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147

ECONOMIES OF SCALE IN COUNTRY GRAIN ELEVATORS

by

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TABLE OF CONTENTS

Page

INTRODUCTION

The production and movement of grain within the state of Iowa is of great economic importance to the midwest and to the United States. Much of the economy of Iowa is geared to agricultural production. Iowa is consistently among the leading states in the production of meat animals and grain crops, particularly corn and soybeans. Due in part to the large volume of production and the growth of volume of output over the years, certain technological and economic inefficiencies have developed. It would be advantageous for most people if these inefficiencies could be alleviated.

The following study is concerned with the movement of grain from the farm field to an elevator complex. Basically the study will consider different elevator sizes and determine the cost associated with each model. After gathering and interpreting data for this study an optimum size model will be determined. The optimum size is defined as the facility which will enable all grain in an area to be handled adequately and at the lowest cost per bushel. The study should have general validity, with minor variations, for any grain producing area.

Statement of the Problem

The state of Iowa is one of the leading areas of the nation and of the world in the production of crops and livestock. For instance, the value of all livestock and poultry on Iowa farms on January 1, 1969, totaled 1.75 billion dollars, 12 percent more than the 1.56 billion dollars a year earlier. The value of livestock and poultry on farms and ranches for the United States as a unit on January 1, 1969, totaled 20.2 billion dollars, an increase of 7 percent from a year earlier (11, p. 1). The grain production figures for the state reveal that Iowa produced an estimated 901,728,000 bushels of corn for the 1968 crop. This figure compares to the total production of 4,374,840 bushels for the United States. In addition, the state produced 110,460,000 bushels of oats and 177,952,000 bushels of soybeans in 1968 (10, p. 1).

Paralleling the increase of crop production throughout the years has been the growth of grain elevators to handle and store the valuable commodities. In many areas in Iowa grain elevators have been established in a seemingly random fashion without any concentrated planning. Today, in fact, it is not uncommon to find elevators located as close as three or four miles from each other. In extreme cases there may be two separate elevators within the boundaries of a small rural Iowa town.

The elevators were constructed initially so that farmers would not have to travel great distances with their grain. In earlier times much of the grain was moved to the elevator by horse and wagon. Consequently, it was necessary to have the elevator complexes close together. Now, however, grain is transported to the elevator in large wagons pulled by tractors and by means of trucks. These modes of transportation enable grain to be moved greater distances than before within the same time period. Therefore, with the given modes of modern transportation, the transportation rates in existence, and the current road systems, the distance a farmer can move his grain has increased relative to past dates. Consequently, the elevators need not be as close together today as in the past.

In addition to the facts discussed above, many elevator managers are currently expanding their storage capacity within a given elevator complex. The cost of this expansion varies with the volume undertaken. A large expansion may cost several hundred thousand dollars or may very well exceed one million dollars.

The nearness of the firms and the expansion of storage facilities would seemingly create competition among the elevators and would therefore be of benefit to the farmer-producers. However, it should be noted that many of these elevators are farmer-owned cooperatives and thus any inefficiencies which occur within the system will be passed on to the farmer. Likewise, advances in technology and efficiency will usually benefit the producers. For example, if two elevators are located in an area which could be served adequately by one enterprise, returns to the farmer will be reduced. Each elevator must install a scale, build an office, hire a manager, and perform other duplicative measures. If these inefficiencies can be eradicated, or at least alleviated, farmers will benefit by an increase in profits. Likewise, returns to farmers could be increased if the capacity of storage facilities were of optimum size. The savings due to the reduction of duplicative efforts has had the effect of reducing the number of elevator systems within the state from approximately 1200 units in 1964 to 1000 units in 1969 as estimated by Mr. Kenneth Ludlow of the Iowa Grain and Feed Dealers Association of Des Moines, Iowa. Thus, the real problem of this study is to determine the size of elevators which should be constructed for the state of Iowa.

Objective

The first main objective of this study is to consider the cost relationship associated with various size elevator complexes. The data gathered and interpreted should enable an elevator manager and/or a farmer-producer to at least approach an estimate of the cost and cost savings involved with various elevator models.

The overall objective of this endeavor is to briefly analyze the state and then determine the optimum size of storage capacity needed for a grain elevator. It should be noted from the outset that this study does not include services and sideline business activities of elevator systems. Each operating unit is assumed to be optimum in the other aspects of the business. The problem at hand is to match the volume of grain to be stored to a storage facility program which serves the needs of the trade area and results in the greatest possible return to the farmer.

Review of Previous Literature

There have been a number of studies conducted which were concerned with the determination of the optimum size of agricultural activities and enterprises. For example, there have been studies undertaken to determine the optimum size of such enterprises as feed manufacturing, turkey production, chicken hatcheries, and soybean processing plants (7, 8, 9, 12, 17, 19, 20). There has also been a limited amount of work conducted concerning elevator size and the corresponding costs encountered, as well as a number of studies concerning related topics such as transportation cost and drying operations.

Ahmed Al-Araji in a 1964 study determined that definite economies of scale of plant size do exist in grain handling (1). For instance, the author found that the average total cost for grain handling activities declined from 6.9 cents per bushel in the smallest plant model, plant I (325,000 bushels annual volume), to 2.18 cents per bushel in the largest plant considered, plant V, with 3,899,000 bushels annual volume or a difference of 4.72 cents per bushel. The models used for the study under discussion are given in Table 1. It was determined that labor cost decreased from 1.6 cents per bushel in plant I to 0.4 cents per bushel in plant II, which had an annual volume handled of 1,464,000 bushels. Administrative cost per bushel was 4.8 cents in plant I, but fell to 1.2 cents in plant II (1, p. 36).

It was also found that unit handling costs tend to decrease with an increase in handling volume, but at a decreasing rate, and create a downward sloping average cost curve. Additional increases in plant volumes beyond 1,464,000 bushels did not result in significant increases in efficiency. Average fixed costs decreased from 7.29 cents per bushel in plant I to 0.72 cents per bushel in plant V. Beyond plant volumes of 1,949,000 bushels the decrease in the average fixed costs were insignificant. Average variable cost decreased from 7.48 cents per bushel in plant I to 1.46 cents in plant V, and additional increases in plant volumes beyond 1,464,000 bushels did not result in significant decreases in average variable cost (1, p. 37).

Economies of plant utilization were also considered. Per unit costs declined at a decreasing rate with each increase in the level of plant utilization. In the smallest plant, plant I, per unit cost decreased

Table 1. Model sizes used in the Al-Araji study to determine the optimum size of country elevators[a]

Model plant	Range in storage capacity (1000 bu.)	Average storage capacity (1000 bu.)	Volume handled (1000 bu.)
I	50- 149	100	125
			225
			325
Ia	150- 249	200	458
			558
			668
Ib	250- 349	300	856
			956
			1,056
II	350- 449	400	293
			586
			879
			1,172
			1,464
III	459- 549	500	390
			780
			1,170
			1,559
			1,949
IV	550- 949	750	586
			1,172
			1,757
			2,343
			2,929
V	950-1449	1,200	780
			1,559
			2,339
			3,119
			3,899
			4,000

[a] Source: (1, p. 34).

from 14.77 cents per bushel when handling 125,000 bushels to 6.9 cents per bushel when 325,000 bushels were handled, or a decrease of 7.87 cents for this particular range. For the large model, plant V, per unit cost decreased from 6.4 cents per bushel for annual volume of 780,000 to 2.18 cents per bushel for 3,899,000 bushels, or a decrease of 4.22 cents per bushel (1,p. 37).

The author assumed the average density for Nebraska (bushels marketed per square mile) was 4009.9 bushels in 1959. The total delivery cost from the farm to the elevator was computed by using the following formula (1, p. 39).

$$TDC = 2/3\ C \sqrt{\frac{V^3}{2D}}$$

where C = the cost per bushel mile for delivery (estimated to be .05 cents plus a fixed charge of 2.5 cents per bushel).

V = the volume of grain,

and, D = the density of grain marketed off farms.

The average cost per bushel for delivering the annual elevator volume was computed by dividing the total delivery cost by the volume handled.

The market area needed to assemble a given volume of grain was computed by dividing the annual volume by the bushels marketed per square mile. The market area needed to assemble a given volume of grain when the density marketed is known is equal to:

$$2X^2 \text{ where } X = \sqrt{\frac{V}{2D}}\ .$$

A plant whose volume was 1,000,000 bushels annually was the optimum size for densities ranging from 4,000 to 16,000 bushels per square mile. Based on the total bushels of grain marketed in Nebraska in 1959, (300,856,294 bushels), a maximum of 300 one-million bushel elevators would have been sufficient to handle this volume. In 1959 there were 975 elevators operating in Nebraska, with estimated gross margins of 2 to 8 cents per bushel, with an average of 5 cents per bushel. Consolidation of elevators to the optimum size would have resulted in the remaining elevators being able to increase their bids for corn from $1.10 per bushel to $1.12 per bushel in 1959. This would have increased the annual income of cash grain producers in the state by approximately $6,017,132 (1, p. 58).

In separate studies Bozeman and Trock noted that grain elevators have increased greatly in size over the years. Trock conducted a survey of 80 country elevators in Montana and North Dakota in 1965. He found that elevators within the 250-749 thousand bushel size category showed an increase of 803 percent in seventy years (1891-1960). Smaller firms, with 100-249 thousand bushels and 50-99 thousand bushels capacity increased storage capacity by 365 percent and 214 percent. Subterminals were found to have had the smallest increase.

The increase in the size of elevators has meant that today there are fewer elevators in number than in the past. From 1930 to 1960, total number of firms in Montana decreased by 125 units. Elevators with 49,000 bushels capacity or less decreased by 75 percent of the number counted in 1930. Elevators with 100-249 thousand bushel capacity increased in number by almost 15 times; those elevators with 250-479 thousand bushels capacity increased by 12 times their number in 1930 (20, p. 6).

The particular study now under discussion included a summary of costs per bushel of grain handled for model elevators in various size groups. The results revealed the model elevator with 1,000,000 bushels of storage capacity had the least cost of handling grain, 3.7 cents (20, p. 34).

A related approach to the elevator problem was taken by Sharp in November, 1963 (17). Sharp surveyed 27 elevators in Ohio by using accounting data and found the average (weighted) cost of storing grain was 12.367 cents per bushel for the 1958-59 period and 13.03 cents per bushel in the 1961-62 period (17, p. 6).

The Economic Research Service has also done work relating to the cost of storing and handling grain. One of the latter efforts by this agency covered the cost of handling and storing grain at commercial elevators in the United States during fiscal 1964-65. The results were based on accounting records of 252 elevators selected to represent the principal storage areas, types, and kinds of construction. The sample included 165 country elevators, 58 inland elevators, and 29 port facilities.

Country elevator records revealed that book costs for storing and handling grain by the most common method averaged 10.4 cents per bushel. This cost included one year's storage plus receiving by truck and shipping by rail. It ranged from an average of 9.2 cents in the south and east to 12.0 cents in the Greak Lakes area. The short-run competitive rate for the combined storage and handling functions was 8.0 cents per bushel. Long-run competitive rates averaged 13.5 cents per bushel. These long-run rates would provide for replacement and a 6 percent return on investment for houses with space necessary to store 1966 volumes when utilized at 75 percent of capacity (4, p. 5).

At inland terminals, the combined book cost for receiving and shipping by rail plus one year's storage, averaged 9.0 cents per bushel for the United States. Comparable averages for the major areas ranged from 8.0 cents per bushel in the Great Lakes area to 11.6 cents in the west. The short-run competitive rate for the combined storage and handling functions for inland terminals of the United States was 7.0 cents per bushel. Long-run competitive rates averaged 12.0 cents per bushel (4, p. 9).

For the United States as a whole, storage costs alone, as shown on the warehouse records, including recorded depreciation and interest actually paid out, averaged 5.4, 5.5, and 7.2 cents per bushel at country plants, inland terminals, and port terminals respectively. There was a somewhat higher cost in the south and east, which was due to the existence of older, less efficient plants in the area.

For all plants combined the average cost for receiving grain by truck was 1.4 cents per bushel. This compared with average costs of 2.1 cents at country facilities and 1.1 cents at inland and port terminals. As would be expected, rail costs for all plants were only slightly higher, averaging 1.5 cents per bushel (4, p. 12).

The average total cost shown by warehouse records for loading out by truck was 2.2 cents for all types of plants combined. The costs ranged from a low of 0.8 cent at inland terminals in the south and east to a high of 3.9 cents at inland terminals in the west. Likewise, costs of loadout by rail were about equal for port and inland terminals, averaging 2.0 and 1.8 cents per bushel respectively; however, such costs averaged 2.9 cents at country elevators (4, p. 14).

The method of transporting grain has also been studied by the Economic Research Service. One particular study divided the state of Iowa into a western and an eastern region. The study revealed that in western Iowa the use of trucks increased from 24 to 43 percent of the total shipments from 1958 to 1963 (3, p. 10). This increase largely reflected the advantage of trucks for hauling to relatively nearby feeding, processing, and river markets. The area in study contained several feed milling and soybean processing plants and was rather centrally located among terminal and river markets at Kansas City, Minneapolis, and in Illinois. The truck-rail distribution of soybean shipments remained fairly stable in eastern Iowa; two-thirds of the trucked soybeans went to interior processors, and most of those remaining were shipped to river elevators.

The truck share of corn shipments has increased over time. Truck shipments accounted for less than 30 percent in 1958 but the percentage increased to over 50 percent in 1963 (3, p. 12). Over two-thirds of the trucked corn went to river elevators, primarily for barge shipments, although feed was milled in the Davenport area.

Corley McCrory considered the elevator problem in 1964. His capacity models included the following: (1) old 20,000 bushel elevator, (2) new 20,000, (3) new 100,000 bushel, plus old 20,000 bushel unit, (4) new 200,000 bushel, plus old 20,000 bushel, (5) new 300,000 bushel, plus old 20,000 bushel and (6) new 600,000 bushel, plus old 20,000 bushel. The maximum annual merchandising or holding capacity was as follows: 250,000 bushels for the old 20,000 bushel elevator, 400,000 bushels for the 100,000 bushel elevator, 600,000 bushels for the 200,000 bushel elevator, 900,000 bushels for the 300,000 bushel elevator, and 1,500,000 bushels for the 600,000 bushel elevator. Maximum storage capacity at any given time was 90 percent of rated capacity in the new concrete elevators and 15,000 bushels in the 20,000 bushel elevators (14, p. 10).

Average total costs for the grain merchandising and handling function at maximum volumes in each model ranged from a high of 5.08 cents per bushel in the new 20,000 bushel model to a low of 2.63 cents per bushel in the model composed of a new 600,000 bushel and old 20,000 bushel elevators (14, p. 21).

At identical merchandising or handling volumes a comparison of expenses showed maximum differences in average variable costs between any two models of only 0.3 cents and 0.1 cents per bushel when volume merchandised or handled was under 400,000 bushels and 400,000 bushels or more, respectively. However, at identical volumes the respective maximum differences in average total costs between models for volumes under 400,000 bushels and 400,000 bushels or more were 6.97 and 1.52 cents per bushel. Therefore, differences in average total costs between models at the same volume of grain merchandised or handled were accounted for almost wholly by fixed costs, i.e., size of plant and equipment. Average total costs of the storage function when maximum storage capacity was used were highest, 11.44 cents per bushel, for the new 20,000 bushel elevator model and lowest, 5.14 cents per bushel, for the model composed of the new 600,000 bushel and the old 20,000 bushel elevator (14, p. 28).

This study later considered a larger elevator, i.e., an elevator with 700,000 bushel capacity and a volume of 2,000,000, and found this model to have the lowest short-run average cost of 3.09 cents per bushel.

Yager's findings in 1963 were similar to those just discussed (24). Per bushel fixed cost for atorage was 5.31 cents per bushel in a plant with 100,000 bushel storage capacity, but fell to 3.54 cents in a model plant having 380,000 bushel capacity.

Yager also conducted a study wherein he considered the various factors or characteristics of an elevator which farmers and elevator managers felt were important. A total of 196 farmers were interviewed: 114 were owners, 44 were tenants, and 38 both owned and rented land (25, p. 3).

As would be expected, one of the most important characteristics of an elevator was the price paid for grain by any given elevator unit. The study found 75 percent of the farmers and 89 percent of the elevator operators felt price was very influential in determining the place of grain delivery. In fact, three out of four farmers felt favorable prices were of utmost importance (25, p. 12).

The speed of unloading grain also ranked high among both elevator managers and farmers. Harvesting a crop when it is ready is of utmost importance to a farmer. A few days lost during harvest may affect the quality of grain and thus mean a loss of revenue. In this particular study 66 percent of the farmers and 86 percent of the elevator operators believed speed of unloading was an important factor in selecting an elevator to patronize. Obviously the importance of speed is greatest during the rush harvest season and the importance declines rapidly after this period.

The elevator problem was considered in 1967 by Terry Yu-Hsien Yu at Purdue University (26). The author used annual accounting records of 206 country elevators for the year ended June 30, 1964. Cost-volume information provided in these records was used as the basis to estimate long-run internal plant cost functions by multiple regression techniques. Data on truck cost were obtained from other studies and were used to generate assembly and distribution cost functions.

The optimum size was determined by a cost model incorporating an internal plant cost function and an assembly or distribution cost function. Two assumptions were made for aggregate least-cost solutions: (1) all assembly-distribution costs were considered regardless of who actually bore the cost and (2) there was no duplication in assembly distribution areas.

The author considered the unit cost of transporting a given volume of a commodity to be approximated by a linear function. Its simplest form is as follows:

$$C = a + bM$$

where C = total cost of transportation per load,

a = fixed cost per load,

b = variable cost per load-mile times 2 (to account for round-trip distance),

and, M = miles traveled.

The production and sales densities were also considered. The following assumptions were used:

1. Grain assembly and farm distribution areas of country elevators were adequately approximated by rectangles.
2. Grain producers and purchasers of farm supplies were both evenly distributed in the areas served.

With these assumptions, production density was defined as (26, p. 28):

$$Dp = \frac{Y}{2N^2}$$

where Dp = production density of product in tons per square mile,

Y = volume of production in tons,

and, N = one-half diagonal of assembly area in miles.

By analogy, sales density was defined as:

$$Ds = \frac{Y}{2N^2}$$

where Ds = sales density of a product in tons per square mile,

Y = volume of sales in tons,

and, N = one-half diagonal of sales area in miles.

Under the conditions of no duplication in trade areas and considering only those transportation costs actually borne by the elevators (Case 1), one elevator for each of the selected counties would have been the most efficient from the firm's cost-minimization point of view. This single elevator would have merchandised approximately 13 million bushels of grain and distributed about 60 thousand tons of feed and 95 thousand tons of fertilizer, on a yearly basis, other sales and rate of capacity utilization remaining the same (26, p. 34).

For the case where all delivery costs were borne by the elevator and overlappings of trade areas were permitted (Case 2), the least-cost number of elevators in the selected counties ranged from 4 to 8. The author felt that as far as the number of elevators is concerned, the solution in Case 2 seemed to be closest to the real world situation.

Using Case 3, where duplication of trade areas was allowed and each elevator was assumed to share 10 percent of aggregate density and only those delivery costs actually paid by the elevators were considered, the optimum number of elevators under the least-cost solutions for the firm was virtually the same as that under least-cost solutions for the county. The reason for this is quite clear. Under Case 1, total unit cost of each sales component was relatively low compared to the aggregate least-cost solution. However, under Case 2, total unit cost for each sales component was relatively high compared to the aggregate least-cost solutions. When Case 1 was combined with Case 2, their relatively low and high total unit costs balanced out.

Mr. Terry Yu-Hsien Yu concluded that from an aggregate cost-minimization point of view, a reduction in the number of elevators by 20 to 50 percent would reduce marketing cost of grain and farm supplies in local areas from about 15 to 35 percent (26, p. 181).

THEORETICAL FRAMEWORK

The appropriate theoretical model for this study is that of the profit-maximizing firm. The theory of the firm assumes decisions will be made on a marginal analysis basis. Marginal analysis for a consumer may be defined as the process of making a choice between alternatives by considering small changes in total satisfaction resulting from small changes in the combination of alternatives (2, p. 30). Cohen and Cyert (2) define marginal analysis for a producing unit as the rate of change of an economic function with respect to the change in a continuous independent variable.

The firm using this approach has three basic economic questions to solve: (1) what is the optimal combination of outputs, (2) what is the optimal combination of inputs, and (3) what is the optimal level of production?

The first question to be answered is that of determining the optimum combination of outputs to produce. Assume the firm will use V units of input per unit of output to produce two outputs per period. If p_1 and p_2 are the selling prices of the two outputs, the firm's total revenue is

$$TR = p_1q_1 + p_2q_2. \tag{1}$$

The total revenue curves for various levels of output are given by the straight lines in Figure 1. The lines are called isorevenue curves, and they represent the locus of all possible combinations of the two outputs which result in the same total revenue. Also, it should be noted that

$TR_1 < TR_2 < TR_3$.

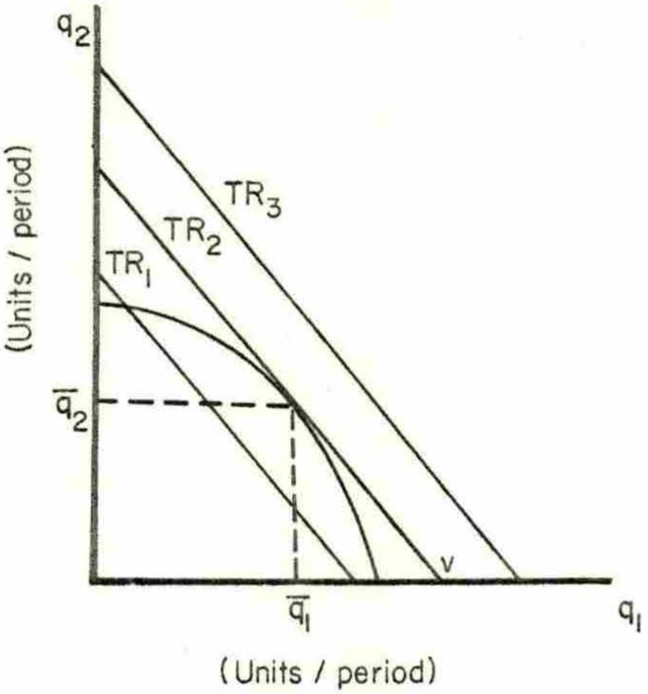

Figure 1. Diagram of the optimal combination of output

The contour lines in Figure 1 are called product transformation curves. Each of these curves is the locus of output combinations which can be obtained from a given amount of output. All the product transformation curves are downward sloping, because an increase in output one must be accompanied by a decrease in output two. The slope of a product transformation curve, dq_2/dq_1, is the rate of product transformation between the two outputs. It is generally assumed that the rate of product transformation (numerically) increases with a movement to the right along a product transformation curve and (numerically) decreases with a movement to the left (2, p. 119). That is, the product transformation curves are concave to the origin.

The point of tangency between the product transformation curve V and the isorevenue curve TR_2 determines the combination of outputs (q_1 and q_2) which gives the firm the highest total revenue when V units of input are used. Any other combination of outputs on the product transformation curve in Figure 1 can also be produced with V units of input, but they represent lower levels of total revenue.

The second problem to consider is that of the optimal input mix. Assume the firm is utilizing N inputs to produce one output. The short-run profit function may be expressed as follows (2, p. 12):

$$\pi = P_oQ - \sum_{i=1}^{N} P_iX_i - A. \tag{2}$$

The P_o is the constant price at which the quantity Q output can be sold and P_i is the constant price at which input X_i can be purchased. Although this is a short-run concept, the influence of fixed cost is reflected by presence of the factor A.

The production function is represented by:

$$Z = f(X_1, X_2, \ldots., X_i, \ldots., X_N). \tag{3}$$

where the X_i's are factors of production.

Equation 3 expresses the maximum amount of output that can be produced from any specified set of inputs, given the existing technology.

The cost function can be represented as follows:

$$C = P_1X_1 + P_2X_2 + \ldots.\ P_iX_i + \ldots.\ P_NX_N \qquad (4)$$

where C respresents the total variable costs, and the P_i represents the cost of each input factor. The firm attempting to maximize profits will maximize the production function subject to the cost restraint. A constrained maximization problem must be solved to determine the most profitable production decision.

To solve the constrained maximization problem, the differential calculus and the Lagrangean multiplier are needed. After a series of manipulations it can be shown that the necessary condition for maximum output is expressed as follows:

$$\frac{MPP_1}{P_1} = \frac{MPP_2}{P_2} = \frac{MPP_N}{P_N}\ . \qquad (5)$$

That is, the factors are employed in the amounts equating the ratios of marginal physical products to price.

From equation 5 it can be shown that

$$\frac{P_1}{MPP_1} = \frac{P_2}{MPP_2} = \frac{P_N}{MPP_N} = MC \qquad (6)$$

where MC equals marginal cost (23, pp. 169-173). It will be shown later that a perfectly competitive firm must equate MC to P_o where P_o is the price of the firm's output. Therefore, it is possible to state the following:

$$\frac{P_1}{MPP_1} = \frac{P_2}{MPP_2} = \frac{P_N}{MPP_N} = P_o. \qquad (7)$$

The above equation states that the value of the marginal product of each input is equal to the price paid for the input. Thus, a necessary condition for maximization of profits is that all inputs be purchased in such quantities that the marginal value products are equated to their factor prices.

The third problem to be considered is that of determining the optimal level of production. When the firm's short-run profit function, Equation 2, is maximized with respect to each X_i, the following result is obtained:

$$\frac{\partial \pi}{\partial X_i} = P_o \frac{\partial Q}{\partial X_i} - P_i = 0. \qquad L = (1, 2, \ldots, N) \tag{8}$$

The necessary condition for optimum output of a single product is obtained when

$$MPP_i = \frac{P_i}{P_o} . \tag{9}$$

From the above equation it can also be shown that

$$P_o = \frac{P_i}{MPP}. \tag{10}$$

Equation 6 revealed that a necessary condition for maximization of a firm's product is expressed by the following:

$$\frac{P_i}{MPP_i} = MC . \tag{11}$$

Therefore, by combining Equation 10 and Equation 11 it is found that the optimal level of production of an output is reached at the point where $MC = P_o$, or marginal cost equals the selling price.

The basic concepts of profit maximization under perfect competition can be illustrated by studying the data presented in Table 2. Initially, it should be noted that the entrepreneur can sell as many units as he pleases and not affect the price. The data reveals that the greatest profit is obtained with an output of either seven or eight units. If the total cost and total revenue curves were graphed, one would find that at these points the slopes of the two lines would be equal and the vertical distance separating the two would be the greatest and most positive of any of the points.

The concept of profit maximization is usually divided into two basic units with respect to time: short-run and long-run. The short-run is a period of time where at least one of the variable resources remains fixed. When considering the long-run it is assumed that all inputs are variable. The profit maximization principle will be considered using both time periods.

The marginal approach is useful in determining the point of profit maximization. Using this approach the marginal cost and marginal revenue columns in Table 2 become the most applicable columns. Marginal revenue is the addition to total revenue attributable to the addition of one unit of sales, while marginal cost is the addition to total cost resulting from the addition of one unit to output (5, p. 201). Profit increases when marginal revenue exceeds marginal cost and diminishes when marginal cost exceeds marginal revenue. Profit must, therefore, attain its maximum in the short run when marginal revenue and marginal costs are equal (5, p. 201). The rate of output is determined by the intersection of the marginal cost and marginal revenue curves.

Table 2. Revenue, cost, marginal revenue, marginal cost and profit for a hypothetical firm

Market price	Rate of output and sales	Total revenue	Total fixed cost	Total var. cost	Total cost	Profit	Marginal revenue or price	Marginal cost	Average total cost	Unit profit
10.00	1	10.00	30.00	4.00	34.00	-24.00	10.00	4.00	34.00	-24.00
10.00	2	20.00	30.00	7.00	37.00	-17.00	10.00	3.00	18.50	- 8.50
10.00	3	30.00	30.00	9.00	39.00	- 9.00	10.00	2.00	13.00	- 3.00
10.00	4	40.00	30.00	11.50	41.50	1.50	10.00	2.50	10.38	- 0.38
10.00	5	50.00	30.00	14.50	44.50	5.50	10.00	3.00	8.90	+ 1.10
10.00	6	60.00	30.00	18.50	48.50	11.50	10.00	4.00	8.08	+ 1.92
10.00	7	70.00	30.00	25.00	55.00	15.00	10.00	6.50	7.86	+ 2.14
10.00	8	80.00	30.00	35.00	65.00	15.00	10.00	10.00	8.12	+ 1.88
10.00	9	90.00	30.00	51.00	81.00	9.00	10.00	16.00	9.00	+ 1.00
10.00	10	100.00	30.00	75.00	105.00	- 5.00	10.00	24.00	10.50	- 0.50

In the long run all inputs are variable. Therefore, this enables the entrepreneur to adjust not only the level of output of final products, but also the size of plants to operate. Underlying any and all adjustments relative to output and plant size is the assumption that the entrepreneur continues to maximize profit.

The first adjustment to consider is that of plant size. Each capacity size under consideration has its own short-run average cost curve. Each curve can be derived and plotted on a graph where output is calculated on the horizontal axis and cost is computed on the vertical axis. After each individual curve is plotted and drawn, a curved line can be drawn tangent to all the individual short-run average cost curves. This tangent or envelope curve is the long-run average total cost curve or LAC. The LAC indicates the least cost of producing, or in this case storing and handling, of various volumes.

An example of these concepts should aid in understanding their value. Initially, assume a short-run situation and that the elevator size can be only three different sizes--one million, two million, and three million bushels in capacity. The short-run average cost curve of size one, the one million bushel model, is graphically portrayed by (SAC_1) in Figure 2. The two million and three million capacity sizes have short-run average cost curves represented by (SAC_2) and (SAC_3). Further, assume the elevator operator expects to store X_1 bushels of grain. He would therefore build storage systems represented by (SAC_1). Later the operator discovers the optimum storage size is actually the volume represented by X_2. He would nevertheless be forced to continue to store the grain in the one million bushel model at a cost of C_1. However,

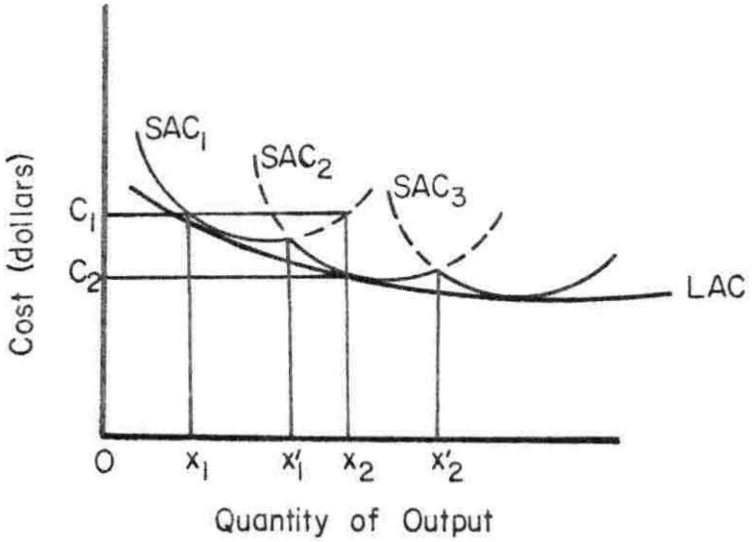

Figure 2. Volume cost relationship

if the conditions are now in the long-term range, the elevator operator would consider the new findings and would consequently build an elevator with a capacity of two million bushels. He would then be on (SAC_2) and the cost of storage would now be C_2 which is substantially below C_1. The heavy dark curved line which is tangent to the various short-run cost curves is the long-run average cost curve, which may be defined as the locus of points representing the least unit cost of producing the corresponding output. The entrepreneur determines the size of plant by reference to this curve (5, p. 179).

The long-run equilibrium for a firm in perfect competition can be shown by using Figure 3.

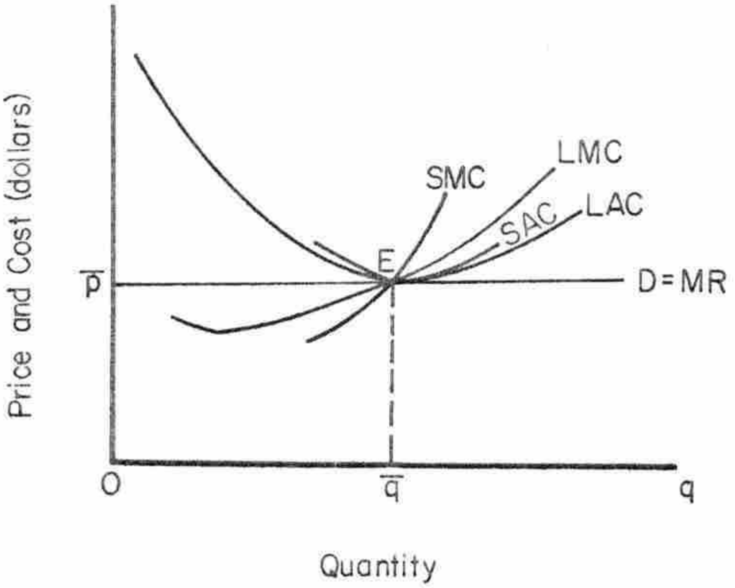

Figure 3. Long-run equilibrium of a firm in a perfectly competitive industry

The demand curve facing each individual entrepreneur is a horizontal line. For a firm to attain its individual equilibrium, price must be equal to marginal cost. Therefore, price must equal both marginal and average total cost. This can only occur at the point where average total and marginal cost are equal, or at the point of minimum average total cost. If the above statement applied solely to the short-run plant that coincides with the minimum point of the long-run average cost curve, equilibrium will be established. If the statement applies to other plant sizes, pure profits would occur and would be accompanied later by a corresponding adjustment. Therefore, it can be stated that the long-run equilibrium for a firm in perfect competition occurs at the point where price equals minimum long-run average cost. At this point minimum short-run average total cost equals minimum long-run average total cost, and the short- and long-run marginal costs are equal (5, p. 214).

The long-run average cost curve in Figure 3 is ⌣ shaped. There are a number of reasons explaining the curvature of this curve.

Basically, the curve slopes downward because of economies of scale. This concept can be dissected into two categories: specialization and division of labor (5, p. 180). For example, if a plant employs but a few workers, each worker will probably be expected to perform not one or two types of tasks, but a multitude of them. This will mean that each worker must perform some task where he is somewhat less than efficient, and also considerable time must be spent transferring from one task to another. If the plant could be expanded, each worker could then be assigned one given task, which would increase specialization and rapidity of completion and would also eliminate time needed to move from task to task.

A further economy of scale is witnessed by the fact that purchase and installation cost for larger machines is usually proportionally less than for smaller units. Thus, the increase in size will result in a proportional decrease in cost.

A final technological element which in fact might be the most important is the fact that as the scale of operation expands there is usually a qualitative, as well as a quantitative, change in equipment (5, p. 182). That is, as production increases there is usually introduction of labor saving devices which tend to reduce production cost per unit.

The above mentioned reasons explained the rationale of the downward slope of the LAC curve. However, the curve does not continue downward indefinitely. Economies of scale caused the downward slope. However, a minimum point is eventually reached and the curve rises due to diseconomies of scale. The main reason for the rise in the curve is management's inability to control and coordinate efficiently all the aspects of the business. An increase in size means more authority must be delegated to employees at various positions. Likewise, daily paperwork controlling the operation of the plant is increased. This overall inefficiency causes production cost per unit to increase and thus the long-run average cost curve must also rise.

In the production process several important assumptions are made. For example, it is assumed that the output rate is held constant during the production period. It is also assumed that all units are used and all outputs are sold during the period under discussion. Furthermore, it is assumed that inputs and outputs are achieved simultaneously.

After considering the brief discussion above it becomes apparent that certain modifications of economic theory are needed to convert the theory concepts to reality. French, Sammet, and Bressler felt that these modifications must deal with the time dimension, plant segmentation, discontinuous costs, and plant stages (7).

The problem sometimes encountered with respect to time is a derivation of a constant marginal cost curve. If, for example, the rates of output are held constant and total output is varied by varying the number of hours worked per day or week, the uniform level of intensification in the rate sense can be expected to produce constant marginal cost (7, p. 548). In reality in many cases variation in output per accounting period results from changes in hours of operation as well as from changes in instantaneous output rates.

This means that the resulting cost functions will tend to be linear or curvilinear, depending on whether the variation in output per accounting period is predominately the result of variation in hours of operation or of changes in output rates per hour. This, along with certain basic difficulties in methods and techniques, makes it impossible to preclude total cost curvature in these studies (7, p. 549).

Plant segmentation is another issue which must be considered. In most of economic theory fixed factors are assumed to be divisible. However, in reality this is not the case. For example, it is not possible to operate 1.5 plants. The producer must operate either one plant or two plants. Likewise, the manufacturer cannot purchase 2.5 machines. He must purchase these inputs in whole increments. Thus, if the producer increases the number of units of machines and he does not change the proportion of other inputs, the total cost curve will be discontinuous. In other words, this means that keeping the intensification of all inputs constant and increasing output by increasing the number of machines will result in a discontinuous cost curve (7, p. 553). For example, with X number of machines the producer may be able to produce 10 units of output. This would mean that the average output per machine is $\frac{10}{X}$. This level of output would be represented by a given fixed cost. Now, however, assume the producer wishes to produce 11 units of output. This increased output would require not X, but (X+1) units of the fixed factor, machines.

Consequently, there would not be a smooth continuous cost curve but instead it would be discontinuous. Figure 4 below depicts this relationship.

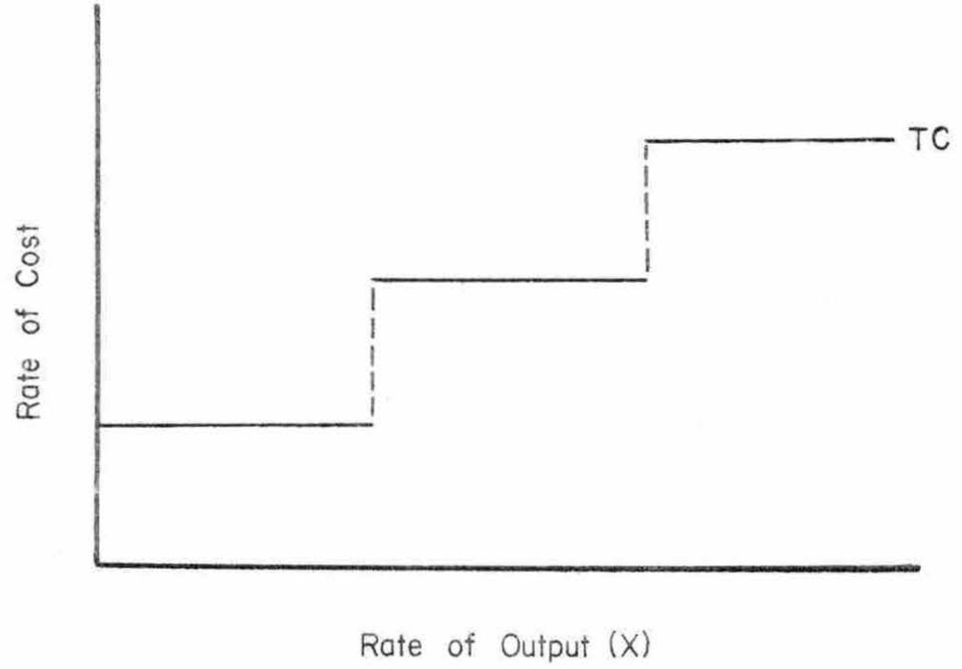

Figure 4. Discontinuous cost curve

A third factor to be considered is related to the second factor and is that of discontinuities in cost. However, the discussion of this factor is more concerned with input cost such as labor and changes in the rate dimension. The discontinuity problem was discussed above regarding plant segmentation and machine operation. However, it must be remembered that men are needed to operate the machines and to perform other tasks which enables the production process to continue. The production of human labor also involves a cost. In economic theory it is usually assumed that plants can increase or decrease the hours of labor per time period with no accompanying change in the wage or cost rate. That is, one hour of labor would cost, for example, $3.00 per hour if the laborer worked ten hours, fifty hours, or seventy hours per time period. However, at least in the United States, this assumption does not usually hold true in the real world. Labor unions and government legislation have created discontinuous cost curves for labor. For example, labor may cost $3.00 per hour up to and including forty hours. However, in some industries, any time over forty hours must be paid at the rate of time-and-a-half or $4.50 per hour. Also, labor cost on Sunday or holidays may be twice that of labor cost during the week on a per hour basis. Some unions have also been able to gain enough strength that they are assured of being paid for a given minimum number of hours a week, regardless if these hours were actually worked. Thus, in some cases a certain amount of labor cost is fixed and then varies discontinuously after a given number of hours worked.

The final aspect of this discussion, plant stages, presents a number of problems. It should be noted that each of the many stages which in the aggregate form a plant is represented by a cost function much as if it were a plant itself (7, p. 555).

The total of the stage cost curves, along with certain overall cost components not associated with specific stages, form the total cost function for the entire plant. The usual theory of production has its most direct application to the individual stage and not the entire firm or plant, except in the rare situations of a firm with a single plant and/or a plant with a single stage. The integration and aggregation of these stages into total plant operations lead to additional problems. The first of these is the problem of finding "harmonious" combinations of capacities for the units of fixed (but discretely divisible) equipment used at each plant stage. With technology constant, this amounts to finding a common denominator of the capacities of all the durable factors that may be employed at the various stages--this common denominator represents the rate of output that minimizes the average total unit cost of production (7, p. 555).

A second related problem, which is certainly recognized in the usual theory but in a somewhat different manner, is the choice of appropriate types of equipment at each plant stage. Modern technology offers many methods and kinds of machines for performing given operations. The economy of a given machine may depend on the rates of plant output, and the choice of machines must be considered simultaneously with the problem of harmony. The aggregation of the various plant stages also adds to the discontinuities noted previously since "kinks" or "breaks" in the cost functions usually will not occur at the same rate for all stages (7, p. 556).

The overall problem pursued in this study is basically similar to that approached by Stollsteimer in his publication on location theory (19). As Stollsteimer pointed out, given I raw material sites, each of which produces a quantity X_i of a material to be assembled and processed at one of L possible locations, the problem is one of determining the number, size, and location of facilities that will minimize the combined cost of assembling and processing the total quantity of raw material produced in the region. Algebraically, this may be stated as follows

(19, p. 632):

$$\text{Minimize TC} = \sum_{j=1}^{J} P_j X_j / L_K + \sum_{i=1}^{T} \sum_{j=1}^{J} X_{ij} C_{ij} / L_K$$

with respect to plant numbers ($J \leq L$) and locational pattern $L_K = 1, \ldots, \binom{L}{J}$ subject to

$$\sum_{j=1}^{J} X_{ij} = X_i$$

equals the quantity of raw material available at origin i per production period,

$$\sum_{i=1}^{T} X_{ij} = X_j$$

equals the quantity of material processed at plant j per production period,

$$\sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} = X$$

equals the total quantity of raw material produced, and

$$X_{ij}, X_j \geqq 0 \text{ and } C_{ij} > 0.$$

In the above original equation the first term represents total processing costs, and the second term, total transfer costs, with a specified number of plants (J) in a specified pattern (L_K), and

TC = total processing and assembly cost,

P_{ij} = unit processing costs in plant j ($j=1, \ldots, J \leq L$) located at L_j,

X_{ij} = quantity of raw material shipped from origin i to plant j located at L_j,

C_{ij} = unit cost of shipping material from origin i to plant j located with respect to L_j,

L_K = one locational pattern for J plants among the $\binom{L}{J}$ possible combination of locations for J plants given L possible locations,

L_{ij} = a specific location for an individual plant (j=1, ..., J) (19, p. 633).

Thus, the problem of determining size and location includes the consideration of two types of cost: in-plant cost and assembly cost. The procedure involves a trade-off between the two mentioned costs. Therefore, it is not possible to merely determine the volume which is represented by the least-cost figure of in-plant operations and to then divide this volume into the production of the area to determine the number of plants to construct. For example, the least-cost volume, considering in-plant cost only, may require excessive assembly cost. Thus, the final optimum size may mean the plant will not operate at the minimum point of the in-plant cost curve.

Stollsteimer considered four basic types of situations possible in the theoretical world; (1) economies of scale in in-plant operations--plant costs independent of location, (2) economies of scale in in-plant operations--plant costs vary with location, (3) no economies of scale in in-plant operation--plant costs independent of plant location, and (4) no economies of scale in in-plant operation--plant costs dependent upon plant location.

Assume initially number (1) of the above conditions. Thus, at each location the form of the long-run plant cost function is assumed to be linear with respect to total output and to have a positive slope. Stollsteimer felt that this particular functional form simplifies the solution of the problem and appears to be applicable to the long-run cost volume relationship in many plant operations. With equal factor costs at all potential plant locations, the long-run cost function will also be invariant with respect to plant location (19, p. 633). Therefore, with the constant marginal processing costs in any given plant, and a positive intercept in the plant-cost function, the total cost of processing a fixed quantity of material X, will increase by an amount equal to the intercept value of the plant-cost function with each increase in plant numbers. This intercept value might be interpreted as the minimum average long-run cost of establishing and maintaining a plant (19, p. 633).

Stollsteimer pointed out that the addition of the minimized total transfer costs and processing costs with varying numbers of plants yields a total assembly and processing cost function minimized with respect to plant location for varying numbers of plants. The number of plants that minimize combined transfer and processing costs depends upon the relative slopes of the minimized total transfer costs, TTC, and total plant cost, TPC, functions. In order that the total costs fall with an increase in plant numbers, J, the decrease in TTC must be greater than the increase in TPC.

The least cost equation can be minimized when using (2) of the above listed by adding to each column of a derived transfer-cost matrix the slope coefficient of the processing cost function applicable for each particular plant site. The procedure described for computing minimum total transfer cost for varying numbers of plants at alternative locations is applied to this combined matrix to obtain minimum combined transfer and processing costs for any given number of plants at any specified locations (19, p. 638). Stollsteimer noted that one must add to these costs the appropriate plant cost intercept values for each plant location being considered to obtain total combined assembly and processing costs for the set of locations being considered. From the $\binom{L}{J}$ values of combined assembly and processing costs, the minimum is selected as a point on the minimized total cost function.

Assuming case (3) of the situations possible, the least cost equation is minimized by minimizing total transport cost. This may be accomplished by assigning the production of each point of origin to the potential plant site for which C_{ij} is a minimum. The optimum number of plants and their location can be determined directly from a simple scanning of the transportation cost matrix, C_{ij}, by rows (origins) (19, p. 639). A plant will be located at each potential plant site which minimizes transfer costs for at least one origin.

Finally, if case (4) is assumed, a solution may be obtained using the procedures outlined for case (3) after appropriate alterations of the transfer cost matrix have been performed. This may be accomplished by adding to each column of the transfer cost matrix the plant cost associated with that particular plant location to obtain a combined plant and transfer cost matrix (19, p. 640). A direct scanning of this total cost matrix will permit specifications of the plant site which minimize combined processing and transfer cost for each region.

Actually, the approach and theory needed can be stated quite simply.

If in fact no economies of scale in plant operations exist, then the problem is to merely determine the location and number of plants which will result in the lowest transportation cost. If on the other extreme, economies of scale exist but there is no assembly cost, then each plant will operate at the minimum of the in-plant cost curve. Moving more towards reality, the problem usually encountered is one in which there is both a variable assembly cost function and a variable in-plant cost function. As was pointed out previously, there is then a trade-off between the two costs. The total cost becomes the addition of assembly and in-plant cost functions.

METHOD OF ANALYSIS

Ideally, the researcher would like a series of paired observations on costs and output which satisfy at least the following conditions:

1. The basic time period for each pair of observations should be one in which the observed output was achieved by a uniform rate of production within the period. It would not be desirable, for instance, to have four weeks as the basic time period if there were substantial weekly variations in the rate of production, because the four-week figures would then be averages which might obscure the true underlying cost curve.
2. The observations on costs and output should be properly paired in the sense that the cost figure is directly associated with the output figure. This condition would not be satisfied, for example, if a researcher paired accounting data for weekly periods where the wages paid in any given week were in fact based on the number of hours in the previous week.
3. There would be a wide spread of output observations so that cost behavior can be observed at widely differing rates of output. This result can be achieved by having a very large number of experimental firms, all of the same fixed capacity, and instructing each to produce at a certain rate, these arbitrary rates being chosen to give the desired range of output levels. Alternatively, the researcher

might have a small number of experimental firms, all of the same fixed capacity, and vary the rate of output over various periods of time. In both cases it would be necessary for the observations on any given rate of output to relate only to periods when the firm was fully adjusted to producing at that rate and doing so with maximum efficiency within the assumed capacity restraint.

4. The experimental data should be uncontaminated by the influence of factors extraneous to the cost-output relationship itself. The researcher would not want different observations to relate to different environments of technical knowledge and expertise; instead the researcher should require that each firm in each time period should have at its disposal the <u>same</u> stock of technical knowledge.

In the short run it is probably not necessary to insist that each management entity be equally efficient in utilizing existing technical knowledge. Any random variations between firms of a given capacity can usually be handled by statistical analysis. However, in the long run, this factor may need additional study.

One of the main problems faced by any researcher is the determination of costs and the gathering of cost data associated with the activities under study. As would be expected there are a number of possible methods available, each of which has certain disadvantages and advantages. No one single method of gathering cost data may be an absolute superior method under all conditions. The most efficient and accurate measure will in many cases depend upon the particular goals and objectives of the study and the time and resources available. If in fact the study is of a broad nature and the time and/or resource restraint becomes quite limiting, the researcher may deem it necessary to use accounting records to determine, or more accurately to approximate, cost curves and to obtain a rough idea of potential economies or diseconomies of size of operations or related topics. In attempting to determine an overall appraisal of a given study or topic a mere trend is all that is often needed. However, if the study is to be more detailed and if the researcher has additional resources at his disposal, more refined methods should probably be used. Several basic approaches are available.

The economic engineering approach is designed for studies concerned with the relative efficiency of various different and alternative technologies and with obtaining cost functions for plants of various sizes. The measurement problems differ somewhat among the major types of inputs and can be divided into four main headings: labor, materials, other operating inputs, and durables. These topics are discussed by the French, Sammet, and Bressler article (7) which is the source of the discussion of these four headings (7, pp. 580-581).

> "Two main sources of data can be used to estimate basic physical and cost-output relationships for labor: (1) plant payroll and output records and (2) engineering studies of actual operations. Each source will be discussed individually.
>
> "Plant payroll records usually show the hours of labor per day or week and the pay rates for each worker in the plant. Where these records indicate, or can be made to indicate, the nature of each worker's job, they may be related to the corresponding volumes of products to develop labor input-output functions for most of the plant stages. It must be recognized, of course, that the changes in input and output from period to period may result from both changes in rates and changes in hours of operation. Time must be intro-

> duced into the function, either directly or as a "deflator," to reduce each period observation to an average rate basis. From the standpoint of developing a function that is the closest possible approximation to "instantaneous" rates, the data should apply to short time periods with nearly constant rates of input and output within each period. As the length of the observation period is reduced, the rates become more uniform within the period. The functions derived from this data then will more closely approximate instantaneous rates of input and output. Data on a daily basis may come closest to meeting these conditions. The observations over periods, in a rate sense, should cover a wide range, of course, if the function is to be stable and valid for many rates of output.
>
> "The disadvantage of payroll records is that they usually reveal little of the specific details of many of the plant jobs. For example, they may conceal the fact that a considerable portion of the man-hours involved in performing a particular job may consist of idle time and that a higher rate of performance or output could be attained under other circumstances. Another difficulty is that the records may contain errors or be incomplete in classifying workers as to the type of work performed. Moreover, since accounting procedures are far from standardized, it will often be difficult to obtain strictly comparable records for a number of plants.
>
> "Engineering studies provide a means of obtaining basic labor data that are not readily available from accounting records. Four specific types of studies are important in this regard: (1) detailed descriptions of plant operations, (2) time studies, (3) work sampling studies, and (4) analysis of standard work data.
>
> "Descriptive engineering studies are useful mainly to provide a general picture of the plant organization--the crew setup, kinds of operations performed, and the like. It consists of detailed descriptions of each plant job, number of workers employed on each job and stage for the observed rates of output, and the flow of materials through the plant. It is intended as a supplement rather than a substitute for other types of studies but in some cases may provide all the needed information."

Direct time studies and work sampling studies are other methods which might be used for certain problems. The work sampling technique, commonly called ratio delay, is essentially a procedure of sampling workers' activities through time. It provides estimates of the proportions of time spent by different workers on various operations. When related to the total man-hour inputs and corresponding outputs, it yields estimates of the unit time requirements for the detailed elements of each job (7, p. 582).

One of the limitations of most time studies--all workers not working at the same time--is still not overcome by the use of the work sampling method. Although this may be considered a limitation, at the same time it represents reality. It is rather obvious that people do not work at the same rate nor do they perform their tasks equally well. In addition, this limitation can be reduced if the study includes a number of workers over a longer period of time. By combining these two approaches, i.e., additional workers and additional time, the study should be able to reveal a fairly accurate normal performance by the workers under study. Other advantages are: it can be applied to some jobs where time study is quite ineffective, the studies reveal where delays and idleness occur, which disclosures may lead to the development of means of minimizing them, the work sampling studies may require less field time to obtain a given amount of data or to cover a given number of operations, and finally, the sampling procedure involved in this method provides an objective measure of the reliability in time measurement (7, p. 582).

French, Sammet, and Bressler consider "materials" to consist of two types: those which are contained within the final product in some definable form and those which are consumed in the production process and do not enter directly into the product (7, p. 583). They suggest accounting data and inventory records as a means of handling these costs. Because this type of cost will not play a significant role in this particular study, this concept will not be developed further.

In addition to the input costs previously discussed, operating plants have additional input costs such as fuel, power, water, supplies, miscellaneous expense, general expenses, and administrative expense.

Power, fuel, water and related input cost can usually be obtained directly from accounting records. However, these records usually indicate only the total monthly or accounting period use based upon the bills received by the power or water companies. Thus, the researcher may be forced to obtain the average cost for rather broad periods of time. If in fact these costs represent a rather small or insignificant fraction of the total cost of operation, such as water for a grain elevator, then the averaging method probably will be adequate. However, if the researcher is attempting to obtain cost-output relationships and/or if the cost of the input represents a substantial portion of the total cost, then the averaging method may be quite unsatisfactory. Under this particular situation the researcher may be forced to use engineering studies which show cost-output relationships. French, Sammet, and Bressler suggest, for example, that a power curve be calculated for each electric motor, showing the relationship between kilowatt hours used and motor load. Fuel and water requirements in relation to rates of electric power output may be determined by engineering calculation in steam generating plants. The physical functions can be converted to cost functions, as in the case of materials and labor, by applying the appropriate prices obtained either from the plant or the suppliers of the power (7, p. 590).

Miscellaneous supplies in a grain elevator operation would consist of such materials as paper, for grain contracts for example, pencils, janitor supplies, chairs for visitors and related items. About the only practical approach the researcher can use here is to use accounting data for various sized operations and then perhaps arbitrarily assign a given dollar cost. The error that would creep in on this particular phase is almost certain to be so small that in almost all cases it would be negligible, especially if the expense is expressed in cost per total bushels of grain hauled.

General expenses such as licenses, donations, and the like also represent an extremely small fraction of the total cost of operation. Once again about all that can be done is to use accounting data from the records of operating plants. In some cases this cost may vary according to size of the plant and if so the researcher may be forced to arbitrarily assign a given dollar amount for each division of the range of plant sizes.

Administrative costs consist of the salaries paid to the managers of a grain elevator. The salaries will probably vary according to the size of the plant, its total sales, and the location. Once again accounting data is about the only source of information open to the researcher. However, sometimes the accounting records will reflect but a portion of the real salary as such. The total amount paid to the manager may be hidden in a number of confidential accounts. For example, some managers may receive automobiles, rent-free houses, or paid utilities in their residence, none of which may appear as such in the accounting records. However, once again the researcher should not be overly alarmed. The error will probably be quite low if expressed on a per bushel handled basis.

Three main sources of data are useful in estimating the costs of durable goods: plant accounting records, engineering-architecture estimates of building costs, and data supplied by manufacturers of equipment and buildings (7, p. 591). The cost of a given input or service of a durable factor may be extremely difficult to define. The cost of the aggregate of these inputs consists of an amount necessary to maintain and replace the durable factor over some time period. The objective in measuring the cost of durable items is to provide estimates of these future maintenance and replacement costs. From this standpoint, the values and charges carried in plant records will usually be of limited value. The records reflect, not future costs of replacement, but past purchase prices at varying dates and price levels (7, p. 591). In addition, depreciation is usually not determined by actual economic reasoning concerning use, but is influenced, if not determined, by taxation laws. In addition, depreciation routines vary from plant to plant, which in turn forces the researcher to make an arbitrary assignment of how to handle this particular factor. The engineering-architecture approach was suggested by French, Sammet, and Bressler as another possible research method (7, p. 591).

> "The engineering-architecture approach to a research problem consists of first estimating the physical requirements involved in replacing any specified structure--i.e., quantities of various materials, man-hours of various types of construction labor. To these physical estimates is applied a set of prices which appear most nearly to reflect costs which can be expected to prevail over some future period. The choice

> of price level is, of course, purely arbitrary. Current prices are commonly used as the best available indication of what may be expected over the not too distant future but by no means are necessarily good estimates of longer term situations.
>
> "The process outlined above provides an estimate of investment replacement costs in terms of current or future prices. Estimates of repair costs and expected useful life based on operating and engineering experience are then used with the estimated investment cost to estimate the average long-run costs of replacement and maintenance. To these costs there must be added, of course, an allowance to cover insurance, taxes, and interest (including normal risks) equivalent to the "going rates" for these items.
>
> "Cost estimates for equipment items may be handled essentially as outlined for buildings. In this case, however, the investment data can be obtained primarily from manufacturers, with as much information as is available concerning rates of wear, deterioration, and repair."

The approach used in this study was a combination of a number of the methods discussed previously. In addition, a number of assumptions were made at this point.

In the introduction of this study a number of statements were made relating to the amount of grain produced in Iowa. Corn, soybeans, and oats constitute the three major cash grain crops. Table 3 lists the annual Iowa production of these grains beginning in 1952. The table reveals that the production of corn has increased in a fairly steady pattern, soybean production has increased over 400 percent, and the production of oats has been reduced by approximately 50 percent. Most publications in this area of study predict continued increases in the production of corn and soybeans. Oat production, however, is expected to continue to decline. The reduction in oat production is due in part to the increase in the value of land and the yield potentials of corn

Table 3. Annual production of corn, soybeans, and oats in Iowa 1952-1968[a]

Year	Corn production (bushels)	Soybean production (bushels)	Oat production (bushels)
1952	662,985,465	37,917,946	208,071,075
1953	586,919,169	34,873,336	145,095,652
1954	560,687,770	54,418,978	222,410,585
1955	515,646,202	44,016,432	253,419,708
1956	528,745,739	49,340,468	152,236,750
1957	630,441,444	75,056,566	214,192,516
1958	658,703,152	77,587,990	215,251,670
1959	793,412,317	60,720,751	184,089,787
1960	764,287,873	65,961,227	169,130,325
1961	749,094,179	95,717,795	139,153,584
1962	748,235,871	92,071,811	126,880,293
1963	858,224,986	107,785,327	122,403,690
1964	768,987,529	119,722,008	110,598,440
1965	812,815,854	123,905,241	102,707,199
1966	902,179,177	144,412,650	103,821,816
1967	981,344,191	140,728,443	99,578,247
1968	901,728,000	177,952,000	110,460,000

[a] Source: (11, p. 2).

and soybeans.

For the purpose of this study, corn and soybeans were the only grains considered. It was felt that oats would continue to decline in overall relative importance. In addition, only 25 to 33 percent of the total oat crop is sold, according to Mr. Fred Thorpe of the Iowa Crop and Livestock Reporting Service of Des Moines, Iowa. Approximately 67 percent of the total bushels of oats that are marketed are sold by September 1. It was found that elevator managers tend to hold a relatively small amount of oats past the initial soybean harvesting date. Oats that are retained by the elevator manager are often placed in a storage facility which is a part of an accompanying feed mill system. Thus, the oat crop would have very little influence in determining elevator sizes. Therefore, for the purpose of this study, the effect of oats was felt to be insignificant.

The problem of obtaining workable data was limited to finding figures on two basic types of variables: transportation and in-plant costs. A number of assumptions were made in each of these two areas.

The transportation cost figures per mile were obtained by averaging published rates listed for the state (6). The rates were assumed to represent the perfectly competitive price and therefore the actual cost of transportation. The rates were then discussed with grain elevator managers and trucking companies regarding authenticity of said rates.

The construction cost figures for grain storage facilities played an important role in this study. The possibility of sending out questionnaires to elevator managers regarding construction cost was considered. This method would have the following advantages:

1. a relatively large sample could be obtained with a minimum of cost,
2. an average of the results obtained should be representative for the state as a unit.

However, it was felt the approach also had a number of inherent disadvantages. The disadvantages would include the following:

1. no guarantee could be given as to the number of responses that would be obtained,
2. the lack of personal contact would create problems regarding interpretation of the results,
3. elevator managers don't always know what their costs are,
4. it would not represent the latest in technology,
5. existing elevators would not allow estimates for volumes beyond observed values.

The approach finally used to obtain construction cost data was that of direct contact with Borton Construction Company of Hutchinson, Kansas. The project was discussed at length upon a visitation by the researcher to the Hutchinson office. Interviews with engineers produced construction cost data that were both current and applicable.

In addition to considering construction and transportation costs, it became necessary to consider what may be termed associated costs. This type of cost includes the following expenses: labor, utilities, depreciation, insurance, land, interest on investment, railroad siding, drying and aeration equipment, and grain handling equipment within each complex. Data for these costs were obtained from published sources and from personal interviews with elevator managers, engineers, and manufacturers of specialized equipment. Data were also obtained from records at Farmers Grain Dealers Association of Des Moines, Iowa, and from personal interviews with employees of that firm.

The overall approach of the study was to consider the costs associated with various elevator model sizes. The models under consideration were of the following size:

350,000 bushels,
500,000 bushels,
1,000,000 bushels,
1,500,000 bushels,
2,000,000 bushels,
2,500,000 bushels,
3,000,000 bushels,
3,500,000 bushels,
4,000,000 bushels.

The study consisted of determining the initial cost of construction of the models, and then equating with each complex the equipment needed. The cost of operating the equipment was calculated by determining the size of machine needed and the operating hours required. Land and railroad siding costs were determined by calculating the amount of each variable needed for the various model sizes. After all individual steps were completed, all the costs were added to give the total cost for one year. The results of this latter step served as the basis for the decision rendered as to the optimum size storage facility.

The turnover rate for each model was assumed to be 1.5. Thus, a model having 1,000,000 bushels capacity would handle 1,500,000 bushels annually. It was assumed that each model would handle 125 percent of its storage capacity at harvest time. The number of bushels handled at harvest in excess of the rated storage capacity was assumed to be shipped out during the harvest season. During the rest of the year it was assumed that twenty-five percent of the storage capacity was emptied and then refilled. It was assumed that by the following crop year all the grain had been removed from the elevator other than a small amount (one or two tanks in the larger models) which would be kept in reserve for feed needs. Eighty percent of the grain which moved through the complexes was assumed to be corn. Although the cost figures and assumptions are considered in somewhat greater depth in subsequent chapters, the following additional assumptions were used in this study:

1. Grain which moved directly from the field to the elevator was transported mostly by trucks and the transportation rates were based on 300 bushel units.

2. Roads were considered to run only in a north-south and east-west direction with no diagonals.

3. Production density was assumed to be homogeneous within the area being considered.

4. All grain was handled within a given area with no overlapping of trade areas.

5. The elevator models were concrete silo type facilities.

6. Depreciation on the building was calculated at 3 percent per year, 10 percent per year on the drying and aeration equipment, and 6.667 percent per year on the plant equipment and heat detection equipment.

7. Insurance cost was calculated on the basis of $1.00 per $1,000 of coverage on the building and equipment.

8. Labor cost was calculated on the basis of $7,300 per year for the main elevator worker and $6,300 for secondary workers for the smallest model. The cost for labor increased in a linear fashion throughout the model range, because it was felt that the larger units would require more responsible workers. These workers could not be secured unless the wages were satisfactory to them.

9. Land was calculated at $5,000 per acre.

10. Railroad spur lines cost $3,000 for the switch setup plus a rate of $14 per foot of track according to a personal interview with Mr. Disher of Marshalltown of the Chicago Northwestern Railroad.

11. Taxes on property were calculated on the basis of $10 per $1,000 of the total taxable figure.

12. Interest on investment (land and railroad siding) was calculated on the basis of 8 percent per year.

13. Costs for items such as advertising, dues, fees, and related expenses were assumed to be of such magnitude as not to influence the results.

Summarizing, the cost data obtained was as realistic as possible to obtain. The figures finally utilized were the result of direct contact with people in the specialized areas under consideration. Previous studies and actual cost records were used as check points or benchmarks whenever possible. It was believed that the method would minimize the error possibility.

ASSEMBLY COST

This particular study has two main variables which must be considered: in-plant cost and assembly cost. The methods used to describe and interpret assembly costs have varied somewhat from researcher to researcher.

The assembly cost problem simply involves moving the grain from the production nodes to the collecting center. With most country elevators the farmer-producer has three basic options at harvest time: (1) sell the grain immediately and deliver to the elevator, (2) store the grain on the farm or (3) store the commodity in the elevator. Irregardless of which option is chosen, eventually a given percentage of a crop will move to the elevator. The actual percentage of the total crop which moves eventually to the elevator varies from state to state, from crop reporting district to crop reporting district, and from county to county. For the state as a unit it has been estimated that 43 percent of the total corn production and 98 percent of the soybean production eventually moves through the marketing channels, according to Mr. Fred Thorpe of the Iowa Crop and Livestock Reporting Service of Des Moines, Iowa. The important factor to consider here is not the production density of a given area, but rather the marketing density. For example, County "A" may have a production density of 15,000 bushels while County "B" may have a production density of but 12,500 bushels. However, this in itself does not guarantee that "A" will market more bushels of grain than "B". If County "A" is in an area of heavy livestock production, then much of the grain will undoubtedly be fed to the livestock and thus the actual marketing density will be quite low. If on the other hand, County "B" is located in an area of very little livestock production, then most of the grain in this county will be marketed and consequently the marketing density will be quite high.

The basic approach used to estimate the assembly cost of in-bound products is quite consistent throughout the literature. Certain modifications are needed for each study, however. A necessary requirement is to list the assumptions used and then be consistent throughout the project.

The approach used in this study is similar to that of earlier studies while at the same time a number of modifications were used. The assembly cost problem is, of course, to determine the marginal cost and accumulated total cost. This in itself would not create any problems if in fact transportation cost were linear. However, such is not the case as will be explained shortly.

Initially, the state is composed of 99 counties. The counties range in size from 376 square miles in Dickinson County in northwest Iowa to 979 square miles in Kossuth County in the north central region. For agricultural crop reporting purposes the state is divided into the following crop reporting districts: northwest, north central, northeast, west central, central, east central, southwest, south central and southeast. The production of corn and soybeans for each county was determined by adding the bushels of corn harvested for grain and the bushels of soybeans harvested for the 1967 crop, as provided by the Iowa Crop and Livestock Reporting Service. The production of these counties was then grouped into a frequency distribution schedule given in Table 4. The production of grain as such in a given county is misleading because of the variance in the size of the counties. A more meaningful measure is the density of crop production which is determined by dividing the total production in a county by the number of square miles in the particular county. Thus, density reflects the output of grain on a per square mile basis. A frequency distribution with respect to density is given in Table 5.

Table 4. Frequency distribution of total grain production by counties

Total bushels produced	Class midpoint	No. of counties
2,499,000 and below	1,250,000	3
2,500,000- 4,999,999	3,750,000	9
5,000,000- 7,499,999	6,250,000	8
7,500,000- 9,999,999	8,750,000	16
10,000,000-12,499,999	11,250,000	17
12,500,000-14,999,999	13,750,000	20
15,000,000-17,499,999	16,250,000	17
17,500,000-19,999,999	18,750,000	2
20,000,000-22,499,999	21,250,000	5
22,500,000 and greater		2

Although there is a rather wide variance in the size of the counties comprising the state, a substantial number are in the 576 square mile range. In fact, 38 of the total of 99 counties are within 21 square miles of the 576 square mile figure. Therefore, for purposes of this

Table 5. Frequency distribution of density of production by counties

Total bushels produced	Class midpoint	No. of counties
0- 4,999	2,500	2
5,000- 9,999	7,500	11
10,000-14,999	12,500	11
15,000-19,999	17,500	16
20,000-24,999	22,500	29
25,000-29,999	27,500	26
30,000-34,999	32,500	3
35,000-39,999	37,500	1

study, 576 square miles was used to represent an average county. The concept of the average county is used only as a means of relating to a more comprehendable unit. That is, it is difficult to comprehend a 24 x 24 mile square unit. However, considering this area relative to a given county enables one to comprehend the unit of measure. Nevertheless, it should be noted that there is nothing special about the county concept. The 576 square miles used as an average unit guide may in the final analysis involve not one, but two, three, or even theoretically four separate and individual counties. More accurately the square miles discussed actually refer to trade areas with the county concept used only as a relative measurement.

Whenever a problem or study involves an area the size of the state of Iowa a number of problems are created which usually do not exist when the area studied is smaller. For instance, the density of production varies considerably across the state, transportation rates differ from area to area, and finally, construction costs vary from firm to firm and from area to area. Consequently, the researcher is forced to make a number of decisions initially that will have a substantial effect upon the study. For example, the researcher must decide if he should attempt to obtain a large number of transportation rates from the different areas and then determine an average rate to use throughout the study. Alternatively, he could divide the state or area into different regions and give average rates for each, or he could determine the rates for one given area and assume this holds throughout the state.

A similar problem exists when considering densities. The researcher may decide to determine the total grain production of the state and divide this total by the number of square miles within the state to arrive at a state average. This procedure would then entail assuming that production density throughout the state is the same from county to county, from area to area. The density problem may also be approached by establishing various classes or sets of a given size and then grouping the counties into a frequency distribution. This approach would then entail the midpoint of the class as the average actual level of production within a given area or county. A more laborious approach would include considering the production density of each county separately, as well as considering the transportation rates individually from county to county.

It should be noted that in almost any approach a researcher decides to use, he faces the issue of averaging, be it production density, assembly cost, or construction cost. The averaging effect need not necessarily result in the obtaining of unmeaningful and useless results. The effect of averaging can be reduced by constructing class limits which are narrow in scope. The narrower the range of a class, the less is the averaging effect. However, a point is usually reached where the gain in the reduction of the effect of averaging is more than offset by the extra cost and time involved in obtaining the results. The number of researchers and research assistants available, the amount of time available to spend on the project, the seriousness of consequence of the potential influence of the study, and the amount of funds allocated to a given project interact to determine to what degree the effect of averaging is reduced.

As Table 6 reveals, the current trend in Iowa and throughout the midwest is a movement towards harvesting corn with a corn combine as opposed to the conventional corn-picker method. The figures compiled by the Iowa Crop and Livestock Service reveal that 34.6 percent of Iowa's 9.7 million acres of corn for grain in 1968 was harvested using combines with corn heads. This compares with 31.5 percent of the acreage combined in 1967 and only 13 percent four years earlier. Approximately 8 percent was harvested with a picker-sheller, giving a total of 43 percent of the corn acreage harvested as shelled corn in 1968. The remaining 57 percent of the acreage was picked by mechanical pickers compared with about 61 percent in 1967 and 81 percent in 1964. Similar surveys conducted in nearby states indicate that the percentage of corn acreage harvested by combine also increased in Illinois and Minnesota.

For 1968, survey data indicates that 4.2 million acres of corn were combined in Iowa, or about 6 percent less than the 4.5 million acres in 1967. Acreage harvested for grain in 1968, however, was 13 percent less than in 1967 (11, p. 1).

The data also reveals that the northwest district of the state has constantly had a higher percentage of the acreage harvested by mechanical pickers than have the other crop reporting districts. Nevertheless, the percentage of acreage harvested by this method was down to 67.4 percent in 1968 compared to 73.5 percent in 1967 and 85.4 percent in 1965. The southeast district harvested less than one-half of the total acreage, 42.4 percent, by the mechanical picker. This figure compares to 45.1 percent of the preceding year and 57.6 percent for 1965.

Eleven percent of the 1968 corn crop was sold directly from the field either as shelled or ear corn. The figure compares with 7 percent for the 1967 corn crop. The percentage of corn marketed directly from fields at harvest was considerably higher in the three other states: Indiana, 27 percent; Illinois, 16 percent; and Minnesota, 17 percent.

Eighty-two percent of Iowa's grain corn production was stored on farms in bins or silos or fed directly from the fields without storing in 1968. This compares with 83 percent handled in this manner in 1967. About 3 percent was fed directly from the fields in both years. Table 7 reveals that in 1968 the southeast district had a higher percentage of corn marketed for grain, 14.3 percent, than any of the other crop reporting districts. The 14.3 percent for 1968 compares with a 9.3 percent for 1967 and 13.3 percent in 1965. The northwest district marketed 10.4 percent of the corn directly from the field in 1968. This compares with 6.6 percent for the preceding year, and only 2.4 percent in 1965.

Paralleling the movement of the trend to new harvesting methods is a movement towards larger farm units. For example, a loss of 4,000 Iowa farms occurred in 1968 so the state now has 143,000 farms. The average size of farm in 1969 is 241 acres compared with 235 in 1968. These figures compare with an average size of 190 acres in 1960, according to the Crop and Livestock Reporting Service. The total farm land area varied only slightly during the past decade, 34,700 acres in 1960 to 34,500 acres in 1969. As farms increase in size, increased importance is created for developing harvesting methods which assure the producer that his crop is harvested at the optimum dates. The movement towards larger farm units and new harvesting methods means that farmers will be harvesting a relative high proportion of the corn crop as high moisture corn. This is due in part also by the high opportunity cost of spring plowing versus fall plowing. This in turn means that the corn must be dried artificially in order that it may be stored without a high proportion of spoilage. Although the question is not yet resolved, there is reason to believe that in many instances it seems reasonable to suppose that it is to the farmer's advantage to move the corn directly from the field at harvest to the country elevator where the crop can be dried as opposed to moving the corn to storage facilities on the farm itself before eventually moving to the elevator.

The original plan for this study was to estimate truck operating costs, but it seemed reasonable to use the going rates charged by independent truck owners, and to consider this as the purely competitive rate. This assumes no profits exist but that all opportunity costs are being met.

It was assumed that most of the grain will be moved by means of trucks in the future. No estimate was made of the proportion of grain which may be delivered by farmers with grain wagons. Data on cost to deliver grain with the latter method is quite variable due to the variety of equipment used. Many variables tend to influence the cost of this method so that it is difficult to derive an average assembly cost figure utilizing a variety of transportation equipment. For instance, the size of tractor and wagon used can vary greatly. In addition, the labor involved can have either very low or very high opportunity costs.

In addition to the problems encountered in obtaining tractor-trailer data, it was also felt that wagon deliveries would have to be restricted to short distances and that in the larger size models only a small percentage of the total grain movement could be delivered by tractor and wagon. Although at the present time it is doubtful if enough trucks of the specified size would be available at harvest to handle the volume of grain necessary, it certainly seems reasonable to assume that if such a demand did exist, the supply would soon be adequate.

In addition, current studies indicate that it is usually to the farmers' advantage to store grain off the farm in an elevator complex rather than use on-the-farm storage facilities. Also, the size of Iowa farms has been increasing and most economists and agronomists predict that over time farm size will continue to increase and production of output will likewise rise. Consequently it is doubtful that in the future grain can be moved fast enough and far enough by the use of tractors and grain wagons. Therefore, most of the grain will probably be moved by truck. For the purpose of this study grain was assumed to be moved in 300 bushel units.

The transportation rates themselves were very important to this study. It becomes impossible to list one given rate structure and have this apply exactly for an area of any given size. Trucking rates vary in such magnitude that it becomes almost impossible to determine a rate as being typical for Iowa. However, the rates used in this study were felt to be representative of the state. The rates used are the regular rates with an additional cent per bushel added to cover the cost of loading directly from a combine. The final rate structure used is given in Table 8. The rates are fairly sensitive, changing almost every one or two miles until the 20 mile range was reached. The rates past 20 miles increased one-half cent per bushel for every five miles or fraction thereof.

The real problem involved in calculating assembly cost is not determining the rate structure. This can be designed almost arbitrarily. The real problem is attempting to determine the total cost of moving a given volume of grain to a given point. The problem arises due to the fact that truck transportation costs are not linear. For example, to move grain five miles the cost per bushel was assumed to be \$0.0325. If in fact transportation costs were linear, then if the mileage were doubled to ten miles, the cost per bushel should likewise double to a cost of \$0.0650. However, such is not the case. Instead of being \$0.0650 per bushel the cost for a 10 mile movement is only \$0.04. If transportation rates were linear it would be possible to determine the average distance farmers are away from an elevator--multiply the volume to be moved by the cost per bushel and arrive at a total cost figure. Earlier work in this area revealed that the average distance would be equal to the following equation (26, p. 74):

$$\bar{M} = 2/3\ (N)$$

where $\bar{M}$ = average distance

and N = 1/2 the diagonal of the square trade area.

To account for a round trip the above equation was multiplied by two. Thus, for a 24 x 24 mile square the average round trip distance would be approximately 22 miles. If rates were linear, the researcher could multiply the rate for this distance by the total amount of grain to be moved and arrive at a total cost figure. However, because of the non-linearity of the rates this approach was not used in this study.

The method used for this study consisted of weighting the cost per bushel by the amount of grain being moved a particular distance. In other words, the cost per bushel for total grain movement was a summation of the weighted cost of the various amounts of grain moved at the different rates. Initially various sized square diagrams were constructed and an east-west and north-south road system placed within the square. The elevator was placed in the middle of the trade area. The results were that the trade area became a tilted box or diagonal shaped configuration. Production nodes were designated by means of dots and placed at the center of each square mile. A general formula was developed to explain the number of production nodes at any given level. The formula is as follows:

a. If X is $< \frac{L}{2}$, then the number of nodes = 4(X),

where X = miles from the elevator

and L = length of one boundary of the square trade area.

b. If X is $> \frac{L}{2}$, then the number of nodes = $4(\frac{L}{2}) - 4Y$,

where X = miles from the elevator,

Y = unit number of miles from the midpoint of the boundary,

and L = length of one boundary of the square trade area.

For example, assume the trade area is a 10 mile x 10 mile square, and it is desired to know the number of points exactly 4 miles away. In this particular example $\frac{L}{2}$ would equal $\frac{10}{2}$ or 5. Therefore, by using the first part of the formula and multiplying (4)(4), it would be clear that 16 points are exactly 4 miles from the plant. If it were desired to determine the number of nodes exactly 6 miles from the elevator with a 10 mile x 10 mile trade area, the second part of the formula should be used. That is, $4(\frac{L}{2}) - 4Y$, would equal $4(5) - 4(1) = 20 - 4 = 16$. This procedure will determine the number of production points at each particular distance. Determining the volume of grain to be moved at each level of distance from the elevator is easy to estimate. The total volume at each distance is merely the number of production nodes multiplied by the density of each node. For example, assume a density of 5,000 bushels. The total volume to be moved would equal 16(5,000) = 80,000 for the distance of 4 miles. The same procedure will generate the volume at the remaining levels of distance from the plant.

The next procedure was to consider various sized square models. A trade area of 4 miles x 4 miles to one of 30 miles x 30 miles at 2 mile intervals was considered. A density of 5,000 was arbitrarily assigned. The procedure then was to determine the amount of grain to be moved at each mile interval and the weighted cost at each interval. The 6 mile x 6 mile trade area will serve as an example. One mile from the plant are located four nodes or a total of 20,000 bushels of grain. This grain can be moved to the elevator at a cost of $0.025 per bushel or a total cost of $500.00. There are eight nodes 2 miles from the plant. This represents a volume of 40,000 bushels of grain to be moved at $0.0275 per bushel or a total of $1,100.00. To move all the grain 2 miles and less from the elevator it is necessary to consider both the cost and volume of movement for both the 1 and 2 mile intervals. Thus, at this point 20,000 plus 40,000 or 60,000 bushels of grain would be moved to the elevator at a cost of $500.00 plus $1,100.00 or $1,600.00. The cost per bushel is then determined by dividing $1,600.00 by 60,000 to obtain a weighted cost per bushel of $0.0266. For a distance of 3 miles the same procedure would be repeated. Here, 60,000 bushels would be moved at $0.03 per bushel for a total cost of $1,800.00. The weighted cost per bushel results in a cost of $0.0283. The procedure is repeated until all levels of miles and each production node is served. This method enables the researcher to determine the volume, marginal cost, total accumulated volume, cost per bushel, total cost, total accumulated cost, and the weighted cost per bushel for the various size trade area models. This procedure can be used for any density or for any time rate schedule.

An example of the weighted cost per bushel concept for a 24 mile x 24 mile trade area is given in Table 9. The total cost curves so generated can be summed with the construction and associated cost figures for the various size elevators to arrive at a total cost figure for each model size.

If in fact a study is concerned with a trade area not defined or limited by county lines, the procedure is modified only slightly. The same approach used to determine the number of production nodes any given distance from the elevator is used for this latter approach. However, because the size of the trade territory is not predetermined, the number of production nodes continues to increase throughout the range instead of reaching a maximum point and then decreasing. The number of nodes for each given distance from an elevator multiplied by the density of each node gives the total production. The total cumulative production can then be found by totaling the production of each of the mile subunits. An example of this method is given in Table 10. The total distance all grain must be moved can be determined by equating the total number of bushels an elevator will handle to the total production of the surrounding area. Thus, in economic terms the quantity of grain equals the handling facilities available.

An important assumption used was that each square mile represented a production point or production node. If a study is confined to a given county or relatively small area it may be necessary to consider a smaller unit as the production point. However, the scope of this particular study was so large as to render the latter mentioned approach infeasible. Each square mile was considered to have its production located directly in the center of the square.

The density of production was assumed to be constant throughout a given area. That is, if at a particular point the study was concerned with a 24 mile x 24 mile square or 576 square miles each square mile was assumed to produce an equal amount of grain. This assumption conforms quite well with reality. It is impossible to consider the production density of every given acre when undertaking a study covering an entire state. It is true that land is not entirely homogeneous in nature. However, the deviation from homogeneity is not enough to influence the results of the study. The latter statement is particularly true if the study is concerned with a relatively small area, such as a 10 mile x 10 mile square. The smaller the area under consideration, the more homogeneous one can expect the land to become. No area considered in this study was large enough to appreciately cause any of the results to become questionable in relation to reality.

CONSTRUCTION COST AND ASSOCIATED COSTS

A study dealing with the issue at hand must of necessity consider the initial construction cost of an elevator system. The determination of the optimal size is made by adding the construction cost and associated costs to the appropriate transportation cost figure. Thus, the approach is quite direct.

During the summer of 1968 Borton Construction of Hutchinson, Kansas, agreed to lend assistance on the project. The researcher visited the Hutchinson office and studied blueprints and cost data with Mr. James Wilcoxson who was in charge of cost estimates. The cost data obtained were the figures used in bids submitted for actual projects. Thus, the figures were both accurate and timely.

The construction of a concrete silo elevator complex is a fairly simple process. Basically the process involves testing and preparing the soil upon which the structure will rest, building a concrete heavily enforced mat upon which the silos are placed, setting the forms for the silos, and then using a slip process to construct the silos themselves. A headhouse is then placed on top of the silos and equipment is installed. The process involves the hiring of highly skilled supervisory personnel and a varying number of unskilled laborers, the number required depending upon the stage of construction.

It should be noted that there is no such thing as an "average" elevator. Consequently, it is impossible to obtain absolute figures for a given size elevator complex. That is to say, the cost of constructing a 500,000 bushel elevator for instance can and will vary substantially. There are a number of factors which can and do affect the cost of constructing an elevator complex. The total cost of the project depends upon the degree of influence each factor plays. Some of the important variables are discussed in the following paragraphs.

The condition of the soil at the job site is very important when deriving a cost figure. In most projects the soil must have a bearing value good for 6,500 pounds per square foot, according to Mr. Wilcoxson. If in fact the soil does not have the characteristics to meet this requirement, then additional packing and excavating will probably be necessary. This additional procedure may cost 5,000 to 8,000 dollars depending upon the size of the project and the seriousness of the problem. Also, the real cost savings in slip concrete elevator building projects is the ability to construct silos of a favorable height. Up to a point, the higher the silo, the lower the cost per bushel. This is true because of the fact that the form has already been set and the ground prepared. All that is needed for additional storage capacity is more concrete, steel and labor. In other words, it would be cheaper in most cases to construct five silos 120 feet high than six silos each 100 feet high with all other dimensions kept constant. Therefore, in areas such as Texas, silos can be built quite economical because of the soil condition. In areas of

Kansas, however, the soil condition is such that the individual silo cannot reach the height where real savings occur and consequently the cost per bushel is increased.

Weather conditions are a second variable which greatly influences cost. Usually the first jobs of the spring and the last projects in the fall result in increased cost. This is especially true in areas such as the midwest where the seasons are very pronounced. The problem arises due to the unfavorable conditions of the winter season. In early spring and/or late fall sudden and sometimes substantial changes in temperature and wind conditions create problems. Obviously, late or early snow storms would be most undesirable. The cost of projects undertaken at this time is oftentimes increased due to the time spent on winterizing certain equipment, construction of additional shelters or reinforcing given shelters, partial days worked, and additional time needed to move and maintain equipment. Unfavorable weather may also mean that certain materials may become frozen to the ground, machines may not start, and large equipment may become mired in mud. A combination of these factors would result in less construction work being completed each day and therefore more days would be needed to complete the project. This in turn means an increase in the cost of the project.

A third important variable is the cost of the concrete used in the slip process. Borton has found that this cost varies as much as $2 per yard, according to Mr. Wilcoxson. By multiplying the number of yards needed in a given project by $2 per yard, one can easily ascertain the effect upon the total cost of the project. In some areas it has been almost impossible to obtain concrete for the elevator projects. This is especially true in areas where there is a heavy concentration of highway construction being undertaken. Other problems occur in that once the slip process begins, most firms favor to operate on a 24-hour day, with two 12-hour shifts or three 8-hour shifts. This forces the concrete dealer to secure drivers for late afternoon and night shifts. In some areas this does not create a problem. However, in a number of areas which are experiencing a labor shortage it has become almost impossible to induce laborers to work these unfavorable hours. If drivers and workers are secured, it is at an increase in wages which in turn is passed on to the construction firm. Problems sometimes exist and hence costs increase in obtaining the correct concrete mix and guaranteeing promptness of delivery. For example, if a truck is late in arriving, the workers must use vibrators to keep the existing concrete from setting up and also a large number of workers would be idle. All of this results in increased cost.

The cost of materials other than concrete also affect the cost of a project. For example, the cost of materials has been increasing so rapidly in the past years that Borton has been forced to revise its estimates at least once every three months, according to Mr. Wilcoxson. Likewise, other companies are forced to do the same. If in fact a construction firm failed to keep up on the increase in cost of materials it would probably submit the lowest bid on a given project, but would build the project with a very small profit or perhaps at a loss. The price of plywood, conventional lumber, and steel must all be considered. The inventories of the above items also influences overall cost. If a firm has a large inventory of steel purchased at a relatively low price, it may submit a bid somewhat lower than its competitors.

The cost of labor influences overall cost. In areas of excess labor this cost can be driven down to as low as the minimum wage. This is especially true in areas which have a concentration of college help during the summer. In localities of high union organization and/or near larger cities, the cost of labor is often driven up. This cost is also affected by the number of overtime hours worked by the employees. If the number of overtime hours can be kept to a minimum, the total cost of the project can be kept lower. The greatest amount of overtime is usually incurred during the actual slip process. If the project is being built in an area of excess supply of labor the construction firm may hire additional workers for two to four weeks while the slip is being completed.

A final factor which influences cost is the peculiar characteristics of a given project. For example, one manager may insist on a hydraulic truck dump while another may prefer a mechanical truck lift. The difference in these two types of equipment may be as much as 70,000 dollars. Some companies insist their elevators must be painted, while others think this is unnecessary. One manager may insist upon having two legs installed, while another manager of an elevator of the same size may feel that one leg is adequate.

Summarizing, the cost of an elevator of any given size is subject to variation. All potential costs must be considered. The summation of all costs may result in a cost difference of 25 to 30 cents per bushel. It is also important to remember that costs may change frequently in the construction business.

Although the construction cost of elevators is subject to wide variation, the study used point estimates for the cost of various model sizes. The cost data used were figures for actual projects which had been completed or were under consideration. In other words, the figures were realistic.

The cost figures used assumed no special problems existed, such as poor soil conditions. The figures used for construction do not include the installation of equipment within the facilities. It was assumed the system would consist initially of a 350,000 bushel elevator. Past this point annexes were added to the main headhouse.

It was determined that a 350,000 bushel unit would cost 232,050 dollars, or 0.663 dollars per bushel. To reach the 500,000 bushel level additional tanks would have to be constructed. This addition would cost 0.96 dollars per bushel. The cost of this addition was rather expensive because of the fact that the first annex complex entails the construction of connective units to the main headhouse. Past the 500,000 bushel unit it was assumed that each 500,000 bushel annex would cost 233,750 dollars or 0.468 dollars per bushel. The cost figure for each model size is given in Table 11. The cost per bushel for construction of an entire complex continued to decline throughout the range and reached a low point of 0.493 dollars per bushel for the 4,000,000 bushel model.

A description of what may be considered a fairly typical 350,000 bushel elevator will reveal the basic characteristics of the complex.

Configuration: 6 - 21ø x 125' - 0" high drive through bins--truck receiving only--rail and truck shipping.

Equipment: One 6500 B.P.H. bucket elevator with an overflow pipe and with a 40 horsepower direct drive motor--one electrically powered distributor--one lot of 10"ø heavy guage metal distributor spouting with quick couplings for ease of turning and maintenance--one 25 bushel automatic shipping scale with 6000 B.P.H. shipping rate--manual distributor below--one rail car spout with a flexible car spout attached--one lot of heavy guage rectangular basement bin spouting with rubber lining at points of wear--all overhead spouts with rack and pinion gates have control ropes to the main floor--one two-man cage-type personnel lift with a two horsepower drive--one mechanical truck lift.

Building: All concrete construction--main tank walls 7" thick--9/12 hoppering in all bins--two bins raised providing 800 square feet of usable storage space--tunnel provided for connection of future storage--interior and exterior walls painted--walls damp proofed to grade--galvanized steel roller curtain type driveway doors--two receiving grain pits--interior wall manholes into six principle bins--roof manholes into all bins.

Limits: Soil must have bearing value good for 6500 pounds per square foot.

After considering this initial construction cost, it became necessary to derive what may be considered associated costs with each model size. That is, for example, with each given size elevator is associated a cost for labor, a depreciation schedule, a tax program, and a land requirement. These associative costs must be considered and added to the previously discussed costs in order that the total cost for each model can be properly derived. The discussion of these costs is given below.

Land

Land is needed for a number of purposes for an elevator operation. Obviously a certain amount of land is needed upon which to place the elevator silos. The amount of land needed for this purpose depends in part upon the number of silos constructed, which in turn is dependent in part upon the height of each individual silo. A certain amount of land is also necessary in order that trucks may turn around, railroad cars can be loaded, and trucks can be weighed. In reality the number of acres owned by an elevator system varies to such an extent that it is difficult to assign a given number of acres for any given model size. Most elevators are not limited solely to grain handling. A certain amount is often needed for feed, storage, fertilizer tanks, and feed trucks. In addition, land cannot always be purchased by an elevator system in the number of acres desired or at the date desired. Consequently some systems have an abundance of land for current and expanded operations, while others are virtually land-locked.

This study assumed land could be purchased when desired at $5,000 per acre. It was further assumed that purchases could be made at .5 acre increments beginning at the one acre level. The amount of land actually needed and therefore charged against any given model size was the result of direct observation of existing systems, personal discussions with elevator managers and communication with personnel at Farmers Grain Dealers Association.

It was determined that one acre of land was required for the 350,000 bushel complex. One acre of land was also sufficient for the 500,000 bushel model. When the elevator system reached the 1,000,000 bushel mark it was necessary to add an additional half acre. A one-half acre addition was added for each 500,000 bushel increment up to the 3,000,000 bushel mark. At the 3,000,000 and 3,500,000 bushel figures one acre was added for each 500,000 bushel increment. The extra amount of land added was a necessary addition in order to be certain that the land area would encompass the elevator complex. The last 500,000 bushel addition resulted in another .5 acre being added to the land system. The amount of land required and the cost involved are given in Table 12.

Equipment Cost

The cost of the equipment within the elevator was obtained by using estimates furnished by Borton Construction after being checked against costs furnished by elevator managers. Basically, the equipment within an elevator consists of the following: legs, dumper, belt, conveyor, distributor, spouts, belt conveyor and tripper, reclaim system, shipping scale, scale, truck hoist, and manlift. The cost associated with each model is given in Table 13.

The 350,000 bushel system had a total equipment cost of $72,945. Past this point, $33,750 was added for each 500,000 bushel increment. At the 2,000,000 bushel level another scale for weighing trucks was added, as was an outside receiving pit. Additional unloading pits were added at the 3,000,000 and 4,000,000 bushel levels. It was assumed that the first pit would cost $6,000 and each additional pit would cost $4,500. The scale was valued at $17,995. These latter additions were deemed necessary in order to meet the heavy demand at harvest time.

Although the total cost for equipment within an elevator system increased with the number of bushels considered, the cost per bushel declined. This is due to the fact that with most increments an annex merely requires increasing the belt conveyor system, reclaim system, and the spouting within the complex. Thus, economies of scale are realized with elevator equipment.

Drier Cost

The size of the drying system for a given elevator complex is influenced by the amount of high moisture grain which is received. As was noted earlier, the current movement is towards an increase in high moisture corn. This in turn will create an increased demand for drying systems.

The cost figures for various size driers were obtained by direct interviews with representatives of Campbell Industries, Inc. of Des Moines, Iowa. These cost figures were checked against data obtained from elevator managers. The following cost figures were used for the various size driers:

1,500 bushels per hour = \$ 59,944,
2,000 bushels per hour = \$ 71,989,
3,000 bushels per hour = \$101,129,
and 4,000 bushels per hour = \$130,217.

The size and number of driers needed was determined for each model by considering the current sizes used, the sizes needed with additional emphasis placed on high moisture corn, and by direct interviews with elevator managers and drier industry personnel.

A 1,500 bushel per hour drier was assigned to the 350,000 bushel model. The size of the drier increased up to the 2,000,000 bushel mark at which point not one, but two driers were used. The increase in the number of driers would add insurance to the operation in that in the event of a breakdown with one unit the second drier would hopefully still be operational. A drier breakdown at harvest time can result in the loss of thousands of dollars due to corn spoilage or damage. The presence of a second drier would reduce this loss if in fact one drier did experience a breakdown. The drier system and corresponding costs for each model are given in Table 14.

Aeration Equipment

Aeration equipment is a necessity in any elevator system which handles wet grain. The amount of equipment used for any given model depends in part upon the type of equipment employed. Some elevator operators use a fan-type system for each tank, while others use a manifold type arrangement. Some managers now are beginning to purchase machinery which can be used to move the aeration equipment from one tank to another. This latter method enables one system to aerate more total bushels of grain. For the purpose of this study this latter discussed method was used. It was assumed that each aeration system could service 5.0 tanks. Each aeration system was valued at $1,657, including the extra cost of the special moving equipment. The aeration systems were assumed to use 15 horsepower motors. Beginning at the 2,000,000 bushel model size, one 25 horsepower system was used in addition to the 15 horsepower units. The larger motor could be used to hold high moisture corn before it reached the drier. The larger system could also act as insurance against corn spoilage in the event of a drier breakdown at harvest time. The larger system was valued at $1,903. The aeration data are given in Table 15.

Heat Detection

Grain which is placed within the confines of an elevator complex cannot be left unattended. It is essential to know when the grain is at a temperature which causes spoilage to begin. This problem can be handled by the use of heat detection equipment which consists basically of a system of cables with attached temperature detectors placed within the tanks. A central control and reading gauge instrument panel is connected to the various cables. This enables the elevator operator to tell at a glance the temperature of the grain at various levels within each tank.

The heat detection system needed for various elevator sizes was obtained by personal interview with representatives of Rolfes, Inc., Boone, Iowa. The 350,000 bushel model needed a system costing $6,109. The cost of the system increased with an increase in storage capacity. However, the cost per bushel declined, because the cost of the most expensive item, the main instrument panel, was spread over a larger volume of grain. The cost figures associated with each model size are given in Table 16.

Railroad Siding

In the system under consideration, grain is brought to the complex from the farm by truck and moved from the elevator to distant points mainly by rail. Therefore, each model under consideration has associated with it a corresponding cost of installing the railroad spur. In earlier times this installation was done by the railroad companies at no expense to the grain dealer. Such is not the case at the present time, however. The current charge for installing a spur line is $14 per foot plus $3,000 for the switching setup, according to Mr. Dishner of Marshalltown of the Chicago Northwestern Railroad.

The number of feet necessary for a spur is a function of the size of the model under consideration and the speed at which grain is desired to be handled. It should be noted that there is no set pattern elevator managers follow. In other words, in some instances the number of feet of railroad may be the same although the size of the elevators may be markedly different. Some managers attempt to keep the installation cost as low as possible and therefore do not allow for expansion of facilities without a corresponding expansion in the spur line. On the other hand, others feel that a factor for expansion must be introduced when considering the number of feet necessary.

The number of feet used for each model size was derived after considering opinions of various managers and checking these figures at Farmers Grain Dealers Association. The number of feet assigned to each model size and the corresponding cost are given in Table 17. It was assumed that railroad cars would be seventy feet long. The length of rail under the system under study need not be as long as for systems wherein large quantities of grain are moved out each day. That is, the turnover rate is very influential.

A length of 300 feet of rail was assigned to the 350,000 bushel model. The length of rail increased gradually with an increase in storage capacity until at the 4,000,000 bushel mark 760 feet were required.

Utilities

The utility cost for an elevator system includes cost for electricity and fuel as sources of power and light. Although most elevator managers maintain a record of expenditures for utilities, none were found to have separate meters for the grain activities. Therefore, this cost was estimated and then compared to elevator records after assigning a given percentage of the records to the grain activities.

The power cost of operating drying equipment was assumed to be \$.008/bushel (13, p. 32). Eighty percent of the grain handled was assumed to be corn. The related cost of aeration was determined by assuming a 15 horsepower motor on each system, except for the heavy air system which required a 25 horsepower motor (21, p. 19). It was estimated that the heavy air system ran 24 hours per day for 20 days. This system could also be used to reduce large "hot spots" from any given tank. One heavy air system was used in the model sizes of 1,000,000 bushels and 1,500,000 bushels. The smaller systems were used to pass a cool front through the grain in the fall and a warm front through in the spring. It was assumed to take 120 hours to pass a front completely through a tank. It was also estimated that each tank would receive on the average 10 hours of air per month from May through September. The following schedule for the amount of storage capacity filled was used for this study:

October 1 to April 1 - full,
May 1 - 80 percent,
June 1 - 60 percent,
July 1 - 40 percent,
August 1 - 20 percent,
and September 1 - 20 percent.

The cost of operating receiving and transfer equipment was generated by the results of a survey taken by Farmers Grain Dealers Association and by discussing the matter with grain elevators.

In reality, the power rates usually become lower on a per unit basis as more kilowatt hours are used. However, for the purpose of this study a rate of 2.6 cents per kilowatt hour was used. It was felt that most elevator systems have accompanying uses for power which in fact would mean that all units could qualify for the lower rates. Table 18 contains the data generated for the cost of utilities.

Repairs

The operation of an elevator system demands that a certain amount of money be spent each year for repairs. The amount needed varies greatly according to the age of the equipment under consideration. A new plant with new equipment would probably spend virtually nothing the first year of operation for repairs. However, over time, replacements must be made and faulty equipment and operations corrected. In the elevator complex the pipes used to move the grain are subjected to great pressures and a high degree of friction. Temperature changes, moisture, and other climatic conditions also decrease the life of the pipes. Machines, pulleys, and other equipment are also subjected to heavy use and must periodically be repaired and replaced.

The amount of money needed for repairs used in this study was determined by a review of a survey conducted by Farmers Grain Dealers Association. The survey considered operations of elevator systems within the membership of the Grain Dealers Association. Although there was considerable variation of cost at any given model size, an average was calculated. The figures used for the study are presented in Table 19. The survey by Farmers Grain Dealers Association indicated slight economies of scale with respect to repairs. Past the 1,000,000 bushel mark estimates were made. The estimates were made by using large terminal type facilities as basic indicators and then adjusting the figures to a system which is principally a storage facility.

Labor Cost

The cost involved in hiring and maintaining an adequate supply of laborers varies from area to area with no given pattern. The laborers involved for the purpose of this study are those individuals who are in charge of weighing trucks, taking samples, unloading trucks, loading boxcars, and the operation of aeration and drying equipment. Although there appears to be a rather substantial number of tasks to perform, many of the efforts are sequential in nature and/or interrelated so that one individual can perform a variety of tasks within a relatively short period of time. The actual number of laborers required for any given model size is a function of the speed at which the grain must be handled and the degree of automation present within the system. For example, a check of the records at Farmers Grain Dealers indicated that a plant in Omaha of the 3,000,000 bushel capacity size employed thirteen men, which was the exact number of employees needed in Des Moines at an elevator of 5,000,000 bushels in size, according to Mr. Peters, Controller, Farmers Grain Dealers Association, Des Moines, Iowa. The Omaha plant used a number of its employees to unload boxcars of grain by hand. However, in Des Moines this operation was conducted by the use of an automatic car unloading machine. Thus, it is difficult to determine the number of laborers needed in an "average" elevator of a given size.

Personal contact with elevator managers and personnel in Des Moines enabled the researcher to assign the number of laborers required for a given size elevator. It was assumed in all cases that one man would be given the responsibility of the operation of the elevator system. In addition, he would have additional helpers to aid him whenever necessary. The additional help would be especially necessary during the harvest season.

The amount paid to laborers is fairly consistent from elevator to elevator. It was found that as the size of the elevator system increased the wages or salaries paid likewise increased. It was assumed initially that the main worker in the 350,000 bushel system cost the elevator $7,300 per year including payments for social security, insurance and retirement. The second worker was paid $6,300. The lower pay for the second worker was due mainly to the lower degree of responsibility he was charged with. Actual cost figures could be obtained up to the 1,500,000 bushel level. Past this mark the cost per laborer was estimated.

The cost per laborer from the 1,500,000 bushel elevator to the 4,000,000 bushel complex increased 20 percent. The costs within the interval were increased in a linear fashion.

Although it is rather obvious, it should be noted that the cost per laborer to the elevator system is not the amount paid the worker. For example, with a cost of $8,079 for a worker the following amounts were paid to the various components:

	insurance	$ 46,
	social security	$324,
and	retirement	$336,

according to Mr. Paul Vaulde, general manager, Ellsworth Co-op, Ellsworth, Iowa. In addition, some elevators pay bonuses at the end of the year.

The number of workers required was determined by constructing a hypothetical year. This method enabled the researcher to determine the slack periods and the times when additional laborers would be needed. It was determined that the laborers would devote 65 hours per week in the grain department during the six week harvest season, 54 hours during the month following the harvest, and 42 hours per week the rest of the year. An example of the method used to determine the labor requirement and corresponding cost for the 1,000,000 bushel complex should reveal the method used.

The harvest season required five men to meet all the demands. This number included the people unloading grain, loading out grain, weighing trucks, and related tasks. The total number of hours required for the harvest was 1950, (5 x 65 x 6). For the one month following the harvest rush, two men each working 54 hours per week were required. These men would be concerned with drying and aeration operations, late harvest operations, and some loading out operations. During the remainder of the year 1.5 men were needed. One man was assumed to have the responsibility of the operation and to have a helper who worked with him half the time. The main worker was assumed to spend 42 hours per week in grain activities. The total number of hours needed for a twelve month period was found by adding the hours needed during the various parts of the year as described above. The total number of hours worked was then divided by 2,870, the latter figure being considered one man-year. The total man-years required was then multiplied by the corresponding costs to obtain the total cost. The cost for all the model sizes was determined by the method discussed above. The figures were then checked with elevator managers for accuracy of the assumptions and total cost amounts. The man-years required and the costs involved are given in Table 20.

Property Taxes

Although the property tax rate schedule varies from area to area, a rate of $10 per $1,000 of the assessed taxable value was used. The tax assessed against an elevator complex is not the tax rate multiplied by the total valuation of the system. Instead the tax rate is levied on 27 percent of the total value of the complex. That is, the total value was established, multiplied by .27, and the product thus obtained was assessed at the rate of $10 per thousand. The results of these calculations are given in Table 21.

It should be noted that elevators are subjected to a tax on the grain which is handled. However, this study assumed that each model had the same turnover rate and that the tax per bushel was constant. Therefore, this tax figure would not influence the results. Thus, the tax on grain was not considered.

Elevators must also pay federal income tax. However, income is a function of management, location, and numerous other variables. This study was concerned with the economies of construction and operation, and was not concerned with elevator income from a tax standpoint. Therefore, income tax was not considered.

Insurance

The elevator system and its contents represents an investment of thousands and sometimes millions of dollars. This large investment is usually protected in part by the use of insurance. The premium rate for an elevator system depends to a large extent upon its location, and the type of material from which it is constructed. For example, a wooden structure would most likely have a higher premium rate than would a concrete silo system. A check of the records at Farmers Grain Dealers revealed that there are no distinguishable economies of scale associated with elevator insurance cost. That is, regardless of the size of the system, and assuming all other factors constant, the premium rate per unit would be the same. The rate found to be the most representative and hence used in this study was \$1 per thousand of the total value of plant and equipment. Table 22 contains the insurance cost data.

In addition to insurance on the structure and equipment the contents of the building are usually insured. The cost of insurance is within the range of $.78 per thousand dollars of the total value of the grain. This cost was not considered, however, because the cost is a function of the amount of inventory carried forward. This cost would not be a function of the model size under study.

Depreciation

The depreciation of a machine or building allows for the gradual wearing out of the item under consideration. Over time a building or machine tends to lose its value because of use and obsolescence. Depreciation as such is a means of considering and allocating this reduction in value. It is important to note, however, that the depreciation schedule usually followed cannot be explained entirely by economic theory. Rather than economic theory or principle serving as the guideline, the taxation laws written by Congress and enforced by the Internal Revenue Service usually are the guiding criteria. Under the present taxation laws most elevator managers depreciate the concrete silos at a rate of two to three percent per year, according to Mr. Peters of the Farmers Grain Dealers Association. For the purpose of this study the silo complex was depreciated at 3 percent per year, equipment and heat detection at 6.667 percent, and aeration and drying equipment at 10 percent. The depreciation schedule for each model is given in Table 23.

Interest on Investment

Interest on investment was calculated on the funds spent for land and railroad siding. This calculation in reality considers what may be termed opportunity cost or the shadow price on these two expenditures.

The expenditures were charged at the rate of 8 percent per year. The results of those calculations are given in Table 24.

SUMMARY AND CONCLUSIONS

After considering each variable separately it becomes necessary to group the subunits into one overall function. The grouping process is actually a form of an assimulation model. By combining all the variables for each model size the total cost for each model can be determined. This particular process was followed in this study.

The initial grouping process, after the transportation cost was determined, consisted of adding together the in-plant cost variables. The cost per year was determined by adding together the following individual costs: depreciation, interest on the investment for the railroad siding and the land, repairs, labor, property tax, insurance, and utilities. The cost on a per bushel basis was calculated by using two different divisors: (1) per bushel storage capacity, and (2) per bushel of the total bushels handled. Table 25 contains the figures generated by summing the various subunits of in-plant costs and Table 26 contains the assembly cost data. Table 27 contains the total yearly cost charged for each model with densities ranging from 5,000 to 30,000 bushels per square mile. Regardless of the size considered, as the marketing density increased the total cost decreased. This is due to the fact that when density increases, the grain must be moved a lesser distance and consequently transportation cost declines. By reading from left to right for any given model size it is possible to determine the effect of density with respect to the total cost. Likewise, it is possible to choose a given density at the top of the table and move downward to determine the effect of changes in model size with respect to total cost.

Beginning with a density of 5,000 and moving down the table, a minimum point range is reached in the model size of 1,500,000 to 2,500,000 bushels. When using method (1) the reduction in cost on a per bushel basis was $0.0310. When using method (2) the decrease in cost was $0.0206 per bushel. Past the 2,500,000 bushel level slight diseconomies of scale were witnessed.

With elevator models greater than 2,500,000 bushels of capacity, "lumps" were generated by the procedure used. This was due to the fact that not all equipment could be purchased at the desired size. For example, some models had excess capacity with driers. However, the next smallest size was too small. Consequently, there was some unused capacity. The "lumps" do not reduce the value of the study, but instead reflect the real world situation.

Definite economies were found to exist with densities greater than 5,000 bushels. In all cases the biggest savings resulted from a movement from the smallest plant to the 1,500,000 bushel elevator. Models larger than 1,500,000 had economies, although the savings was small and there was some "lumpiness." As the density increased to the 15,000 and higher levels, Table 27 indicated elevators in the 2,500,000 bushel range resulted in the lowest cost on a per bushel basis.

An overall view of the results indicates that there are definite economies of scale with larger elevator systems. In all cases the highest cost per bushel was obtained with the smallest elevator model. From a practical standpoint the study indicated that it would be to the farmers' financial advantage to have fewer, larger elevators as compared to more numerous smaller units. For example, four 1,000,000 bushel units could handle 6,000,000 bushels of grain. If the marketing density were 10,000 bushels, this would mean these four elevators could handle the grain in an area the size of a typical Iowa county.

A number of valuable comparisons can be made by using Table 27. For example, assume a marketing density of 10,000 bushels. One 1,000,000 bushel unit would handle 1,500,000 bushels of grain at a cost of $117,180. To handle the same amount of grain two 500,000 bushel units would be needed. This latter model size elevator system would cost $141,400 (2 x 70,700), or $24,220 more per year than the 1,000,000 bushel elevator. Converting this to a more comprehendible figure, the savings secured by moving to the larger unit would be $0.01615 per bushel. Moving to units larger than 1,000,000 would produce slightly increased savings on a per bushel basis. Also, if the marketing density were 30,000 bushels and a comparison of a 500,000 bushel and a 2,000,000 bushel were calculated, the savings would be found to be $0.0200006 per bushel. Thus, if the savings could be passed on to the farmer, each farmer would receive 2.0 cents per bushel more for his grain.

It is important to reemphasize that the major savings were found to exist when moving from the 350,000 or 500,000 bushel models to the 1,000,000 to 2,000,000 bushel range. Under current conditions elevators of these larger sizes seem feasible. In fact, a number of units in north central Iowa are now in the 1,500,000 bushel range, and the managers are contemplating expanding their facilities. A general statement regarding the results of this study would be that elevators should be at least 1,500,000 bushels in size and that there appears to be slight economies of scale past this point.

If a study is to be conducted to determine the optimum number of elevators in a box-like trade area, the process discussed at some length in the assembly cost section should be used. That is, the total number of bushels to be moved should be determined and then various size models should be theoretically placed within the area until the least-cost model is found.

In conclusion, there are economies of scale with respect to the typical country elevator system. If these savings could be passed on to the farmer-producer, farm income could be increased.

LIMITATIONS OF THIS STUDY AND SUGGESTED FUTURE RESEARCH

Almost any economic study has a number of limitations associated with it. These limitations do not mean that the research is not adequate. The limitations merely mean that some variables have not been considered in depth and consequently some of the findings may deviate slightly from reality. There are two main sources which cause research limitations.

The amount of money appropriated for a given study influences the depth at which each variable can be considered. Indeed the allocation of funds may, in fact, limit the number of variables which can be considered. Usually the greater the number of variables which must be considered, the greater is the demand for research funds. Lack of research funds may force the researcher to make assumptions which are somewhat questionable in respect to reality.

The second important reason why economic reasearch usually has certain limitations is due to the factor of time. Most research has an initial proposed finishing date. If in fact this date is quite flexible in nature, then no real problems may arise. However, if the date cannot be changed, the researcher must somehow budget his time so as to finish in the allocated amount of time. Unforeseen difficulties may arise during the researching period and consequently the researcher may be forced to make a number of concessions in order to complete the project on time.

This study considered the state of Iowa as one unit with classes of homogeneous subunits. Truck transportation rates were established and were assumed to be constant throughout the state. Construction cost for the model sizes was derived by hypothetically designing an "average" or typical elevator. Construction rates were assumed to be identical for the models throughout the state. Also, the study did not consider in any depth the presence of existing elevators and the impact they would have on the final conclusions. Finally, the study assumed the firms possessed sufficient funds or were in a position so that additional funds could be acquired to meet all building expense.

In reality, truck transportation rates and construction rates do not remain constant from area to area. The cost per bushel for an elevator construction project can and does vary depending upon the conditions of the soil, the geographical location, and time of the year, for instance. In reality, too, most elevator complexes are built in stages rather than one initial and final stage. That is, for example, initially a 300,000 bushel structure may be built and serve the area adequately. However, over time, production per acre has increased, harvesting methods have changed, and storage methods have changed. Consequently, these changes probably mean that the original complex is too small. Therefore, an annex system may be added. This process of annexation is continued over time as the need arises.

The study also assumed the firms could command adequate funds to build any structure desired. In reality this may not be the case. Therefore, certain proposed changes may have to be temporarily foregone. It was not possible, however, to consider the different problems encountered in securing adequate funds for construction and the ramifications of such efforts. This issue in itself could well serve as a topic for additional research.

Although a number of assumptions used in this study deviated from reality, it is believed no serious problems were created. What is essential to remember is that conditions and prices do vary from area to area. To apply the logic developed in this study merely requires one to modify slightly the assumptions used in this project. That is, for example, an elevator manager in a given area may face a slightly different construction cost schedule due to the land formulation in his locality. However, after all modifications have been made, the approach to use would be that developed in this study.

The elevator problem for Iowa has had very little attention given to it in any of the previous literature. In fact no literature concerning this specific issue for the state of Iowa was found. Although this study considered the problem in depth, more research and statistical analysis is needed (16). For example, a study could be conducted wherein a smaller unit than the entire state would be considered. That is, a study for a particular county or a group of counties could be conducted. A study of this magnitude would allow the researcher to consider the variables peculiar to that area, such as soil conditions and transportation costs.

A study could also be initiated to determine and analyze the factors which affect the construction cost of elevators. This study could divide the state into various subdivisions and determine the construction cost at a given locality. Paralleling this approach would be a study to determine the transportation rates at various points throughout the state and the factors which influence these rates. In other words, more general background research would be of value.

Even though this study does have a number of limitations, it should be of value to elevator managers, and other individuals concerned with grain handling and grain storage facilities.

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APPENDIX

Table 6. Corn for grain: percent of acreage harvested by designated methods, Iowa and selected states, 1965-1968[a]

Area	Mechanical picker				Field picker-sheller				Corn head on combine				Other[b]			
	1965	1966	1967	1968	1965	1966	1967	1968	1965	1966	1967	1968	1965	1966	1967	1968
	percent				percent				percent				percent			
Iowa Districts																
Northwest	85.4	77.6	73.5	67.4	4.6	5.5	5.6	4.0	10.0	16.9	20.9	27.1				1.5
North Central	74.0	64.8	55.7	53.0	4.8	6.9	9.3	7.8	21.2	28.3	34.8	38.9			0.2	0.3
Northeast	79.5	76.0	62.4	59.9	4.2	5.2	11.3	8.0	15.7	17.8	25.7	31.2	0.6	1.0	0.6	0.9
West Central	75.6	67.9	66.3	63.9	6.8	7.6	4.2	5.6	17.6	24.5	29.5	30.5				
Central	69.7	59.9	51.2	53.7	8.2	6.5	7.2	9.2	22.1	33.6	41.6	35.9				1.2
East Central	75.8	65.1	57.5	55.0	4.1	8.3	8.9	10.3	20.0	26.4	33.3	34.2	0.1	0.2	0.3	0.5
Southwest	77.6	65.9	65.9	56.3	7.0	5.9	10.7	10.0	15.4	28.2	23.4	33.7				
South Central	78.3	73.7	69.0	48.6	4.8	3.1	7.1	11.1	16.9	22.3	23.7	39.0		0.9	0.2	1.3
Southeast	57.6	44.6	45.1	42.4	7.1	10.3	6.6	9.1	35.3	44.7	48.1	47.7		0.4	0.2	0.8
IOWA	75.2	66.2	60.5	56.6	5.8	6.8	7.7	7.9	18.9	26.9	31.5	34.6	0.1	0.1	0.3	0.9
Illinois	46.5	43.0	36.0	35.0	8.5	8.5	8.0	8.0	45.0	48.5	56.0	57.0	X[c]	X[c]	X[c]	X[c]
Indiana	44.0	33.7	28.8	32.0	7.6	6.7	8.7	8.4	47.7	59.3	62.2	58.8	0.7	0.3	0.3	0.8
Minnesota	XX[d]	XX[d]	58.4	51.6	XX[d]	XX[d]	9.4	8.0	XX[d]	XX[d]	31.4	40.3	XX[d]	XX[d]	0.8	0.1

[a] Source: (11, p. 2).

[b] Mostly husked by hand.

[c] Less than 0.5 percent reported.

[d] Not available.

Table 7. Corn for grain: methods of handling at harvest, Iowa and selected states, 1965-1968[a]

Area	Marketed direct from field				Stored on farms								Stored by producer off-farm			
					In silos				In cribs, bins, or piles							
	1965	1966	1967	1968	1965	1966	1967	1968	1965	1966	1967	1968	1965	1966	1967	1968
	percent				percent				percent				percent			
Iowa Districts																
Northwest	2.4	9.9	6.6	10.4	3.5	3.6	3.3	6.8	92.5	82.2	82.5	73.8	1.6	4.3	7.6	9.0
North Central	7.1	8.5	8.3	12.1	3.7	4.1	3.8	4.0	87.8	80.5	75.9	74.8	1.4	6.9	12.0	9.1
Northeast	7.7	8.8	7.3	9.4	2.7	1.7	2.3	2.2	88.0	87.0	84.3	85.7	1.6	2.5	6.1	2.7
West Central	8.6	11.3	6.1	14.1	3.3	3.5	3.6	7.2	86.7	76.9	83.7	73.0	1.4	8.3	6.6	5.7
Central	7.2	7.0	6.1	10.2	0.5	0.6	1.9	0.7	87.3	79.2	79.1	81.1	5.0	13.2	12.9	8.0
East Central	8.8	7.7	7.7	12.7	3.5	6.7	2.8	2.3	85.8	81.0	83.4	83.1	1.9	4.6	6.1	1.9
Southwest	6.7	7.0	4.0	3.6	2.0	4.7	1.8	6.0	86.5	83.2	86.1	83.8	4.8	5.1	8.1	6.6
South Central	7.1	10.1	9.6	12.6	0.2	0.1		6.1	91.4	86.9	80.3	73.5	1.3	2.9	10.1	7.7
Southeast	13.3	8.0	9.3	14.3	3.7	1.0	2.9	0.5	76.0	80.3	68.8	74.6	7.0	10.7	19.0	10.6
IOWA	7.5	8.7	7.0	11.3	2.7	3.1	2.8	3.8	86.9	81.2	80.5	78.1	2.9	7.0	9.7	6.8
Illinois	25.0	18.0	17.5	16.5	3.0	3.0	4.0	4.0	66.0	68.5	64.5	69.0	6.0	10.5	14.0	10.5
Indiana	31.0	30.3	31.4	27.4	2.5	1.9	2.1	2.1	55.5	54.5	50.9	59.3	9.1	10.7	12.8	9.4
Minnesota	X[b]	X[b]	11.5	16.7	X[b]	X[b]	5.8	6.4	X[b]	X[b]	77.7	74.6	X[b]	X[b]	5.0	2.3

[a] Source: (11, p. 2).

[b] Not available.

Table 8. Assembly cost rates - direct from field to elevator

Miles	Cost/bu.
1	.0250
2	.0275
3	.0300
4	.0325
5	.0325
6	.0350
7	.0350
8	.0375
9	.0375
10	.0400
11	.0400
12	.0425
13	.0425
14	.0450
15	.0450
16	.0450
17	.0500
18	.0500
19	.0500
20	.0550
21	.0550
22	.0550
23	.0550
24	.0550
25	.0600

Table 9. Assembly cost associated with various densities with one plant in a 24 x 24 mile square

Miles	Weighted cost/bu.	Densities							
		5,000	10,000	15,000	20,000	25,000	30,000	35,000	40,000
1	.025000	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
2	.026670	1,600	3,200	4,800	6,400	8,000	9,600	11,200	12,800
3	.028333	3,400	6,800	7,200	13,600	17,000	20,400	23,800	27,200
4	.030000	6,000	12,000	18,000	24,000	30,000	36,000	42,000	48,000
5	.030834	9,250	18,500	27,750	37,000	46,250	55,500	64,750	74,000
6	.032023	13,450	26,900	40,350	53,800	67,250	80,700	94,150	107,600
7	.032767	18,350	36,700	55,050	73,400	91,750	110,100	128,450	146,800
8	.033819	24,250	48,700	73,050	97,400	121,750	146,100	170,450	194,800
9	.034556	31,100	62,200	93,300	124,400	155,500	186,600	217,700	248,800
10	.035545	39,100	78,200	117,300	156,400	195,500	234,600	273,700	312,800
11	.036288	47,900	95,800	143,700	191,600	239,500	287,400	335,300	383,200
12	.037244	58,100	116,200	174,300	232,400	290,500	348,600	406,700	464,800
13	.037893	67,450	134,900	202,350	269,800	337,250	404,700	472,150	539,600
14	.038611	76,450	152,900	229,350	305,800	382,250	458,700	535,150	611,600
15	.039143	84,550	169,100	253,650	338,200	422,750	507,300	591,850	676,400
16	.039547	91,750	183,500	275,250	367,000	458,750	550,500	642,250	734,000
17	.040142	98,750	197,500	296,250	395,000	493,750	252,500	691,250	790,000
18	.040601	104,750	209,500	314,250	419,000	523,750	628,500	733,250	838,000
19	.040951	109,750	219,500	329,250	439,000	548,750	658,500	768,250	878,000
20	.041359	114,150	228,300	342,450	456,600	570,750	684,900	799,050	913,200
21	.041649	117,450	234,900	352,350	469,800	587,250	704,700	822,150	939,600
22	.041836	119,650	239,300	358,950	478,600	598,250	717,900	837,550	957,200
23	.041927	120,750	241,500	362,250	483,000	603,750	724,500	845,250	966,000

Table 10. Assembly cost with non-square trade area

Miles from plant (1)	No. of nodes (2)	No. of bu. (3)	Cum. bu. (4)	Cost per bu. (5)	Total cost (3x5) (6)	Cum. cost (7)	Cum. cost per bu. (8)
1	4	20,000	20,000	.0250	500	500	.0250
2	8	40,000	60,000	.0275	1,100	1,600	.0267
3	12	60,000	120,000	.0300	1,800	3,400	.0283
4	16	80,000	200,000	.0325	2,600	6,000	.0300
5	20	100,000	300,000	.0325	3,250	9,250	.0308
6	24	120,000	420,000	.0350	4,200	13,450	.0320
7	28	140,000	560,000	.0350	4,900	18,350	.0328
8	32	160,000	720,000	.0375	6,000	24,350	.0338
9	36	180,000	900,000	.0375	6,750	31,100	.0345
10	40	200,000	1,100,000	.0400	8,000	39,100	.0355
11	44	220,000	1,320,000	.0400	8,800	47,900	.0363
12	48	240,000	1,560,000	.0425	10,200	58,100	.0372
13	52	260,000	1,820,000	.0425	11,050	69,150	.0380
14	56	280,000	2,100,000	.0450	12,600	81,750	.0389
15	60	300,000	2,400,000	.0450	13,500	95,250	.0397
16	64	320,000	2,720,000	.0450	14,400	109,650	.0403
17	68	340,000	3,060,000	.0500	17,000	126,650	.0414
18	72	360,000	3,420,000	.0500	18,000	144,650	.0423
19	76	380,000	3,800,000	.0500	19,000	163,650	.0431
20	80	400,000	4,200,000	.0550	22,000	185,650	.0442
21	84	420,000	4,620,000	.0550	23,100	208,750	.0452
22	88	440,000	5,060,000	.0550	24,200	232,950	.0461
23	92	460,000	5,520,000	.0550	25,300	258,250	.0468
24	96	480,000	6,000,000	.0550	26,400	284,650	.0474
25	100	500,000	6,500,000	.0600	30,000	314,650	.0484

Table 11. Construction cost of various size elevator models

Model size	Total cost	Cost/bu.
350,000	232,050	0.663
500,000	336,690	0.673
1,000,000	570,444	0.570
1,500,000	804,190	0.536
2,000,000	1,037,940	0.518
2,500,000	1,271,690	0.509
3,000,000	1,505,440	0.502
3,500,000	1,739,190	0.497
4,000,000	1,972,940	0.493

Table 12. Land cost associated with each model

Model size	No. of acres	Price per acre	Total cost
350,000	1.0	5,000	5,000
500,000	1.0	5,000	5,000
1,000,000	1.5	5,000	7,500
1,500,000	2.0	5,000	10,000
2,000,000	3.0	5,000	15,000
2,500,000	3.5	5,000	17,500
3,000,000	4.5	5,000	22,500
3,500,000	5.5	5,000	27,500
4,000,000	6.0	5,000	30,000

Table 13. Equipment cost for each model

Model size	Total cost	
350,000	72,945	
500,000	83,070	
1,000,000	116,820	
1,500,000	150,570	
2,000,000	212,815 --	add scale ($17,995) add two outside pits ($6,000 & $4,500)
2,500,000	246,565	
3,000,000	284,815 --	add outside pit ($4,500)
3,500,000	318,565	
4,000,000	356,815 --	add outside pit ($4,500)

Table 14. Drier cost for each model size[a]

Model size	Drier size (bu./hour)	Total drier equip. cost
350,000	1,500	59,944
500,000	2,000	71,989
1,000,000	2,000	71,989
1,500,000	3,000	101,129
2,000,000	2,000 and 1,500	131,933
2,500,000	2,000 and 2,000	143,978
3,000,000	2,000 and 3,000	173,118
3,500,000	2,000 and 3,000	173,118
4,000,000	3,000 and 3,000	202,258

[a] Source: cost estimates, Mr. Arendts, Campbell Indus., Des Moines, Iowa.

Table 15. Aeration equipment

Model size	Total cost
350,000	3,314
500,000	3,314
1,000,000	8,531
1,500,000	13,502
2,000,000	18,719
2,500,000	23,690
3,000,000	28,661
3,500,000	33,632
4,000,000	38,603

Table 16. Heat detection[a]

Model size	Total cost	Cost/bu.
350,000	6,109	.0174
500,000	11,576	.0232
1,000,000	15,412	.0154
1,500,000	18,018	.0120
2,000,000	21,314	.0106
2,500,000	23,516	.0094
3,000,000	25,218	.0083
3,500,000	26,632	.0076
4,000,000	28,106	.0072

[a] Source: Mr. William Sturtz, Rolfs, Boone, Iowa.

Table 17. Feet of railroad siding required by each model size

Model size	No. of feet required	Cost/foot (dollars)	Total footage cost (dollars)	Switch cost (dollars)	Total cost (dollars)
350,000	300	14	4,200	3,000	7,200
500,000	300	14	4,200	3,000	7,200
1,000,000	380	14	5,320	3,000	8,320
1,500,000	460	14	6,440	3,000	9,440
2,000,000	460	14	6,440	3,000	9,440
2,500,000	520	14	7,280	3,000	10,280
3,000,000	600	14	8,400	3,000	11,400
3,500,000	680	14	9,520	3,000	12,520
4,000,000	760	14	10,640	3,000	13,640

Table 18. Utility cost for various size elevators

Model size	Utility cost
350,000	3,918
500,000	6,579
1,000,000	12,993
1,500,000	18,911
2,000,000	24,892
2,500,000	30,873
3,000,000	36,975
3,500,000	42,729
4,000,000	48,784

Table 19. Repair cost per year for selected elevator sizes

Model size (bushels)	Total cost[a] (dollars)
350,000	1,987
500,000	2,412
1,000,000	2,660
1,500,000	2,890[b]
2,000,000	3,125[b]
2,500,000	3,310[b]
3,000,000	3,500[b]
3,500,000	3,825[b]
4,000,000	4,250[b]

[a] Source: Farmers Grain Dealers Association survey.

[b] Estimated.

Table 20. Labor cost associated with the operation of elevators of various sizes

Model size	Laborers needed (total man-years)	Total cost
350,000	1.22	(7,300)(1) + (.22)(6,300) = $ 8,686
500,000	1.37	(7,400)(1) + (.37)(6,378) = $ 9,759
1,000,000	1.71	(7,735)(1) + (.71)(6,614) = $12,430
1,500,000	2.25	(8,070)(1) + (1.25)(6,900) = $16,695
2,000,000	2.54	(8,390)(1) + (1.44)(7,175) = $18,772
2,500,000	2.70	(8,710)(1) + (1.75)(7,450) = $21,748
3,000,000	3.04	(9,030)(1) + (2.03)(7,725) = $24,789
3,500,000	3.19	(9,350)(1) + (2.19)(8,000) = $26,870
4,000,000	3.39	(9,684)(1) + (2.39)(8,280) = $29,473

Table 21. Property tax incurred on a per year basis

Model size	Total value of plant and equipment (dollars)	Total tax[a] (dollars)
350,000	374,854	1,021
500,000	507,131	1,369
1,000,000	784,176	2,117
1,500,000	1,089,131	2,941
2,000,000	1,424,935	3,847
2,500,000	1,712,391	4,623
3,000,000	2,020,942	5,456
3,500,000	2,295,565	6,198
4,000,000	2,603,888	7,030

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[a] Tax rate: \$10/\$1,000 of taxable assessed value; total value x 27% = taxable value.

Table 22. Insurance cost on plant and equipment

Model size	Value of plant and equipment (dollars)	Total cost (dollars)
350,000	374,854	375
500,000	507,131	507
1,000,000	784,186	784
1,500,000	1,089,131	1,089
2,000,000	1,424,935	1,425
2,500,000	1,712,391	1,712
3,000,000	2,020,942	2,021
3,500,000	2,295,565	2,296
4,000,000	2,603,888	2,604

Table 23. Depreciation on buildings, driers, aeration equipment, plant equipment, and heat detection equipment

Model size	Depr. on buildings	Depr. on drier(s) and aeration	Depr. on equip. and heat detection	Total depr.
350,000	6,961	6,326	5,270	18,557
500,000	10,100	7,530	7,718	25,348
1,000,000	17,113	8,052	8,816	33,981
1,500,000	24,125	11,463	11,240	46,828
2,000,000	31,138	15,065	15,609	61,812
2,500,000	38,150	16,767	18,006	72,923
3,000,000	45,163	20,178	20,670	86,011
3,500,000	52,175	20,675	23,014	95,864
4,000,000	59,188	24,086	25,663	108,937

Table 24. Interest on investment on land and railroad siding

Model size	Interest charge
350,000	$ 976
500,000	$ 976
1,000,000	$1,265
1,500,000	$1,555
2,000,000	$1,955
2,500,000	$2,222
3,000,000	$2,712
3,500,000	$3,201
4,000,000	$3,491

Table 25. Total in-plant cost associated with various elevator model sizes

Model size	Depr. cost/ year	Interest on invest.	Repairs	Labor cost	Property tax	Ins. cost	Utilities	Total	Cost/bu.
350,000	18,557	976	1,987	8,686	1,021	375	3,918	35,520	(.1014)[a] (.0676)[b]
500,000	25,348	976	2,412	9,759	1,369	507	6,579	46,950	(.0939) (.0626)
1,000,000	33,981	1,265	2,660	12,430	2,117	784	12,993	66,230	(.0662) (.0441)
1,500,000	46,828	1,555	2,890	16,695	2,941	1,089	18,911	90,909	(.0606) (.0404)
2,000,000	61,812	1,955	3,125	18,772	3,847	1,425	24,892	115,828	(.0579) (.0386)
2,500,000	72,923	2,222	3,310	21,748	4,623	1,712	30,873	137,411	(.0549) (,0366)
3,000,000	86,011	2,712	3,500	24,789	5,456	2,021	36,975	161,464	(.0538) (.0358)
3,500,000	95,864	3,201	3,825	26,870	6,198	2,296	42,729	180,983	(.0517) (.0344)
4,000,000	108,937	3,491	4,250	29,473	7,030	2,604	48,784	204,569	(.0511) (.0340)

[a] Cost per bushel calculated on the volume of storage.

[b] Cost per bushel calculated on the total bushels handled.

Table 26. Total assembly cost associated with various model sizes and various marketing densities

Model size	Total bu. handled	Density					
		5,000	10,000	15,000	20,000	25,000	30,000
350,000	525,000	$ 17,125	$ 16,062	$ 15,562	$ 15,062	$ 14,750	$ 14,550
500,000	750,000	$ 25,475	$ 23,750	$ 22,875	$ 22,375	$ 21,875	$ 21,375
1,000,000	1,500,000	$ 55,550	$ 50,950	$ 48,350	$ 47,500	$ 46,250	$ 45,750
1,500,000	2,250,000	$ 88,500	$ 80,200	$ 76,425	$ 73,775	$ 72,500	$ 71,250
2,000,000	3,000,000	$123,650	$111,100	$105,300	$103,900	$ 99,250	$ 97,500
2,500,000	3,750,000	$161,150	$143,250	$135,300	$130,400	$127,375	$120,975
3,000,000	4,500,000	$202,100	$177,000	$166,650	$160,400	$155,500	$152,850
3,500,000	5,250,000	$243,400	$210,750	$198,525	$190,200	$185,500	$180,975
4,000,000	6,000,000	$284,650	$247,300	$231,750	$222,200	$215,500	$210,600

Table 27. Total cost, including total in-plant cost and assembly cost, calculated on a yearly basis for selected model sizes

Model Size	5,000	10,000
350,000	(.1504)[a]	(.1473)
	(.1002)[b]	(.0982)
	52,645[c]	51,582
500,000	(.1448)	(.1414)
	(.0965)	(.0942)
	72,425	70,700
1,000,000	(.1218)	(.1171)
	(.0811)	(.0781)
	121,780	117,180
1,500,000	(.1196)	(.1140)
	(.0797)	(.0760)
	179,409	171,109
2,000,000	(.1197)	(.1134)
	(.0798)	(.0756)
	239,478	226,928
2,500,000	(.1194)	(.1122)
	(.0796)	(.0748)
	298,561	280,661
3,000,000	(.1211)	(.1128)
	(.0807)	(.0752)
	363,564	338,464
3,500,000	(.1212)	(.1119)
	(.0808)	(.0746)
	424,383	391,733
4,000,000	(.1223)	(.1129)
	(.0815)	(.0753)
	489,219	451,869

[a] Cost per bushel calculated by dividing the total cost by the volume of storage capacity.

[b] Cost per bushel calculated by dividing the total cost by the volume of bushels handled.

[c] Total yearly cost.

Density			
15,000	20,000	25,000	30,000
(.1459)	(.1445)	(.1436)	(.1430)
(.0972)	(.0963)	(.0957)	(.0953)
51,082	50,582	50,270	50,070
(.1396)	(.1386)	(.1376)	(.1366)
(.0931)	(.0924)	(.0917)	(.0911)
69,825	69,325	68,825	68,325
(.1145)	(.1137)	(.1124)	(.1119)
(.0763)	(.0758)	(.0749)	(.0746)
114,580	113,730	112,480	111,980
(.1115)	(.1097)	(.1089)	(.1081)
(.0743)	(.0731)	(.0726)	(.0720)
167,334	164,684	163,409	162,159
(.1105)	(.1098)	(.1075)	(.1066)
(.0737)	(.0732)	(.0716)	(.0711)
221,128	219,728	215,078	213,328
(.1090)	(.1071)	(.1059)	(.1033)
(.0727)	(.0714)	(.0706)	(.0689)
272,711	267,811	264,786	258,386
(.1093)	(.1072)	(.1056)	(.1047)
(.0729)	(.0715)	(.0704)	(.0698)
328,114	321,864	316,964	314,314
(.1084)	(.1060)	(.1047)	(.1034)
(.0722)	(.0707)	(.0698)	(.0689)
379,508	371,183	366,483	361,958
(.1090)	(.1066)	(.1050)	(.1037)
(.0727)	(.0711)	(.0700)	(.0691)
436,319	426,769	420,069	415,169