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Economies of scale in grain train loading facilities: A case study

by

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CHAPTER I. INTRODUCTION AND OBJECTIVES

Introduction

Historically, the grain elevators in Iowa and the Midwest were located close to the farms they served, with the movement of grain from farms tied closely first to the horse and wagon and then to small farm tractors and wagons. The country elevator shipped the grain in random single-car movements to processors and eastern consumption points using the "standard" 40-foot box car with little volume moving to export points. Thus, a proliferation of small country elevators and light branch rail lines emerged in Iowa.

This structure for grain distribution resulted in relatively stable price relationships between origins and final markets. But recent changes in the supply of and demand for corn and soybeans and innovations in grain harvesting and transportation have created serious problems in the grain distribution system. Corn and soybeans are becoming increasingly important products in domestic and foreign trade. From 1962-63 to 1972-73, U.S. corn and soybean production increased from 4.3 billion bushels to 6.8 billion bushels. During this same time period, corn and soybean exports increased from 538 million bushels to 1.5 billion bushels (17, 18).

The increases in grain production and grain exports are not the only factors contributing to the grain transportation and storage problems. Innovations in grain harvesting and transportation equipment along with the development of a good highway system have permitted farmers to move large quantities of corn and soybeans into storage or to market in short periods of time. On a state-wide basis the proportion of the fall corn movement shipped to elevators has increased from ten percent in 1964, to 32 percent in 1972 (8). This, coupled with railroad branch line abandonment and periodic shortages in transportation equipment, has often forced elevator operators to store thousands of bushels of corn on streets and roads.

Innovations have also occurred in the transportation system. The 2,000 bushel-capacity box car is rapidly being replaced by the jumbo covered hopper car, capable of hauling up to 3,300 - 3,500 bushels of grain. The number of 40-foot box cars in the United States has declined from 563,470 in 1960 to 164,662 in 1974. During the same period of time, covered hopper cars increased from 64,255 to 204,926 cars.

In addition to encouraging the use of larger size rail cars for the transport of grain, railroads have issued multiple-car rates which are significantly lower than single-car rates. For example, from a station near Fort Dodge, Iowa, the single-car export rate for shipping corn to the Gulf is 27 cents per bushel; the 25-car rate to the Gulf is 24 cents per bushel; and the 50-car rate is only 22.4 cents per bushel.

These innovations, however, have not solved the grain transportation problems. Many of the rail lines in Iowa's grain producing regions are incapable of carrying the heavy hopper cars and the multiple-car trains. With the declining number of 40-foot box cars, the country elevator on a light branch rail line is faced with a serious marketing disadvantage.

A recent grain transportation study of the Fort Dodge, Iowa area completed at Iowa State University (2) (here after referred to as the Iowa State study) suggests that a cooperative system of country elevators and train loading facilities on heavy rail lines would be more economical and efficient for the entire grain marketing industry than the traditional system of random single-car shipments. The study indicates that net revenue to a producing area could be significantly increased if the grain was moved in large volume multi-car shipments.

During the first two years following the introduction of multiple-car rates into Iowa in 1971, over 54 locations were upgraded or built new facilities to handle multiple-car units (3). But, many uncertainties and questions still exist. Where should train loading facilities be located and how large should they be? How far apart should the facilities be? The overall purpose of the analysis presented here is to answer some of these questions and to determine the economies of size of alternative size train loading facilities (25-, 50-, 75-, and 120-car) with various potential market area sizes, taking into account the existing country elevator capacities within these areas.

Objectives

The specific objectives of this study are:

1. Estimate the economies of size in alternative size train loading facilities based on (a) an engineering cost simulation for

a specific site, when existing country elevator facilities within the various potential market area sizes are used as collection points and the grain is transshipped to train loading facilities and (b) an engineering cost simulation which assumes away existing facilities at country elevators.

2. Compare the grain marketing costs obtained in the analysis when existing country elevator facilities are used as collection points for transshipment to subterminals with the costs obtained in the analysis which omits existing facilities at country elevators.
3. Synthesize grain delivery costs for farmers and elevator operators shipping grain to train loading facilities.
4. Estimate the optimal train loading facility size and market area for given densities of grain sold through commercial channels.

CHAPTER II. ANALYSIS OF GRAIN MARKETING COSTS

The typical costs considered in the analysis of the optimum size of grain elevator facilities include three major segments: (1) the internal plant costs of grain handling and processing, (2) the assembly costs of moving grain from the farms to the elevators, and (3) an integration of internal plant costs and grain assembly costs to determine the optimal elevator size and market area. The present analysis is not only concerned with the in-plant costs of subterminals and the cost of moving grain from farms to the subterminal but additionally the operating costs at country elevators and the cost of moving grain from farms to country elevators to subterminals. It is also concerned with the cost savings -- in the form of reduced transportation rates -- for large volume shipments at the subterminals.

The cost curves presented in Figure 1 show the typical cost curves usually considered in the optimum facility analysis. Average costs, in dollar units, are shown on the vertical axis. Volume, in bushels, is shown on the horizontal axis. The curve APC represents the long-run average in-plant production cost. Typically, this curve decreases at a decreasing rate as plant volume increases, reflecting the economies of scale as volume increases. The assumptions implicit in the shape of the APC curve are a constant cost level for all inputs and a given state of technology.

Curve AA represents the average assembly costs for grain moving from farms to elevators as volume per plant varies. This curve typically increases at a decreasing rate as plant volume and trade area size is increased. It assumes that marketing densities, assembly methods, and assembly costs remain unchanged as plant volume and market area varies.

The summation of the two curves, APC and AA, yields the curve CAC, the combined average cost of in-plant and assembly costs. As volume increases, this curve decreases at a decreasing rate until it reaches a minimum and then increases at an increasing rate. The minimum point occurs when the AA curve increases at a faster rate than the APC curve decreases.

Review of Previous Elevator Cost Studies

The economies of scale in grain elevators has been considered by various authors over time. Yu analyzed 1964 annual accounting records of 206 country elevators in Indiana (20). Cost-volume information provided in these records was used as the basis to estimate long-run internal plant cost functions by multiple regression techniques. All assembly or distribution costs were considered in determining the optimum size in addition to the internal plant costs. The author assumed no duplication or overlapping in assembly or distribution areas.

Yu found the estimated combined least cost volume for grain merchandizing, using a two-ton truck for assembly, at a marketing density of 15 thousand bushels per square mile to be 4.2 million bushels, requiring an 11.8 mile radius trade area. At the 25 thousand bushel density, the least cost volume was 5.0 million bushels, requiring a radius of 9.9 miles. As the density increased, the minimum cost volume increased and the required trade area size decreased.

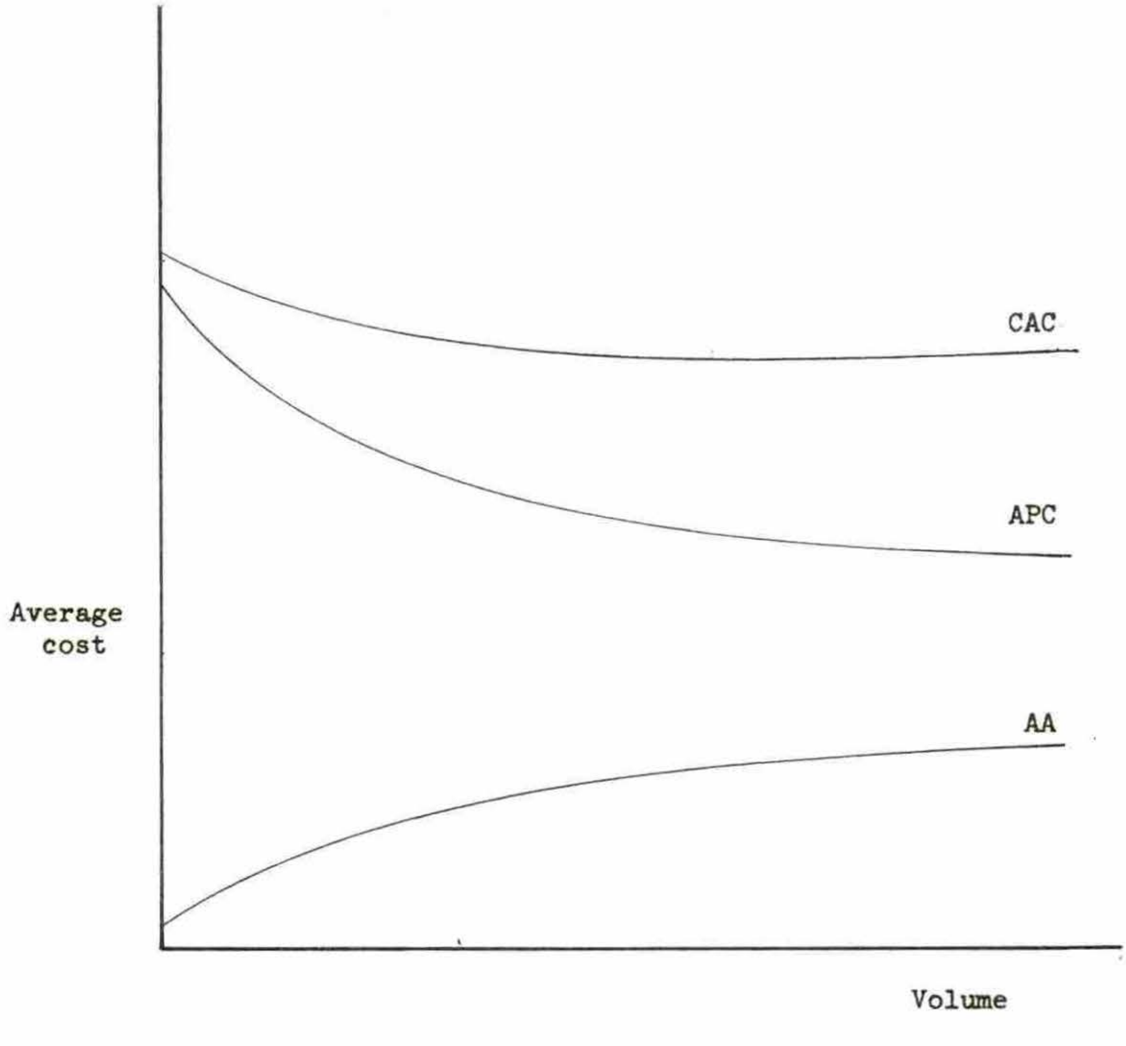

Figure 1. Hypothetical volume-cost relationships in grain elevators including typical in-plant and assembly costs.

In 1969, Halverson found significant economies of scale existing in grain elevator operations (5). Halverson used engineering cost estimates to consider elevators ranging in size from 350 thousand to four million bushels in storage capacity.

The in-plant costs for each elevator size were estimated based on 80 percent corn and 20 percent soybean receipts and a 1.5 turnover rate of storage capacity. Approximately 80 percent of the annual grain volume would be received during the fall harvest season. Assembly costs were based on the prevalent truck rates charged for a 300 bushel truck.

Using this turnover rate, the cost per bushel in the smallest model was 6.76 cents, compared to 3.40 cents per bushel in the largest model. With a marketing density of five thousand bushels per square mile, the minimum cost range was reached in the model size of 1.5 million to 2.5 million bushels. Past the 2.5 million bushels, slight increases in cost occurred. With a marketing density of 25 thousand bushels per square mile, the minimum cost size was 2.5 million bushels. Again, as the density was increased, the optimum volume increased and the average cost per bushel decreased slightly.

In 1971, Mikes estimated the economies of scale in country elevators based on a statistical analysis of cost data from 168 elevators and on an engineering cost simulation of alternative size model elevators (10). The author used an assembly cost function based on a linear regression of the truck rates used in the Halverson study. The engineering cost analysis was also based on the basic data in the

Halverson model with some modifications. The modification of the Halverson model resulted in an increased cost per bushel. For example, Halverson found a cost of 6.8 cents per bushel in the 350 thousand bushel model compared to 15.2 cents in the analysis by Mikes.

The analysis by Mikes resulted in the average total cost at a 1.5 turnover rate declining from 14.1 cents per bushel in the 500 thousand bushel size to 10.6 and 8.5 cents per bushel in the one million and four million bushel sizes, respectively. The author concluded: "Most of the economies of size are captured in the movement from the 500 thousand bushel size elevator to the one million bushel size elevator" (10, page 108).

The statistical analysis by Mikes resulted in a cost curve that tended to flatten out at a lower volume and slightly lower average cost than the engineering cost curve. The variation in the two cost curves was greatest at the lower volumes and decreased as volume levels increased. Thus, the engineering simulation model exhibited greater economies of scale than the statistical cost model. The author suggests that one of the factors that contributes to this discrepancy is that the engineering model is based largely on a specialized grain handling operation, whereas the statistical cost model is from multi-product firms.

Present Analysis

The present study uses the economic engineering approach to analyze the economies of size in grain train loading facilities (subterminals) through two different procedures. The first procedure uses a case study approach to find the optimal subterminal size for a specific market area under the assumption that grain would be received by country elevators at harvest and transshipped through the subterminal to market. The second procedure assumes the subterminal would receive all of the grain in the market area directly from farms. The conventional cost analysis presented in the beginning of this chapter is used in this latter procedure. The basic model and method of solution for the case study approach will be presented here. The deletion of all elements in this model that pertain to country elevators results in the model used for the second procedure.

Description of case area

In the Iowa State University grain transportation study, system costs, potential subterminal locations, rail line networks, and selected multiple-car rates were evaluated on the basis of the transportation system yielding the greatest net return to a six and one-half county area around Fort Dodge, Iowa (2). The system that would return the highest net revenue to the area would use six large subterminal elevators on mainline railroads, each loading up to 18 million bushels of grain per year into 115-car trains running continuously to the Gulf of Mexico ports.

To obtain this type of system, cooperation between country elevators and the subterminal in an area is essential. The country elevators would be needed to receive and dry grain during harvest, and then store the grain until the subterminal could ship the grain out in large multiple-car shipments. The subterminal would be needed to receive grain at harvest time directly from farms located only a short distance away from the subterminal. After harvest, grain from a much larger market area would be shipped directly to the subterminal for loading into large multiple-car trains. Thus, the purpose of this case study is to analyze the grain marketing costs in a market area and derive the optimum market area size for this type of system.

The specific subterminal site used in the case study analysis is one of the potential subterminal sites selected in one of the higher net revenue solutions of the Iowa State study. It is located in a heavy cash-grain producing region which currently has a commerical grain density of almost 30,000 bushels per square mile. Many country elevators are located in the area surrounding the subterminal location and range in size from 186 thousand bushels to 1.2 million bushels. The total storage capacity of the country elevators located selected distances from the subterminal site are presented in Table 1.

Many of the country elevators in the area surrounding the subterminal site are located on either light branch rail lines or on abandoned rail lines. Coordination between these country elevators and the subterminal is assumed in the case study analysis. All of the commercial grain received by country elevators from a specified market area size surrounding the subterminal would be shipped through the subterminal to market. This study deals only with commercial grain which was defined as grain moving out of the local region where it was produced.

The grain handling and storage investments existing at country elevators are considered to be "sunk" costs. No investment costs are

Table 1. Number and total storage capacity of country elevators located selected distances from the subterminal site.

Distance from subterminal site (miles)	Number of country elevators	Total storage capacity of country elevators (bushels)
6	2	730,000
7	2	968,000
8	1	658,000
9	1	408,000
10	1	213,000
11	2	1,730,000
12	3	1,375,000
13	1	723,000
14	1	186,000
15	2	835,000
16	3	2,062,000
17	2	1,135,000
18	1	733,000

charged for these facilities. Only variable operating costs are charged to existing facilities.

Costs are synthesized for selected size train loading facilities: 25-car, 50-car, 75-car, and 120-car. All model subterminal sizes were designed to harmonize their receiving and drying capacities with the expected annual volumes that could be handled by each subterminal size. The load-out capacities required at subterminals were based on the volume and time requirements of the corresponding multiple-car rail tariffs. The storage capacity was made a function of the receipt and shipment patterns of the subterminal subject to a minimum storage capacity. In the following three major sections, the economic theory and methodology used in developing the costs for each segment of the analysis are presented.

Internal costs

In-plant costs included in the model are the costs of merchandizing, storing and drying grain at country elevators and the subterminal. But, before discussing the framework used to estimate the internal costs, the standard economic theory of short-run and long-run cost curves is reviewed.

Short-run cost curves represent the total and average costs for a fixed plant as its output is varied. In the short-run, the firm cannot alter the size of its plant, but it can vary other inputs and their combination with the fixed plant (4, 6).

In the long-run, all inputs including the plant are variable. Thus, the firm may vary the size of its plant as the level of output is varied.

For a specific plant size, the total cost and average cost curves must always be at least as high at every output level as the total and average cost curves when all inputs are variable.

The long-run average cost curve is obtained from the loci of the least cost plant in the short-run for each output level. Consequently, the long-run average cost curve is commonly known as an envelope curve of the short-run average cost curves (Figure 2).

A linear long-run total cost curve has a constant marginal cost which is always less than or equal to the average cost. Thus, economies of scale are definable for increases in output over the relevant output range of the long-run total cost function.

The internal costs estimated in the present analysis are based on equations which assume linear in-plant costs over the relevant range of annual volumes. Several grain elevator cost studies have employed some form of linear long-run total costs (9, 13). The equations developed in this analysis assume a fixed size of plant for each subterminal size with respect to receiving, drying and load-out capacities. But, they allow storage capacity to vary with the receipt and shipping patterns of the market area, subject to a minimum storage requirement for each subterminal size. Since only part of the physical plant at the subterminal is allowed to vary, these equations are referred to as semi long-run cost equations. From these semi long-run cost equations, a series of point estimates are derived which estimate the internal grain marketing costs for the various combinations of subterminal and market area sizes.

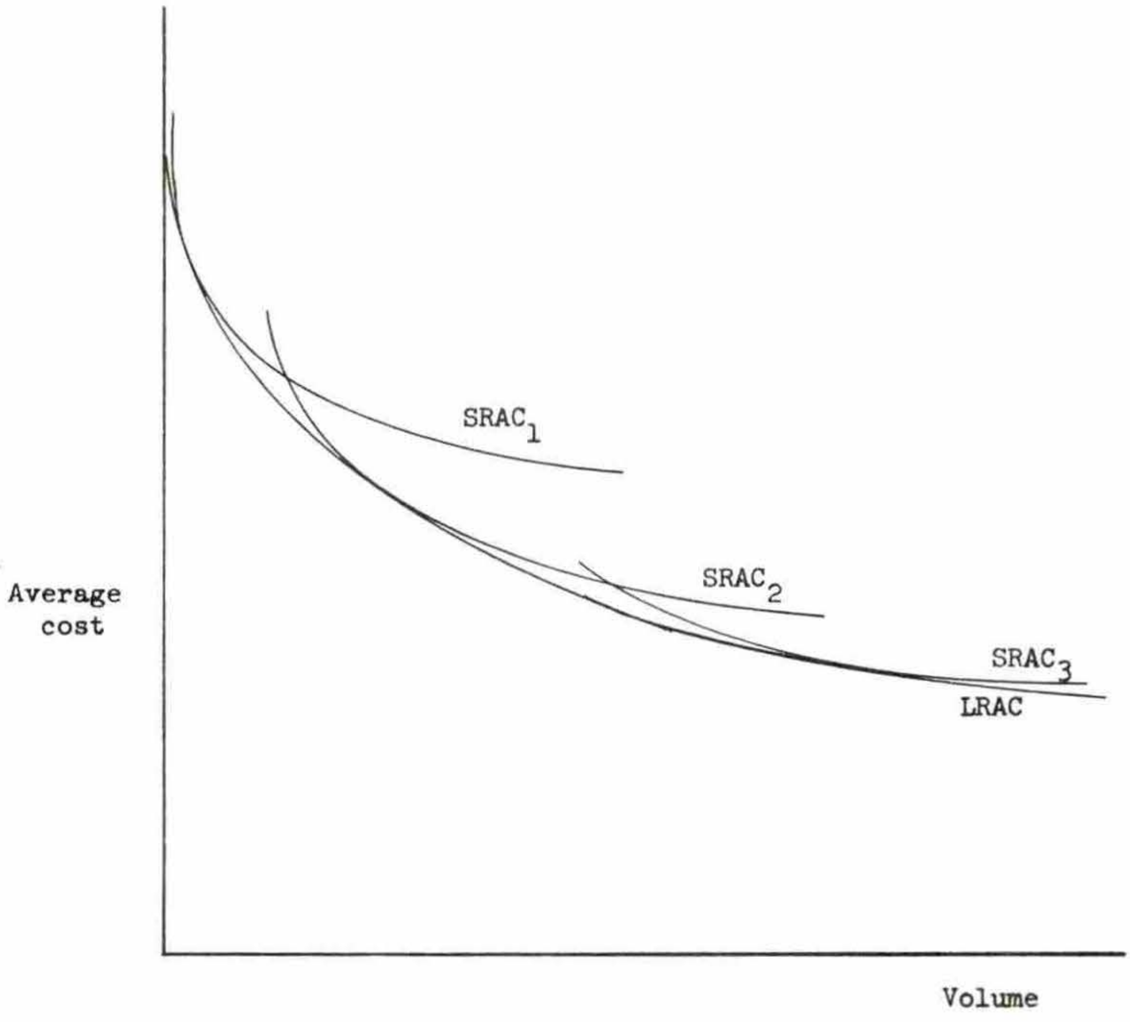

Figure 2. Short-run and long-run average cost curves for an industry with continuous increasing returns to scale over the relevant range of output.

The in-plant costs included in the analysis are divided into three separate grain activities: 1) grain handling and merchandising; 2) grain storage; and 3) grain drying. Grain handling and merchandising at country elevators and the subterminal includes: the buying and selling of grain; the physical receiving and sampling of grain; the blending, grading and loading of grain for shipment; and the office operations associated with grain merchandising. Grain storage consists of moving grain into and out of storage and storing grain for relatively long periods of time at the country elevators or subterminals. The physical handling, conditioning and drying of grain defines grain drying.

Grain handling and merchandising was selected as the primary activity of a subterminal because 1) the abundance of small country elevators within the study area with a large amount of sunk cost in their storage facilities, 2) the merchandising activity is a prerequisite for entering the storage business, and 3) the high opportunity cost faced by farmers in traveling long distances at harvest time.

Grain storage costs are the marginal costs of adding the grain storage activity to the merchandising activity. Once the subterminal is established to merchandise a large volume of grain, the marginal cost of adding the grain storage facilities and operation is relatively low.

The grain drying activity complements both the grain merchandising and storage activities. In order to obtain a share of the high-moisture corn marketed and stored off-farms during the harvest season, a subterminal must be equipped to handle and dry a large volume of corn in a short period of time.

Subterminals require large receiving capacities because they receive grain from both farmers and country elevators. Train loading facilities also require a large load-out capacity because multiple-car freight tariffs allow only 24 hours for loading. Therefore, the equation developed in this analysis to estimate the grain handling and merchandising costs for the various subterminal and market area sizes includes a fixed annual investment cost for receiving and load-out facilities for each size of subterminal. It also considers a fixed management cost for each size of subterminal which reflects the costs incurred by a subterminal that are not solely a function of the volume handled.

In addition to the fixed costs at the subterminal, the marginal handling and merchandising costs at the subterminal and all country elevators located within a specified market area size are included. Thus, the annual cost of handling and merchandising grain for a market area of size n serviced by a specific size subterminal can be expressed by the following equation.

$$(1) \quad TMC_k^n = R_k + L_k + M_k + \sum_{i=1}^{n} \sum_{t=1}^{n} (H^s SV_{it} + H^e EV_{it})$$

where:

TMC_k^n = total merchandising cost for a market area of size n serviced by a subterminal of size k

R_k = annual investment cost in receiving facilities for subterminal size k

L_k = annual investment cost in load-out facilities for subterminal size k

M_k = annual management costs for subterminal size k

k = index for the size of subterminal (1 = 25-car, 2 = 50-car, 3 = 75-car, and 4 = 120-car)

i = index of miles from the subterminal

t = index of months (1 = October, 2 = November, etc.)

H^s = marginal handling and merchandising cost per bushel of grain at the subterminal

SV_{it} = grain volume received by the subterminal from farms and country elevators in the ith mile from the subterminal in month t

H^e = marginal handling and merchandising cost per bushel of grain at the country elevator

EV_{it} = grain volume received by country elevators located in the ith mile from the subterminal in month t

Therefore, the total handling and merchandising cost for a specified market area size consist of the annual investment cost in receiving and load-out facilities at the subterminal, the annual management cost of the subterminal, plus the variable handling costs at the subterminal and the country elevators within the area.

The case study analysis assumes the annual costs of storing grain for a market area are a function of the annual volume and the receipt and shipping patterns of the country elevators and the subterminal in the area. The costs considered in the analysis are the minimum annual investment cost of storage facilities at the subterminal; the marginal annual cost of expanding storage at the subterminal; and, the marginal operating and maintenance cost of storage facilities at the country elevators and the subterminal.

The minimum annual investment cost of storage facilities at the subterminal is assumed to vary by size of subterminal. This cost reflects the annual costs of interest, depreciation, insurance and taxes on the initial investment in the assumed minimum storage facilities required for the selected subterminal sizes.

Since it is possible for elevators or subterminals to expand their storage capacity by adding as little as a 25- or 50-thousand bushel storage tank, this analysis includes a marginal annual expansion cost of storage. This cost reflects the additional costs incurred when the storage capacity of the subterminal is increased by one bushel. The expansion cost is included for all subterminal and market area sizes, subject to the minimum storage capacity requirements of the selected subterminal sizes.

The marginal operating and maintenance cost of storage facilities reflects the average monthly per bushel cost of insurance on inventory, direct labor, utilities and repairs incurred in the operation of storage facilities at the country elevators and the subterminal. Thus, the following equation is used to express the total annual storage costs for a market area of size n serviced by a subterminal of a specific size.

$$(2) \quad TSC_k^n = S_k + EC(DS_k^n) + SC \sum_{t=1}^{12} ST_t^n$$

where:

(3) $$DS_k^n = [\underset{t}{\text{MAX.}} \sum_{t=1}^{12} (\sum_{i=1}^{n} SV_{it}) - VS_t] - SM_k \quad \text{if}$$

$$[\underset{t}{\text{MAX.}} \sum_{t=1}^{12} (\sum_{i=1}^{n} SV_{it}) - VS_t] > SM_k$$

or

(4) $$DS_k^n = 0 \quad \text{if } [\underset{t}{\text{MAX.}} \sum_{t=1}^{12} (\sum_{i=1}^{n} SV_{it}) - VS_t] \leq SM_k$$

and

(5) $$ST_t^n = (\sum_{i=1}^{n} SDV_{it} + EV_{it}) + ST_{t-1} - VS_t$$

The symbols used in the above equations are defined as follows:

TSC_k^n = total annual storage cost for a market area of size n serviced by subterminal size k

S_k = annual investment cost of the minimum required storage facilities at subterminal size k

EC = annual per bushel expansion cost of storage facilities at the subterminal

DS_k^n = difference between the assumed minimum storage capacity requirement of subterminal size k and the storage requirement required by the receipt and shipping patterns of market area size n

SC = marginal monthly per bushel operating and maintenance cost of storage facilities at country elevators and the subterminal

ST_t^n = grain volume in storage at country elevators or subterminal for market area size n at the end of month t

= zero for ST_{12}^n

SV_{it} = grain volume received by the subterminal from farms and country elevators in the ith mileage increment from the subterminal in month t

VS_t = grain volume shipped by the subterminal in month t

SM_k = minimum storage capacity required for subterminal size k

SDV_{it} = grain volume received by the subterminal directly from farms in the ith mileage increment in month t

EV_{it} = grain volume received by country elevators located in the ith mileage increment in month t

Therefore, the total annual storage costs for a specified market area size consist of 1) an annual investment cost for the minimum storage capacity required for each subterminal size, 2) the annual investment cost for any additional storage capacity required at the subterminal due to the receipt and shipping patterns of the market area, and 3) the marginal cost of storing grain at country elevators or the subterminal for longer than one month. Equation 3 and 4 simply say that the storage required by the receipt and shipping patterns cannot be less than the minimum storage assumed for a subterminal of size k. Equation 5 simply defines the ending monthly inventory of grain in storage at the subterminal and country elevators within a specified market area.

Since the investment costs in drying facilities at country elevators are considered to be "sunk" costs, the annual drying costs for a market area are assumed to be a function of the size of dryer at the subterminal, the volume of corn dried at country elevators or the subterminal and the moisture extraction range of the grain dried. Annual investment costs for drying facilities are synthesized for the different size subterminals. The moisture content of corn receipts from farms delivered to country elevators or subterminals was assumed to vary by months. Thus, the annual drying costs for a market area of size n serviced by a specific subterminal size can be expressed by the following equation:

$$(6) \quad TDC_k^n = DD_k + \sum_{t=1}^{12} D_t \sum_{i=1}^{n} (SDV_{it}^c + EV_{it}^c)$$

where:

TDC_k^n = total annual drying cost for a market area of size n serviced by a subterminal size k

DD_k = annual investment cost of drying facilities for subterminal size k

D_t = marginal per bushel drying cost for corn received at the country elevators or subterminal in month t

SDV_{it}^c = direct corn receipts from farms in the ith mileage increment to the subterminal in month t

EV_{it}^c = corn receipts at elevators in the ith mileage increment in month t

Therefore, the total annual drying costs for a specified market area size consist of the annual investment cost for drying facilities at the subterminal plus the variable costs of drying all of the corn within the specified market area.

Grain assembly costs

In addition to the internal plant costs, grain assembly costs are important in estimating the economies of size in subterminals. Grain assembly costs consist of delivery costs from farm to subterminal and country elevator and from country elevator to subterminal. Assembly costs are closely associated with the market area of a subterminal and the density of grain available for commercial sale off-farm.

The market area served by each subterminal is shaped such that the total grain delivery costs are minimized. This analysis assumes that the trade area of a subterminal is served by an East-West, North-South grid road network with grid intervals of one mile and that farmsteads and country elevators are located adjacent to the road. This pattern of road network and farmstead location exists in the study area and is prevalent throughout Iowa.

A square rotated 45 degrees provides the loci of an equal distance boundary to the subterminal by road. In this study, the area of the rotated square is the measure of market area. Figure 3 shows various size market areas superimposed on a rectangular grid road system. The general relationship which defines the total market area is:

$$(7) \quad TMA = \sum_{i=1}^{n} (4i - 2)$$

where:

TMA = total market area in square miles

i = index of miles from subterminal

n = specified distance from subterminal

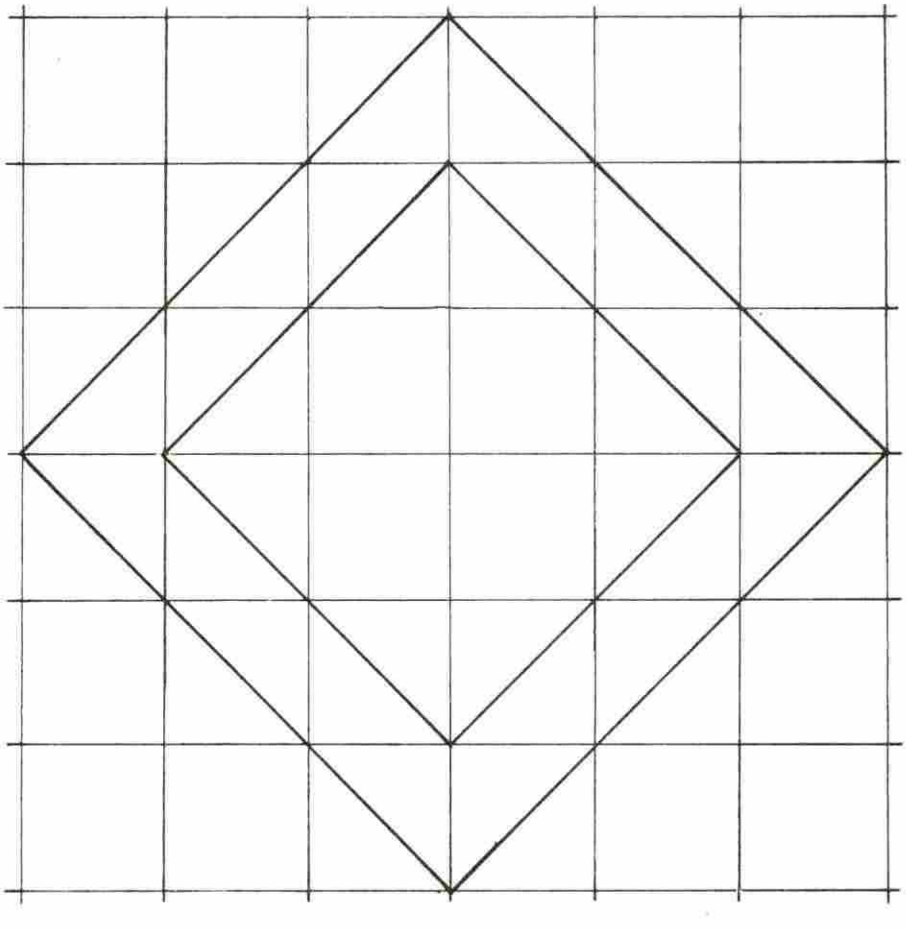

Figure 3. Market areas superimposed on a rectangular grid road system.

The total annual volume from a specified market area is obtained by multiplying the density of commercial grain sales per square mile times the total market area in square miles. To determine the volume obtained by increasing the market area size an additional mile, the number of square miles in the increment is multiplied by the density per square mile.

This analysis assumes the annual volume from the market area is divided into the subterminal volume received directly from farms and the volume transshipped through the country elevators to the subterminal. This division of volume is based upon the market shares obtained by the country elevators and the subterminal in the study area for each mileage increment away from the subterminal. The market shares are assumed to depend upon time (harvest or non-harvest) and distance from the subterminal. Thus, the subterminal volume received directly from farms in the ith mile from the subterminal can be expressed by the following:

$$(8) \quad SDV_i = MD \sum_{t=1}^{12} MSS_{it} \, (4i - 2)$$

where:

SDV_i = subterminal volume received directly from farms in the ith mileage increment

MD = marketing density of commercial grain sales

MSS_{it} = subterminal market share for month t in the ith mile from the subterminal

i = index of miles from the subterminal

t = index of months

The difference between the total volume in a specified market area of size n and the total volume shipped directly from farms to the subterminal was defined as the total volume available for country elevator receipt and storage. This difference in volume was then allocated to each of the country elevators in the specified market area on the basis of their storage capacity.

$$(9) \quad EV_i^n = \sum_{i=1}^{n} (V_i - SDV_i) \frac{ES_i}{\sum\limits_{i=1}^{n} ES_i}$$

where:

EV_i^n = volume at country elevators located in the ith mile from the subterminal for market area of size n

V_i = total annual volume originating in the ith mile from the subterminal

SDV_i = subterminal volume received directly from farms in the ith mileage increment

ES_i = country elevator storage located in the ith mile from the subterminal

Assembly costs are assumed to be a function of miles traveled. The cost function used in this analysis for the farm to subterminal movement is of a linear form and includes a fixed cost component, A, and a variable cost component that varies with distance from the subterminal. The cost per unit (C_i) in the ith mileage increment can be defined as $C_i = A + B$ (i miles). The volume obtained from farms from each mileage increment is multiplied by the respective cost for that increment. Thus, the total cost of assembly for the farm to subterminal movement is obtained by multiplying the cost per bushel for the ith mileage increment times the farm volume in the ith mileage increment and then summing the n mileage increments.

The assembly costs for the farm to country elevator grain movement are based on the above linear cost function assuming an average distance for grain assembly to country elevators. This results in a constant marginal cost ($\bar{C}$) for each bushel of grain received by country elevators.

The assembly cost function for the country elevator to subterminal movement includes a constant marginal cost component for each mileage increment. The cost per unit (D_i) for a country elevator i miles from the subterminal can be defined as $D_i = d$ (i miles). The total assembly cost for a market area of size n can be expressed by the following equation:

$$(10) \quad TAC^n = \bar{C} \sum_{i=1}^{n} EV_i + \sum_{i=1}^{n} (SDV_i C_i + EV_i D_i)$$

Equation 10 says that the total assembly cost for a market area of size n consists of 1) the assembly cost from farms to country elevators, 2) the assembly cost from farms to subterminal, and 3) the assembly cost from country elevators to subterminal.

Optimal subterminal size and market areas

With the semi long-run costs developed previously in this chapter, optimal subterminal sizes and market areas are estimated by equating the economies of scale in internal costs with the diseconomies in producer and country elevator delivery costs. The summation of the total internal costs and assembly costs for each size of market area with a given grain density serviced by a specific size subterminal results in the combined total costs for the various market areas. Dividing the total combined costs by the respective annual volumes of the market areas yields the combined average cost for each market area. The minimum combined average cost indicates the optimum volume and corresponding optimum market area for a specific size of subterminal.

For a comparison of subterminal size (25-, 50-, 75-, or 120-car) and an estimation of the minimum long-run grain marketing costs in a market area, the frieght rate reductions obtained for the larger volume multiply-car shipments must also be considered. Freight reductions for multiple-car shipments can be expressed as a constant marginal cost savings per bushel. Therefore, the combined average cost for a specific subterminal size and market area can be decreased by the freight rate reductions for the multiple-car shipments larger than 25 cars. This yields the adjusted combined average cost for each of the market area sizes. These average cost estimates are analogous to the long-run cost estimates that are usually derived from an envelope curve in the typical analysis. The minimum adjusted combined average cost indicates the long-run optimum subterminal and market area size.

Current multiple-car freight tariffs specify the minimum number of tons which are required in a multiple-car shipment to an export point. Most tariffs also require a minimum of five consecutive shipments and/or a minimum annual volume shipped. If these volume requirements are not met, the freight rate savings are reduced. Also, the highest net price for the subterminal may not always be at an export point. It may be more profitable for part of the volume in the market area to be shipped to domestic processors by the traditional single-car method. Therefore, the application of the entire rate reduction for the larger multiple-car shipments on the combined average costs for a market area serviced by a specific size of subterminal may over-state the actual cost savings.

Hence, the present analysis assumes three alternative levels of utilization of the multi-car rates to the Gulf by the subterminal, 50 percent, 75 percent, and 100 percent. These utilization levels can be interpreted as a specific size train loading facility shipping 50 percent, 75 percent or 100 percent of its annual volume to the Gulf by the corresponding multiple-car rate. Thus, the market area serviced by a specific size subterminal can reduce its combined average cost by only 50, 75 or 100 percent of the actual rate savings.

CHAPTER III. DATA

The data required to evaluate the economies of size in grain train loading facilities using the method of analysis described in Chapter II include: (1) the supply of grain forthcoming from farms and country elevators in each month; (2) the monthly shipping pattern of the subterminal; (3) grain handling costs for receiving, drying, storing, and load-out activities; and (4) transportation costs from farms and country elevators to the subterminal.

Much of the data used in this analysis came from the Iowa State study (2). The above study ranks alternative grain transportation systems, including potential subterminal sites, yielding the highest net income in a six and one-half county area around Fort Dodge, Iowa. The specific subterminal site studied in this analysis is one of the potential subterminal sites chosen in the above study.

Monthly Grain Flows

Grain is harvested and dried in the fall and stored for shipment to domestic consumption or export points throughout the year. A larger volume of grain has been moving off the farm during the fall harvesting months due to significant changes in harvesting techniques in the last several years. For the state of Iowa, the amount of grain moving off the farm in the fall as a proportion of total grain movement increased from 31 percent in 1964 to 46 percent in 1969. During the same period of time in a 12 county district in which the subterminal site is located, the amount of grain moving off the farm in the fall as a proportion of total grain movement increased from 29 percent to 59 percent. Most of the increase in the amount of corn moving from the farm to elevators in the fall is due to the increasing use of picker-shellers and combines in corn harvesting. Because of its high moisture content, field shelled corn requires the use of aeration and drying equipment. This equipment is often more accessible at elevators during harvest than on farms.

Three alternative marketing densities of commercial grain sales were used in this analysis. These densities were 24,000, 30,000 and 36,000 bushels per square mile. The total annual commercial grain sales were assumed to consist of two-thirds corn and one-third soybeans.

Monthly receipt patterns of the country elevators and subterminal

In the Iowa State study (2), a survey was taken to estimate the monthly flow of grain from farms to elevators. The monthly flow of grain from farms to elevators was adjusted to reflect changes in 1) Commodity Credit Corporation corn and soybean storage, 2) harvesting techniques, 3) grain production and the relatively lower costs of drying and storing grain in elevators compared with on-farm storage. The estimated monthly percentage flows from farms to subterminal or country elevator used in the present analysis are presented in Table 2.

Because of the sunk costs in existing receiving, storage and drying facilities at country elevators and the high opportunity cost of hauling grain long distances at harvest, this analysis assumes that country elevators will receive grain during harvest (October and November). After harvest, all of the grain will flow directly to the subterminal. Thus, the present analysis allows for the overlapping of the trade (market)

Table 2. Estimated percent distribution of receipts of corn and soybeans at elevator or subterminal from farms by 1980

	Percent of total receipts	
Month	Corn	Soybeans
October	24	50
November	45	5
December	6	2
January	3	3
February	2	3
March	1	4
April	2	6
May	2	6
June	5	8
July	4	6
August	4	2
September	2	5
Total	100	100

areas of country elevators and subterminals during harvest. Information from questionnaires on the trade area of the country elevators and the potential subterminal site was used to construct the harvest time market shares obtained by the subterminal for each one mile increment away from the subterminal. The non-harvest market shares obtained by the subterminal were assumed to be 100 percent for all mileage increments of any size trade area. The estimated harvest market shares of the subterminal by mileage increment are presented in Table 3.

The harvest volume for each mileage increment not going directly to the subterminal was allocated to the country elevators within each

Table 3. Estimated harvest time market share of the subterminal for selected mileage increments by 1980

Miles from subterminal	Harvest market share
1	1.00
2	1.00
3	1.00
4	0.95
5	0.85
6	0.70
7	0.50
8	0.25
9	0.05
10	0.00
15	0.00
18	0.00

specified market area based on their proportion of the total storage capacity within the market area. The total storage capacity of the country elevators located in the ith mile from the subterminal is listed in Table 1 in Chapter II.

Since this study assumes cooperation between country elevators and the subterminal serving the market area, and that country elevators will receive grain only at harvest, the shipping pattern of country elevators to the subterminal was allowed to fluctuate according to the demands of the shipping pattern of the subterminal. This results in minimizing excess storage capacity at the subterminal.

Monthly shipping patterns of the subterminal and marketing area

It was necessary to develop monthly shipping patterns of the subterminal. They are identical to the shipping patterns of the market area since all commercial grain was assumed to be shipped through the subterminal. Three alternative shipping patterns were specified. The first alternative is a constant shipping pattern that requires equal amounts of grain to be shipped out of the subterminal each month. The second alternative is based on the actual monthly rail shipments from the Fort Dodge area during the October 1970 to September 1971 period. The third alternative is based on a five year average (1968 - 1972) of monthly export shipments out of the Great Lakes and Gulf ports (19). These three alternatives are presented in Table 4.

Subterminal Investment Costs

The engineering costs developed for this study are based on data gathered from elevator managers and elevator engineering consultants. The analysis employed engineering economy concepts based on the time value of money.

The engineering economy technique is an exact method of computing investment costs. Several other approximations are commonly used because they are convenient and do not require the use of compound interest tables. One such method is to calculate depreciation on a straight-line basis and a desired return, interest charge, on the average investment. This approximation method uses an arithmetic

Table 4. Specified monthly percentage distribution of corn and soybean shipments from subterminal to final markets.

Month	Constant pattern	Actual pattern	Export pattern
October	8.3	4.8	9.8
November	8.3	5.3	11.7
December	8.3	4.0	10.1
January	8.3	7.3	7.0
February	8.3	5.8	6.3
March	8.3	8.3	7.4
April	8.3	7.6	7.4
May	8.3	11.5	7.7
June	8.3	16.2	7.4
July	8.3	14.7	7.9
August	8.3	10.0	8.9
September	8.3	4.5	8.4

average of investment without adjustments for the time value of money. Smith points out that understatement of costs will occur if: 1) the first cost exceeds the salvage realized; 2) the life of the investment is over one year; and 3) the desired rate of return is greater than zero (12).

This analysis used the annual equivalent value approach to determine subterminal investment costs. This equivalent, commonly referred to as capital recovery, provides repayment of the investment and a return on the investment during its life.

The basic formula used in this analysis has the form:

$$(11) \quad AEC = B(a/p)_n^i - V(a/f)_n^i$$

where:

AEC = annual equivalent cost

B = initial cost of the facility

V = salvage value

i = interest rate (or rate of return)

n = years of facility life

$(a/p)_n^i = \frac{i(1+i)^n}{(1+i)^n - 1}$ = annual equivalent of a present sum

$(a/f)_n^i = \frac{i}{(1+i)^n - 1}$ = annual equivalent of a future sum

This analysis assumed a before-tax rate of return on investment of ten percent. No provision was made in the analysis for the effect of income taxes. Zero salvage value was assumed for all facilities.

The annual investment costs were based on 1972 estimated costs and included the annual capital recovery costs plus annual insurance and property taxes on the facilities. Property taxes were computed at the rate of 80 mills on 27 percent of the initial installed cost -- approximately 2.1 percent of installed cost. The annual insurance cost on facilities and inventory was assumed to be 18 mills per dollar of installed cost. Insurance on facilities alone was assumed to be 15 mills per dollar of installed cost -- equivalent to 1.5 percent of installed cost.

Minimum capacities required to receive, dry, and load-out grain at subterminals were specified by elevator managers and elevator engineering consultants. It was estimated that loading 25-car train units at a subterminal would require a receiving capacity of 7,500 bushels per hour; drying capacity, rated at ten points moisture removal, of 1,500 bushels per hour; and load-out capacity of 10,000 bushels per hour. The 50-car train units were assumed to require receiving capacity of 15,000 bushels per hour; drying capacity of 3,000 bushels per hour; and load-out capacity of 20,000 bushels per hour. For the 75-car train loading facility, receiving, drying, and load-out capacities were assumed to be 22,500; 4,500; and 30,000 bushels per hour respectively. The assumed requirements for the 120-car train loading facility, were 30,000; 6,000; and 40,000 bushels per hour.

Receiving costs

The initial construction and annual investment costs of grain receiving facilities were based on the estimated costs of facilities with 10,000 bushels per hour; 20,000 bushels per hour; and 40,000 bushels per hour capacities. A linear regression of these estimated costs resulting in the following functions.

(12) Installed Cost ($) = 56,014 + 5.478 (x bushels/hour)

(13) Annual Cost ($) = 9,842 + 0.978 (x bushels/hour)

The annual cost function was used to approximate the annual costs of the specified receiving capacities required for the alternative sub-terminal sizes.

Receiving facilities were assumed to include a semi-truck scale, scale house and office, and sampling equipment at an estimated cost of \$30,500 for the 10- and 20-thousand bushel per hour capacities. An additional truck scale, scale house and sampling equipment were added for the 40,000 bushels per hour capacity. Hoists for straight trucks and wagons were estimated to cost \$6,000 per hoist. A semi-hoist costing \$25,000 was needed for the 20- and 40-thousand bushel per hour capacities. Three, four and seven dump pits were assumed necessary for the 10-, 20- and 40-thousand bushels per hour capacities, respectively. The first dump pit per leg was estimated to cost \$6,000, each additional dump pit \$5,500, and the semi dump pit \$8,000. The cost of the conveyors in the pits was estimated to be \$110 per foot.

The cost of receiving legs varies by capacity and height. Two receiving legs were assumed necessary for the 10,000 bushels per hour rated capacity at a cost of \$22,000. Three receiving legs were needed for the 20,000 bushels per hour rated capacity at a cost of \$34,000 and four legs were assumed necessary for the 40,000 bushels per hour rated capacity at an estimated cost of \$110 per foot. Estimated installed and annual costs for receiving facilities are presented in Table 5.

Drying costs

The initial construction and annual investment costs of drying facilities were based on the estimated cost of three, six and twelve

Table 5. Estimated installed and annual cost of receiving facilities for three rated capacities at 1972 price levels

Cost item	Years for depreciation	10,000 bushels/ hour	20,000 bushels/ hour	40,000 bushels/ hour
Scale house and office	20	$ 12,500	$ 12,500	$ 17,500
Truck scale (s)	20	15,000	15,000	30,000
Sampler, tester, etc.	5	3,000	3,000	6,000
Truck hoists	20	18,000	43,000	61,000
Dump pits	30	17,500	25,500	42,500
Belt in pits	10	6,750	9,000	15,750
Legs	10	22,000	34,000	67,000
Distributors	10	8,375	8,375	16,750
Belt to 1st storage bin	10	4,400	6,600	8,800
Spouting and miscellaneous	5	5,400	5,400	10,900
Total installed cost		$112,925	$162,375	$276,200
Annual equivalent cost of equipment with life of	5 years	$ 2,216	$ 2,216	$ 4,458
	10 years	6,758	9,435	17,626
	20 years	5,344	8,281	12,744
	30 years	1,856	2,705	4,508
Annual insurance and tax @ 3.6% of installed cost		4,065	5,845	9,943
Total annual cost		$ 20,239	$ 28,482	$ 49,279

thousand bushels per hour capacities rated at ten point moisture removal. Drying facilities were assumed to include driers with a ten point moisture removal capacity, cleaners, legs, spouts, and conveyors from wet storage holding bins to the drier legs and back to the first dry storage bin. Estimated installed and annual costs for drying facilities are presented in Table 6. From these estimated installed and annual costs of drying facilities the following linear functions were derived.

(14) Installed cost (\$) = 11,000 + 40.181 (x bushels/hour)

(15) Annual cost (\$) = 2,186 + 7.986 (x bushels/hour)

The annual cost function for drying facilities was used to approximate the annual costs of the specified drying capacities required for the alternative subterminal sizes.

Storage costs

The initial construction and annual investment costs of storage facilities were based on the estimated cost of 300-thousand, 500-thousand and one million bushel storage facilities. Storage facilities included the cost of concrete storage bins and tunnel with top and bottom conveyors at a cost of \$110 per foot, heat detection and aeration equipment. Land cost was also included in the storage facilities. A minimum of four acres of land at \$2,500 per acre was assumed for the 300- and 500-thousand bushel facilities. An additional one-half acre of land was assumed necessary for every 250-thousand bushels of storage

Table 6. Estimated installed and annual cost of drying facilities for three rated capacities at 1972 price levels

Cost item	Years for depreciation	10,000 bushels/ hour	20,000 bushels/ hour	40,000 bushels/ hour
Driers	10	\$106,400	\$212,800	\$425,600
Cleaners	10	7,500	11,500	15,500
Legs, conveyors and spouts	10	17,500	28,000	52,000
Total installed cost		\$131,400	\$252,300	\$493,100
Annual equivalent cost		\$ 21,385	\$ 41,062	\$ 80,252
Annual insurance and tax @ 3.6% of installed cost		4,730	9,083	17,751
Total annual cost		\$ 26,115	\$ 50,145	\$ 98,003

above the 500-thousand bushel facility. The estimated installed and annual costs for storage facilities are presented in Table 7. From these estimated installed and annual costs of storage facilities, the following linear functions were derived.

(16) Installed cost (\$) = 69,240 + 0.487 (x bushels)

(17) Annual cost (\$) = 8,638 + 0.086 (x bushels)

The annual cost function for storage facilities was used to estimate the annual costs of the minimum specified storage capacities required for the alternative subterminal sizes.

Table 7. Estimated installed and annual cost of storage facilities by size of capacity at 1972 price levels

Cost item	Years for depreciation	300,000 bushels	500,000 bushels	1,000,000 bushels
Silos and tunnel	50	$210,000	$300,000	$550,000
Aeration and heat detection equipment	10	10,500	17,000	28,000
Conveyors	10	16,720	33,440	66,880
Land	--	10,000	10,000	12,500
Total installed cost		$247,220	$360,440	$657,380
Annual equivalent cost of equipment with life of	10 years	$ 4,430	$ 8,209	$ 15,442
	50 years	21,181	30,258	55,473
Annual insurance and tax @ 3.6% of installed cost		8,900	12,976	23,666
Total annual cost		$ 34,511	$ 51,443	$ 94,581

The storage capacities required for the selected subterminal sizes were obtained by the use of the receipt and shipping patterns subject to the following minimum capacities: 300-thousand bushels for the 25- and 50-car subterminal sizes; 500-thousand bushels for the 75-car subterminal; and one million bushels for the 120-car subterminal. The storage requirements, when determined by the receipt and shipping patterns of the area, were increased five percent to account for within month variations in the receipt and shipping patterns.

To determine the additional annual investment costs of storage above the minimum required, the difference between the assumed minimum storage capacity requirement of a specific size subterminal and the storage requirement determined by its receipt and shipping patterns is multiplied by an annual per bushel expansion cost. The value of the slope coefficient in the annual investment cost function, 8.6 cents per bushel, was used as an estimate of the annual per bushel expansion cost of storage facilities.

Load-out costs

The initial construction and annual investment costs for load-out facilities were based on the estimated costs of two-, ten-, twenty- and forty-thousand bushels per hour load-out facilities. Rail siding requirements for the two-, ten-, twenty- and forty-thousand bushels per hour capacities were assumed to be 10, 25, 50 and 115 hopper cars, respectively. Rail siding cost was estimated at \$25 per foot for 1.5 times the length required to hold the specified number of rail cars. Switches were estimated at \$4,000 per switch. A trackmobile or equivalent means of moving rail cars was assumed necessary for each size of load-out facility. The cost of load-out conveyors and belts was assumed to include only a conveyor from the nearest storage bin to the load-out leg at a cost of \$110 per foot. The estimated installed and annual costs of load-out facilities are presented in Table 8. From these estimated costs, the following linear functions were estimated.

$$\text{(18)} \quad \text{Installed cost } (\$) = 30{,}950 + 12.149\ (x \text{ bushels/hour})$$

(19) Annual cost (\$) = 5,296 + 1.770 (x bushels/hour)

The annual cost function for load-out facilities was used to estimate the annual costs of the specified load-out capacities required for the alternative subterminal sizes.

Table 8. Estimated installed and annual costs of load-out and cleaning facilities by size of load-out facility at 1972 price levels

Cost item	Years for depreciation	2,000 bushels/ hour	10,000 bushels/ hour	20,000 bushels/ hour	40,000 bushels/ hour
Rail siding & switches	50	$ 30,500	$ 64,250	$124,500	$274,750
Trackmobile or equivalent	15	10,000	25,000	25,000	50,000
Scales	20	5,800	18,000	30,000	60,000
Load-out legs and belts	10	10,300	25,300	40,600	81,200
Cleaners	10	6,800	15,000	25,000	50,000
Spouts and miscellaneous	5	3,900	4,900	5,900	11,800
Total installed cost		$ 67,300	$152,450	$251,000	$527,750
Annual equivalent cost of equipment with life of	5 yrs.	$ 1,029	$ 1,293	$ 1,556	$ 3,113
	10 yrs.	2,783	6,559	10,676	21,353
	15 yrs.	1,315	3,287	3,287	6,574
	50 yrs.	3,076	6,480	12,557	27,711
Annual insurance and tax @ 3.6% of installed cost		2,423	5,488	9,036	18,999
Total annual cost		$10,626	$ 23,107	$ 37,112	$ 77,750

Subterminal Operating Costs

Grain handling costs

The grain handling costs for the marketing area were defined to include the costs of the receiving, sampling, blending, loading-out and merchandising of grain. The grain handling and merchandising costs were composed of three basic cost components: 1) a fixed management cost at the subterminal; 2) a constant marginal operating and maintenance cost of grain handling at the country elevators; and 3) a marginal grain handling cost at the subterminal. All cost components were estimated by analyzing grain elevator records and by personal interviews with elevator managers.

The annual management cost was specified at $9,500 for a 25-car train loading facility; $10,500 for a 50-car facility; $11,500 for a 75-car facility; and $12,500 for a 120-car train facility. The management costs reflect the costs incurred by a subterminal which are not solely a function of the volume handled by the subterminal. These costs include: 1) the cost of an annual audit; 2) a portion of the fuel, power and light expense which is required to light and heat the elevator facilities regardless of the volume handled; 3) telephone and licensing costs; and 4) a portion of the manager's annual salary.

From the analysis of elevator records and personal interviews with elevator managers, the marginal operating and maintenance cost of grain handling at country elevators was estimated to be 2.32 cents per bushel. The marginal operating and maintenance cost of grain handling includes the cost of direct labor, repairs, fuel, power and lights. Adjusting the estimated grain handling cost at country elevators to account for increased volume and a higher mechanization of facilities at the subterminal resulted in an estimated handling cost of 1.34 cents per bushel at the subterminal.

Grain drying costs

Besides the annual fixed investment cost of drying facilities described previously in this chapter, the marginal operating cost of drying facilities must be estimated by months. The marginal drying cost varies by months because of the various moisture conditions of the corn received from farms. During October, November, and December it was assumed that corn receipts required ten points of moisture removed. From January through March, corn receipts were assumed to require four points of moisture removed. During the remainder of the year, corn received from farms required no drying. Marginal drying costs, assuming ten and four points moisture removed from corn, were estimated at 3.00 and 1.20 cents per bushel. Several drying cost analyses have resulted in similar estimates for the marginal costs of drying (1, 7, 11).

Grain storage costs

Grain storage costs are divided into three components: 1) the minimum annual start-up cost of storage facilities at the subterminal; 2) the annual per bushel cost of expanding storage facilities at the subterminal; and 3) the marginal operating and maintenance costs of storing grain at the country elevators and the subterminal. The estimated annual start-up cost of storage facilities and the annual cost of expanding storage facilities were discussed previously in this chapter.

The marginal operating and maintenance costs of storing grain varied by the length of time the grain was stored. The marginal cost of storing a bushel of grain one month was estimated to be 0.34 cents per bushel per month. The cost of storing a bushel of grain for more than one month was estimated by multiplying the number of months in storage by the monthly storage cost. The marginal storage cost includes the cost of labor, utilities, repairs, administrative expense and insurance on the grain. The estimated storage cost of 0.34 cents per bushel per month is comparable to the estimated storage costs in recent USDA studies (14, 15, 16).

Assembly Cost Methodology

This section presents the methodology for estimating the transportation costs for the farm to country elevator or subterminal grain movement and the country elevator to subterminal movement. Various modes of transportation, farm tractors and wagons and various size trucks, may be used to assemble grain in each of these movements.

The basic methodology for estimating operating costs of trucks and farm tractors and wagons contains three components: 1) variable costs which are associated with trip distance; 2) annual fixed costs; and 3) transfer costs which are a function of the number of trips per year. Variable costs include fuel and oil, tires, wages and maintenance and repair costs. Fixed costs include interest, depreciation, license fees, insurance, management expenses, and highway use tax. Finally, transfer costs include the labor cost of loading and unloading waiting time.

The operating costs of a truck or wagon generally depend upon the trip distance, number of trips per year, and average speed. Therefore, the unique behavioral assumptions for operating each type of truck or wagon will be specified in their respective cost analysis.

Farm to Country Elevator and Subterminal Assembly Costs

The data used in this analysis were collected from various sources including truck and wagon dealers, tire dealers, state documents and interviews with truck operators. This analysis is based on the actual 1972 price levels in Iowa.

In this study, it was assumed that the transportation cost coefficients for the farm to subterminal or country elevator grain movement would be based on equally weighted cost estimates for farm tractors and 300 bushel wagons, farm tractors and 450 bushel wagons, and 300 bushel farm trucks. This assumption is consistent with the actual types and sizes of vehicles which delivered grain to elevators in the Fort Dodge area in 1971 as shown in Table 9. These data were obtained from the Iowa State study (2).

Operating costs of farm tractor wagon combinations

The following analysis estimates operating costs for combinations of two 300 bushel wagons with a 110 horsepower tractor and two 450 bushel wagons with a 140 horsepower tractor. The estimated operating costs for 300 bushel and 450 bushel wagons are based on the following assumptions: 1) wagons will make 50 trips per year at 12 miles per hour and 2) the tractor has been purchased for field work and only variable costs are charged to the grain hauling function.

Table 9. Estimated grain receipts at country elevators by type of delivery vehicles, Fort Dodge area 1970-71 crop year

Type of vehicle	Percent of receipts
Farm tractor and wagon	38.8
Truck - 300 bushel capacity or smaller	35.0
Truck - over 300 bushel capacity	26.2

The annual fixed cost of interest and depreciation on the investment in 300 bushel and 450 bushel wagons was calculated by the capital recovery formula discussed previously in this chapter. A ten percent interest rate and 12 year life expectancy with zero salvage value were used in the analysis. The list and the actual price of 300 and 450 bushel wagons at 1972 price levels are listed in Table 10.

Table 10. List price and purchase price of 300 and 450 bushel wagons

	List price				Purchase
Size of wagon	Box	Gear	Side board	Total	price
300 bushel:					
without brakes	$445	$538	$64	$1,047	$ 838
with brakes	445	751	64	1,260	1,008
450 bushel:					
without brakes	745	694	80	1,519	1,215
with brakes	745	904	80	1,729	1,383

The resulting annual equivalent costs are:

Size of wagon	Annual equivalent cost
300 bushel, without brakes	\$ 838 x 0.1468 = \$123.02
300 bushel, with brakes	1,008 x 0.1468 = 147.97
450 bushel, without brakes	1,215 x 0.1468 = 178.36
450 bushel, with brakes	1,383 x 0.1468 = 203.02

Only the costs for wagons with brakes were used in this analysis. The insurance costs on the tractor and wagons were assumed to be included in a blanket insurance policy and no license fees are assessed on farm implements. Thus, there were no additional fixed costs.

The variable cost for wagons consists of tire cost and repair and maintenance cost. The initial tire cost for the 300 and 450 bushel wagons was estimated to be \$90 and \$173 per pair, respectively. The life expectancy of the tires was assumed to be 6,000 miles. Thus, the tire cost for the 300 bushel wagon was 3.00 cents per mile. The tire cost per mile for the 450 bushel wagons was 5.77 cents per mile. There is generally little repair and maintenance cost on wagons for the first seven years and only a small amount after seven years. Therefore, it was ignored in this analysis.

The basic assumptions and estimates used in computing the operating costs of tractors are as follows:

1. The price of diesel fuel is \$0.29 per gallon. The fuel consumption is estimated to be 4.94 gallons per hour for the 110 H.P. tractor and 6.15 gallons per hour for the 140 H.P. tractor. The average speed of these tractors is assumed to be 12 miles per hour. Thus, the fuel cost per mile for the

110 H.P. and 140 H.P. tractors is 11.94 and 14.86 cents per mile, respectively.

2. The estimated oil cost assumes an oil change every 120 driving hours. The cost of an oil change including oil filter is $9.80 for the 110 H.P. tractor and $10.40 for the 140 H.P. tractor. Thus, the oil cost per mile is 0.68 cents per mile for the 110 H.P. tractor and 0.70 cents per mile for the 140 H.P. tractor.
3. Driver's wages for farm tractors are assumed to be $2.00 per hour for the 110 H.P. tractor and $3.00 per hour for the 140 H.P. tractor. The resulting driver's wage per mile for the 110 H.P. and 140 H.P. tractors is 16.7 and 25.0 cents per mile, respectively.
4. The total initial cost of tractor tires for the 110 H.P. and 140 H.P. tractors is estimated to be $757 and $976, respectively. The tires are assumed to be replaced at the end of five years. On the average for one acre of land, 135 minutes of tractor time is used to produce the crop and 16.5 minutes to ship the grain. Therefore, grain hauling time is only 12 percent of total tractor time. The resulting tire cost per year for the 110 H.P. tractor is $18.17 and $23.42 for the 140 H.P. tractor.
5. Since only 12 percent of total tractor time is estimated to be used for hauling grain, no maintenance and repair cost is included in this analysis.

The annual transfer cost of the farm tractor and wagon combinations includes the unloading and waiting costs. This analysis assumes a transfer cost of \$2.00 per trip for all size wagons. Thus, the annual transfer cost, assuming 50 trips per year, is \$100.

Operating cost of 300 bushel farm trucks

The estimated operating costs for 300 bushel farm trucks are based on the following assumptions: 1) each truck will make 200 trips per year and 2) the average speed is 20 miles per hour.

The annual fixed cost of interest and depreciation on investment was calculated by the capital recovery formula discussed previously in this chapter. An initial purchase price of \$7,500, a ten percent interest rate and a ten year life expectancy with a \$1,155 salvage value were used in the analysis. The resulting annual equivalent cost was \$1,150.

Annual license fees were calculated from a table of truck rates and weights for Iowa. The license fee was \$310 for a gross weight of 13 tons. Annual insurance costs depend upon the amount of coverage. In this analysis an annual insurance cost of \$150 for a 300 bushel truck was assumed.

The fuel and oil costs were based on a gasoline fuel engine averaging 6.9 miles per gallon and the price of gas fuel is \$0.37 per gallon. The oil and oil filter were changed every 5,000 miles at a cost of \$7.80. Thus, the fuel and oil cost was \$0.0552 per mile.

An initial tire cost of \$97 per pair with a life expectancy of 28,000 miles was assumed in this analysis. The resulting tire cost for the 300 bushel farm truck was \$0.0104 per mile. The average repair and maintenance cost was estimated to be \$0.0450 per mile.

This analysis assumed that the driver's wage per hour was \$2.00 and that the average speed was 20 miles per hour. Thus, the driver's wage per mile was calculated to be \$0.10 per mile.

Transfer cost, the cost of unloading and waiting time, was based on a wage rate of \$2.00 per hour. The assumed unloading time for a 300 bushel farm truck was 20 minutes per trip. Thus, the estimated transfer cost, assuming 200 trips per year, was \$133 per year.

Using the above estimated operating costs for the two tractor wagon combinations and the farmer-owned 300 bushel truck, the estimated assembly costs by mode for selected round trip distances are presented in Table 11. By equally weighting the estimated assembly costs for the three modes, the following farm to subterminal assembly cost function was derived:

$$(20) \quad C_i = 1.8202 + 0.1239 \text{ (i miles)}$$

where:

C_i = cost per bushel in the ith mileage increment in cents

The assembly cost for the farm to country elevator grain movement was based on the above equation and assumed an average hauling distance of four miles. This resulted in an assembly cost of 2.32 cents per bushel for the farm to country elevator grain movement.

Table 11. Estimated assembly costs by mode for selected round trip distances in cents per bushel at 1972 price levels

Round trip distance	Cents per bushel Two 300 bushel wagons	Two 450 bushel wagons	300 bushel farm truck
2	1.4978	1.2891	3.0454
4	1.6155	1.4027	3.1858
6	1.7332	1.5163	3.3262
8	1.8509	1.6299	3.4666
10	1.9686	1.7435	3.6070
12	2.0863	1.8571	3.7474
14	2.2040	1.9707	3.8878
16	2.3217	2.0843	4.0282
18	2.4394	2.1979	4.1686
20	2.5571	2.3115	4.3090

Elevator to Subterminal Assembly Costs

This analysis assumes that grain trucked from country elevators to the subterminal was hauled by 810 bushel tractor-trailer trucks. It also assumes that the trucks were owned and operated by independent truckers or elevator operators.

The operating costs for the 810 bushel tractor-trailer trucker were based on the following assumptions: 1) each truck makes four trips per day and the average traveling distance is 20 miles per trip; 2) there are 275 working days per year; and 3) each truck travels 44,000 miles per year at an average speed of 35 miles per hour.

Annual fixed cost for interest and depreciation is based on the annual equivalent cost of an initial investment of $31,300 for the tractor and trailer. A ten percent interest rate and a five year life expectancy with a salvage value of $10,900 was used in the analysis. The resulting annual equivalent cost was $6,476.

The annual license fees of $1,260 were figured for a 36 gross ton vehicle. The annual insurance cost was estimated at $1,500 per year and a federal highway user tax of $220 per year was also included. Total management costs of $150 per year were assumed for each truck.

The fuel and oil costs were calculated by assuming a diesel engine in each truck averaging four miles per gallon. The oil and oil filter were changed every 4,000 miles at a cost of $7.80. Thus, the fuel and oil cost was $0.075 per mile.

Tire cost for the 810 bushel tractor-trailer truck was based on each truck having 16 units of 1100/20 inch 12 ply tires (88,000 mile life) and two units of 700/20 inch 10 ply tires (50,000 mile life) costing $130 and $76 per unit, respectively. The resulting estimated tire cost was $0.027 per mile.

The annual repair and maintenance cost was assumed to be five percent of the initial cost of the truck. Assuming 44,000 miles per year, the estimated repair and maintenance cost was $0.036 per mile.

This analysis assumes an average speed of 35 miles per hour and the average driver's wage is $4.50 per hour. The resulting wage cost per mile was $0.129. In addition to the cost of driver's wages while driving, the driver must be paid during loading and unloading time. The estimated loading and unloading time was 40 minutes per trip. Thus, the transfer cost for loading and unloading time, assuming four trips per day and 275 working days per year, was estimated at $3,300 per year.

Using the above estimated operating costs for the 810 bushel tractor-trailer, the estimated assembly cost for the country elevator to subterminal grain movement was computed to cost $0.0007 per bushel per mile.

Multiple-Car Rate Reductions

All of the rail tariffs available in Iowa until the summer of 1971 were for single-car rates. In the summer of 1971, the Chicago, Rock Island and Pacific Railroad Company issued Freight Tariff 37019 (I.C.C. C-13821) creating 27- and 54-car export rates for grain shipped from their Iowa stations to Houston, Texas. This led to similar tariffs being issued by the Chicago and Northwestern Transportation Company and the Chicago, Milwaukee, St. Paul and Pacific Railroad Company establishing 25- and 50-car export rates from Iowa stations to Chicago and New Orleans. Recently, the Illinois Central Gulf Railroad Company issued 60- and 120-car export rates to New Orleans.

The 25- and 50-car trains might be called occasional trains because the tariffs require a minimum of five consecutive shipments from a subterminal. Five consecutive shipments are also required for the 60- and 120-car rates. But, additionally, they require a minimum annual volume to be shipped to the Gulf. Table 12 lists the transportation rates and minimum volumes for shipping corn from Fort Dodge, Iowa to New Orleans for various sizes of rail shipments.

Table 12. Multiple-car rail transportation rates, in cents per bushel, and minimum annual volumes, in bushels, for moving corn from Fort Dodge, Iowa to New Orleans by size of shipment, 1974.

Size of shipment	Rate	Miminum volume
25-car	24.0	430,250
50-car	22.4	860,500
60-car	21.3	2,065,000
120-car	20.2	4,130,000

The present analysis uses the 25-car rate to the Gulf as its base rate. Therefore, for a 50-car train loading facility operating at a 50 percent utilization level of the 50-car rate, the 1.6 cent per bushel rate reduction would result in a 0.8 cent per bushel decrease in the combined average costs for the market area. For the 75 percent and 100 percent utilization levels, the decrease in the combined average cost would be 1.2 and 1.6 cents per bushel, respectively.

Since there are no published 75-car rates at present, the 60-car rate was used as a substitute. The decrease in the combined average costs due to freight reductions for the 75-car facility over the 25-car average costs, assuming utilization levels of 50, 75 and 100 percent, are 1.4, 2.0 and 2.7 cents per bushel. Likewise, the 120-car facility costs would have cost reductions of 1.9, 2.9 and 3.8 cents per bushel.

CHAPTER IV. RESULTS

In this chapter, the estimated combined grain marketing and transportation costs will be presented for the alternative subterminal sizes and market areas. Both the case study analysis, which considers existing country elevator facilities, and the conventional cost analysis, which assumes away existing country elevator facilities, will be presented.

Case Study Analysis

The optimal train loading facility size and market area in the case study analysis are estimated for three shipping patterns, three utilization levels of multiple-car rates, and three commercial grain density levels. The semi long-run cost equations for merchandising, storing and drying grain in the various market area sizes were used to estimate the internal economies of size for alternative annual volumes and market areas. Freight rate reductions for the multiple-car shipments larger than 25 rail cars with the various utilization levels of these rates represent additional economies of size in train loading facilities. The estimated delivery costs for grain shipped from farms and country elevators to the subterminal represent the diseconomies of size.

For a given density of commercial grain, the summation of the average assembly and in-plant costs plus the rate reductions for multiple-car shipments larger than 25 cars provides a family of adjusted combined average costs for specific subterminal sizes and market areas.

The minimum adjusted combined average cost for each selected market area size identifies the optimum subterminal size for that market area. The least cost volume and subterminal size would occur when the adjusted combined costs reach a minimum as market area and volume increase.

The results of the case study analysis using a grain marketing density of 30,000 bushels per square mile and the actual shipping pattern of the country elevators will be presented in detail in the following three sections for the three alternative rate utilization levels. Appendix Tables 20, 21, and 22 present the case study results obtained with varying assumptions regarding multiple-car rate utilization levels, shipping patterns and marketing densities.

One hundred percent of the grain shipped in multiple-car trains

The estimated minimum adjusted combined average costs for selected market area sizes when all of the grain from a market area is shipped in multiple-car trains are shown in Table 13. The adjusted combined average costs show rather significant economies to size up to the range of 10 to 12 million bushels and a market area with a radius of 13 to 14 miles. Only slight decreases in average costs occurred thereafter.

The theoretical least cost volume and subterminal size would occur when the adjusted combined average costs reach a minimum as market area and volume increase. However, the adjusted combined average costs indicate that this minimum point would occur at a market area size in excess of an 18 mile radius. It appears perhaps the more relevant volume and market area size are the ones that achieve most of the

Table 13. Estimated grain marketing costs, least cost subterminal size and required subterminal storage using the case study analysis, the actual shipping pattern, and a 30,000 bushel grain marketing density and a 100 percent multiple-car rate utilization level

Market area size[a]	Market area volume[b]	Required subterminal storage capacity[c]	Least cost subterminal size	Adjusted combined average costs[d]
(miles)	(000 bu.)	(000 bu.)		(cents per bu.)
5	1,500	785	25-car	16.0
6	2,160	1,027	25-car	14.2
7	2,940	1,208	50-car	12.7
8	3,840	1,265	75-car	11.3
9	4,860	1,191	120-car	9.8
10	6,000	1,070	120-car	8.7
11	7,260	1,000	120-car	8.2
12	8,640	1,000	120-car	7.9
13	10,140	1,000	120-car	7.6
14	11,760	1,000	120-car	7.3
15	13,500	1,000	120-car	7.1
16	15,360	1,000	120-car	7.0
17	17,340	1,000	120-car	6.9
18	19,440	1,000	120-car	6.8

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Minimum storage requirements at the subterminal obtained by the receipt and shipping patterns of the area subject to minimum requirements for each subterminal size.

[d] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

economies of size. Thus, the 120-car train loading facility serving a market area with a radius of 13 to 14 miles would appear to be the "optimum" subterminal size.

Based on the actual shipping pattern, the required storage capacity for the "optimum" subterminal size would be at the assumed minimum level of one million bushels for the 120-car facility. The storage requirements determined by the receipt and shipping patterns of the market area increase as the size of market area increases from five to eight miles from the subterminal site. For the market areas larger than eight miles, the storage requirements decrease as the area increases. The explanation for this phenomenon is that as annual volume increases the amount shipped out by the subterminal at harvest time increases. At the same time, the direct receipts of the subterminal at harvest are slowly increasing for the market area sizes with radii of five to nine miles, but remain constant for any market area larger than nine miles.

Three-fourths of the grain shipped in multiple-car trains

Table 14 shows the estimated minimum adjusted combined average costs for selected market area sizes when three-fourths of the grain from a market area is shipped in multiple-car trains. The adjusted combined average costs range from 16.0 cents per bushel for the 25-car facility serving a market area with a five mile radius down to 7.7 cents per bushel for the 120-car facility serving a market area with an 18 mile radius. Again most of the economies of size are obtained with a 120-car facility serving a market area with a 14 mile radius

Table 14. Estimated grain marketing costs, least cost subterminal size and required subterminal storage using the case study analysis, the actual shipping pattern, a 30,000 bushel grain marketing density and a 75 percent multiple-car rate utilization level

Market area size[a] (miles)	Market area volume[b] (000 bu.)	Required subterminal storage capacity[c] (000 bu.)	Least cost subterminal size	Adjusted combined average costs[d] (cents per bu.)
5	1,500	785	25-car	16.0
6	2,160	1,027	25-car	14.2
7	2,940	1,208	25-car	13.0
8	3,840	1,265	50-car	11.8
9	4,860	1,191	50-car	10.8
10	6,000	1,070	75-car	9.9
11	7,260	936	75-car	9.3
12	8,640	790	75-car	8.8
13	10,140	1,000	120-car	8.5
14	11,760	1,000	120-car	8.2
15	13,500	1,000	120-car	8.0
16	15,360	1,000	120-car	7.9
17	17,340	1,000	120-car	7.8
18	19,440	1,000	120-car	7.7

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Minimum storage requirements at the subterminal obtained by the receipt and shipping patterns of the area subject to minimum requirements for each subterminal size.

[d] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

at an adjusted combined average cost of 8.2 cents per bushel. Storage requirements at this "optimal" subterminal size were one million bushels, the assumed minimum storage required at a 120-car facility.

One-half of the grain shipped in multiple-car trains

Table 15 shows the estimated minimum adjusted combined average costs for selected market area sizes when one-half of the grain from a market area is shipped in multiple-car trains. The adjusted combined average costs range from 16.0 cents per bushel for the 25-car facility serving a market area with a five mile radius down to 8.6 cents per bushel for the 120-car facility serving a market area with an 18 mile radius. For this type of marketing situation, most of the economies of size are achieved with a 75-car train loading facility serving a market area with a 13 mile radius at a cost of 9.1 cents per bushel. Storage requirements at this "optimal" subterminal size were 500 thousand bushels, the assumed minimum required at a 75-car train loading facility.

Alternative shipping patterns

The alternative shipping patterns did not change the "optimum" size of train loading facilities. However, they did affect the level of the combined average costs. As the proportion of grain moving out of the area during the fall months increased, the storage capacity requirements and ending monthly inventories declined, thereby decreasing the storage costs of the area. For example, Appendix Table 20 shows that the adjusted combined average costs for a market area with a

Table 15. Estimated grain marketing costs, least cost subterminal size and required subterminal storage using the case study analysis, the actual shipping pattern, a 30,000 bushel grain marketing density and a 50 percent multiple-car rate utilization level

Market area size[a]	Market area volume[b]	Required subterminal storage capacity[c]	Least cost subterminal size	Adjusted combined average costs[d]
(miles)	(000 bu.)	(000 bu.)		(cents per bu.)
5	1,500	785	25-car	16.0
6	2,160	1,027	25-car	14.2
7	2,940	1,208	25-car	13.0
8	3,840	1,265	25-car	12.1
9	4,860	1,191	50-car	11.2
10	6,000	1,070	50-car	10.5
11	7,260	936	50-car	10.0
12	8,640	790	75-car	9.4
13	10,140	631	75-car	9.1
14	11,760	500	75-car	8.9
15	13,500	500	75-car	8.8
16	15,360	500	75-car	8.7
17	17,340	500	75-car	8.7
18	19,440	1,000	120-car	8.6

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Minimum storage requirements at the subterminal obtained by the receipt and shipping patterns of the area subject to minimum requirements for each subterminal size.

[d] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

radius of 14 miles and a 30,000 bushel grain density range from 7.3 cents per bushel for the actual shipping pattern to 6.9 cents per bushel for the export shipping pattern. The constant shipping pattern results in an adjusted combined average cost of 7.0 cents per bushel.

Alternative densities of commercial grain

The results obtained in the case study analysis indicate that the density of commercial grain in an area does affect the optimum size of train loading facility and the grain marketing costs of an area. For example, Appendix Table 20 shows that the minimum adjusted combined average cost and least cost subterminal size for a market area with an eight mile radius ranged from 12.2 cents per bushel for a 50-car facility at a 24,000 bushel density to 10.4 cents per bushel for a 120-car facility at a 36,000 bushel density. For the 30,000 bushel density, the minimum adjusted combined average cost was 11.3 cents per bushel for a 75-car train loading facility. Thus, as the grain marketing density in an area increases, the optimum subterminal size increases, the average grain marketing costs decrease and the optimum market area size decreases.

Conventional Cost Analysis

The optimal subterminal size and market area in the conventional cost analysis are estimated for three shipping patterns of the market area, three utilization levels of multiple-car rates, and three selected commercial grain densities. The semi long-run cost equations developed in Chapter II were modified for this conventional cost analysis. All elements in the cost equations that pertained to country elevators were deleted in this analysis. These modified equations for merchandising, storing and drying grain at the subterminal were used to estimate the internal economies of size for alternative annual volumes and market areas. The freight rate reductions for the multiple-car shipments larger than 25 rail cars with the selected utilization levels represent additional economies of size in train loading facilities. The estimated delivery costs for grain shipped from farms to the subterminal represent the diseconomies of size.

The results of the conventional cost analysis using a grain marketing density of 30,000 bushels per square mile and the actual shipping pattern will be presented in the following three sections for the three alternative rate utilization levels. Appendix Tables 23, 24 and 25 present the results of the conventional cost analysis obtained with varying assumptions regarding multiple-car rate utilization levels, shipping patterns and marketing densities.

One hundred percent shipped in multiple-car trains

The estimated minimum adjusted combined average costs for selected market area sizes when all of the grain from a market area is shipped in multiple-car trains are shown in Table 16. The adjusted combined average costs range from 16.3 cents per bushel for the 25-car facility serving a market area with a five mile radius down to 9.7 cents per bushel for the 120-car facility serving a market area with an 18 mile radius. Most of the economies of size are obtained with a 120-car

Table 16. Estimated grain marketing costs, least cost subterminal size and required subterminal storage using the conventional cost analysis, the actual shipping pattern, a 30,000 bushel grain marketing density and a 100 percent multiple-car rate utilization level

Market area size[a]	Market area volume[b]	Required subterminal storage capacity[c]	Least cost subterminal size	Adjusted combined average costs[d]
(miles)	(000 bu.)	(000 bu.)		(cents per bu.)
5	1,500	865	25-car	16.3
6	2,160	1,245	25-car	14.9
7	2,940	1,695	50-car	13.8
8	3,840	2,214	75-car	12.9
9	4,860	2,802	120-car	11.8
10	6,000	3,459	120-car	11.2
11	7,260	4,185	120-car	10.7
12	8,640	4,981	120-car	10.4
13	10,140	5,845	120-car	10.1
14	11,760	6,779	120-car	9.9
15	13,500	7,782	120-car	9.8
16	15,360	8,854	120-car	9.8
17	17,340	9,996	120-car	9.7
18	19,440	11,206	120-car	9.7

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Minimum storage requirements at the subterminal obtained by the receipt and shipping patterns of the area subject to minimum requirements for each subterminal size.

[d] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

facility handling 10.1 million bushels of grain from a 13 mile radius market area size at an adjusted combined average cost of 10.1 cents per bushel.

Based on the actual shipping pattern, storage requirements at this "optimal" size of train loading facility were 5,845,000 bushels. Storage requirements in this conventional cost analysis increase steadily as the market area size increases. They are not affected by the minimum storage requirements assumed for each subterminal size. Thus, the storage capacity requirements at the subterminal become solely a function of the receipt and shipping patterns of the market area size and not a function of the train loading facility size.

Three-fourths of the grain shipped in multiple-car trains

Table 17 shows the estimated minimum adjusted combined average costs for selected market area sizes when three-fourths of the grain from a market area is shipped in multiple-car trains. The adjusted combined average costs range from 16.3 cents per bushel for the 25-car facility serving a market area with a five mile radius down to 10.6 cents per bushel for the 120-car facility serving a market area with an 18 mile radius. Again most of the economies of size were achieved with a 120-car facility serving a market area with a 13 mile radius at an adjusted combined average cost of 11.0 cents per bushel. The storage requirement was 5,845,000 bushels for this "optimal" market area size.

Table 17. Estimated grain marketing costs, least cost subterminal size and required subterminal storage using the conventional cost analysis, the actual shipping pattern, a 30,000 bushel grain marketing density and a 75 percent multiple-car rate utilization level

Market area size[a] (miles)	Market area volume[b] (000 bu.)	Required subterminal storage capacity[c] (000 bu.)	Least cost subterminal size	Adjusted combined average costs[d] (cents per bu.)
5	1,500	865	25-car	16.3
6	2,160	1,245	25-car	14.9
7	2,940	1,695	25-car	14.1
8	3,840	2,214	50-car	13.4
9	4,860	2,802	75-car	12.8
10	6,000	3,459	120-car	12.1
11	7,260	4,185	120-car	11.6
12	8,640	4,981	120-car	11.3
13	10,140	5,845	120-car	11.0
14	11,760	6,779	120-car	10.8
15	13,500	7,782	120-car	10.7
16	15,360	8,854	120-car	10.7
17	17,340	9,996	120-car	10.6
18	19,440	11,206	120-car	10.6

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Minimum storage requirements at the subterminal obtained by the receipt and shipping patterns of the area subject to minimum requirements for each subterminal size.

[d] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

One-half of the grain shipped in multiple-car trains

The estimated minimum adjusted combined average costs for selected market area sizes when one-half of the grain from a market is shipped in multiple-car trains are shown in Table 18. The adjusted combined average costs range from 16.3 cents per bushel for the 25-car facility serving a market area with a five mile radius down to 11.6 cents per bushel for the 120-car facility serving a market area with an 18 mile radius. Again most of the economies of size were achieved with a 120-car facility serving a market area with a 13 mile radius at an adjusted combined average cost of 12.0 cents per bushel.

Alternative shipping patterns

The alternative shipping patterns did not change the "optimum" size of train loading facility. However, they did affect the level of the combined average costs. For example, Appendix Tables 23, 24 and 25 show that the adjusted combined average costs for the actual shipping pattern at any rate utilization level and for any size of market area are 1.5 cents per bushel higher than the costs for the export shipping pattern. The adjusted combined average costs for the constant shipping pattern are 0.5 cent per bushel higher than the export shipping pattern. Thus as the proportion of grain moving out of the area during the fall months increased, the storage capacity requirements and ending monthly inventories declined, thereby decreasing the storage costs of the area.

Table 18. Estimated grain marketing costs, least cost subterminal size and required subterminal storage using the conventional cost analysis, the actual shipping pattern, a 30,000 bushel grain marketing density and a 50 percent multiple-car rate utilization level

Market area size[a] (miles)	Market area volume[b] (000 bu.)	Required subterminal storage capacity[c] (000 bu.)	Least cost subterminal size	Adjusted combined average costs[d] (cents per bu.)
5	1,500	865	25-car	16.3
6	2,160	1,245	25-car	14.9
7	2,940	1,695	25-car	14.1
8	3,840	2,214	25-car	13.6
9	4,860	2,802	50-car	13.2
10	6,000	3,459	50-car	12.9
11	7,260	4,185	75-car	12.6
12	8,640	4,981	75-car	12.3
13	10,140	5,845	120-car	12.0
14	11,760	6,779	120-car	11.8
15	13,500	7,782	120-car	11.7
16	15,360	8,854	120-car	11.7
17	17,340	9,996	120-car	11.6
18	19,440	11,206	120-car	11.6

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Minimum storage requirements at the subterminal obtained by the receipt and shipping patterns of the area subject to minimum requirements for each subterminal size.

[d] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Alternative densities of commercial grain

Alternative densities of commercial grain affect the optimum size of train loading facility and the optimum size of market area. For example, Appendix Table 23 shows that the minimum adjusted combined average cost and least cost subterminal size for a market area with an eight mile radius ranged from 13.7 cents per bushel for a 50-car facility at a 24,000 bushel density to 11.9 cents per bushel for a 120-car facility at a 36,000 bushel density. For the 30,000 bushel density, the minimum adjusted combined average cost was 12.9 cents per bushel for a 75-car train loading facility. Thus, as the grain marketing density in an area increases, the optimum subterminal size increases, the average grain marketing costs decrease and the optimum market area size decreases.

CHAPTER V. SUMMARY AND CONCLUSIONS

The Problem

The historical structure of the Iowa grain elevator industry consisted of many firms serving a trade area extending only five to seven miles from the elevator. Many of these country elevators were located on light branch rail lines. They shipped their grain in random single-car movements to processors and eastern consumption points using the "standard" 40-foot boxcar with little volume moving to export points.

This structure for grain distribution resulted in relatively stable price relationships between origins and final markets. But recent changes in the supply of and demand for corn and soybeans have created serious problems in the grain distribution system. In the past decade, U. S. corn and soybean production have increased more than 50 percent. During the same time, corn and soybean exports have almost tripled, requiring more grain to be shipped longer distances. Shifts in harvesting techniques have enabled farmers to move large quantities of corn and soybeans into storage or to market in short periods of time. This, coupled with railroad branch line abandonment and periodic shortages in transportation equipment, has often forced elevator operators to store thousands of bushels of corn on streets and roads.

In an attempt to provide more transportation capacity, railroads have issued multiple-car tariffs to capture the efficiencies of faster turnaround times and to reduce delays in loading, switching and unloading cars. In addition, railroads are encouraging the use of larger size rail cars for the transport of grain. The jumbo covered hopper car capable of hauling up to 3,300 - 3,500 bushels of grain is rapidly replacing the 2,000 bushel capacity boxcar.

However, these innovations have not solved the grain transportation problems. Many of the rail lines in Iowa's grain producing regions are incapable of carrying the heavy hopper cars and the multiple-car trains. With the declining number of 40-foot boxcars, the country elevator on a light branch rail line is faced with a serious marketing disadvantage.

Summary and Comparison of the Results

The purpose of this research was to determine the economies of size of alternative size train loading facilities with various potential market area sizes. Two methods of analysis were used: 1) A case study analysis based on an engineering cost simulation for a specific train loading facility site, when existing country elevator facilities within the various potential market area sizes are used as collection points and the grain is transshipped to train loading facilities; and 2) A conventional cost analysis based on an engineering cost simulation which assumes away existing country elevator facilities.

Four alternative size train loading facilities, (25-, 50-, 75-, and 120-car) with various potential market area sizes were evaluated. The "optimal" train loading facility size and market area were estimated for three alternative shipping patterns of the market area, three alternative utilization levels of multiple-car rates, and three selected commercial grain densities. The "optimal" train loading facility size and market area were defined as those subterminal and market area sizes that achieved most of the economies of size based on the minimum adjusted combined average cost for that market area. The combined average assembly and in-plant costs were adjusted for the freight rate savings obtained under alternative utilization levels of the multiple-car rates requiring shipments larger than 25 rail cars.

In the case study analysis, the minimum adjusted combined average costs indicate that for any of the selected grain densities and for the 75 and 100 percent multiple-car rate utilization levels the 120-car train loading facility serving a market area with a 14 mile radius achieves most of the economies of size. For the 50 percent rate utilization level, the 75-car facility serving a market area with a 13 to 14 mile radius would achieve most of the economies of size. By comparison and with one exception, the results obtained under all of the alternative marketing situations evaluated in the conventional cost analysis indicate that the 120-car train loading facility serving a market area with a radius of 13 miles would achieve most of the economies of size. The one exception to this result occurs under the marketing situation where a 24,000 bushel grain density exists and only 50 percent of the grain is shipped in multiple-car trains. Under this marketing situation, the "optimal" subterminal size is the 120-car train loading facility serving a market area with a radius of 15 miles.

In general, most of the economies of size were obtained by a 120-car train loading facility serving a market area with a 13 to 14 mile radius. This suggests that if railroads were located in a grid system, 120-car train loading facilities located 26 to 28 miles apart would reduce the overall cost of grain marketing in Iowa. The magnitude of the cost savings could well be within a range of four to eight cents per bushel, depending on the grain density, receipt and shipping patterns and multi-car rate utilization levels of an area (Appendix Tables 20 through 25). However, it should be noted that neither analysis reached a market area size or volume where the adjusted combined average costs increased.

Further comparison of the results of the case study analysis with the results of the conventional cost analysis reveals that the minimum adjusted combined average costs in the case study analysis are lower than the costs estimated in the conventional cost analysis. Table 19 shows that the minimum adjusted combined average costs in the case study analysis for a market area with a 14 mile radius are as much as 3.0 cents per bushel lower than the costs estimated in the conventional cost analysis. These differences in costs are mainly due to the large differences in storage capacity required at the subterminal. For example, using a 30,000 bushel grain density and the actual shipping pattern, almost six times as much storage capacity is required at the "optimum" subterminal in the conventional cost analysis than in the case study analysis. This indicates the use of existing facilities at country elevators as collection and conditioning points of grain

Table 19. Estimated grain marketing costs, least cost subterminal size and required subterminal storage for a market area with a 14 mile radius using the case study and conventional cost analyses, and the actual shipping pattern

			Case study analysis			Conventional cost analysis		
Market area volume[a] (000 bu.)	Market area density (bu. per sq. mi.)	Multi-car rate utilization level	Required subt. storage capacity[b] (000 bu.)	Least cost subt. size	Minimum adjusted combined avg. cost[c] (¢/bu.)	Required subt. storage capacity[b] (000 bu.)	Least cost subt. size	Minimum adjusted combined avg. cost[c] (¢/bu.)
9,408	24,000	100%	1,000	120-car	7.7	5,423	120-car	10.4
11,760	30,000	100%	1,000	120-car	7.3	6,779	120-car	9.9
14,112	36,000	100%	1,000	120-car	6.7	8,135	120-car	9.7
9,408	24,000	75%	1,000	120-car	8.6	5,423	120-car	11.3
11,760	30,000	75%	1,000	120-car	8.2	6,779	120-car	10.8
14,112	36,000	75%	1,000	120-car	7.6	8,135	120-car	10.6
9,408	24,000	50%	500	75-car	9.2	5,423	75-car	12.4
11,760	30,000	50%	500	75-car	8.9	6,779	120-car	11.8
14,112	36,000	50%	551	75-car	8.6	8,135	120-car	11.6

[a] Volume of grain handled from a 14 mile radius market area with the specified grain density.

[b] Minimum storage requirements at the subterminal obtained by the receipt and actual shipping pattern of the area subject to minimum requirements for each subterminal size.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

for transshipment to train loading facilities is less costly than bypassing the country elevators at harvest time, and having all of the storage and conditioning facilities at the subterminal. If, however, the variable operating costs at country elevators plus, the difference in transportation cost between the farm to subterminal movement and the cost for the farm to country elevator to subterminal movement, exceeds the annual cost of constructing additional facilities at the subterminal, it would become more economical to bypass the country elevators.

Both analyses indicate that the "optimum" size of subterminal is not independent of the utilization levels of the multiple-car rates or the density of commercial grain. In general, as the density of commercial grain and/or the utilization levels of the multiple-car rates increased, the "optimum" size of train loading facility increased, the adjusted combined average costs decreased, and the "optimum" market area size decreased.

The adjusted combined average costs estimated in the case study analysis exhibit slightly more economies of size, as market area and volume increase, than the costs estimated in the conventional cost analysis. This can be accounted for by the large differences in the annual investment costs for the storage capacity required at the subterminal under the two methods of analysis. In the case study analysis, storage requirements increase as the market area radius increases to eight miles, thereafter storage requirements decrease subject to the assumed minimum capacity required at each size subterminal. But, the storage requirements determined in the conventional cost analysis increase continuously as market area size increases, always exceeding the assumed minimum storage capacity of each size subterminal.

The results of these analyses are specifically for a heavy cash grain producing area near Fort Dodge, Iowa. The specific subterminal site is located about 200 miles from the Mississippi River. The results are directly applicable only to that area and under the assumptions made in the study. It should be recognized that the optimal train loading facility size and market area size for any other particular geographic area should be determined by considering the factors included in this analysis, plus a detailed examination of transportation facilities available in that area.

This study did not consider the multi-product aspects of elevator operations. One very important extension of this research would be to incorporate other products, such as feed, fertilizer and other farm supplies, into the analysis. The possibility of multiple-car rates on inbound fertilizer shipments would be of particular interest.

Facility costs, based on the conventional type of elevator facility where the grain is re-elevated for loading into rail cars, were used in this study. Another possible extension of the study would be to incorporate the costs of elevated storage tanks which can be placed directly above the rail siding. This would allow the grain to be loaded directly into the rail cars by gravity reducing the grain handling costs.

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APPENDIX

Table 20. Estimated grain marketing costs and least cost subterminal size using the case study analysis and a 100 percent multiple-car rate utilization level in an area with 24,000, 30,000, and 36,000 bushels per square mile marketing density with alternative shipping patterns and market area sizes

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c]		
			Shipping pattern		
			Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
		24,000:			
5	1,200	25-car	16.2	17.1	15.7
6	1,728	25-car	14.2	15.1	13.6
7	2,352	50-car	12.8	13.7	12.2
8	3,072	50-car	11.3	12.2	10.8
9	3,888	75-car	10.0	10.9	9.5
10	4,800	75-car	8.9	9.8	8.8
11	5,808	75-car	8.4	9.1	8.4
12	6,912	75-car	8.1	8.6	8.0
13	8,112	120-car	7.8	8.1	7.7
14	9,408	120-car	7.4	7.7	7.3
15	10,800	120-car	7.2	7.5	7.1
16	12,288	120-car	7.0	7.3	6.9
17	13,872	120-car	6.9	7.2	6.8
18	15,552	120-car	6.8	7.1	6.7

30,000:

5	1,500	25-car	15.1	16.0	14.6
6	2,160	25-car	13.3	14.2	12.8
7	2,940	50-car	11.8	12.7	11.3
8	3,840	75-car	10.5	11.3	9.9
9	4,860	120-car	9.2	9.8	9.1
10	6,000	120-car	8.3	8.7	8.2
11	7,260	120-car	7.9	8.2	7.8
12	8,640	120-car	7.6	7.9	7.5
13	10,140	120-car	7.3	7.6	7.2
14	11,760	120-car	7.0	7.3	6.9
15	13,500	120-car	6.8	7.1	6.7
16	15,360	120-car	6.7	7.0	6.6
17	17,340	120-car	6.6	6.9	6.5
18	19,440	120-car	6.5	6.8	6.4

---

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Table 20 (continued)

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern		
			Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
		36,000:			
5	1,800	25-car	14.2	15.1	13.7
6	2,592	50-car	12.6	13.5	12.1
7	3,528	75-car	11.2	12.1	10.7
8	4,608	120-car	9.5	10.4	9.1
9	5,832	120-car	8.3	9.1	8.1
10	7,200	120-car	7.6	8.1	7.5
11	8,712	120-car	7.2	7.6	7.1
12	10,368	120-car	6.9	7.2	6.8
13	12,168	120-car	6.6	6.9	6.5
14	14,112	120-car	6.4	6.7	6.3
15	16,200	120-car	6.3	6.6	6.2
16	18,432	120-car	6.3	6.6	6.2
17	20,808	120-car	6.2	6.5	6.1
18	23,328	120-car	6.2	6.5	6.1

Table 21. Estimated grain marketing costs and least cost subterminal size using the case study analysis and a 75 percent multiple-car rate utilization level in an area with 24,000, 30,000, and 36,000 bushels per square mile marketing density with alternative shipping patterns and market area sizes

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c]		
			Shipping pattern		
			Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
			24,000:		
5	1,200	25-car	16.2	17.1	15.7
6	1,728	25-car	14.2	15.1	13.6
7	2,352	25-car	12.8	13.7	12.2
8	3,072	50-car	11.7	12.5	11.1
9	3,888	50-car	10.5	11.4	9.9
10	4,800	50-car	9.6	10.5	9.1
11	5,808	50-car	9.1	10.0	8.9
12	6,912	75-car	8.8	9.3	8.7
13	8,112	75-car	8.6	8.9	8.5
14	9,408	120-car	8.3	8.6	8.2
15	10,800	120-car	8.1	8.4	8.0
16	12,288	120-car	7.9	8.2	7.8
17	13,872	120-car	7.8	8.1	7.7
18	15,552	120-car	7.7	8.0	7.6

			30,000:		
5	1,500	25-car	15.1	16.0	14.6
6	2,160	25-car	13.3	14.2	12.8
7	2,940	25-car	12.2	13.0	11.6
8	3,840	50-car	11.0	11.8	10.4
9	4,860	50-car	9.9	10.8	9.4
10	6,000	75-car	9.0	9.9	8.7
11	7,260	75-car	8.5	9.3	8.4
12	8,640	75-car	8.3	8.8	8.1
13	10,140	120-car	8.1	8.5	8.0
14	11,760	120-car	7.9	8.2	7.8
15	13,500	120-car	7.7	8.0	7.6
16	15,360	120-car	7.6	7.9	7.5
17	17,340	120-car	7.5	7.8	7.4
18	19,440	120-car	7.4	7.7	7.3

---

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Table 21 (continued)

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern		
			Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
36,000:					
5	1,800	25-car	14.2	15.1	13.7
6	2,592	25-car	12.8	13.7	12.3
7	3,528	50-car	11.6	12.5	11.1
8	4,608	50-car	10.5	11.4	10.0
9	5,832	75-car	9.4	10.3	8.9
10	7,200	75-car	8.6	9.5	8.2
11	8,712	120-car	8.1	8.5	8.0
12	10,368	120-car	7.8	8.1	7.7
13	12,168	120-car	7.5	7.8	7.4
14	14,112	120-car	7.3	7.6	7.2
15	16,200	120-car	7.2	7.5	7.1
16	18,432	120-car	7.2	7.5	7.1
17	20,808	120-car	7.1	7.4	7.0
18	23,328	120-car	7.1	7.4	7.0

Table 22. Estimated grain marketing costs and least cost subterminal size using the case study analysis and a 50 percent multiple-car rate utilization level in an area with 24,000, 30,000, and 36,000 bushels per square mile marketing density with alternative shipping patterns and market area sizes

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
		24,000:			
5	1,200	25-car	16.2	17.1	15.7
6	1,728	25-car	14.2	15.1	13.6
7	2,352	25-car	12.8	13.7	12.2
8	3,072	25-car	11.7	12.5	11.1
9	3,888	25-car	10.7	11.6	10.2
10	4,800	50-car	10.0	10.9	9.5
11	5,808	50-car	9.5	10.4	9.3
12	6,912	50-car	9.2	9.9	9.1
13	8,112	50-car	9.1	9.6	9.0
14	9,408	75-car	9.0	9.2	8.9
15	10,800	75-car	8.8	9.1	8.7
16	12,288	75-car	8.8	9.1	8.7
17	13,872	75-car	8.7	9.0	8.6
18	15,552	120-car	8.7	9.0	8.6

30,000:

5	1,500	25-car	15.1	16.0	14.6
6	2,160	25-car	13.3	14.2	12.8
7	2,940	25-car	12.2	13.0	11.6
8	3,840	25-car	11.2	12.1	10.6
9	4,860	50-car	10.3	11.2	9.8
10	6,000	50-car	9.6	10.5	9.1
11	7,260	50-car	9.1	10.0	8.8
12	8,640	75-car	8.9	9.4	8.7
13	10,140	75-car	8.7	9.1	8.6
14	11,760	75-car	8.6	8.9	8.5
15	13,500	75-car	8.5	8.8	8.4
16	15,360	75-car	8.5	8.7	8.4
17	17,340	75-car	8.4	8.7	8.4
18	19,440	120-car	8.4	8.6	8.3

---

[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Table 22 (continued)

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	 Actual	 Export
(miles)	(000 bu.)		(cents per bushel)		
		36,000:			
5	1,800	25-car	14.2	15.1	13.7
6	2,592	25-car	12.8	13.7	12.3
7	3,528	25-car	11.7	12.6	11.2
8	4,608	50-car	10.9	11.8	10.4
9	5,832	50-car	10.0	10.8	9.4
10	7,200	50-car	9.3	10.2	8.7
11	8,712	50-car	8.8	9.6	8.5
12	10,368	75-car	8.5	9.1	8.4
13	12,168	75-car	8.4	8.8	8.3
14	14,112	75-car	8.3	8.6	8.2
15	16,200	75-car	8.2	8.5	8.1
16	18,432	120-car	8.2	8.5	8.1
17	20,808	120-car	8.1	8.4	8.0
18	23,328	120-car	8.1	8.4	8.0

Table 23. Estimated grain marketing costs and least cost subterminal size using the conventional cost analysis and a 100 percent multiple-car rate utilization level in an area with 24,000, 30,000, and 36,000 bushels per square mile marketing density with alternative shipping patterns and market area sizes

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
		24,000:			
5	1,200	25-car	16.5	17.5	16.0
6	1,728	25-car	14.7	15.7	14.2
7	2,352	25-car	13.7	14.7	13.2
8	3,072	50-car	12.7	13.7	12.2
9	3,888	75-car	11.9	12.9	11.4
10	4,800	120-car	10.9	11.9	10.4
11	5,808	120-car	10.3	11.3	9.8
12	6,912	120-car	9.9	10.9	9.4
13	8,112	120-car	9.6	10.6	9.1
14	9,408	120-car	9.4	10.4	8.9
15	10,800	120-car	9.2	10.2	8.7
16	12,288	120-car	9.1	10.1	8.6
17	13,872	120-car	9.0	10.0	8.5
18	15,552	120-car	8.9	9.9	8.4

30,000:					
5	1,500	25-car	15.3	16.3	14.8
6	2,160	25-car	13.9	14.9	13.4
7	2,940	50-car	12.8	13.8	12.3
8	3,840	75-car	11.9	12.9	11.4
9	4,860	120-car	10.8	11.8	10.3
10	6,000	120-car	10.2	11.2	9.7
11	7,260	120-car	9.7	10.7	9.2
12	8,640	120-car	9.4	10.4	8.9
13	10,140	120-car	9.1	10.1	8.6
14	11,760	120-car	8.9	9.9	8.4
15	13,500	120-car	8.8	9.8	8.3
16	15,360	120-car	8.8	9.8	8.3
17	17,340	120-car	8.7	9.7	8.2
18	19,440	120-car	8.7	9.7	8.2

---

[a] Miles from subterminal in periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Table 23 (continued)

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	 Actual	 Export
(miles)	(000 bu.)		(cents per bushel)		
			36,000:		
5	1,800	25-car	14.5	15.5	14.0
6	2,592	50-car	13.2	14.2	12.7
7	3,528	75-car	12.1	13.1	11.6
8	4,608	120-car	10.9	11.9	10.4
9	5,832	120-car	10.2	11.2	9.7
10	7,200	120-car	9.6	10.6	9.1
11	8,812	120-car	9.3	10.3	8.8
12	10,368	120-car	9.0	10.0	8.5
13	12,168	120-car	8.8	9.8	8.3
14	14,112	120-car	8.7	9.7	8.2
15	16,200	120-car	8.6	9.6	8.1
16	18,432	120-car	8.6	9.6	8.1
17	20,808	120-car	8.5	9.5	8.0
18	23,328	120-car	8.5	9.5	8.0

Table 24. Estimated grain marketing costs and least cost subterminal size using the conventional cost analysis and a 75 percent multiple-car rate utilization level in an area with 24,000, 30,000, and 36,000 bushels per square mile marketing density with alternative shipping patterns and market area sizes

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern		
			Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
24,000:					
5	1,200	25-car	16.5	17.5	16.0
6	1,728	25-car	14.7	15.7	14.2
7	2,352	25-car	13.7	14.7	13.2
8	3,072	25-car	13.0	14.0	12.5
9	3,888	50-car	12.4	13.4	11.9
10	4,800	75-car	11.9	12.9	11.4
11	5,808	120-car	11.2	12.2	10.7
12	6,912	120-car	10.8	11.8	10.3
13	8,112	120-car	10.5	11.5	10.0
14	9,408	120-car	10.3	11.3	9.8
15	10,800	120-car	10.1	11.1	9.6
16	12,288	120-car	10.0	11.0	9.5
17	13,872	120-car	9.9	10.9	9.4
18	15,552	120-car	9.8	10.8	9.3

30,000:

5	1,500	25-car	15.3	16.3	14.8
6	2,160	25-car	13.9	14.9	13.4
7	2,940	25-car	13.1	14.1	12.6
8	3,840	50-car	12.4	13.4	11.9
9	4,860	75-car	11.8	12.8	11.3
10	6,000	120-car	11.1	12.1	10.6
11	7,260	120-car	10.6	11.6	10.1
12	8,640	120-car	10.3	11.3	9.8
13	10,140	120-car	10.0	11.0	9.5
14	11,760	120-car	9.8	10.8	9.3
15	13,500	120-car	9.7	10.7	9.2
16	15,360	120-car	9.7	10.7	9.2
17	17,340	120-car	9.6	10.6	9.1
18	19,440	120-car	9.6	10.6	9.1

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[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Table 24 (continued)

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
		36,000:			
5	1,800	25-car	14.5	15.5	14.0
6	2,592	25-car	13.3	14.3	12.8
7	3,528	50-car	12.5	13.5	12.0
8	4,608	75-car	11.9	12.9	11.4
9	5,832	120-car	11.1	12.1	10.6
10	7,200	120-car	10.5	11.5	10.0
11	8,712	120-car	10.2	11.2	9.7
12	10,368	120-car	9.9	10.9	9.4
13	12,168	120-car	9.7	10.7	9.2
14	14,112	120-car	9.6	10.6	9.1
15	16,200	120-car	9.5	10.5	9.0
16	18,432	120-car	9.5	10.5	9.0
17	20,808	120-car	9.4	10.4	8.9
18	23,328	120-car	9.4	10.4	8.9

Table 25. Estimated grain marketing costs and least cost subterminal size using the conventional cost analysis and a 50 percent multiple-car rate utilization level in an area with 24,000, 30,000, and 36,000 bushels per square mile marketing density with alternative shipping patterns and market area sizes

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	Actual	Export
(miles)	(000 bu.)		(cents per bushel)		
		24,000:			
5	1,200	25-car	16.5	17.5	16.0
6	1,728	25-car	14.7	15.7	14.2
7	2,352	25-car	13.7	14.7	13.2
8	3,072	25-car	13.0	14.0	12.5
9	3,888	25-car	12.6	13.6	12.1
10	4,800	50-car	12.4	13.4	11.9
11	5,808	50-car	12.0	13.0	11.5
12	6,912	50-car	11.8	12.8	11.3
13	8,112	75-car	11.5	12.5	11.0
14	9,408	75-car	11.4	12.4	10.9
15	10,800	120-car	11.1	12.1	10.6
16	12,288	120-car	11.0	12.0	10.5
17	13,872	120-car	10.9	11.9	10.4
18	15,552	120-car	10.8	11.8	10.3

30,000:

5	1,500	25-car	15.3	16.3	14.8
6	2,160	25-car	13.9	14.9	13.4
7	2,940	25-car	13.1	14.1	12.6
8	3,840	25-car	12.6	13.6	12.1
9	4,860	50-car	12.2	13.2	11.7
10	6,000	50-car	11.9	12.9	11.4
11	7,260	75-car	11.6	12.6	11.1
12	8,640	75-car	11.3	12.3	10.8
13	10,140	120-car	11.0	12.0	10.5
14	11,760	120-car	10.8	11.8	10.3
15	13,500	120-car	10.7	11.7	10.2
16	15,360	120-car	10.7	11.7	10.2
17	17,340	120-car	10.6	11.6	10.1
18	19,440	120-car	10.6	11.6	10.1

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[a] Miles from subterminal to periphery of market area, assuming grid road system.

[b] Volume of grain handled in specified size of market area.

[c] Average assembly and in-plant costs adjusted for the proportion of the rate savings obtained for shipments larger than 25 rail cars.

Table 25 (continued)

Market[a] area size	Market[b] area volume	Least cost subterminal size	Adjusted combined average costs[c] Shipping pattern Constant	 Actual	 Export
(miles)	(000 bu.)		(cents per bushel)		
		36,000:			
5	1,800	25-car	14.5	15.5	14.0
6	2,592	25-car	13.3	14.3	12.8
7	3,528	25-car	12.7	13.7	12.2
8	4,608	50-car	12.3	13.3	11.8
9	5,832	50-car	11.9	12.9	11.4
10	7,200	75-car	11.5	12.5	11.0
11	8,712	75-car	11.2	12.2	10.7
12	10,368	120-car	10.9	11.9	10.4
13	12,168	120-car	10.7	11.7	10.2
14	14,112	120-car	10.6	11.6	10.1
15	16,200	120-car	10.5	11.5	10.0
16	18,432	120-car	10.5	11.5	10.0
17	20,808	120-car	10.4	11.4	9.9
18	23,328	120-car	10.4	11.4	9.9