AN ECONOMIC ANALYSIS OF OKLAHOMA COUNTRY GRAIN ELEVATOR OPERATIONS

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PREFACE

This study was undertaken to analyze the broad spectrum of country grain elevator activities. Included were the relative profitability of different products and services, the effects of different market conditions on elevator profits, and the effects of variability of grain handling and storage volumes on elevator profits. Since firms are characterized by excess capacity but many facilities have useful life remaining, attention was focused on how to best utilize existing facilities. Analyses were made using several variants of a deterministic linear programming model and a stochastic model of a typical grain elevator.

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CHAPTER I

INTRODUCTION

Oklahoma country elevators have traditionally 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 typically perform many related functions such as storing, grading, and blending grains. Country elevators have also expanded the scope of their activities to include merchandising farm inputs related to grain and livestock production such as feed, seed, fertilizer, and petroleum products.

Individual elevators differ with respect to variables such as the type and amount of storage capacity, form of the business, and the range of products and services provided. Most modern elevators are of upright concrete construction although many firms have flat storage facilities. Storage capacities range from a few thousand bushels to several million bushels.[1] Private, line, and cooperative business forms are common with cooperatives making up 30 percent of the total number of firms. About 25 percent of the firms are multi-location firms having facilities at more than one location.[2] Facilities at some of these locations serve merely as satellites in that they do not handle sidelines and remain open only during the harvest season. This is especially true of non-cooperative multi-location firms. While some firms operate only grain departments, most firms also operate feed, seed, fertilizer, and petroleum departments.

The present structure of the Oklahoma country elevator industry can best be described as atomistic. However, locational differences, product and service differentiation, and resource immobility cause the structure to be less than purely competitive. In a given locality, grain buying most resembles oligopsony with a few elevators buying interdependently from many farms. On the other hand, sideline sales occur under conditions resembling those of oligopoly with a few firms selling interdependently to many farms. As larger areas are considered, lesser degrees of concentration become apparent. Excess grain storage capacity exists, and exit is slow due to the low value of elevator facilities in alternative uses and because many facilities have already paid for themselves and will remain in operation as long as variable costs are covered.[3]

Problem

Many changes have occurred in country grain elevator operations. Firms have grown larger and fewer in number and sidelines have increased in importance. In the past, government programs created incentives for the expansion of grain storage capacity through occupancy contracts, accelerated ammortization, and storage and handling agreements.[4] Loans from the Cooperative Banks were readily available to cooperative associations for construction of storage facilities for Commodity Credit Corporation (CCC) Grain as were commercial loans to non-cooperative firms. Schnake and others have found that from 1957 to 1962, a period during which average yearly CCC stocks of wheat in Oklahoma increased by nearly 25 million bushels, the total number of firms increased by 28 percent with some trend toward diversification.[5] The increase in demand for storage of 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.

This incentive for expansion of storage space has changed, however, in that CCC stocks declined rapidly from 1962 to a level of about six million bushels in 1967.[6] During this period, the total number of firms in the industry declined by 23 percent. Small firms without sideline activities showed definite movements toward exit from the industry while those with sideline activities remained relatively stable or expanded.[7] Large firms without sideline activities revealed movements toward contraction in size or exit while large firms with sideline departments were highly stable. Thus, a reduction in the number of firms occurred in all categories except those with a high degree of diversification. Apparently firms found it necessary to exit from the industry or adapt existing facilities to feed, fertilizer, seed, and petroleum departments for revenues. An increase in the demand for farm inputs, especially fertilizer, was an important factor as well as the decrease in the level of CCC storage stocks.

A study by Duerst provides evidence of the importance of storage on elevator earnings. In 1962, 35 percent of the gross earnings of a sample of cooperative grain elevator firms was derived from storage.[8] An average earnings index value was highest among small firms and lowest among large firms, with average earnings values decreasing as total gross earnings increased. The mean earnings index was highest when storage income made up 60 percent or more of total income.[9] The study disclosed a trend toward lower earnings as non-storage income increased as a percent of total income with the highest earnings among cooperatives deriving less than five percent of their total income from non-storage grain income. Many of the facilities and equipment necessary for such services are underemployed.

When petroleum sales as a percent of commodity sales and petroleum income as a percent of total gross income increased, the mean earnings index value decreased markedly. The mean earnings index was highest when grain sales were between 90 and 100 percent of commodity sales. A strong trend toward higher earnings was also found as grain income as a percent of total income increased. The highest earning value was found among cooperatives dealing primarily in grain with grain storage the chief source of income.

In addition to the previously mentioned changes, grain production is highly variable from year-to-year due to changing weather conditions, acreage allotments, and insect damage. The effects of handling volume variations have also been studied. Corley determined short-run grain handling costs for elevators with ten different storage capacities at selected handling volumes above and below base volumes.[10]

Most studies undertaken to date have focused their attention on particular aspects of country elevator operations such as grain handling, the feasibility of hedging, seed cleaning operations, feed milling, or financial analysis rather than on the entire spectrum of elevator activities. More information is needed on the relative profitability of providing different products and services with facilities typical of large country elevator firms. In addition, the effects of the most important factors causing variation should be studied.

Objectives

The objectives of this study are to investigate (1) the relative profitability of providing different products and services with facilities typical of those owned by grain elevator firms, (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 with facilities having a number of years of useful life remaining, attention will be focused on the problem of how to best utilize existing facilities. This problem will first be 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 will be made to analyze the effects of such variation on the profitability of elevator operation.

Organization of the Study

A typical country grain elevator firm will be constructed on the basis of a 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 and north central Oklahoma. Available secondary data will be supplemented by direct inquiry to necessary sources and used to formulate models soluble by linear programming algorithms. The Monte Carlo procedure will be used to study the effects of variability in the volumes of grain handled and stored on the operating profitability of these facilities.

The remainder of the study consists of five chapters. Chapter II includes a discussion of the nature of country elevator operations in northwest and north central Oklahoma. Revenue generating activity in the grain department is discussed. The discussion also includes other components of the business emphasizing the types of products sold, facilities used, merchandising practices, and the seasonality of operations.

Chapter III contains a discussion of models of the firm. Included are a review of the contemporary economic theory of the multiple factor-multiple product firm, the Hicksian model, mathematical programming models, and simulation models.

Chapter IV describes empirical models developed within a deterministic linear programming framework. Departments considered include grain, feed, seed, fertilizer, and petroleum departments. The empirical models are analyzed under different sets of market assumptions.

In Chapter V, the results of the Monte Carlo analysis are discussed. The effects of variability in grain handling and storage volumes on returns to the firm are evaluated under the assumption that these factors are random variables with specified probability distributions.

Finally, Chapter VI contains a summary discussion of the conclusions, limitations, and implications of the analysis. Suggestions for further research are included.

FOOTNOTES

[1]Oklahoma State University Extension Service, _Commercial Grain Warehouses in Oklahoma_ (Stillwater, 1968).

[2]Oklahoma Grain and Feed Dealers Association, _Official Directory_ (Enid, 1966).

[3]Donald R. Knop, "Economies of Oklahoma Country Grain Elevator Size: Market Structure, Conduct, and Performance Considerations" (unpub. manuscript, Oklahoma State University, 1967), pp. 13-15.

[4]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.

[5]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.

[6]U. S. Department of Agriculture, _Grain Marketing News_, Consumer and Marketing Service, XVI (Washington, 1968), p. 11.

[7]Schnake, Sanders, and Bloyd, p. 7.

[8]John Addison Duerst, "the Development and Analysis of Financial Indices for Cooperative Elevators in Oklahoma" (unpub. M. S. thesis, Oklahoma State University, 1967), p. 2.

[9]Ibid., p. 99.

[10]Corley, p. 112.

CHAPTER II

THE NATURE OF OKLAHOMA COUNTRY GRAIN ELEVATOR OPERATIONS

This chapter contains a discussion of the nature of country grain elevator operations in northwest and north central Oklahoma. The operating practices of firms are discussed with respect to revenue generating activity in the grain department. The discussion is then extended to include other components of the business, emphasizing the types of products sold, facilities used, merchandising practices, and the seasonality of operations.

Northwest and north central Oklahoma is the major wheat producing area of the state. Wheat accounted for more than 80 percent of all grains produced from 1963 through 1967 in the nineteen county study area shown in Figure 1. In addition, more than 60 percent of all wheat produced in the state during the same period was produced in the area.[1] As a consequence, elevators in the area typically center their operations on wheat. Other grains produced in the area in significant quantities include grain sorghum, barley, and oats, most of which are utilized in the area as a part of swine, dairy and feeder cattle rations. In fact, additional quantities of these grains must be shipped into the area to

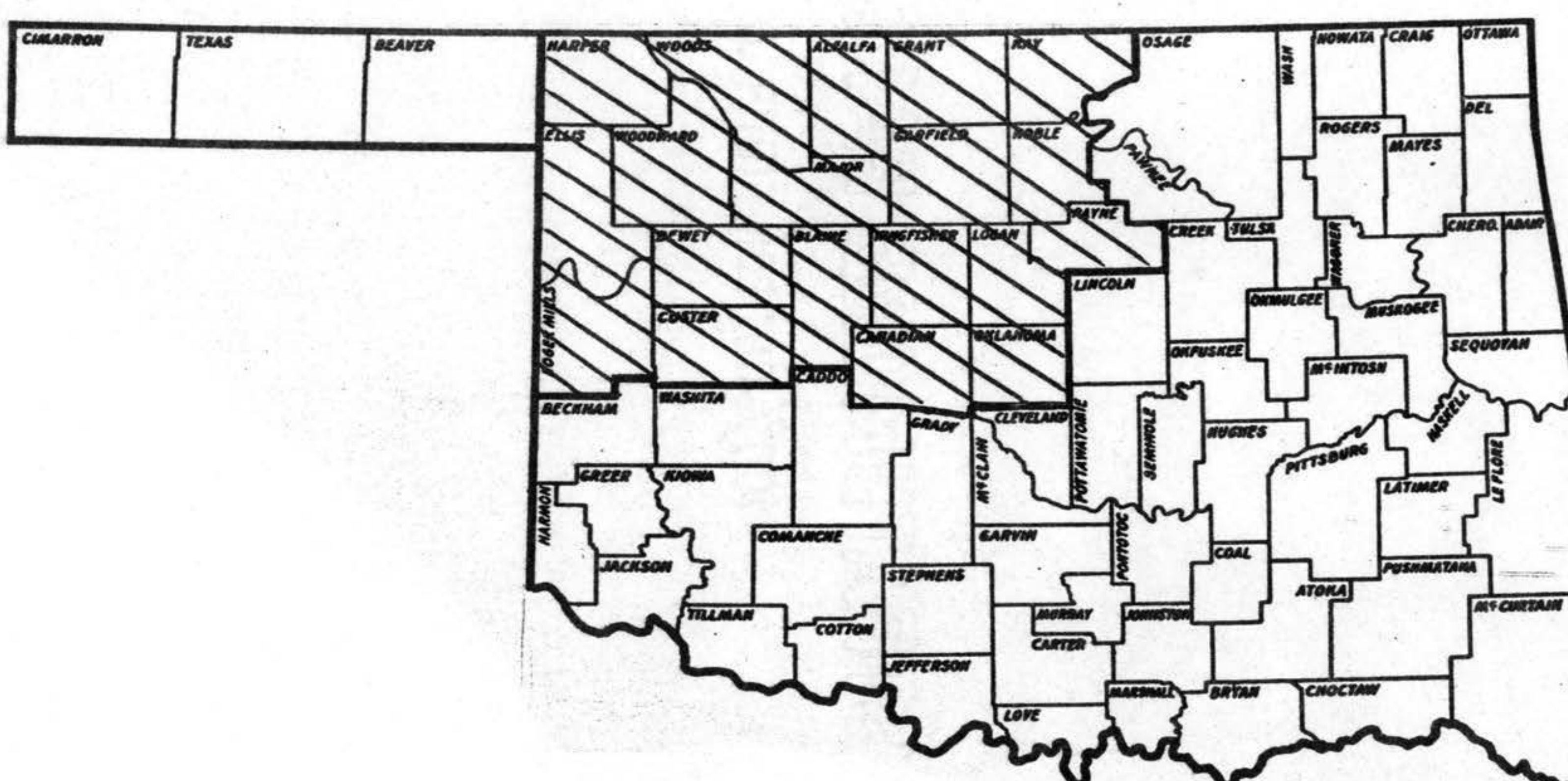

Figure 1. Nineteen County Study Area in Northwest and North Central Oklahoma

satisfy feeding requirements.

Although the activities of most firms center on grain operations, they typically include sales of sideline products and services which are only indirectly related to grain operations. Most of these products and services are sold through feed, seed, and fertilizer departments. Such activities vary in importance between localities depending on factors such as soil type, number and type of livestock, and the number and type of competitors providing similar services.

Grain Activities

Revenues from grain are derived primarily from handling and storage margins. The handling margin for a particular grain consists of the difference between the price paid to farmers and the net price the elevator receives when the grain is sold, after allowing for shrinkage.

Grain elevators in the area typically have more storage capacity than can be justified on the basis of the handling function, partly because of previous Commodity Credit Corporation incentives for the creation of storage facilities.[2] Since the area is characterized by deficit on-farm storage, some of this excess capacity is utilized by producers in lieu of constructing on-farm storage facilities. Elevators, thus, derive storage revenues from rental of some of their excess storage capacity. Although elevators in many areas of the United States typically hold large inventories of owned grains to facilitate operation of the business, especially where feed milling is a sideline, a minimum amount of grain is stored for such purposes in this area, partly because price uncertainty cannot necessarily be overcome by hedging.[3] Little grain is stored by elevators in anticipation of price increases for similar reasons. Storage rates tend to stabilize at the official Uniform Grain Storage Agreement rates.

Oklahoma wheat prices are determined primarily by export market conditions at the Texas Gulf Ports. The effective price at a given Oklahoma country point is the Gulf price minus transfer costs from the point in question to the Gulf. Thus, the price paid to producers at a country point depends on the size of the handling margin and transfer costs, consisting primarily of transportation.[4]

Elevators in the area typically employ two types of pricing policies. First, an attempt is often made to achieve some average margin for the year by subtracting a fixed margin from the daily Gulf cash price to determine the price offered producers. Since truck transportation rates are often lowest when trucks are available, and trucks are not always available, a seasonal transportation rate differential sometimes exists. In this case, the realized margin depends on the proportion of grain actually shipped at each rate. Uncertainty arising from seasonal rate differentials is borne by the elevator.

A more common pricing procedure is to deduct a fixed margin from the effective selling price at the elevator as determined by quotations from brokers or commission men or by local market conditions. The price offered producers in this case is directly affected by seasonal transportation rate differentials. Uncertainty arising from seasonal rate differentials is transferred to producers rather than being borne by the elevator.

Elevators may sell grain for either immediate or later delivery. Since Oklahoma country elevators have traditionally been hesitant to accept the risks involved in future sales, they have attempted to transfer price uncertainty to buyers by choosing appropriate methods of sale.[5] Thus, three types of sales are commonly used by firms in the area. Selling "to arrive" and "on track" are the most important, especially during the nonharvest season. The "to arrive" method of sale is also known as "track destination" or "f.o.b. destination".[6] The selling price is determined prior to shipment and the buyer assumes price uncertainty. However, physical risks and transportation charges are assumed by the seller. The sales contract also specifies the date by which the grain must be delivered to a specified location.

Selling "on track" also guarantees a price to the elevator prior to shipment. This method differs from the "to arrive" method in that the buyer assumes physical risk and transportation charges in addition to price uncertainty. The seller is required only to load the specified quantity and quality of grain by a specified date.

Driscoll and Martin have found local sales and sales to itinerant truckers to be of some importance.[7] They have also found sales to itinerant truckers to be relatively more important during the harvest season.[8] Grain sorghum, barley, and oats sales for feeding purposes constitute the most important type of local grain sales. The demand for wheat for feeding purposes becomes relevant only when the price of wheat is low relative to the prices of other feed grains.

Given the handling "margin", handling revenue is dependent upon quantity handled. Quantity handled fluctuates greatly from year-to-year due to factors such as acreage and yield in the area, and success relative to competitors in attracting grain. Quantity handled may be viewed as a random variable.

Storage revenue, given the storage "charge", is dependent upon quantity stored and the storage interval. Quantity stored and the storage interval for a given year depend largely on the price situation during the post-harvest season of that year. If prices are favorable relative to expectations for later in the season, less wheat is stored and the storage interval tends to be short. If prices are near the support price and low relative to expectations for later in the season, more wheat is stored and the storage interval tends to be long. Quantity stored and the storage interval, too, may be viewed as random variables. Thus, quantity handled, quantity stored, and the storage interval are all largely beyond the control of elevator management in the short run and may be viewed as random variables.

The seasonality of grain production causes serious problems for grain firms. Most of the wheat is received and must be either shipped out or put into storage during the last two weeks of June. In addition, most of the barley and oats is received during the same period. Thus, it is necessary for firms to maintain labor and equipment capable of handling large volumes of grain during short time intervals and which is used at capacity only during such intervals. The grain sorghum harvest is less concentrated, occurring from October 15 to November 15. However, this period is also characterized by considerable demands in sideline departments such as feed, seed, and fertilizer.

Feed Activities

Feed demand in the area consists generally of dairy, swine, and feeder cattle rations and high protein supplements for wintering cow-calf operations. Dairy, swine, and feeder cattle rations differ somewhat in content although all generally consist of ground feed grains mixed with high protein supplements. Dairy rations usually contain a high protein supplement such as soybean oil meal, minerals and other ingredients, and molasses. Swine rations also contain a high protein supplement such as soybean oil meal and other additives. In addition to high protein supplements such as cottonseed meal and urea, feeder cattle rations often contain a premix including antibiotics. High protein supplements such as cottonseed cake are used individually for wintering cow-calf operations. These supplements are not processed and are required primarily from October through April.

Use of the feed mill is required to grind the grain and mix the rations, usually on a custom basis. Custom grinding and mixing refers to the grinding and mixing of ingredients according to the specifications of individual farmers.[9] While additional feed grains are shipped into the area and many feed customers deliver grains to be used in rations, many rations are custom ground and mixed from grain banking operations. Grain banks operate by holding feed grains in storage in anticipation of their being withdrawn for use in grinding and mixing operations.[10] Grain banking tends to reduce customer shifts from plant-to-plant and to allow more efficient use of resources in grinding and mixing operations through better scheduling. Large custom orders for rations are usually handled in bulk while small orders are more frequently bagged. In many cases feeds are delivered.

Feed revenues originate from two sources. Generally, a fixed charge per ton is assessed for grinding and mixing with additional charges for bagging and delivery. In addition, a margin is obtained from the sale of supplements and other feed ingredients, regardless of whether grinding or mixing is involved. A storage charge is derived from banked grains ground into feed, and if farmers buying rations do not have the proper quantities and types of feed grains in the grain bank the elevator also obtains a margin from grain used. While the demand for dairy, swine, and feeder cattle rations is heaviest during the winter months, it is relatively less concentrated in these months than is the demand for supplements for cow-calf operations. The demand for dairy and swine rations is less seasonal than that for feeder cattle rations.

Custom feed operations frequently do not directly pay their way because of inefficient scheduling and because of considerable excess capacity, especially during the summer months. In addition, such mills are often too small to benefit from efficient technology. However, many firms believe that custom grinding and mixing services enhance their grain business, increase storage revenues through grain banking operations, and increase feed ingredient sales.

Seed Cleaning and Treating

Custom seed cleaning and treating services are performed by many elevators in the area. Custom seed cleaning and treating refers to the processes of cleaning and treating locally produced seed which is returned to the farms for planting.[11] The demand for such services differs between locations primarily because of different amounts of wheat produced and the nature of competition for cleaning and treating services. The demand for these services is highly seasonal with the greatest demand falling in a 30-day period during the two months prior to wheat planting in the fall. Limited quantities of seeds other than wheat are custom cleaned and treated.

Charges are usually assessed on the basis of the weight of the uncleaned seed and competition appears to be an important determinant of these charges. Separate charges are made for cleaning and treating, but most seed is both cleaned and treated. Additional charges are made for bagging, but little seed is bagged. Single and double unit plants are common to the area.

Fertilizer Activities

Due to the importance of wheat and feed grain production, many grain firms in the area also sell fertilizers. The traditional mode of fertilizer sale has been that of mixed fertilizers and fertilizer materials in the bagged form. A mixed fertilizer contains two or three of the primary plant nutrients (N, P, K) in definite, predetermined percentages while a fertilizer material is a single-nutrient fertilizer such as superphosphate, potassium chloride, or ammonium sulphate. Some two-nutrient fertilizers, particularly ammonium phosphates, are also referred to as fertilizer materials.[12] While sales of mixed fertilizers and fertilizer materials in the bag form are still important, the past decade has witnessed a rise in the popularity of bulk blending.

Bulk blending refers to the purchase of granular fertilizer materials in the bulk form and combining them to individual farmers' orders or to meet recommendations based on soil tests.[13] A blend, then, is a mixed fertilizer obtained by a mechanical mixture of granular fertilizer materials, sometimes including micronutrients. Many granular fertilizer materials are also sold in their unblended form. Granular fertilizer materials most commonly sold in bulk form in the area are ammonium nitrate (33.5-0-0) and diammonium phosphate (18-46-0). Other important materials are triple superphosphate (0-46-0), potassium chloride (0-0-60), and urea (45-0-0).[14]

Handling bagged fertilizers requires warehouse facilities similar to those required for feeds. Many firms warehouse feeds and fertilizers together. Bulk handling, on the other hand, requires specialized facilities and equipment, usually in the form of a bulk blending plant. Although fertilizers are not usually delivered, spreaders are often rented with the sale of either blended or unblended fertilizers. The demand for fertilizers is highly seasonal with most sales occurring during the spring and fall months. Most fertilizer is applied to wheat and feed grains prior to planting or as a starter at planting time. In addition, a nitrogen top dressing is usually applied. A three to one fall-spring sales ratio is common to this area.[15]

Fertilizer revenues are obtained from several sources.

Most firms add a fixed charge to the wholesale price for mixed fertilizers and fertilizer materials. In addition, a blending charge is assessed for those materials which are blended and a rental fee is obtained from spreader use.

FOOTNOTES

[1]Oklahoma Crop and Livestock Reporting Service, Oklahoma Wheat: Acreage, Yield and Production, Statistical Reporting Service (Oklahoma City), selected issues.

[2]For analyses of the effects of CCC Activities on grain storage facilities in Oklahoma see James L. Driscoll, "An Analysis of Expected Returns to Oklahoma Grain Elevators From Alternative Hedged Wheat Storage Practices" (unpub. Ph.D. dissertation, Oklahoma State University, 1969), pp. 9-20, 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), and 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), pp. 22-27.

[3]Driscoll, "An Analysis of Expected Returns to Oklahoma Grain Elevators From Alternative Hedged Wheat Storage Practices," pp. 129-134.

[4]Ibid., p. 26.

[5]Ibid., pp. 26-27.

[6]For a discussion of various methods of sale common to country elevators, see Arthur B. Sogn, Grain Merchandising at the Country Elevator, South Dakota State College Agricultural Economics Pamphlet 102 (Brookings, 1959), pp. 10-15.

[7]James L. Driscoll and James E. Martin, Structural Changes in the Oklahoma and Texas Grain Marketing Industries, 1959-1964, Oklahoma State University Department of Agricultural Economics Processed Series P-571 (Stillwater, 1967).

[8]Ibid.

[9]Carl J. Vosloh, Jr., and V. John Brensike, The Changing Feed Mixing Industry: Practices in Selected States, Marketing Research Report 506, Economic Research Service (Washington, 1961), p. 14.

[10]Ibid., p. 15.

[11]Roland D. Smith, "An Economic Analysis of Custom Seed Cleaning Operations in Oklahoma" (unpub. M.S. thesis, Oklahoma State University, 1968), p. 2.

[12]Travis P. Hignett, Bulk Blending of Fertilizers: Practices and Problems, Proceedings No. 87, The Fertilizer Society of London (1965), p. 3.

[13]Ibid.

[14]Oklahoma State Department of Agriculture, Tonage Distribution of Fertilizer in Oklahoma Counties by Grades and Material, Seed, Feed and Fertilizer Division (Oklahoma City), selected issues.

[15]Oklahoma State Board of Agriculture, Charts and Maps Showing Fertilizer Consumption in Oklahoma, Seed, Feed and Fertilizer Division (Oklahoma City), selected issues.

CHAPTER III

FIRM MODELS

A country grain firm engaged in handling and storing grains and selling farm inputs such as seed, fertilizer, feed, and petroleum may be viewed as a multiple factor-multiple product firm. In the short run, variable factors such as product ingredients, power and capital are used in conjunction with fixed physical facilities and managerial skill to produce the numerous products and services.

This chapter begins with a review of the contemporary economic theory of the multiple factor-multiple product firm, followed by a statement of Hicks' mathematical model embodying the traditional marginal analysis. A linear mathematical programming model is developed as an alternative to the Hicksian model in the short run. Finally, nonlinear programming, stochastic programming, and simulation models are discussed as additional alternatives.

The Contemporary Economic Theory of the Multiple Factor-Multiple Product Firm

The contemporary economic theory of the firm has grown out of the marginalist doctrine of the neoclassical period. Although relatively little attention has been focused on general theories of the multiple factor-multiple product firm, numerous contributions exist. The current economic theory of the multiple factor-multiple product firm is well summarized by Henderson and Quandt.[1]

The firm is viewed as being operated by a rational decision making unit that allocates scarce resources to the production process in such manner as to maximize profits. The decision making unit is assumed to be perfectly informed concerning all prices and technology, to adjust to minute changes in its decision environment, and to be rational in the sense that it consistently maximizes profits. Profits are defined as the difference between revenue and costs where costs include a normal rate of return on resources used in the production process.

The firm itself can be viewed as a technical unit in which factors are transformed into products subject to the rules of a production function. The production function is viewed as a mathematical expression specifying maximum quantities of outputs attainable by the employment of given quantities of inputs. Both factors and products may be in the form of either goods or services. Factors may be the products of other firms and products may be used as factors by other firms.

For a given production period, inputs are classified as fixed or variable. A fixed input is defined as one whose quantity cannot be readily augmented or diminished to increase or decrease output while the quantity of a variable input may be changed at will. Fixed costs are incurred independent of the level of output and variable costs are incurred in accordance with output. Fixed inputs are relevant to operating decisions only to the extent that they limit physical output. The distinction between fixed and variable inputs is temporal in that inputs fixed for a given time period become variable when a longer time period is considered. The short run is defined as a time period for which some inputs are fixed. In the long run, all inputs become variable.

A Hicksian Model of the Firm

Hicks has developed a mathematical model of the multiple factor-multiple product firm which embodies the traditional marginal analysis.[2] The firm's production function is given by

$$F(X_1, \ldots, X_j, \ldots, X_n; V_1, \ldots, V_k, \ldots, V_r) = 0 \qquad (3.1)$$

where X_j $(j = 1, \ldots, n)$ is the output of the j^{th} product and V_k $(k = 1, \ldots, r)$ is the input of the k^{th} variable factor. Technical efficiency is assumed but may be constrained by fixed factors of production. The production function is assumed to have continuous first and second order partial derivatives within the domain of the definition.

In a perfectly competitive economy, the price of the j^{th} product R_j $(j = 1, \ldots, n)$ and the price of the k^{th}

variable factor P_k ($k = 1, \ldots, r$) are given to the firm. Profit is then given by

$$\pi = \sum_{j=1}^{n} R_j X_j - \sum_{k=1}^{r} P_k V_k \tag{3.2}$$

In the case of fixed factors of production, profit is viewed as earnings of the fixed factors.

The firm's objective of profit maximization subject to the technical restraints imposed by the production function is given by

$$J = \sum_{j=1}^{n} R_j X_j - \sum_{k=1}^{r} P_k V_k + \lambda F\ (X_j\ ;\ V_k\ ) \tag{3.3}$$

The Lagrangean differential gradient method can be used to derive the familiar first order conditions for profit maximization.

Condition one states that the marginal rate of product transformation between any two outputs--holding the levels of all other inputs and outputs constant--equals their price ratio:

$$\frac{\partial X_j}{\partial X_i} = \frac{R_i}{R_j} \qquad \begin{array}{l}(i,\ j = 1, \ldots, n)\\ (i \neq j)\end{array} \tag{3.4}$$

Condition two states that the value marginal productivity of an input with respect to each output equals its price:

$$R_j \frac{\partial X_j}{\partial X_k} = P_k \qquad \begin{array}{l}(j = 1, \ldots, n)\\ (k = 1, \ldots, r)\end{array} \tag{3.5}$$

Condition three states that the marginal rate of technical substitution for every pair of inputs--holding the levels of all outputs and all other inputs constant--equals their price ratio:

$$\frac{\partial V_i}{\partial V_k} = \frac{P_k}{P_i} \qquad (i,\ k = 1,\ \ldots,\ r) \quad (i \neq k) \tag{3.6}$$

Second order conditions require that the relevant bordered Hessian determinants alternate in sign. This implies an increasing marginal rate of product transformation between any two outputs, a decreasing marginal product for each input-output combination, and a decreasing marginal rate of technical substitution between any two inputs.

The foregoing model offers little more than a neat point of departure for prescriptive analyses. The specification of a continuous nonlinear production function, estimation of its parameters, and solution of a large system of nonlinear equations is so difficult that it limits use of the model to firms having a few inputs and a few outputs. In addition, the marginal analysis requires the firm to have a continuqus production function in order for the Lagrangean differential gradient method to be applicable. Such is seldom the case, especially in non-agricultural situations.[3] In light of such problems, consideration of alternative models of the firm is necessary. One pragmatic alternative is that of linear mathematical programming.

A Linear Programming Model of the Firm

Linear mathematical programming, as opposed to the calculus embodied in the Lagrangean differential gradient technique, is applicable to problems involving the maximization of a linear function subject to a system of linear inequalities. A linear programming model of the multiple factor-multiple product firm can be viewed as an alternative to the short-run Hicksian model in which the smooth production surface with continuous first and second order derivatives is replaced by a discrete linearly homogeneous production function characterized by a set of independent linear activities. An activity is characterized by a set of ratios of variable factors from the market and fixed factors on hand to the output of a particular product. These ratios are constant and independent of the level of activity use. Activities are additive with respect to both resource use and product output. The firm's short-run profit maximizing problem, thus, becomes one of selecting that feasible combination of activities which maximizes the earnings of the fixed factors.

A mathematical model of the multiple factor-multiple product firm amenable to solution by linear programming follows. The firm's production function is given by

$$V_{jk} = g_{jk} X_j \qquad (j = 1, \ldots, n;\ k = 1, \ldots, r) \qquad (3.7)$$

$$B_{ij} = a_{ij} X_j \qquad (i = 1, \ldots, m;\ j = 1, \ldots, n) \qquad (3.8)$$

and

$$\sum_{j=1}^{n} B_{ij} \leq B_i \qquad (i = 1, \ldots, m) \qquad (3.9)$$

where g_{jk} is the quantity of the variable factor k required to produce a unit of product j, a_{ij} is the quantity of the fixed factor i required to produce a unit of product j, and B_i is the quantity of the i^{th} fixed factor available for use in production activities.[4]

The firm's profit function is given by

$$\pi = \sum_{j=1}^{n} R_j X_j - \sum_{k=1}^{r} P_k V_k \qquad (3.10)$$

which is equivalent to (3.2). The profit function can be simplified by letting C_j $(j = 1, \ldots, n)$ be the profit to the firm from production and sale of a unit of the j^{th} product. Thus, (3.2) and (3.10) can be restated as

$$Z = \sum_{j=1}^{n} C_j X_j \qquad (3.11)$$

The firm's objective of maximizing profit subject to the technical restraints imposed by the production function is, thus, given by

$$\text{Max} \quad Z = \sum_{j=1}^{n} C_j X_j \qquad (3.12)$$

Subject to

$$\sum_{j=1}^{n} A_{ij} X_j \leq B_i \qquad (i = 1, \ldots, m) \qquad (3.13)$$

and

$$X_j \geq 0 \qquad (j = 1, \ldots, n) \tag{3.14}$$

where the final restriction limits the production of outputs to non-negative levels.

The foregoing problem can be solved by one of several variations of Dantzig's "simplex algorithm".[5] The criterion for the linear programming optimal solution is the change in profit associated with introducing one unit of a product not in the current solution. This can be expressed as

$$\Delta Z = \sum_{i=1}^{n} C_i \frac{\Delta X_i}{\Delta X_k} - C_k \tag{3.15}$$

where the i^{th} product is in the current solution and the k^{th} product is not. If the profit foregone by introducing a unit of product X_k is less than the amount of revenue added by producing a unit of X_k, profit would be increased by making the change.

The existence of numerous computer routines, many of them embodying the Revised Simplex Method, allows efficient solution of large linear programming problems. An example of such a procedure built into a special programming language is the IBM Mathematical Programming System for use on the IBM Model 360 Computer.[6] In addition to efficiently finding optimal solutions to large linear programming problems, such routines usually contain post optimal procedures useful in determining how sensitive the optimal solution is to the values assumed for particular parameters in the model. Ranging procedures allow the user to readily determine the effects of individual changes in the coefficients C_j ($j = 1, \ldots, n$) and B_i ($i = 1, \ldots, m$) and parameteric procedures allow the user to study the effects of simultaneously changing coefficients of C_j, A_{ij}, or B_i over specified intervals.

The optimality conditions for linear programming models of the firm similar to the one presented above are somewhat different from those of the traditional marginal analysis. Naylor has summarized the optimality conditions of a linear programming model of the firm into decision rules by which to compare it to the Hicksian marginal analysis model.[7] Those rules which are appropriate for the foregoing linear programming model follow.

Rule one states that the unit price of each activity must be less than or equal to the sum of the imputed costs of the fixed and variable factors used to produce one unit of that activity (product can be substituted for activity if each activity is assigned to a different product).

Rule two states that for each variable factor-activity (product) combination, the unit price of the given variable factor must be greater than or equal to the marginal value imputed to the variable factor with regard to the given activity (product).

Rule three states that the firm's total profit after paying the costs of its scarce resources (fixed factors) must equal zero.

Rule four states that the total value imputed to the scarce resources available to the firm must equal the imputed value of the scarce resources used by the firm in production operations.

Furthermore, if more than one activity is assigned to each product, the first order conditions for the marginal analysis hold in inequality form and similar logic can be used in describing the optimum position of the firm.

Alternative Models

Due to several limitations of the linear programming approach, some alternative models of the firm will be discussed. Relaxing the assumption of linearity allows the programming approach to include nonlinear components. Although no efficient solution procedure is in sight for the general nonlinear problem, routines do exist for special cases. Quadratic programming, which conventionally refers to the problem of maximizing or minimizing a quadratic objective function subject to a system of linear restraints, is one such special case. Wolfe's Simplex Method for Quadratic Programming is probably the best known solution procedure for the case where the objective function is concave and the objective is to maximize, or the objective function is convex and the objective is to minimize.[8] Separable programming may be used to obtain an approximate solution to certain nonlinear programming maximization problems having separable objective functions with concave components or minimization problems having separable objective functions with convex components.[9] This method can also be extended to problems which have nonlinear separable restraints whose components are all convex. The IBM Mathematical Programming System/360 previously mentioned can also be used to solve such problems.[10] However, the solution of either quadratic or separable programming problems requires considerably more computation than the solution of strictly linear programming problems.

A limitation of each of the programming models cited above is that parameters of the models are required to be known with certainty. The use of previously mentioned "post optimal" procedures and solving the model under different sets of assumptions concerning parameter values can be helpful. However, in many cases some or all of the model parameter values are more realistically random variables. Models in which at least one of the operating characteristics is given by a random variable are said to be stochastic models.

Two basic approaches to the solution of stochastic programming problems are (a) selecting the decision vector before observing the random variables and (b) observing the random variables before selecting the decision vector. These approaches have been referred to as "here and now" and "wait and see" approaches, respectively.[11] If the "here and now" or active approach is taken, linear programming problems may be formulated in two ways.[12] One way is to require restraints to hold with a probability of one. Another way, usually referred to as chance-constrained programming, is to allow feasible solutions to have a specified probability of violating some restraints. The general approach to these problems is to reduce them to problems solvable by simplex type routines. However, this tends to be impossible except for special cases.

The "wait and see" or passive approach, although not strictly valid for decision problems, can be effectively dealt with by so-called distribution methods. Through this approach solutions of deterministic linear programming problems based on observed values of the random variables are used to approximate the solution of the stochastic problem.

Because stochastic models are inherently more complex than deterministic models, the adequacy of analytical techniques for obtaining solutions to these models is quite limited. For this reason, simulation is much more attractive as a method for analyzing and solving stochastic models. Basically, simulation is a technique which involves setting up a mathematical or logical model of a real situation and performing experiments on the model, usually by a digital computer.[13] Simulation typically provides statistical estimates and compares alternatives rather than generating an optimal solution. Simulation often refers to the technique of performing sampling experiments on a model of a system in cases where experiments involving the real system would be inconvenient, prohibitively expensive, excessively time consuming, or impossible.

Although the simulation approach and the mathematical programming approach are inherently different, they may be combined to solve the previously mentioned distribution problem. The stochastic programming problem can be written in matrix notation as

$$\text{Maximize} \qquad Z = C'X \tag{3.16}$$

$$\text{Subject to} \qquad AX \leq B \tag{3.17}$$

$$X \geq 0 \tag{3.18}$$

where C is a column vector containing n prices, X is a column vector containing n activities, A is a technology matrix of size (m $\times$ n), B is a column vector containing m resource availabilities, and Z is the value of the objective function to be maximized. At least one of the elements of C, A, or B is a random variable. If values of the random variables are observed before the selection of the decision vector, the problem reverts to a deterministic linear programming problem. Since some elements of C, A, or B are random variables with specified distribution functions, Z has a related distribution function.[14] If a set of variates drawn from the probability distributions of the random elements of the problem are used in solving the resulting deterministic problem, the solution is a variate of the distribution of the solution of the true stochastic problem. This distribution can be approximated by repeating this procedure until the desired degree of approximation is attained. Simulation is a particularly desirable means of achieving this result.

Babbar has proposed a direct method of approximating distributions of the decision vector and the objective function of the stochastic problem based on the linear terms in a Taylor's series.[15] However, his method results in difficult computational problems.

FOOTNOTES

[1]James M. Henderson and Richard E. Quandt, Microeconomic Theory: A Mathematical Approach (New York, 1958), Chapter 3.

[2]J. R. Hicks, Value and Capital (2nd ed., London, 1946), pp. 319-320.

[3]See Robert Dorfman, Application of Linear Programming to the Theory of the Firm (Berkeley, 1948), Ben C. French, L. L. Sammet, and R. G. Bressler, "Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears," Hilgardia, XXIV (1956), pp. 543-721, and William J. Baumol, Economic Theory and Operations Analysis (2nd ed., Englewood Cliffs, 1965), Chapter 12.

[4]This statement of the production function is a modification of that given by Thomas H. Naylor in "The Theory of the Firm: A Comparison of Marginal Analysis and Linear Programming," Southern Economic Journal, XXXII (1966), pp. 263-274.

[5]George B. Dantzig, Linear Programming and Extensions (Princeton, 1963).

[6]IBM, Mathematical Programming System/360 (360A-CO-14X) Linear and Separable Programming - User's Manual, Technical Publications Department (New York, 1968).

[7]Naylor, "The Theory of the Firm: A Comparison of Marginal Analysis and Linear Programming," p. 273.

[8]Philip Wolfe, "The Simplex Method for Quadratic Programming," Econometrica, XXVII (1959), pp. 382-398.

[9]Frederick S. Hillier and Gerald J. Lieberman, Introduction to Operations Research (San Francisco, 1967), pp. 581-586.

[10]IBM, p. 166.

[11]A. Madansky, "Methods of Solution of Linear Programs Under Uncertainty," Operations Research, X (1962), pp. 463-471.

[12]Hillier and Lieberman, pp. 531-532.

[13]Thomas H. Naylor et al., Computer Simulation Techniques (New York, 1966), p. 2.

[14]Gerhard Tintner, "A Note on Stochastic Programming," Econometrica, XXVIII (1960), pp. 490-495.

[15]M. M. Babbar, "Distributions of Solutions of a Set of Linear Equations With An Application to Linear Programming," Journal of the American Statistical Association, L (1955), pp. 854-869.

CHAPTER IV

OPERATIONS ANALYSIS UNDER CERTAINTY

The basic model used in this analysis is constructed within the framework of the deterministic linear programming model of the firm described in Chapter III. 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 wheat handling, custom seed cleaning and treating, bag and bulk fertilizer merchandising and bulk blending, protein supplement sales and custom feed grinding and mixing and delivery, and 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 I. It was necessary to partition the year in this manner in order to make the model reflect highly seasonal operations in several departments. Table I utilizes the following numerical codes for departmental operations: 1 - wheat, barley, and oats; 2 - seed; 3 - fertilizer; 4 - petroleum; 5 - feed; 6 - grain sorghum.

TABLE I

CRITICAL PERIODS FOR DEPARTMENTAL OPERATIONS

Period Number	Length	Time Interval	Department[a]
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

[a]Departmental codes are:

1 - wheat, barley, and oats

2 - seed

3 - fertilizer

4 - petroleum

5 - feed

6 - grain sorghum

General characteristics of these operations have been discussed in Chapter II with the exception of petroleum sales and delivery which involves only storage and delivery from May 1 through October 31.

Fixed Factors in the Model

The basic facilities of the grain elevator, seed cleaning plant, bulk fertilizer plant, and feed mill are listed in Appendix A, Tables XVII through XX, respectively. The firm owns 1,000,000 bushels of upright grain storage capacity, 500 tons of warehouse storage capacity, 720 tons of bulk fertilizer storage capacity, and 60,000 gallons of petroleum storage capacity. 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 the equivalent of a 16 man labor force are required to operate the firm during the harvest season. 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.

A firm with these characteristics would seem to be fairly typical for the study area based on a survey of research on various aspects of country elevator and related sideline operations and based on discussions with extension grain marketing specialists and representatives of the Oklahoma grain trade.

Variable Factors in the Model

Variable factors in the model include product ingredients, power, maintenance and repair, and overtime use of the labor force. It is assumed that twelve 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.[1] The major 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 was used to estimate power requirements in kilowatt hours (KWH) for performing various operations.[2] 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 B, Tables XXI through XXIV. Other power requirements are not significant.

Depreciation costs are conventionally assumed to be a function of time. In this case they are fixed and 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.[3] Depreciation is properly a function of use as well as time, and use depreciation is a variable cost. Estimated maintenance and repair costs were used as a measure of 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.[4] These costs were inflated to make them representative of current price levels. Unit maintenance and repair costs for individual pieces of equipment are listed in Appendix C, Table XXV. They were obtained by dividing inflated actual costs by observed use levels. Unit costs for individual pieces of equipment were then aggregated to obtain unit costs for performing 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 have been found by Smith to be .75 percent of total replacement cost per year based on an operating standard of 42,228 bushels cleaned per year.[5] Feed mill costs are based on the findings of Vosloh and Austin and Nelson.[6]

Vosloh used 7 percent of total replacement costs per year for firms operating at capacity while Austin and Nelson found annual maintenance and repair costs to be 5 percent of equipment replacement costs for plants operating at capacity. Six percent of equipment replacement costs was used as the appropriate figure for this study for capacity operation. However, since it was estimated that most custom mills operate at about 25 percent of capacity, an annual figure of 1.5 percent of replacement 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 consist of payloader operating costs and upkeep of fertilizer plant equipment. Payloader operating costs were estimated from a study by Bowers.[7] Operating costs per hour were divided by loading capacity per hour to determine unit operating costs for the payloader. Fertilizer plant equipment upkeep costs were estimated from a study of actual costs in typical plants.[8] Average costs per ton based on an annual volume of 4,000 tons were estimated from these data. Unit maintenance and repair costs for fertilizer plant equipment are listed in Appendix C, Table XXVI.

Truck operating costs for feed and petroleum delivery are based on a standard figure of $.073 per mile obtained from a truck rental agency.[9] This figure is 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 and Market Restrictions

Several variants of the basic linear programming model were run to reflect different market conditions. Gross margins representative of normal charges made by firms in the area for similar products and services were specified. These basic gross margins apply to each variant of the model and are listed in Table II. All margins assume a cash sale and are adjusted to account for losses due to shrinkage and waste.

The basic linear programming model was first run under the assumption of unlimited markets. This run specifies how much of each product should be sold to maximize returns to the firm given unlimited markets at the charges specified in Table II and reflects an upper limit for potential sales and returns. This run also gives an indication of which products and services are most profitable to the firm at the specified charges and which factors are most limiting. Finally, this run gives an indication of the firm's excess capacity by comparing potential sales with more realistic sales volumes for firms of this size.

TABLE II

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

The basic model was then run under the assumption of standard sales volumes for each sideline department with the firm free to allocate sales of products and services within departments. Runs were made assuming wheat crop receipts of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels. These runs set upper limits on returns to the firm at reasonable handling volumes in each department and further indicate which products and services in each department are most profitable to the firm at the specified charges.

Finally, runs were made assuming different handling volumes, storage volumes, and lengths of the average storage interval in the grain department in conjunction with standard sales volumes for each product and service in each sideline department. In this case, the firm is free to choose only the mode of transportation to be used to ship grain and whether or not to remain open additional hours and hire overtime labor during the wheat harvest. 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 assuming different percentages of each grain handling volume were stored for an average interval of six months in normal years. These runs set realistic limits on returns to the firm over a range of grain handling volumes, storage volumes, and different types of market years. In addition, these runs specify capacity utilization and indicate changes which would increase returns to the firm.

Analysis Under the Assumption of Unlimited Markets

The unrestricted solution assuming unlimited markets at the charges shown in Table II is summarized in Table III. Large sales volumes exist in each department except the seed department which is not operated. However, some products and services within each department are more profitable than others in the same department.

Grain volume is 16,918,230 bushels, fertilizer volume is 8,639.82 tons, petroleum volume is 1,079,784 gallons, and feed volume is 18,912.05 tons, all of which are higher than realistic market limits would allow. Storage capacities in each operating department are used at full capacity at these sales volumes. Feed mill operating capacity and grain loading capacity are also utilized at full capacity. Labor is used at capacity during the first one-half of September and the last one-half of October and is utilized at near capacity the year round. The grain department operates 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 working 8 hours per day overtime is required. Overtime labor is allowed only during the wheat harvest and for the equivalent of a 13 man grain receiving and loading crew.

In the grain department, 1,000,000 bushels of wheat are

TABLE III

PROFIT MAXIMIZING SALES VOLUMES OF PRODUCTS AND SERVICES UNDER THE ASSUMPTION OF UNLIMITED MARKETS

Product or Service	Sales Volume
Grain	
Receive and ship wheat by hoppercar at harvest	709,304.00 bu.
Receive and ship wheat by hoppercar outside harvest season	6,652,225.00 bu.
Receive and ship wheat by truck at harvest	684,524.00 bu.
Receive and ship wheat by truck outside harvest season	7,872,177.00 bu.
Retain wheat in storage for the entire year	1,000,000.00 bu.
Fertilizer	
Sell bulk blended fertilizer in spring	4,319.91 tons
Sell bulk blended fertilizer in fall	4,319.91 tons
Petroleum sale and delivery	1,079,784.04 gal.
Feed	
Sell protein supplement in winter	6,419.95 tons
Sell protein supplement in summer	3,852.10 tons
Sell bulk custom ground and mixed molasses feed from grain shipped into the area in winter	4,730.15 tons
Sell bulk custom ground and mixed molasses feed from grain shipped into the area in summer	2,838.22 tons
Deliver bulk custom ground and mixed molasses feed from grain shipped into the area in winter	669.85 tons

TABLE III (Continued)

Product or Service	Sales Volume
Deliver bulk custom ground and mixed molasses feed from grain shipped into the area in summer	401.78 tons

stored. It is more profitable 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 remains in storage or is shipped out before the end of the year. The firm receives and ships 14,524,402 bushels outside the harvest season and 1,393,828 bushels during the June 16 through June 30 harvest season. About one-half of the wheat shipped is by truck and about one-half is by hoppercar. No wheat is shipped by boxcar. If the effective transportation rates for shipping by boxcar, hoppercar, and truck are equal, the order of preference is for truck, hoppercar, and boxcar shipment in that order due to efficiences in the use of labor and loading time.

Bulk blending of fertilizer materials makes the most profitable use of the fertilizer department. The same charges are made for materials but an additional $5 per ton is charged for blending. Operation of the seed department is not profitable because labor can be more productively utilized by delivering custom ground and mixed molasses feed in the summer from grain shipped into the area.

In the feed department, 10,272.05 tons of high protein supplement are sold independently and 8,640 tons of feed are custom ground and mixed. Of high protein supplement sales, 6,419.95 tons are sold during the winter period between October 16 and April 30 and 3,852.10 tons are sold during the summer period between May 1 and October 15. No high protein supplement delivery is allowed. The 8,640 tons of custom ground and mixed feed consist of molasses feed for which grain is shipped into the area. Molasses feeds are more profitable than non-molasses feeds due to the additional markup. It is also more profitable to grind and mix feed from grain the firm has had shipped in from outside the area than to grind and mix feed from grain that customers deliver for this purpose or from grain held by customers in the grain bank. Of the custom ground and mixed feed, 5,400 tons are sold during the winter. All 5,400 tons are sold in the bulk form with 669.85 tons delivered. In addition, 3,240 tons, all bulk, are sold during the summer with 401.78 tons delivered. Of total feed sales, 11,819.95 tons are sold during the winter and 7,092.10 tons are sold during the summer.

Needless to say, the assumption of unlimited markets is an unrealistic one. For example, assuming transportation could be obtained, at least 15,918,230 bushels out of a single wheat crop would be handled by the elevator at this grain handling volume. Between 1963 and 1967 wheat production in the total nineteen county area of northwest Oklahoma ranged from a low of 47 million bushels in 1963 to a high of 80.5 million bushels in 1965 with a 5 year average of nearly 60 million bushels.[10] In order for the elevator to receive an average of 15,918,230 bushels from each crop, the elevator would have to receive nearly 27 percent of the entire 19 county area's production.

In addition, the foregoing analysis assumes the existence of truck and hoppercar availability which is far greater than that which could reasonably be expected. It is highly unlikely that 215 hoppercars and 856 trucks could be obtained as needed during the wheat harvest and that 2,016 hoppercars and 9,840 trucks could be obtained as needed during the rest of the year. At such large volumes of business, unit maintenance and repair costs could also be considerably different from those assumed because the estimates from some departments were obtained from much lower operating volumes. The unrestricted solution, however, does serve to point out the tremendous amount of excess capacity of firms in the area, especially outside the harvest season.

Analysis Under the Assumption of Standard Sales Volumes for Each Department

The basic model was run three times under assumed standard sales volumes for each sideline department. Standard sideline department sales volumes are 42,228 bushels of seed, 5,000 tons of fertilizer, 1,000,000 gallons of petroleum, and 2,950 tons of feed. In this case, the firm is free to allocate sales to the most profitable products and services within departments. The three runs were made assuming grain handling volumes of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels, respectively.

Table IV lists profit maximizing sales volumes of products and services in the firm under the foregoing

TABLE IV

PROFIT MAXIMIZING SALES VOLUMES FOR PRODUCTS AND SERVICES WITH CROP RECEIPTS OF 500,000 BUSHELS, 1,000,000 BUSHELS, AND 1,500,000 BUSHELS, RESPECTIVELY, UNDER THE ASSUMPTION OF STANDARD SALES VOLUMES FOR EACH SIDELINE DEPARTMENT

Activity	Unit	Activity Level		
		at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Grain	bu.			
Receive and ship wheat by truck at harvest				342,268.62
Receive and ship wheat by truck outside harvest season				157,731.38
Retain wheat in storage		500,000.00	1,000,000.00	1,000,000.00
Seed cleaning and treating sale	bu.	42,228.00	42,228.00	42,228.00
Fertilizer	tons			
Sell bulk blended fertilizer in spring		4,319.91	4,319.91	4,319.91
Sell bulk blended fertilizer in fall		680.09	680.09	680.09
Petroleum sale and delivery	gal.	1,000,000.00	1,000,000.00	1,000,000.00
Feed	tons			
Deliver bag custom ground and mixed molasses feed from grain shipped into the area in winter		1,469.00	1,469.00	2,469.00

TABLE IV (Continued)

Activity	Unit	Activity Level at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Deliver bag custom ground and mixed molasses feed from grain shipped into the area in summer	tons	1,481.00	1,481.00	481.00

assumptions. Returns to the firm are $177,253.21, $229,531.13, and $259,300.75, respectively, at the three grain handling volumes. At a handling volume of 500,000 bushels, the entire amount is held in storage by the elevator. In the seed department, seed cleaning and treating is more profitable to the firm than seed cleaning without treating. Selling bulk blended fertilizer most profitably utilizes the fertilizer department for similar reasons as in the unrestricted model. During the spring period of February 1 through April 30, 4,319.93 tons are sold and during the fall period from August 1 through October 31, 680.89 tons are sold. Petroleum is sold and delivered at the allowable market limit of 1,000,000 gallons. Sale and delivery of bag molasses feed from grain shipped into the area by the firm most profitably utilizes the firm's resources from feed sales. During the winter period from October 16 through April 30, 1,481 tons are sold and delivered and during the summer period from May 1 through October 15, 1,469 tons are sold and delivered. Excess capacity exists with respect to all factors except bulk fertilizer storage capacity in the spring and bag feed delivery capacity during the summer.

At a handling volume of 1,000,000 bushels, the entire amount is also held in storage fully utilizing the firm's storage capacity. Sideline sales in this case are identical to the 500,000 bushel case. Excess capacity exists with respect to all factors except grain storage capacity, bulk fertilizer storage capacity during the spring, and bag feed delivery during the summer.

At a handling volume of 1,500,000 bushels, several changes take place in the most profitable operation of the firm. In addition to retaining 1,000,000 bushels of wheat in storage, the firm receives and ships 342,268.62 bushels of wheat at harvest and 157,731.38 bushels of wheat outside the harvest season. All grain is shipped by truck. At this grain handling volume, a change also occurs in the most profitable use of the feed mill. Sale and delivery of molasses feed from grain shipped into the area by the firm in the winter period is increased to 2,469 tons and sale and delivery of the same feed during the summer period is decreased to 481 tons. Excess capacity exists with respect to all factors except grain storage capacity, bulk fertilizer storage capacity during the spring, truck loading capacity during the wheat harvest, and bag feed delivery capacity during the winter.

Results with respect to the grain department at each handling volume are consistent with those of the unrestricted model. Holding grain in storage up to capacity is highly profitable. Also, as much grain as possible is shipped by truck. However, results with respect to sideline departments do differ from those of the unrestricted model. Notably, operation of the seed department to clean and treat seed is profitable. Also, no independent protein supplement sales are profitable in the feed department.

Custom ground and mixed molasses feed from grain shipped into the area provides most profitable use of resources in the feed department. However, as opposed to the unrestricted model, all feed is sold in the bag form and is also delivered. In the fertilizer department, bulk blending is again the most profitable type of sale and in the petroleum department, the allowable quantity is sold and delivered. Finally, considerable excess capacity is also evident.

Analysis Under the Assumption of Standard Sales Volumes for Products and Services in Sideline Departments

The model was run twenty-one times under the assumption of standard sales volumes for each product and service in each sideline department. 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, and years with high prices at harvest. In addition, the model was run assuming different percentages of each grain handling volume were stored for an average storage interval of six months in normal years.

For normal years, it is assumed that 90 percent of the wheat crop is received at harvest and an equivalent of 10 percent of the crop is received at a constant rate outside the harvest season. All wheat received outside the harvest season is shipped directly and does not enter storage.

One-half of the grain received at harvest is put into storage and one-half is shipped immediately without entering storage. Grain put into storage is 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 six months in length. No wheat is stored continuously. In addition, runs were made assuming that 0, 25, 75, and 100 percent of the wheat received at harvest entered storage.

For years with low prices at harvest relative to the support price, it is assumed that 90 percent of the grain from each crop is received at harvest and 10 percent is received at a constant rate during the six weeks immediately preceding the next harvest. As much as possible of the grain received at harvest is placed in storage at harvest and shipped out at a constant rate during the six weeks immediately preceding the next harvest. The 10 percent of each crop received during the six week period preceding the next harvest is shipped directly and does not enter storage.

For years with high prices at harvest relative to the support price, it is assumed that all grain received during the year is received during the harvest season and shipped directly without entering storage.

Several assumptions were made with respect to operations within sideline departments in specifying standard sales volumes as shown in Table V. These assumptions are based in part on the discussion of departmental operations

TABLE V

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

TABLE V (Continued)

Product or Service	Standard Sales Volume
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

TABLE V (Continued)

Product or Service	Standard Sales Volume
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
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

TABLE V (Continued)

Product or Service	Standard Sales Volume
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

TABLE V (Continued)

Product or Service	Standard Sales Volume
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

in Chapter II. The seed department standard of 42,228 bushels of seed is based on the findings of Smith in the northwest Oklahoma area.[11] He also found that 75 percent of the small grains cleaned (mostly wheat) was also treated.

The fertilizer department standard of 5,000 tons is based on the experience of a fertilizer merchandiser in northwest Oklahoma.[12] Four thousand tons are assumed to be sold through the bulk blending plant with 50 percent blended and 1,000 tons of mixed fertilizers and fertilizer materials are assumed to be sold in the bag form. As reported in Chapter II, a three to one fall-spring sales ratio tends to exist in the area. One million gallons of petroleum are assumed to be sold and delivered.

Of the 2,950 tons of feed sold, 1,950 tons were assumed to be custom ground and mixed and 1,000 tons were assumed to be independent high protein supplement sales. It is the opinion of persons familiar with custom feed mills in the area that such mills generally operate in the neighborhood of 25 percent of capacity, which for the model mill is 1,950 tons.[13] It is assumed that 75 percent of the feed custom ground and mixed is non-molasses feed and that 25 percent is molasses feed. Eighty percent of custom ground and mixed feed is assumed to be sold in the bulk form and 80 percent of the total feed ground and mixed is assumed to be delivered. Of grain used in the feed mill, 50 percent is assumed to be stored in the grain bank, 30 percent is assumed to be shipped into the area, and 20 percent is assumed to be delivered by farmers for grinding and mixing.

Analysis for Normal Years in Which 50 Percent of the Grain Received at Harvest Enters Storage

Table VI lists activity levels in the grain department of the firm for normal years under the assumption of standard sales volumes for products and services in sideline departments and with wheat crop receipts of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels, respectively. One-half the grain received at harvest is assumed to be shipped directly and one-half is assumed to enter storage and be sold out at a constant rate before the next harvest. Returns to the firm are $143,109.64, $182,628.27, and $220,793.31, respectively, at the three grain handling volumes. The highest volume requires keeping the firm open an additional 39.64 hours during the harvest season with a crew consisting of the assistant manager and 12 workers, thus hiring 515.28 hours of overtime labor.

All grain received and shipped out at harvest is shipped by truck at a handling volume of 500,000 bushels. At a handling volume of 1,000,000 bushels, 24 percent is shipped by boxcar and 76 percent is shipped by truck and at a handling volume of 1,500,000 bushels, 29 percent is shipped by boxcar and 71 percent is shipped by truck. The 10 percent of each crop which is received and shipped outside the harvest season is shipped by truck. Likewise, all grain shipped out of storage is shipped by truck. These

TABLE VI

GRAIN DEPARTMENT ACTIVITY LEVELS FOR 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 FOR PRODUCTS AND SERVICES IN SIDELINE DEPARTMENTS

Activity	Activity Level at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
	bushels		
Receive grain at harvest and ship directly by boxcar		109,076	192,765
Receive grain at harvest and ship directly by truck	225,000	340,924	482,235
Receive grain outside harvest season and ship directly by truck	50,000	100,000	150,000
Receive grain at harvest, store, and ship out by truck	225,000	450,000	675,000

findings are consistent with results from the model under the assumption of unlimited markets except for the fact that boxcar shipment is more profitable than hoppercar shipment. This is because returns are slightly higher for boxcar shipment but labor and loading time requirements are less for hoppercar shipment. Since labor and loading time were taxed in the unrestricted model, hoppercar shipment was preferred. However, in this case labor and loading requirements are not taxed and boxcar shipment is preferred. A rate differential in favor of any mode of transport would result in that mode being most profitable.

Additional insight into the operation of the firm can be gained by studying capacity utilization of resources in each department at the three grain handling volumes. It has been noted that the grain department of the firm must operate overtime during the wheat harvest at the high grain handling volume. Otherwise, excess capacity is indicated with respect to all fixed factors in all departments. Capacity utilization of those factors which are used only in sideline activities will be discussed first. Included are warehouse storage capacity, bulk fertilizer storage capacity, petroleum storage capacity, seed cleaning capacity, bulk fertilizer handling capacity, petroleum delivery capacity, feed milling capacity, and bulk and bag feed delivery capacity. Capacity utilization of those factors which are not used solely in sideline activities will then be discussed. These factors include grain storage capacity, grain receiving capacity, car loading capacity, truck loading capacity, bookkeeping time, labor, and overtime labor.

Table VII lists availability and utilization of those factors used only in sideline departments. A maximum of 205.8 tons of warehouse storage capacity is required to handle protein supplement and bagged fertilizer inventories, assuming that sales of feed and fertilizer occur at constant rates between September 16 and October 31 and that the order interval is two weeks in length. Thus, the assumed warehouse storage capacity of 500 tons would support a doubling of feed and fertilizer sales or an order interval of one month for inventories. Or, looking at the situation in another way, a considerable amount of slack is available to take care of brief periods of much higher than usual feed or bag fertilizer sales. This might be necessary to satisfy fertilizer demands caused by a sudden improvement in field conditions or other factors during the fall period between August 1 and October 31. In many cases capital costs of holding inventories could result in an order interval of less than two weeks which would have the effect of further increasing excess warehouse storage capacity. However, it should be noted that the need to carry inventories of numerous types of supplements and fertilizers could absorb much of this apparent excess storage capacity. An even greater amount of excess capacity exists with respect to warehouse storage during other periods of the year.

Excess bulk fertilizer storage capacity also seems to

TABLE VII

AVAILABILITY AND UTILIZATION OF FACTORS USED SOLELY IN SIDELINE ACTIVITIES UNDER THE ASSUMPTION OF STANDARD SALES VOLUMES FOR PRODUCTS AND SERVICES

Factor	Factor Availability	Factor Utilization
Warehouse storage capacity		
Period 1	500 tons	80.80 tons
Period 2	500 tons	122.47 tons
Period 3	500 tons	19.78 tons
Period 4	500 tons	19.78 tons
Period 5	500 tons	19.78 tons
Period 6	500 tons	144.78 tons
Period 7	500 tons	144.78 tons
Period 8	500 tons	205.80 tons
Period 9	500 tons	205.80 tons
Period 10	500 tons	80.80 tons
Period 11	500 tons	80.80 tons
Bulk fertilizer storage capacity		
Spring	720 tons	166.67 tons
Fall	720 tons	500.01 tons
Petroleum storage capacity	60,000 gal.	55,566.61 gal.
Seed cleaning capacity	384 hrs.	168.91 hrs.
Bulk fertilizer handling capacity		
Spring	576 hrs.	50.00 hrs.
Fall	576 hrs.	149.99 hrs.

TABLE VII (Continued)

Factor	Factor Availability	Factor Utilization
Petroleum delivery capacity	1,464,000 gal.	1,000,000.00 gal.
Feed milling capacity		
Winter	5,400 tons	1,560.00 tons
Summer	3,240 tons	390.00 tons
Bulk feed delivery capacity		
Winter	3,600 tons	998.00 tons
Summer	2,160 tons	249.00 tons
Bag feed delivery capacity		
Winter	2,469 tons	252.72 tons
Summer	1,481 tons	59.28 tons

exist. Assuming that bulk fertilizer sales occur at a constant rate between February 1 and April 30, 166.67 tons of bulk fertilizer storage capacity are required to support an order interval of two weeks. Excess capacity is much less during the fall sales period between August 1 and October 31 in that 500 tons of storage capacity are required to support sales at a constant rate with an order interval of two weeks. In fact, since sales may tend to be bunched into short periods due to changing field conditions and other factors, and if numerous fertilizer materials must be kept on hand, bulk fertilizer storage could be taxed during the August 1 through October 31 period with the assumed bin capacity of 720 tons.

A problem could exist with respect to petroleum storage capacity. Sixty thousand gallons of petroleum storage capacity and a two week order interval are assumed. If sales occur at a constant rate between February 1 and October 31, 60,000 gallons of storage capacity and a two week order interval results in 4,433.33 gallons of storage capacity being unused. However, since sales probably tend to 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, and since both gasoline and diesel fuel are probably sold, 60,000 gallons of petroleum storage capacity may be too little unless the order interval is reduced.

Seed cleaning capacity of 168.91 hours is required to handle a seed cleaning volume of 42,228 bushels. If the firm operates 8 hours per day six days per week during the September 1 through October 31 period, 384 hours are available, resulting in about 44 percent of the total capacity being utilized. However, it should be noted that the seed cleaning plant, too, is subjected to more concentrated demands in some parts of the period than in others. Thus, the plant may be required to remain open more than eight hours per day on some days during the September 1 through October 31 period. This would also require overtime labor to be hired.

Considerable excess capacity also exists in bulk fertilizer handling capacity. If the bulk fertilizer plant remains open eight hours per day during both the spring period from February 1 through April 30 and the fall period from August 1 through October 31, only 8.7 percent of the spring handling capacity is utilized and 26 percent of the fall capacity is utilized. However, as previously mentioned, a high handling rate is probably necessary to serve concentrated demands, especially during certain days of the fall period. It may be necessary to keep the bulk fertilizer plant open more than eight hours per day for some days during this period, also requiring overtime labor to be hired.

About 46 percent more petroleum delivery capacity is available than is required. This is based on the assumption that two trucks are available for delivery eight hours per day six days per week during the February 1 through

October 31 period. It is also assumed that petroleum is delivered in 300 gallon lots with four lots delivered per 25 mile round trip. If fewer gallons of petroleum are delivered per mile and per unit of driving time, excess delivery capacity is overstated.

Only 1,560 tons or nearly 29 percent of the total 5,400 tons of winter feed milling capacity are utilized and only 390 tons or about 12 percent of the 3,240 tons of summer feed milling capacity are utilized. This is based on the assumption that the feed mill is open eight hours per day six days per week the year around. Bulk feed delivery capacity in winter and bulk feed delivery capacity in summer are utilized at 28 percent and 12 percent of capacity, respectively. Bag feed delivery capacity in winter and bag feed delivery capacity in the summer are utilized at 10 percent and 4 percent of capacity, respectively. A bulk feed truck and a flatbed truck with grain body are 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.

Table VIII lists availability and utilization of those factors which are not used solely in sideline departments at the three grain handling volumes in normal years. Considerable excess capacity exists in grain storage. At a handling volume of 500,000 bushels only 240,000 bushels of grain storage capacity are required, at a handling volume of 1,000,000 bushels only 465,000 bushels of grain storage

TABLE VIII

AVAILABILITY AND UTILIZATION OF FACTORS NOT USED SOLELY IN SIDELINE DEPARTMENTS FOR NORMAL YEARS IN WHICH 50 PERCENT OF THE GRAIN RECEIVED AT HARVEST ENTERS STORAGE AT SELECTED GRAIN HANDLING VOLUMES

Factor	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	127,863.35	235,472.05	343,080.75
Period 2		1,000,000	104,889.46	192,994.09	281,098.71
Period 3		1,000,000	36,157.17	65,413.28	94,669.40
Period 4		1,000,000	239,034.54	464,034.54	689,034.54
Period 5		980,000[a]	238,339.36	463,339.36	688,339.36
Period 6		1,000,000	217,367.73	422,803.00	628,238.27
Period 7		1,000,000	196,397.55	382,268.10	568,138.64
Period 8		1,000,000	185,911.49	361,998.94	538,068.38
Period 9		1,000,000	164,970.08	321,492.80	478,015.52
Period 10		1,000,000	153,494.39	300,234.01	446,973.63
Period 11		980,000[a]	142,001.15	278,957.68	415,914.20

TABLE VIII (Continued)

Factor	Unit	Factor Availability	Factor Utilization at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Bookkeeping time	man min.	124,800	13,730.08	14,337.69	14,945.30
Labor	man min.				
Period 1		184,320	16,966.95	17,649.00	18,331.05
Period 2		552,960	106,080.85	108,103.61	110,126.36
Period 3		276,480	33,668.47	34,666.68	35,664.90
Period 4		92,160	42,139.27	75,474.89	[b]
Period 5		184,320	23,261.90	24,717.42	26,172.95
Period 6		184,320	30,477.01	31,178.62	31,880.23
Period 7		92,160	22,606.77	22,956.11	23,305.45
Period 8		184,320	55,457.10	56,152.84	56,848.59
Period 9		92,160	27,785.89	28,132.30	28,478.70
Period 10		92,160	8,545.35	8,890.77	9,236.20
Period 11		276,480	25,454.40	26,484.81	27,515.21
Overtime labor in period 4	man min.	74,880			30,916.60

TABLE VIII (Continued)

Factor	Unit	Factor Availability	Factor Utilization at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Grain receiving capacity at harvest	trucks	6,019.2	2,879.28	5,691.78	[b]
Car loading capacity at harvest	min.	11,520		2,985.81	[b]
Truck loading capacity	min.				
Before harvest		63,360	2,715.64	4,929.00	7,142.37
At harvest		5,760	3,809.13	5,760.00	[b]
At harvest		69,120	2,907.81	5,322.39	7,736.97

[a] Assumes one bin must be kept empty for turning grain.

[b] Number not computed because of forced overtime operation.

capacity are required, and at a handling volume of 1,500,000 bushels only 690,000 bushels of grain storage capacity are required. Assuming a bin capacity of 20,000 bushels and that one bin must be kept empty to facilitate turning of wheat during the month of July, 260,000 bushels, 485,000 bushels, and 710,000 bushels of grain storage capacity, respectively, would be required at the three grain handling volumes during July. If wheat, oats, barley, and grain sorghum are all stored they must be kept in separate bins. As many as four additional bins could be required if quantities of each of the grains are such that partial bins of each are required. This would raise the maximum July grain storage capacity requirements at the three grain handling volumes to 340,000 bushels, 565,000 bushels, and 790,000 bushels, respectively. Storage capacity requirements in other months are lower than in July. The need to keep different qualities of different grains in separate bins could also increase grain storage capacity requirements.

If bookkeeping requires two minutes per transaction, 13,730.08 minutes, 14,337.69 minutes, and 14,945.30 minutes of bookkeeping time are 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 is required if the bookkeeper puts in a 40 hour week. It does not appear that a full-time bookkeeper can be justified if one is available on a part-time basis unless the bookkeeper also does a considerable amount of secretarial work.

During the wheat harvest, the assistant manager and 15 man work force are utilized at 45.7 percent of capacity at a grain handling volume of 500,000 bushels and 81.9 percent of capacity at a grain handling volume of 1,000,000 bushels. Because of limited grain receiving capacity, the firm must remain open 39.64 hours more than the usual 48 hours per week during the harvest season at a handling volume of 1,500,000 bushels. This requires hiring the 13 man grain receiving and loading crew (including the assistant manager who is not paid overtime) a total of 515.28 hours overtime even though labor is not fully utilized during normal operating hours. This should be interpreted as a lower limit on the hours of overtime labor required because the firm probably will not be able to 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 15 man work force (including the assistant manager) is utilized at about 10 percent of capacity during November, December, and January, 20 percent of capacity during February, March, and April, between 10 and 20 percent of capacity during May, June (excluding the harvest season from June 15 through June 30), July, and August, 25 percent of capacity during the first one-half of September, and 30 percent of capacity during the last one-half of September and the entire month of October. Although these figures may be somewhat low because they do not allow time for changing jobs, they do serve to point out the large amount of slack which exists.

Grain receiving capacity at wheat harvest is utilized at 47.8 percent of capacity at the low grain handling volume and 94.6 percent of capacity at the medium grain handling volume. As previously mentioned, the high volume of grain cannot be received unless the firm remains open more than eight hours per day on some days during the harvest season. These figures and the amount of additional time that the firm must remain open during the harvest season must also be considered as lower limits. The capacity of the firm to receive grain will be taxed considerably more if wheat receipts tend to be highly concentrated during a few days of the harvest season. Bouland has 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 arrives during a two week interval as assumed in this study, and that 50 percent or more may arrive during an interval only three to four days in length.[14] Most of the grain was harvested during an interval 10 days in duration with about 22 percent harvested in a single day. During large crop years, the peak harvest and delivery period was shorter than usual.

Since 90 percent of the wheat is assumed to be received at harvest, if 22 percent would be received in a single day 99,000 bushels would be received at the low handling volume requiring nearly 10 hours of operation, 198,000 bushels would be received at the medium handling volume requiring 20 hours of operation, and 297,000 bushels would be received at the high grain handling volume requring 30 hours of operation. Obviously, the elevator cannot receive such a large percentage of the high volume of grain on a single day unless average load size received is considerably larger than the assumed load size of 160 bushels.

No car loading capacity is utilized at the low grain handling volume because all grain is shipped by truck. Truck loading capacity utilization before and after wheat harvest is not significant. Truck loading capacity at wheat harvest is utilized at a level of 3809.13 minutes or 66 percent of capacity.

At the medium grain handling volume, truck loading capacity at wheat harvest is not adequate to allow all grain shipped at harvest to be shipped by truck if the firm operates 48 hours per week and if only one leg is set up to load trucks. Hence, 109,076 bushels are shipped by boxcar requiring 2,985.81 minutes or 25.9 percent of the available car loading time if two legs are set up to load cars. Truck loading capacity outside the harvest season is not significantly utilized and no wheat is shipped by rail outside the harvest season.

Since limited grain receiving capacity at the high grain handling volume requires at least 39.64 hours of overtime operation, both truck loading capacity and car loading capacity at harvest are increased. However, limited truck loading capacity requires 192,765 bushels to be shipped by boxcar. As in the case of the medium grain handling volume, truck loading capacity outside the wheat harvest is not significantly utilized and no grain is shipped by rail outside the harvest season.

It should be noted that one-half the grain received at harvest is assumed to be shipped directly without entering storage. A bottleneck could develop if transportation is not available in sufficient quantity to allow loading as grain is received, even allowing for one-half the grain to enter storage. If adequate transportation is not available, some grain to be shipped must 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 three grain handling volumes in normal years in which 50 percent of the grain received at harvest enters storage as shown in Table IX. 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 $59.54 at the low grain handling volume, by $59.46 at the medium grain handling volume, and by $56.08 at the high grain handling volume. Receiving and shipping an additional 1,000 bushels

TABLE IX

VALUE TO THE FIRM OF ADDITIONAL MARKET UNITS OF PRODUCTS AND SERVICES IN NORMAL YEARS IN WHICH 50 PERCENT OF THE GRAIN RECEIVED AT HARVEST ENTERS STORAGE AT SELECTED GRAIN HANDLING VOLUMES

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

of grain at a constant rate outside the harvest season would increase returns to the firm by $59.54 at all three grain handling volumes. Receiving and placing an additional 1,000 bushels into storage at harvest and shipping it at a constant rate during the marketing year 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 are 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 services are 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 have slightly lower values. The values of additional market units of products and services in each sideline department are listed in Appendix D, Table XXVII.

Analysis for Normal Years With Different Percentages of Grain Received at Harvest Entering Storage

Table X lists returns to the firm at the three grain handling volumes in normal years with different percentages of the grain received at harvest entering storage. Percentages entering storage are 0, 25, 50, 75, and 100 percent. Thus, the previous case is included. Since storage capacity is not sufficient to allow 75 percent of the grain received at harvest to enter storage at the high grain handling volume, grain which cannot enter storage is shipped directly. Returns to the firm range from $133,342.53 with no grain entering storage to $152,867.71 with 450,000 bushels or all grain received at harvest entering storage at the low grain handling volume. As previously noted, the average storage interval is six months. Returns to the firm range from $163,068.21 to $202,153.45 at the medium grain handling volume and from $191,242.48 to $233,458.35 at the high grain handling volume. At the high grain handling volume, returns to the firm are $233,458.35 once grain storage capacity is completely utilized.

The importance of the volume stored on returns is borne out by the fact that returns are higher with 675,000 bushels placed in storage at harvest and sold out at a constant rate throughout the year at a handling volume of 1,000,000 bushels than at a handling volume of 1,500,000 bushels if no

TABLE X

RETURNS TO THE FIRM IN NORMAL YEARS WITH DIFFERENT PERCENTAGES OF THE GRAIN RECEIVED AT HARVEST ENTERING STORAGE AT SELECTED GRAIN HANDLING VOLUMES

Percent of Grain Received at Harvest Entering Storage	Returns		
	at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
	dollars		
0	133,342.53	163,068.21	191,242.48
25	138,230.60	172,851.57	206,127.17
50	143,109.64	182,628.27	220,793.31
75 or as much as capacity will allow	147,988.68	192,395.31	233,458.35
as much as capacity will allow	152,867.71	202,153.45	233,458.35

grain enters storage. In addition, since fixed costs are the same in each case, there is a $19,525.18 range in profits at the low handling volume, a $39,085.24 range in profits at the medium grain handling volume, and a $42,215.87 range in profits at the high grain handling volume. An average storage interval longer than six months would accentuate these differences. The range on returns at the high grain handling volume would be greater if more storage capacity were available.

No overtime operation is required at the low and medium grain handling volumes. At the high grain handling volume, 45.64 hours of overtime operation are required if no grain received at harvest enters storage and 39.64 hours of overtime operation are required if at least 25 percent of the grain received at harvest enters storage. If no grain received at harvest enters storage, harvest season labor becomes a limiting factor and if at least 25 percent of the grain received at harvest enters storage, grain receiving capacity becomes a limiting factor. A crew equivalent to the assistant manager and a 12 man work force is hired for overtime operation. 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. Capacity utilization of factors used solely in sideline departments is identical to the previous case.

As in previous cases, the returns listed in Table X should be considered as upper limits on actual amounts attainable. For previously discussed reasons, effective storage capacity requirements are in many cases greater than those assumed. Thus, capacity may not be available to store as much grain as assumed at high grain handling volumes where a high percentage of the grain enters storage. Likewise, more overtime operation may be required due to a more concentrated pattern of grain arrivals. Also, a bottleneck may develop in that grain cannot be loaded as rapidly as it is received at the high grain handling volume in cases where little of the grain enters storage. Limited availability of trucks or railroad cars would add to this problem.

The values of additional market units of grain department services are somewhat different in the various cases. Receiving and shipping another 1,000 bushels at harvest would increase returns by $59.54 if at least 25 percent of the grain received at harvest enters storage at the low grain handling volume and if at least 75 percent of the grain received at harvest enters storage at the medium grain handling volume. Receiving and shipping another 1,000 bushels at harvest would increase returns to the firm by at least $59.41 for other storage percentages at the low and medium grain handling volumes and by at least $55.71 at the high grain handling volume. Receiving and shipping another 1,000 bushels outside the harvest season would increase returns by $59.54 for each storage percentage and grain handling volume considered. Receiving and placing another 1,000 bushels into storage at harvest and selling it out at a constant rate for the rest of the marketing year would increase returns by $102.91 for each storage percentage considered at the low and medium grain handling volumes. At the high grain handling volume, receiving and placing another 1,000 bushels into storage at harvest and selling it out at a constant rate for the rest of the marketing year would have lower returns if less than 75 percent of the grain received at harvest enters storage and capacity is not available to place more than 75 percent of the grain received at harvest into storage.

The values of additional market units of sideline products and services are analogous to those for normal years in which 50 percent of the grain received at harvest is put into storage for all grain handling volumes and storage percentages except the case in which no grain received at harvest enters storage at the high grain handling volume. In this case, competition for labor during the harvest season reduces the value of products and services sold during this period. For example, sale and delivery of another 300 gallon lot of petroleum during the summer months would increase returns to the firm by $10.08 rather than $10.18 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 rather than $12.52.

Analysis for Years With Low Prices at Harvest Relative to the Support Price

Table XI lists activity levels in the grain department of the firm for years with low prices at harvest relative to the support price under the assumption of standard sales volumes for products and services in sideline departments and with wheat crop receipts of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels. Returns to the firm are $172,776.44, $241,970.64, and $276,215.05, respectively, at the three grain handling volumes. These returns are substantially higher than those for similar handling volumes in normal years, regardless of the percentage of grain entering storage. These higher returns are due primarily to the longer storage interval. Because of limited grain receiving capacity, the highest grain handling volume requires keeping the firm open an additional 39.64 hours during the harvest season with a crew equivalent to the assistant manager and 12 workers as in normal years when at least 25 percent of the grain received at harvest enters storage.

At the low grain handling volume, 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 are shipped by truck. At the medium grain handling volume, 96,960 bushels received are shipped by truck and 3,040 bushels received are shipped by boxcar during the May 1 through June 15 period. Nine hundred thousand bushels are

TABLE XI

GRAIN DEPARTMENT ACTIVITY LEVELS FOR YEARS WITH LOW PRICES AT HARVEST AT SELECTED GRAIN HANDLING VOLUMES

Activity	Activity Level at 500,000 Bu.	Activity Level at 1,000,000 Bu.	Activity Level at 1,500,000 Bu.
	bushels		
Receive grain at harvest and ship directly by truck			383,340
Receive grain before harvest and ship directly by boxcar		3,040	119,700
Receive grain before harvest and ship directly by truck	50,000	96,960	30,300
Receive grain at harvest, store, and ship out by truck before the next harvest	450,000	900,000	966,660

shipped out of storage by truck during the same period. At the high grain handling volume, 383,340 bushels are received and shipped by truck at harvest because there is 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 are shipped by truck and 119,700 bushels of the grain received are shipped by boxcar. During the same period, 966,660 bushels are shipped out of storage by truck.

The analysis of capacity utilization of factors used solely in sideline departments is identical to that for normal years. Capacity utilization of factors not used solely in sideline departments at the three grain handling volumes is listed in Table XII. At the low grain handling volume, considerable excess capacity exists with respect to grain storage capacity. However, since some wheat, barley, oats, and grain sorghum are stored in grain banking operations and since different qualities of different grains must be kept in separate bins, considerably more grain storage capacity could be required. At the medium and high grain handling volumes, grain storage capacity is fully utilized and is not adequate if the foregoing factors are important.

Bookkeeping capacity utilization at each grain handling volume is similar to that in normal years. During the May 1 through June 15 period prior to harvest, the assistant manager and 15 man work force is utilized at 16 percent of

TABLE XII

AVAILABILITY AND UTILIZATION OF FACTORS NOT USED SOLELY IN SIDELINE DEPARTMENTS IN YEARS WITH LOW PRICES AT HARVEST AT SELECTED GRAIN HANDLING VOLUMES

Factor	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	470,254.65	920,254.65	986,915.05
Period 2		1,000,000	466,784.84	916,784.84	983,445.24
Period 3		1,000,000	456,901.05	906,901.05	973,561.45
Period 4		1,000,000	464,034.64	914,034.64	980,695.04
Period 5		980,000[a]	463,339.46	913,339.46	979,999.86
Period 6		1,000,000	461,932.54	911,932.54	978,592.94
Period 7		1,000,000	460,537.07	910,527.07	977,187.47
Period 8		1,000,000	459,824.10	909,824.10	976,484.50
Period 9		1,000,000	458,447.40	908,447.40	975,107.80
Period 10		1,000,000	456,754.80	906,754.80	973,415.20
Period 11		980,000[a]	455,044.65	905,044.65	971,705.05

TABLE XII (Continued)

Factor	Unit	Factor Availability	Factor Utilization at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Bookkeeping time	man min.	124,800	13,622.48	14,122.48	14,622.48
Labor	man min.				
Period 1		184,320	16,374.89	16,464.89	16,478.23
Period 2		552,960	104,328.10	104,598.10	104,638.10
Period 3		276,480	44,142.63	55,688.45	63,470.64
Period 4		92,160	38,352.78	65,266.65	b
Period 5		184,320	23,396.37	24,986.37	25,221.90
Period 6		184,320	29,865.40	29,955.40	29,968.73
Period 7		92,160	22,302.43	22,347.43	22,354.10
Period 8		184,320	54,851.36	54,941.36	54,954.69
Period 9		92,160	27,484.49	27,529.49	27,536.15
Period 10		92,160	8,244.92	8,289.92	8,296.59
Period 11		276,480	24,588.99	24,693.99	27,713.99
Overtime labor in period 4	man min.	74,880			30,916.60

TABLE XII (Continued)

Factor	Unit	Factor Availability	Factor Utilization at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
Grain receiving capacity	trucks				
Before harvest		18,057.6	312.50	625.00	937.50
At harvest		6,019.2	2,879.28	5,691.78	b
Car loading capacity	min.				
Before harvest		31,283		83.22	3,276.64
At harvest		11,520			b
Truck loading capacity	min.				
Before harvest		17,280	8,916.72		
At harvest		5,760	22.63	22.63	b

[a]Assumes one bin must be kept empty for turning grain.

[b]Number not computed because of forced overtime operation.

capacity at the low grain handling volume, at 20 percent of capacity at the medium grain handling volume, and at 23 percent of capacity at the high grain handling volume. Harvest season labor utilization is 42 percent and 71 percent of capacity, respectively, at the low and medium grain handling volumes. Capacity utilization of the work force during the remainder of the year is similar to that in normal years. As in the analysis for normal years, these figures may be a bit low because they do not allow time for changing jobs.

Grain receiving capacity during the May 1 through June 15 pre-harvest period is utilized at 1.73 percent of capacity at the low grain handling volume, 3.46 percent of capacity at the medium grain handling volume, and 5.19 percent of capacity at the high grain handling volume. Grain receiving capacity during the wheat harvest is utilized at levels similar to those in normal years.

As in the case of normal years in which at least 25 percent of the grain received at harvest enters storage, no car loading capacity is utilized at the low grain handling volume because all grain is shipped by truck. Truck loading capacity during the May 1 through June 15 period is utilized at a level of 8,916.72 minutes or 51.6 percent of capacity and truck loading capacity at harvest is not significantly utilized at the low grain handling volume.

At the medium grain handling volume, a limited amount of the available car loading capacity is utilized because truck loading capacity before harvest is utilized at full capacity if the firm operates 48 hours per week and one leg is set up to load trucks.

At the high grain handling volume, truck loading capacity before harvest is fully utilized and truck loading capacity at harvest is highly utilized. Car loading capacity during the May 1 through June 15 period is utilized at 9 percent of capacity and car loading capacity during harvest is more highly utilized. As previously noted, this grain handling volume requires the firm to remain open an additional 39.64 hours during the harvest season in order to make available enough grain receiving capacity. This also requires the firm to hire 515.28 hours of overtime labor. As in the case for normal years, these figures should be considered to be lower limits on the actual amounts required because the timing of grain receipts is such that the firm will probably receive grain at less than capacity during some parts of the harvest season and, thus, be forced to increase overtime operation.

Table XIII 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 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

TABLE XIII

VALUE TO THE FIRM OF ADDITIONAL MARKET UNITS OF GRAIN SERVICES IN YEARS WITH LOW PRICES AT HARVEST AT SELECTED GRAIN HANDLING VOLUMES

Product or Service	Value of Additional Market Unit at 500,000 Bu.	Value of Additional Market Unit at 2,000,000 Bu.	Value of Additional Market Unit at 1,500,000 Bu.
	----------- dollars per thousand bushels ---------		
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

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 grain handling volume, by $147.07 at the medium grain 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 grain handling volume, by $102.87 at the medium grain handling volume, and by $99.45 at the high grain handling volume.

However, it must be noted that no storage capacity is available to allow activities requiring grain storage to be increased. Activities in this category include receiving and placing grain in storage at harvest and shipping it out during the six weeks prior to the next harvest and putting grain into storage at harvest and shipping it out at a constant rate before the next harvest. The values of additional market units of sideline products and services are equivalent to those for normal years in which at least 25 percent of the grain received at harvest enters storage.

Analysis for Years With High Prices at Harvest Relative to the Support Price

Table XIV lists activity levels in the grain department

TABLE XIV

GRAIN DEPARTMENT ACTIVITY LEVELS FOR YEARS WITH HIGH PRICES AT HARVEST AT SELECTED GRAIN HANDLING VOLUMES

Activity	Activity Level		
	at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
	bushels		
Receive grain at harvest and ship directly by boxcar	159,076		
Receive grain at harvest and ship directly by hoppercar		633,710	937,461
Receive grain at harvest and ship directly by truck	340,924	366,290	562,539

of the firm for years with high prices at harvest relative to the support price under the assumption of standard sales volumes for products and services in sideline departments and with wheat crop receipts of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels. Returns to the firm are \$133,338.40, \$162,812.68, and \$190,668.29, respectively, at the three grain handling volumes. During the harvest season, the medium grain handling volume requires the hiring of 92.49 hours of overtime labor and the high grain handling volume requires the hiring of 808.10 hours of overtime labor. This is accomplished by keeping the firm open an additional 7.11 hours at the medium grain handling volume and an additional 62.96 hours at the high grain handling volume.

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

The analysis of capacity utilization of factors is similar to that for normal years and years with low prices at harvest. Capacity utilization of factors used solely in sideline departments is identical to previous cases. However, in this case no grain storage capacity is utilized except for grain banking operations since no other grain enters storage. Labor during the harvest season is utilized at 58 percent of capacity at the low grain handling volume and overtime labor is required at the medium and high grain handling volumes. Grain receiving capacity at harvest is utilized at 53 percent of capacity at the low grain handling volume and nearly at capacity at the medium and high grain handling volumes. Truck loading capacity is fully utilized at each grain handling volume and cars must be loaded at two legs in order to handle the high volume of grain. Thus, limited loading capacity at the high grain handling volume causes rail shipment to be by hoppercar rather than boxcar.

Table XV 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 grain 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 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 grain handling volumes.

The values of additional market units of sideline

TABLE XV

VALUE TO THE FIRM OF ADDITIONAL MARKET UNITS OF GRAIN SERVICES IN YEARS WITH HIGH PRICES AT HARVEST AT SELECTED GRAIN HANDLING VOLUMES

Product or Service	Value of Additional Market at 500,000 Bu.	at 1,000,000 Bu.	at 1,500,000 Bu.
	---------- dollars per thousand bushels ----------		
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

products and services at the low grain handling volume are equivalent to those for normal years and for years with low prices at harvest. However, the values of additional market units of products and services sold during the summer months at the medium and high grain handling volumes are lower than the corresponding values in normal years in which at least 25 percent of the grain received at harvest enters storage and years with low prices at harvest because these products and services must compete for labor during the harvest season. As in the case for normal years in which no grain enters storage at the high grain handling volume, at the medium and high grain handling volumes 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.

Chapter Summary

Several variants of a deterministic linear programming model of a typical country grain elevator firm were used to analyze the relative profitability of providing different products and services by country grain elevators and to analyze the effects of different market conditions on elevator returns.

With unlimited markets, large sales volumes exist in each department except the seed department which is not operated. Service oriented activities tend to be the most profitable. It is profitable for the firm to keep its grain storage capacity filled whenever possible, and if the effective transportation rates are equal, truck is the preferred mode of grain shipment with hoppercar second. Sales volumes for products and services are much higher than could reasonably be expected, reflecting the large amount of excess capacity of the model, especially outside the harvest season. Large amounts of overtime operation are profitable during the harvest season.

Assuming average sales volumes for each sideline department with the firm free to allocate sales of products and services within departments, results are generally consistent with those of the unrestricted model. However, in this case operation of the seed department to clean and treat seed is profitable because feed sales are restricted to a level which allows labor to be profitably utilized in the seed department. Also, if the effective transportation rates are equal, boxcar shipment is preferred to hoppercar shipment because returns are slightly higher and available labor and loading time are not completely utilized.

Different handling volumes, storage volumes, and lengths of the average storage interval in the grain department in conjunction with standard sales volumes for each product and service in each sideline department have important effects on returns to the firm. Otherwise, findings are generally consistent with those of the unrestricted model and the model with standard sales volumes for sideline departments. However, with standard sales volumes for products and services and with 50 percent of the grain received at harvest entering storage, returns or profits were lower by $34,143.57 at a handling volume of 500,000 bushels and by $38,507.44 at a handling volume of 1,500,000 bushels than under the assumption of standard sales volumes for sideline departments because the firm was unable to concentrate on sales of the most profitable products and services.

With the same respective handling volumes and with the percentage of grain received at harvest entering storage ranging from zero to elevator storage capacity, profits ranged by $100,115.82. Changes in the percentage of grain received at harvest entering storage gave rise to a $19,525.18 range in profits at the low grain handling volume and a $42,215.87 range in profits at the high grain handling volume. With 50 percent of the grain received at harvest entering storage, there was a $77,683.67 range in profits between the low and high grain handling volumes.

Years with low prices at harvest relative to the support price result in high returns because large amounts of grain are stored for long intervals, and years with high prices at harvest relative to the support price result in low returns because small amounts of grain are stored for short intervals. Years with low prices at harvest relative to the support price resulted in profits which were

$39,438.04 higher at the low grain handling volume and $51,302.35 higher at the high grain handling volume.

Firms may be able to increase their returns in years with high prices at harvest relative to the support price through the use of carrying-charge hedging. Wheat could be purchased at harvest, stored, and sold later in the year. While returns to hedging tend to be low and highly variable, Driscoll has found that profits can be expected most of the time in such years.[15]

FOOTNOTES

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

[2]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.

[3]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.

[4]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).

[5]This figure was obtained from a survey of custom seed cleaning operations in Oklahoma by Roland D. Smith at Oklahoma State University in 1967 as background for his M.S. thesis entitled "An Economic Analysis of Custom Seed Cleaning Operations in Oklahoma."

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

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

[8]These figures were obtained from discussions and correspondence with a representative of Farmland Industries, Enid, Oklahoma.

[9]This figure was obtained from discussions with a representative of Ryder Truck Rentals, Oklahoma City.

[10] Oklahoma Crop and Livestock Reporting Service, Oklahoma Wheat: Acreage, Yield and Production, Statistical Reporting Service (Oklahoma City), selected issues.

[11] This figure was obtained from the survey of custom seed cleaning and treating operations in Oklahoma by Roland D. Smith at Oklahoma State University in 1967.

[12] This figure was obtained through discussions with a representative of Farmland Industries, Enid, Oklahoma.

[13] This asumption is based on discussions with persons doing research on costs in custom feed mills in Oklahoma and on study of an earlier survey.

[14] Bouland, pp. 9-11.

[15] James L. Driscoll, "An Analysis of Expected Returns to Oklahoma Grain Elevators From Alternative Hedged Wheat Storage Practices" (unpub. Ph.D. dissertation, Oklahoma State University, 1969), pp. 101-120.

CHAPTER V

A STOCHASTIC ANALYSIS

In Chapter II, three factors largely beyond the control of elevator management were postulated as being important determinants of the firm's profitability. These were grain handling volume, storage volume, and length of the storage interval. In Chapter IV, the effects of these factors on the firm's returns were studied under the assumption of certainty. Since it was also suggested in Chapter II that these factors were highly variable and could be usefully viewed as random variables, this Chapter contains an analysis of the effects of two of these factors, grain handling volume and storage volume, on returns to the firm under the assumption that these factors are random variables with specified probability distributions. The third factor, length of the average storage interval, is assumed to remain constant at six months.

The Stochastic Model

The deterministic linear programming model used in the analysis in Chapter IV is extended to include random components and the Monte Carlo procedure is used to derive a solution through the distribution method described in

Chapter III.[1] Grain handling volume is 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 gives 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 in Chapter IV, 90 percent of the grain handled is assumed to be received at a constant rate during the harvest season and 10 percent is assumed to be received at a constant rate outside the harvest season. However, the percentage of grain received at harvest which enters storage is 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 is drawn, the percentage entering storage is assumed to be zero, and if a random percentage greater than 100 percent is drawn, the percentage entering storage is assumed to be one hundred. Maximum effective grain storage capacity is 966,660 bushels because 33,340 bushels of storage capacity are required for grain banking operations. Consequently, not more than 966,660 bushels of grain received at harvest which are not a part of grain banking operations are allowed to be stored. No grain received outside the harvest season is 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 and 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 $178,861.39 with a standard deviation of $27,571.69. Figure 2 shows the distribution of returns in the form of a histogram. Returns less than $133,900 were achieved 5 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 achieved 7.5 percent of

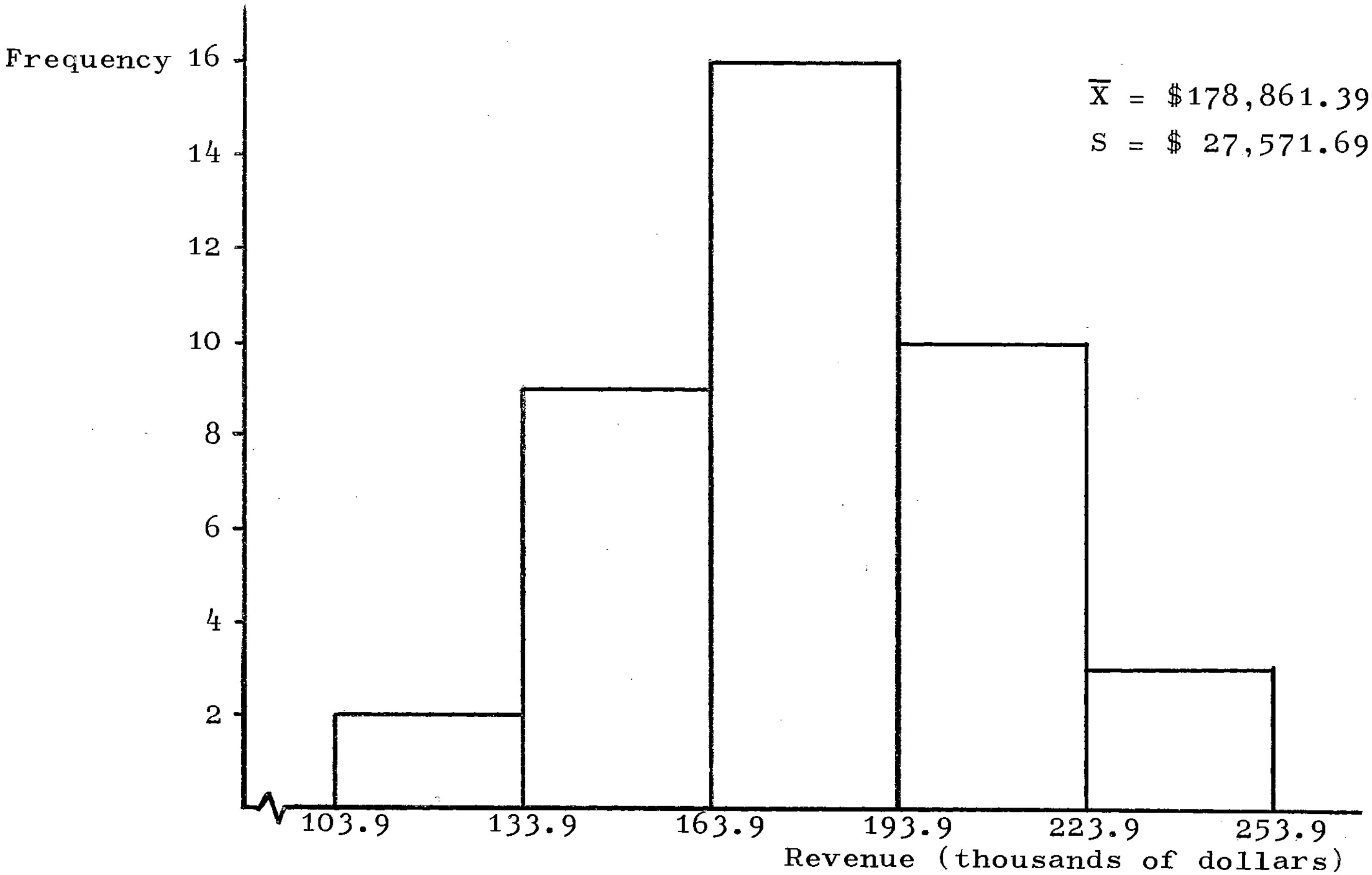

Figure 2. The Distribution of Returns to the Firm Assuming Grain Handling Volume and the Percentage of Grain Received at Harvest Entering Storage are Random Variables

the time. If the distribution of returns is normal, returns would be between $160,085.07 and $197,637.71 fifty percent of the time and between $123,139.00 and $234,583.78 ninety-five percent of the time.

Overtime operation during the harvest season was required 35 percent of the time with maximum overtime operation of 58.21 hours. When overtime operation was required, average overtime operation was 25.12 hours. The distribution of hours of overtime operation 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 XVI. Receiving and shipping an additional 1,000 bushels of grain at harvest would increase returns to the firm by an amount between $56.08 and $59.54. This activity would have a value of $56.08 thirty-two and one-half percent of the time, a value of $56.13 two and one-half percent of the time, a value of $59.46 twenty-seven and one-half percent of the time, and a value of $59.54 thirty-seven and one-half percent of the time. Receiving and shipping an additional 1,000 bushels outside the harvest season would increase

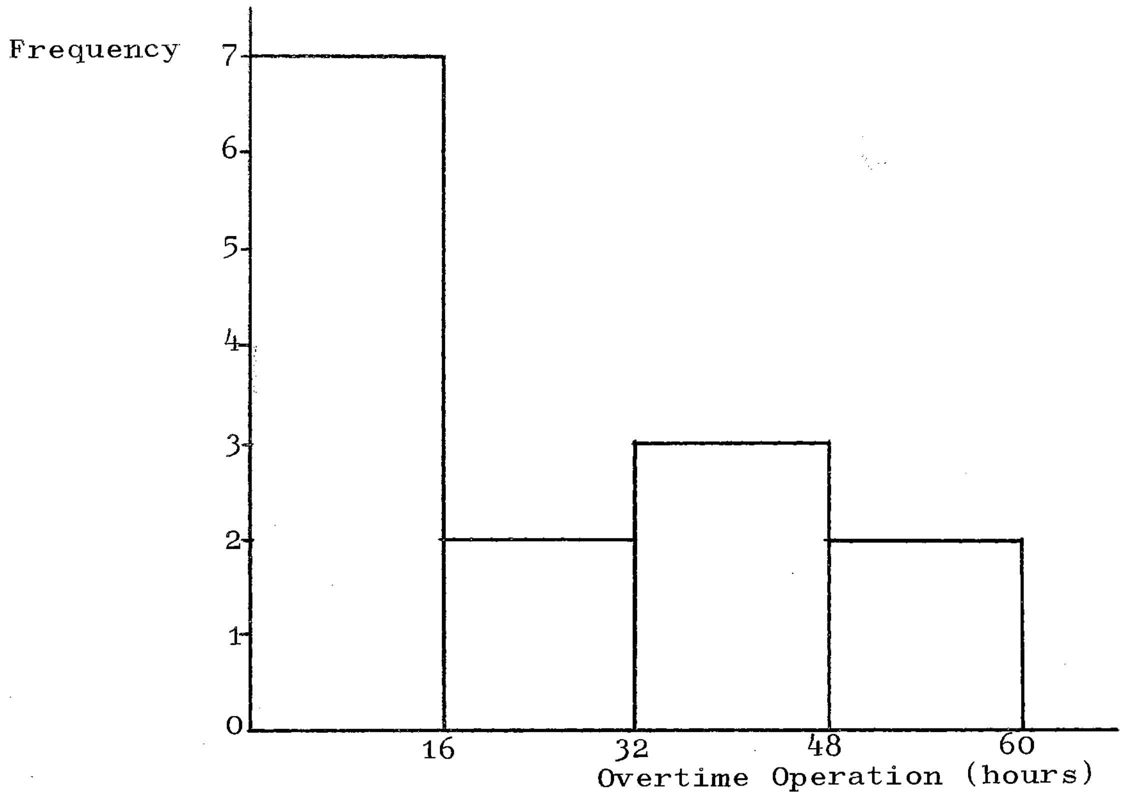

Figure 3. The Distribution of Hours of Overtime Operation When Overtime Operation is Required Assuming Grain Handling Volume and the Percentage of Grain Received at Harvest Entering Storage are Random Variables

TABLE XVI

VALUE TO THE FIRM 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

Product or Service	Value (Dollars Per Thousand Bushels)	Relative Frequency (Percent)
Receive grain at harvest and ship directly	56.08	32.5
	56.13	2.5
	59.46	27.5
	59.54	37.5
Receive 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

returns to the firm by $59.54 in each case.

Receiving and placing an additional 1,000 bushels of grain into storage at harvest and shipping it out at a constant rate throughout the marketing year would increase returns by an amount between $99.50 and $102.91. This activity would have a value of $99.50 two and one-half percent of the time, a value of $99.55 thirty-two and one-half percent of the time, and a value of $102.91 sixty-five percent of the time. The values of additional market units for sideline products and services are similar to those for normal years in which 50 percent of the grain received at harvest enters storage as discussed in Chapter IV and shown in Appendix D, Table XXVII. Values equivalent to the 500,000 and 1,000,000 bushel cases would be achieved 65 percent of the time and values equivalent to the 1,500,000 bushel case would be achieved 35 percent of the time.

Limitations of the Stochastic Analysis

It is important to examine the assumptions upon which the foregoing discussion is based. First, the distribution of returns is based on the assumption of known parameter values for coefficients and probability distributions in the model, including the form of the probability distributions therein. Consequently, the distribution of returns is limited to the extent that this assumption is valid. Secondly, the distribution of returns is based on the effectiveness of the sampling procedure in obtaining appropriate values of the random variables to be used for each solution of the model.

Samples of size 40 from each of the distributions should give fairly reliable results. According to conventional formulas for estimating the sample size required for specified degrees of sampling accuracy from continuous distributions with known mean and variance, a sample of size 43 from the distribution of grain handling volumes should have a mean within 10 percent of the population mean 95 percent of the time and a sample of size 16 from the distribution of the percentages of grain received at harvest entering storage should have a mean within 10 percent of the population mean 95 percent of the time.[2]

In the samples used, grain handling volume averaged 955,388 bushels rather than 1,000,000 bushels and the percentage of grain received at harvest which enters storage averaged 50.4 rather than 50.0. The standard deviation of grain handling volume was 350,331 bushels rather than 333,333 bushels and the standard deviation of the percentage of grain received at harvest which enters storage was 10.6 percent rather than 10.0 percent.

Chapter Summary

A deterministic linear programming model was extended to include random components in order to analyze the effects of variable grain handling and storage volumes on elevator profits. Grain handling volume and the percentage of grain received at harvest entering storage were assumed to be normally distributed random variables with means of 1,000,000 bushels and 50 percent, respectively. Their assumed respective standard deviations were 333,333 bushels and 10 percent. The Monte Carlo procedure was used to derive a solution through the distribution method of stochastic programming.

Returns to the firm were highly variable. The average return was $178,861.39. If returns are normally distributed, returns would be between $160,085.07 and $197,637.71 fifty percent of the time and between $123,139.00 and $234,583.78 ninety-five percent of the time. Profits would be even more variable. Overtime operation during the harvest season was required 35 percent of the time and some grain received at harvest was shipped by rail 60 percent of the time. 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 grain received at harvest entering storage. Receiving and placing additional grain into storage at harvest and shipping it at a constant rate throughout the marketing year was the most profitable grain alternative in each year. In addition, receiving and shipping additional grain directly outside the harvest season is at least as profitable as receiving additional grain and shipping directly at harvest and is more profitable 62.5

percent of the time. The values of additional market units of all sideline products and services were similar to those for normal years in which 50 percent of the grain received at harvest enters storage.

FOOTNOTES

[1]Monte Carlo analysis refers to a simulation procedure in which random samples are drawn from the probability distribution of a random variable and used to obtain random outcomes.

[2]William G. Cochran, Sampling Techniques (2nd ed., New York, 1963), pp. 75-77.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Many changes have occurred in country grain elevator operations. Firms have grown larger and fewer in number and sidelines have increased in importance. In addition, grain production is highly variable from year-to-year due to changing weather conditions, acreage allotments, and insect damage. Since elevators must compete for this variable grain production, handling volume of individual elevators varies even more from year-to-year. Furthermore, with a handling volume which differs from year-to-year and with different price conditions in different years, storage volume for a particular firm also varies from year-to-year.

This study was undertaken to analyze the broad spectrum of elevator activities. Specific objectives were to investigate (1) the relative profitability of providing different products and services with facilities typical of those owned by country grain elevator firms, (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 many facilities have a number of years of useful life remaining, attention was focused on the problem of how to best use existing facilities. This problem was first attacked under the assumption of certainty. Then, since factors such as grain handling and storage volumes which are important determinants of profits are subject to a high degree of variability from year-to-year due to factors largely beyond the control of elevator management in the short run, the analysis was extended to include the case where these factors were assumed to have specified probability distributions.

Findings and Results

Several variants of a deterministic linear programming model were used to meet the first two objectives. The 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.

Under the assumption of unlimited markets, large sales volumes exist in each department except the seed department. Some products and services in each department are more profitable than others in the same department. Generally, the service oriented activities are the most profitable. It is profitable for the firm to keep its grain storage space filled to capacity whenever possible. Truck is the preferred mode of grain shipment with hoppercar shipment second. Storage capacities, feed mill operating capacity, and grain loading capacity were fully utilized and labor was utilized at near capacity. The sales volumes for products and services were much higher than could reasonably be expected, reflecting the large amount of excess capacity in the model, especially outside the harvest season.

Under the assumption of average sales volumes for each sideline department with the firm free to allocate sales of products and services within departments, results were generally consistent with those of the unrestricted model. Standard sideline department sales volumes were 42,228 bushels of seed, 5,000 tons of fertilizer, 1,000,000 gallons of petroleum, and 2,950 tons of feed. Grain handling volumes of 500,000 bushels, 1,000,000 bushels, and 1,500,000 bushels resulted in returns to the firm of $177,253.21, $229,531.13, and $259,300.75, respectively. Fixed costs for the model were computed to be $166,484. Thus, profits would be incurred at each of the three grain handling volumes with small profits at the low handling volume and large profits at the medium and high handling volumes.

Excess capacity existed with respect to all factors except bulk fertilizer storage capacity in the spring and bag feed delivery capacity during the summer. A notable departure from the results under the assumption of unlimited markets is that operation of the seed department to clean and treat seed is profitable. This is because feed sales are restricted to a level which allows labor to be profitably utilized in the seed department. Truck is the preferred mode of grain shipment, but boxcar shipment is second in this case. Actually, hoppercar shipment is preferred if labor and loading time are limited, but boxcar shipment is preferred if labor and loading time are readily available.

An attempt was also made to ascertain 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. In this case, the firm was free to choose only the mode of transportation to be used to ship grain and whether or not to remain open additional hours and hire overtime labor during the wheat harvest. 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 assuming different percentages of each grain handling volume entered storage in normal years. 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. Wheat received outside the harvest season was assumed to be shipped directly without entering storage. All grain placed in storage was assumed to be shipped out at a constant rate before the next harvest, making the effective storage interval six months. Runs were made assuming 0, 25, 50, 75, and 100 percent of the grain received at harvest entered storage.

For years with low prices at harvest relative to the support price, 90 percent of the grain was received at harvest and 10 percent was received during the six weeks preceding the next harvest. As much as possible of the grain received at harvest was assumed to be placed in storage and shipped out during the six weeks preceding the next harvest, making the effective storage interval nearly 12 months. None of the 10 percent of each crop received during the six weeks before the next harvest was assumed to enter storage.

For years with high prices at harvest relative to the support price, it was assumed that all grain received during the year was received during the harvest season and did not enter storage. Thus, the effective storage interval was zero months.

In normal years with different percentages of the grain received at harvest entering storage for an average interval of six months at the three grain handling volumes, findings were generally consistent with those of the unrestricted model and the model with standard sales volumes for sideline departments. Returns to the firm ranged from a low of

$133,342.53 with no grain entering storage at the low grain handling volume to a high of $233,458.35 with storage at capacity at the high grain handling volume. Thus, fixed costs of $166,484 would result in a loss of $33,141.47 in the former case and a profit of $66,974.35 in the latter case. Returns were $143,109.64, $182,628.27, and $220,793.31, respectively, at the three grain handling volumes with 50 percent of the grain received at harvest entering storage, resulting in a loss at the low grain handling volume and profits at the medium and high grain handling volumes.

Changes in the percentage of grain received at harvest gave rise to a $19,525.18 range in profits at the low handling volume, a $39,085.24 range in profits at the medium handling volume, and $42,215.87 range in profits at the high handling volume. Returns and profits were lower than under the assumption of standard sales volumes for sideline departments because the firm was unable to concentrate on sales of the most profitable products and services in these departments.

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

Years with low prices at harvest relative to the support price result in high returns because more grain tends to be stored and the storage interval tends to be longer. Returns to the firm were $172,776.44, $241,970.64, and $276,215.05, 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 high profits would be incurred at the medium and high grain handling volumes.

If capacity is 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 thousand bushels. Receiving and shipping directly at harvest had values ranging from $56.13 to $59.54 per thousand bushels and receiving and shipping directly before harvest had values ranging from $59.46 to $59.54 per thousand bushels. At high grain handling volumes, receiving and shipping grain before the next harvest is more profitable than shipping at the current harvest because receiving and loading facilities are less taxed before harvest.

Years with high prices at harvest relative to the support price result in low returns because little or no grain enters storage and the storage interval tends to be short. Returns to the firm were $133,338.40, $162,812.68, and

$190,668.29, 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 at the high grain handling volume. More overtime operation during the harvest season is required at high grain handling volumes because of labor requirements. Overtime operation is also required because of grain receiving and loading requirements at high grain handling volumes. The values of all grain and some sideline products and services requiring harvest season labor tend to be lower at high grain handling volumes in years with high prices at harvest. Sideline products and services in this category include petroleum sale and delivery and feed sales and delivery. However, to the extent that feed sales during this period are of limited importance, this is not a serious problem.

To meet the third objective, a deterministic linear programming model was extended to include the assumption that grain handling volume and storage volume were random variables with specified probability distributions. 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. 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. 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. No grain received outside the harvest season was assumed to enter storage.

Grain handling volume ranged from a low of 191,000 bushels to a high of 1,707,000 bushels. Receiving and shipping grain at harvest averaged 428,500 bushels with a standard deviation of 183,300 bushels and 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 $178,861.39 with a standard deviation of $27,571.69. With fixed costs of $166,484, profits would have been incurred 70 percent of the time. If the distribution of returns is normal, returns would be between $160,085.07 and $197,637.71 fifty percent of the time, and between $123,139.00 and $234,583.78 ninety-five percent of the time. Overtime operation during the harvest season was required 35 percent of the time with a maximum overtime operation of 58.21 hours. When overtime operation was required, average overtime operation was 25.12 hours. Some grain received 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.

Interpretations and Recommendations

Results of the study 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 cash wheat prices relative to the support price. Firms may be able to reduce their losses in years with high prices relative to the support price through the use of carrying charge hedging.

A transportation rate differential in favor of any mode tends to make that mode the most profitable. Consideration should be given to insuring the availability of transportation as needed.

Operation of all sideline departments appears to be profitable. 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 tend to be the most profitable. In the seed department, seed cleaning and treating should be encouraged at the expense of cleaning. In the fertilizer department, bulk blended sales should be encouraged. However, increasing bag fertilizer sales would be more profitable than increasing unblended bulk sales. In the feed department, high protein supplement sales are more profitable than custom ground and mixed feed sales. Molasses feeds are more profitable than non-molasses feeds and delivery is more profitable than non delivery. It is more profitable to custom grind and mix feed from grain shipped into the area than from banked grains. However, it is more profitable to custom grind and mix feed from banked grain than from grain delivered for grinding and mixing. Bag sales are more profitable than bulk sales.

If several skilled workers could be hired as needed during the harvest season, the firm could hire fewer full-time employees, reducing fixed costs and excess labor capacity outside the harvest season. Perhaps skilled workers could travel with custom combine crews.

Limitations and the Need for Further Study

This study, like most, is subject to several limitations. Many assumptions may not be valid in particular instances. Also, operating capital requirements and the cost of credit were not considered and are important factors in many cases. Results are valid only in a short run context and in cases in which labor is considered to be a fixed cost.

A better knowledge of demand conditions for various products and services would increase the reliability of the results. Persons familiar with country elevator operations have expressed the belief that demands for sideline products and services are positively related to demands for grain services rather than independent of them as assumed in this study. Such relationships, if known, could easily be included in the model developed in this study.

Information is also needed on operating capital requirements and credit costs for different products and services. The inclusion of such information into the model should increase the validity of the results and allow the determination of optimal credit policies.

The analysis could also be extended to include multiple plant firms which are prevalent in the industry. Such questions as whether or not sideline products and services should be offered at different locations could be answered and profit maximizing grain movements could be determined.

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APPENDIX A

TABLE XVII

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

TABLE XVIII

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 system & walkways	250	5.0	2,848.70
		Total Cost	34,378.63

TABLE XIX

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' schuttle-but	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	
½ ton loader	30		
		Total Cost	32,164.00

TABLE XX

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

TABLE XX (Continued)

Item	Capacity	H.P. Rating	Replacement Cost
	(Tons per Hour)	(Horsepower)	(Dollars)
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 B

TABLE XXI

UNIT POWER REQUIREMENTS FOR OPERATION OF GRAIN ELEVATOR EQUIPMENT

Item	HP	KWH[a]	Capacity	KWH
		(Total)	(Bushels Per Hour)	(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

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

TABLE XXII

UNIT POWER REQUIREMENTS FOR OPERATION OF SINGLE UNIT SEED CLEANING AND TREATING PLANT

Equipment	HP	KWH[a] (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

[a]KWH = (HP)(.8)

TABLE XXIII

UNIT POWER REQUIREMENTS FOR OPERATION OF BULK FERTILIZER BLENDING PLANT

Equipment	HP	KWH[a] (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

[a]KWH = (HP)(.8)

TABLE XXIV

UNIT POWER REQUIREMENTS FOR OPERATION OF 30 TON FEED MILL EQUIPMENT

Equipment	HP	KWH[a] (Total)	Capacity (Tons Per Hour)	KWH (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

[a]KWH = (HP)(.8)

APPENDIX C

TABLE XXV

UNIT MAINTENANCE AND REPAIR COSTS FOR OPERATION OF GRAIN ELEVATOR EQUIPMENT

Item	Maintenance and Repair[a]
	(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

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

TABLE XXVI

UNIT MAINTENANCE AND REPAIR COSTS FOR OPERATION OF BULK FERTILIZER BLENDING PLANT EQUIPMENT

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

[a]Based on an annual handling volume of 4,000 tons.

[b]Based on an annual blending volume of 2,000 tons.

APPENDIX D

TABLE XXVII

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

	Value of Additional Market Units	
Product or Service	at 500,000 Bu. and 1,000,000 Bu.	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

TABLE XXVII (Continued)

Product or Service	Value of Additional Market Units at 500,000 Bu. and 1,000,000 Bu.	at 1,500,000 Bu.
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

TABLE XXVII (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 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
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

TABLE XXVII (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 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

TABLE XXVII (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 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

TABLE XXVII (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.
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 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

TABLE XXVII (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 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

TABLE XXVII (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.
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

VITA

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