/ton	$10.04/ton
Sell bag custom ground and mixed molasses feed from grain shipped into the area in summer	$10.04/ton	$10.04/ton
Sell bulk custom ground and mixed feed from banked grain in winter	$ 6.35/ton	$ 6.32/ton
Sell bulk custom ground and mixed feed from banked grain in summer	$ 6.74/ton	$ 6.70/ton
Sell bag custom ground and mixed feed from banked grain in winter	$ 7.74/ton	$ 7.71/ton
Sell bag custom ground and mixed feed from banked grain in summer	$ 8.13/ton	$ 8.10/ton
Sell bulk custom ground and mixed molasses feed from banked grain in winter	$ 7.72/ton	$ 7.69/ton
Sell bulk custom ground and mixed molasses feed from banked grain in summer	$ 8.06/ton	$ 8.03/ton
Sell bag custom ground and mixed molasses feed from banked grain in winter	$ 9.11/ton	$ 9.08/ton
Sell bag custom ground and mixed molasses feed from banked grain in summer	$ 9.46/ton	$ 9.42/ton
Deliver bulk custom ground and mixed feed from farmer delivered grain in winter	$ 7.74/ton	$ 7.74/ton
Deliver bulk custom ground and mixed feed from farmer delivered grain in summer	$ 7.74/ton	$ 7.68/ton
Deliver bag custom ground and mixed feed from farmer delivered grain in winter	$ 9.28/ton	$ 9.28/ton
Deliver bag custom ground and mixed feed from farmer delivered grain in summer	$ 9.28/ton	$ 9.22/ton
Deliver bulk custom ground and mixed molasses feed from farmer delivered grain in winter	$ 9.23/ton	$ 9.23/ton

Appendix Table XII.—(Continued).

Product or Service	Value of Additional Market Units at 500,000 Bu. and 1,000,000 Bu.	at 1,500,000 Bu.
Deliver bulk custom ground and mixed molasses feed from farmer delivered grain in summer	$ 9.23/ton	$ 9.17/ton
Deliver bag custom ground and mixed molasses feed from farmer delivered grain in winter	$10.77/ton	$10.77/ton
Deliver bag custom ground and mixed molasses feed from farmer delivered grain in summer	$10.77/ton	$10.71/ton
Deliver bulk custom ground and mixed feed from grain shipped into the area the area in winter	$ 9.74/ton	$ 9.74/ton
Deliver bulk custom ground and mixed feed from grain shipped into the area in summer	$ 9.74/ton	$ 9.73/ton
Deliver bag custom ground and mixed feed from grain shipped into the area in winter	$11.28/ton	$11.28/ton
Deliver bag custom ground and mixed feed from grain shipped into the area in summer	$11.28/ton	$11.28/ton
Deliver bulk custom ground and mixed molasses feed from grain shipped into the area in winter	$10.98/ton	$10.98/ton
Deliver bulk custom ground and mixed molasses feed from grain shipped into the area in summer	$10.98/ton	$10.97/ton
Deliver bag custom ground and mixed molasses feed from grain shipped into the area in winter	$12.52/ton	$12.52/ton
Deliver bag custom ground and mixed molasses feed from grain shipped into the area in summer	$12.52/ton	$12.52/ton
Deliver bulk custom ground and mixed feed from banked grain in winter	$ 8.68/ton	$ 8.65/ton
Deliver bulk custom ground and mixed feed from banked grain in summer	$ 9.07/ton	$ 9.03/ton
Deliver bag custom ground and mixed feed from banked grain in winter	$10.22/ton	$10.19/ton
Deliver bag custom ground and mixed feed from banked grain in summer	$10.61/ton	$10.57/ton
Deliver bulk custom ground and mixed molasses feed from banked grain in winter	$10.05/ton	$10.02/ton
Deliver bulk custom ground and mixed molasses feed from banked grain in summer	$10.39/ton	$10.36/ton
Deliver bag custom ground and mixed molasses feed from banked grain in winter	$11.59/ton	$11.56/ton
Deliver bag custom ground and mixed molasses feed from banked grain in summer	$11.94/ton	$11.90/ton