OPTIMUM NUMBER, SIZE AND LOCATION
OF GRAIN HANDLING FACILITIES
IN OKLAHOMA

By

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Bachelor of Science

Oklahoma State University

Stillwater, Oklahoma

1972

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
July, 1975

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PREFACE

This study is concerned with determining the optimum number, size and location of grain handling facilities in Oklahoma. The study is based on existing data which projects feed grain and wheat production and utilization for the year 1990. Existing grain transportation rates and elevator operating costs were incorporated into the general transportation model to obtain the least-cost solution. An iterative-expansion approach was used to evaluate the changes in number and size of elevators as the number of locations varied from 1 to 57. An analysis of that iteration which resulted in minimum combined operating and transportation costs is presented with comparisons to existing conditions in Oklahoma's grain elevator industry.

The author wishes to express his appreciation to his major adviser, Dr. Robert L. Oehrtman, for his guidance and assistance throughout this study. Appreciation is also expressed to the other members of the author's graduate committee, Dr. Paul D. Hummer, Dr. John R. Franzmann, and Mr. R. E. (Gus) Page, for their helpful suggestions and assistance in preparation of the final manuscript.

Special thanks are due to the Department of Agricultural Economics at Oklahoma State University for providing financial assistance during my graduate program. A note of thanks is given to Mrs. Dee Wells for her assistance in typing earlier drafts of the manuscript.

Thanks are also due to the corp of graduate students enrolled in the Department of Agricultural Economics at Oklahoma State University from September, 1972, through February, 1974, whose fellowship and friendship made the course of my graduate program more enjoyable.

The author is deeply grateful to the Arkansas Farm Bureau Federation for its cooperation and support required to complete this study. A debt of gratitude is extended to Mr. W. F. Wright, Director of Commodity Activities, Arkansas Farm Bureau Federation, for his encouragement, patience, and understanding throughout the writing of this thesis.

Sincere appreciation is expressed to the author's parents, Mr. and Mrs. A. F. Justice, for their neverending faith, moral support, assistance and sacrifices throughout the author's entire educational career.

Finally, the author gives special recognition, deepest gratitude and much love to his wife, Emma, for her excellence in typing the final manuscript and also her assistance, encouragement, patience and sacrifices during the author's entire college life.

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CHAPTER 1

INTRODUCTION

Oklahoma's country elevator industry is the most numerous and widespread type of business organization engaged in grain marketing beyond the farm level. The primary function performed by a country elevator is the assembly of grain received from farmers for later delivery to storage terminals, mills and/or export terminals. In addition to the assembly of grain, country elevators render other related activities such as storing, grading, cleaning and treating, and blending grains. Country elevators have also broadened their range of activities to include sales of farm inputs such as feed, seed, fertilizer, and petroleum products.

Although those functions performed by country elevators are similar, there exist several differences among individual elevators. Individual elevators differ with respect to the amount of storage capacity and type of ownership and organization. Elevators in Oklahoma vary in size from several thousand to several million bushels of storage capacity. Table I gives an indication of the size distribution of Oklahoma elevators[1]. The most popular types of business forms are private, line[2], and cooperative. Cooperative elevators make up approximately one-third of the total number of firms, while about one-fourth of the total are multi-location or line firms.

TABLE I

NUMBER AND PERCENTAGE DISTRIBUTION OF OKLAHOMA ELEVATORS ACCORDING TO RATED GRAIN STORAGE CAPACITY, 1970

Grain Storage Capacity in bu.	Number of Elevators	Percent in each Size Interval
0 - 99,999	138	33.74
100,000 - 399,999	154	37.65
400,000 - 699,999	60	14.67
700,000 - 999,999	23	5.62
1,000,000 - 1,999,999	25	6.11
2,000,000 and over	9	2.20

Significant changes have occurred in the country elevator industry in Oklahoma. The average size of country elevators has increased while the number of firms in the industry has declined. From 1960 to 1970 the average size elevator increased 20 percent, while the total number of grain handling firms decreased 19 percent as can be verified in Table II[3]. Prior to 1960, the United States government, through its operating agency, the Commodity Credit Corporation, provided inducements that were in the form of occupancy guarantee and accelerated ammortization[4]. The economic incentives were successful in increasing storage capacity via expansion of existing firms and new firms entering the industry. Since 1960, acquisition of grain by the CCC has declined

TABLE II

TOTAL GRAIN STORAGE CAPACITY, NUMBER AND AVERAGE SIZE OF OKLAHOMA'S COUNTRY ELEVATORS 1960, 1965, and 1970

Region	1960	1965	1970
	Total Grain Storage Capacity in Thousands of Bushels		
Western one-third of Okla.	43,714	54,418	51,238
Central one-third of Okla.	98,310	109,610	91,966
Eastern one-third of Okla.	20,495	23,506	14,583
Total	162,519	187,534	157,787
	Number of Elevators		
Western one-third of Okla.	200	180	161
Central one-third of Okla.	212	193	185
Eastern one-third of Okla.	43	42	23
Total	455	415	369
	Average size of elevator		
Western one-third of Okla.	218,570	302,322	318,248
Central one-third of Okla.	463,726	567,927	497,113
Eastern one-third of Okla.	476,628	559,666	634,043

sharply, thus decreasing the demand for storage space. This, accordingly, reduced the need for expansion of storage facilities. The effect this change in government policy has had on the Oklahoma grain elevator industry is apparent in Table II, namely a reduction in total number of firms. This reduction in number of firms and a corresponding increase in average firm size indicates that those firms exiting the industry were smaller, below average size firms. The areas described are shown in Figure 1.

Problem Description

The grain marketing industry in Oklahoma is faced with several economic problems. First, the end result of CCC storage expansion program has left the grain industry in Oklahoma with excess total storage capacity. This situation exists even though some grain elevators in certain parts of the state have grain storage capacities that are insufficient relative to average volumes of grain handled by other elevators with similar grain storage capacities. Second, increase export demand for U.S. grain has put severe pressure on all modes of grain transportation. The transportation industry is an important link between many firms and agencies in the grain marketing system. Failure of the transportation industry to meet the demands placed on it causes serious problems to all firms in the marketing channel. Increased grain traffic has caused shortages of railroad cars and transport trucks at various locations. Thus, the problems of excess storage capacity and shortages of railroad cars and transport trucks at various locations would seem to indicate that the number and/or location of grain elevators is not consistent with economic efficiency.

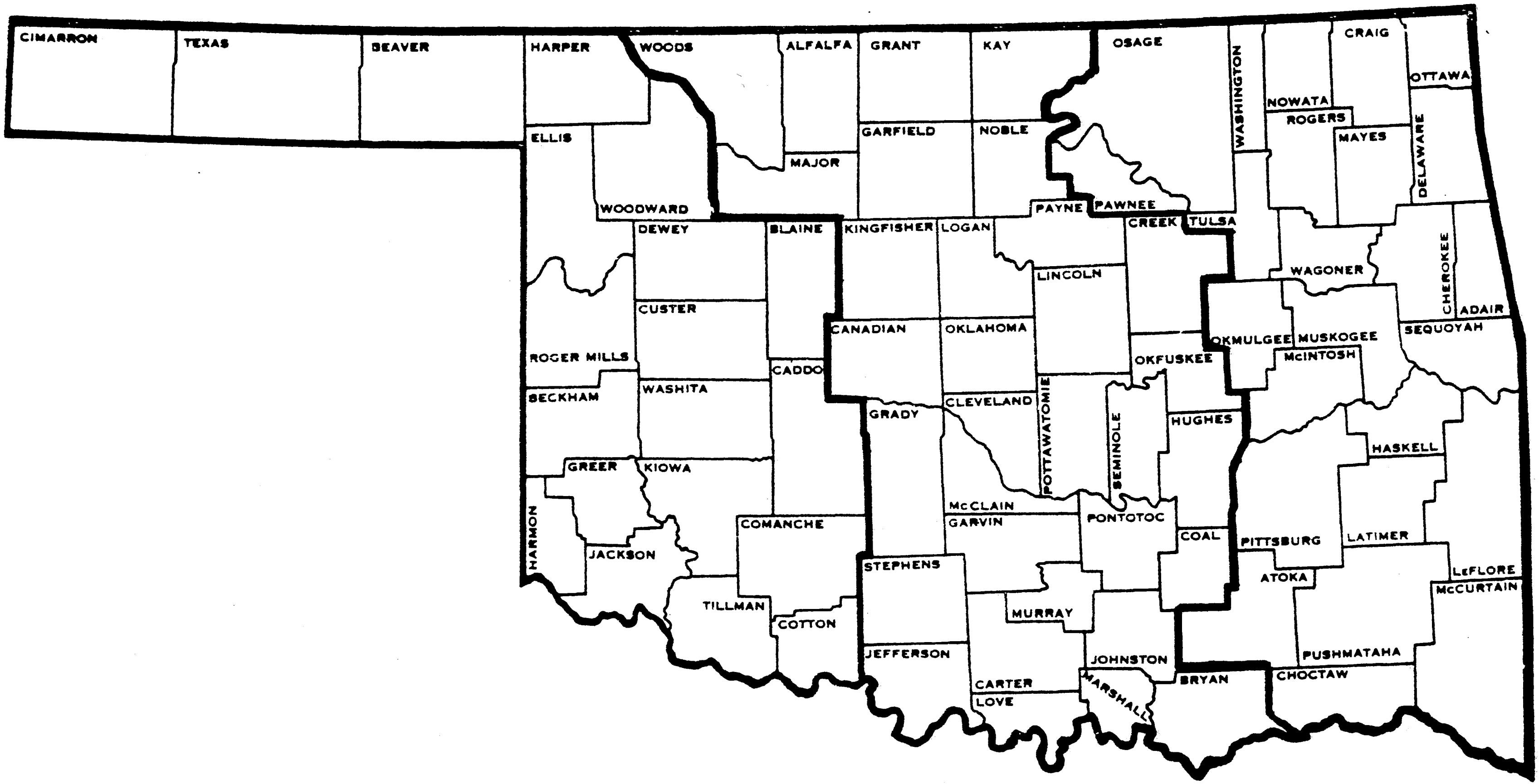

Figure 1. Counties Within Each Selected One-Third of Oklahoma Used in This Study

Country elevators have also experienced significant increases in their costs of operation. Labor costs, which make up the largest percentage of total operating costs, have been increasing at an estimated 10 percent per year[5]. Other cost items vary somewhat from previous years; but overall, the annual expense budget for all sizes of country elevators has greatly increased. The magnitude of change in each expense item in the operating budget will be discussed later in greater detail.

Another problem of increasing concern to grain elevators in Oklahoma is that of pollution abatement, primarily dust pollution. Under regulations set forth in Public Law 90-148, the Clean Air Act, many elevators may be forced to install dust control systems or renovate their plant to meet certain specifications. The addition of adequate dust control systems will undoubtedly increase the elevator's cost of operation. If renovation is warranted, the cost of renovation may be of such magnitude to force some firms to change their existing size of plant or exit from the industry entirely[6].

Purpose of Study

Technological developments and changes in federal agricultural policies have changed important variables determining the number, size and location of Oklahoma's grain handling facilities that is consistent with an efficient grain marketing system. The exiting of firms from the country elevator industry is evidence that certain variables or combination of variables have shifted causing a state of disequilibrium. Given that operating costs per bushel of grain tend to decrease over a certain range as plant size increases, a change in the level of operating costs will affect optimum plant size. With the knowledge of current operating expenses for different size elevators operating at different handling volumes, one can determine the optimum size and number of grain facilities that will minimize total handling expenses for the entire industry. Recent pressures on grain transportation systems, i.e., shortages of railroad cars and transport trucks, may also lead one to suspect that the number and location of grain elevators is non-optimal.

This thesis is concerned with answering a basic normative question of market structure. That is, "Does the structure of the grain elevator industry reflect the number and size of firms that is consistent with economic efficiency?".

The broad objective of this study is to determine the optimum number, size and location of grain handling facilities in Oklahoma that minimize grain elevator handling and distribution costs to the system for the year 1990 using existing data which give projected feed grain and wheat production and utilization for the year 1990. Specific objectives are as follows:

1. Estimate operating costs per bushel of grain for different sizes of grain handling facilities.
2. Determine a least-cost size combination and associated number of grain handling facilities at each location of supply and demand.
3. Given the current transportation rate structure of both rail and truck transport systems, determine that optimum flow of grain and mode of transportation within Oklahoma and for export at Houston, Texas.

FOOTNOTES

[1]Oklahoma State University, Commercial Grain Warehouses in Oklahoma (Stillwater, 1968).

[2]Line elevators are defined as several firms at various locations under the same ownership.

[3]Oklahoma Grain and Feed Dealer Association Official Directory, (Enid, Oklahoma) selected issues.

[4]U.S. Department of Agriculture, Farm Commodity and Related Programs, Agricultural Stabilization and Conservation Service, Agriculture Handbook No. 345 (Washington, 1968).

[5]U.S. Department of Agriculture, Costs of Storing and Handling Grain in Commerical Elevators, 1970-71, and Projections for 1972-73, Economic Research Service, ERS-501 (Washington, 1972), p. 34.

[6]Ibid., p. 36.

CHAPTER II

REVIEW OF LITERATURE

Location Theory

To determine the optimum number and size of grain handling facilities for a specific region, an analysis must consider the spatial aspects associated with plant location. A review of pertinent location theory is required to account for the effects of space on a firm's location and why an industry develops a marked locational scheme, as has the grain elevator industry.

Most of the early work in location theory was performed by J. H. von Thünen and Alfred Weber. Authors later contributing to the literature on locational analysis included Freiduch, Lösch, Hoover, and Isard.

Von Thünen's work in location theory was focused on the most efficient location for agricultural production[1]. His analysis assumed an "isolated state" made up of a central city surrounded by a homogeneous plain of farm land. The farm sector was assumed purely competitive and farmers were free to select whatever type of production they wanted. Only a single mode of transportation was available and was readily accessible to all farmers for transporting their products to the city. The central city was assumed the only market for agricultural products produced on the homogeneous plain. Von Thünen's main objective was to explain what kind of agricultural production would occur at different locations within the plain. His analysis used as variables the cost of transportation and rent of land to explain agricultural locations.

The results of von Thünen's work indicated that perishable products and products whose value was low in relation to their weight would be produced near the central city. Other products displaying opposing characteristics to those above would be produced further away from the city. In von Thünen's analysis the location is assumed given and the type of production is to be obtained, as opposed to Weber's theory where the types of production is assumed given and the location of that production is to be determined[2]. Weber's theory is probably more applicable to the locational analysis of industries than agricultural production.

Weber's work was directed toward determining the least-cost location of an individual firm performing a specific activity. This theory is one which directly applies to the grain elevator industry.

Weber assumed an even plain with equal transportation rates throughout. Unlike von Thünen, he assumed many consuming centers scattered over the plain. He also assumes varying fertility throughout the plain which implies uneven distribution of raw products[3].

Weber identifies three groups of general location factors: transportation costs, labor costs, and agglomerating (or conversely, deglomerating) factors. Since the problem of location is one of spatial distribution, it is essential to consider transportation costs as a determining factor. The extent to which labor costs affect the locational pattern is determined by the ratio of labor costs per ton of product and total weight of all goods being transported. The third general location factor, agglomeration economies and diseconomies (deglomeration) acts, following Weber, to congregate or disperse industries throughout a region[4]. The interplay of agglomerating factors with transport and labor costs tend to dictate location when only slight advantages exist between the other two factors for alternative locations.

Transportation Costs and Firm Location

Whether producers are attracted to locate in the vicinity of either their source of raw materials or market depends upon the magnitude of the costs associated with assembling raw materials and distributing products to distant consumers. Transportation factors can be crucial in the orientation of firms to alternative locations. Those industries where transportation cost differences overshadow differences in production costs are commonly called transportation-oriented industries[5]. These industries may be subdivided into market-oriented and material-oriented industries, depending on which element of cost (transportation or production) dominates. In industries where there is substantial weight loss in processing a particular product or the transportation costs per unit is higher on raw materials than on products, firms will locate nearer the source of their raw materials. Conversely, in industries where there is a considerable increase in weight during the production process or transportation costs per unit is higher on products than on raw materials, firms will locate nearer to their markets[6]. Because of the nature of their cost structure or production process, many industries are neither material-oriented nor market-oriented. These industries are referred to as foot-loose industries. In general these industries will find it advantageous to locate at points between their sources of raw materials and their markets[7].

A further explanation of those location orientation schemes presented above can be made by considering Weber's model[8]. The model assumes a single market and two raw materials, each of which are located at different points away from the market. This condition is represented in Figure 2 where C depicts a market where the product is consumed, and M_1 and M_2 represent sources of raw materials one and two, respectively. A processing firm will locate somewhere within the triangle say at location P, except in the unique case where the importance of one material to the processing phase overshadows the increased transport distance of the other material. The exact processing location will depend on the quantities of each material used and their weight loss-weight gain characteristics. If both materials are used in equal quantities, processing will locate nearer the material losing the most (gaining the least) weight, whereas it will locate nearer the material used in the greatest quantity when weight losses (gains) for both materials are equal. The greater (less) the weight loss of the materials, the further from (nearer to) the market processing will locate.

Whether an industry be material-oriented, market-oriented or foot-loose, its best location will be that point corresponding to the lowest total transportation cost, other costs remaining the same.

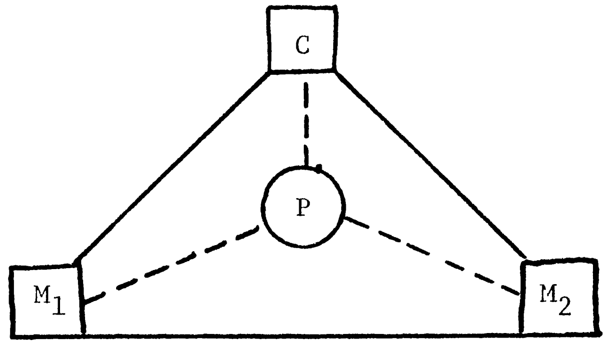

Figure 2. Weber's Locational Triangle

<u>Processing Costs and Firm Location</u>

Processing costs corresponding to various locations may vary due to immoble factors or production. So, in those industries characterized by immoble factors processing costs as well as transportation costs may effect the choice of location. In minimizing processing costs, a location should be chosen that provides for intense application of productive factors and a proper scale of output for that specific location.

In those industries exhibiting economies of scale in plant operations, generally, large scale plants are more efficient than smaller scale plants, but per unit processing costs do not decrease indefinitely in the short run with large plants, hence there is a limit set to plant size. Plants approaching this limit may further decrease their per unit processing costs in the long run by increasing output via a larger supply area. However, increased procurement costs to the industry due to a larger supply area again restrict the least-cost size of plant. Corley has shown that in the grain elevator industry, processing or in-plant costs do not dominate the cost structure so as to become a determining factor in the location decision[9]. Lösch has discussed this situation of economies of scale regarding the brewery industry[10]. Economies of scale will favor the brewer, but transportation costs will deter the size of plant. As with the brewing industry, breweries are located nearer their markets due to distribution costs and are limited in size due to procurement costs.

The above discussion implies that each individual firm in an industry, exceeding unusual situations, has its own market and/or supply area. A market area depicts a geographic area in which a firm provides a service or product. A supply area describes a geographic area from which a processor is supplied with raw materials[11].

Location Theory and the Grain Elevator Industry

The above discussion of relationships between a firm and its supply area most appropriately depicts the grain elevator industry. That is, in order for a grain elevator to handle a sufficient quantity of grain, it must obtain that grain from many producers. The industry as a whole is an example of an areal agglomeration of locations, which is a network of supply areas of grain elevators[12]. This type of locational pattern differs from others in that firms are distributed with fair regularity throughout a region, namely the grain belt, and are restricted to it. A priori reasoning indicates that transportation costs (those bore by producers in delivering grain to the elevator and/or other demand points) are determinants of this type of pattern, since in-plant or handling costs do influence, but do not dominate plant size.

Truck transportation is most commonly used in transporting grain from the farm to the elevator. This is the most economical method of transportation considering the dispersion of grain production and the relatively small quantity of grain each farmer produces. However, as transportation data indicate, truck transportation is only most economical for relatively short distances[13]. Railroads and barges are most economical for intermediate and long distances, respectively. So, given this transportation rate structure, grain is marketed most economically by assembling large quantities at country elevators dispersed throughout a region. These country elevators then perform their material-oriented service of assembling carload lots of grain for shipment to other points.

In the following theory of economic regions, individual grain elevators appear as collecting points in a system of local supply areas for grain produced in those areas. They appear again as units making up the assembled-grain supply areas of terminal markets, flour mills, and export centers. Finally, to the extent that they may supply seed directly to planters and feed grain to livestock producers and cattle feeders, they have their individual market areas we well.

The Model

The model used in this study is referred to as the spatial or transportation model. This model represents a special class of linear programming problems. In this class of problems, special computing routines apply which, for their intention, are more efficient than the simplex method[14]. The transportation method of programming has numberous applications to economic problems. The first application was to minimize distance traveled by cargo ships subject to certain transportation requirements. This method has been used to determine the least-cost sources of raw materials for processing firms. It has been used to analyze problems of distributing products from various plants to numerous consuming centers. Given a productive capacity for various plants and a demand at each consuming center, this procedure will determine the quantity of products from each location that should be transported to each consuming center in order to minimize transportation costs. The transportation model has also been adopted to analyze problems of product flows, comparative advantage, changes in transportation rate structures, and other problems of spatial equilibruim.

The General Transportation Model

The objective in the general transportation model is to minimize a linear function with respect to specific linear constraints. The general tableau format of the transportation model is shown in Figure 3[15]. In this tableau, m is the number of shipping origins, n is the number of shipping destinations, a_i is the amount of product at the i-th shipping origin, b_j is the amount of product demanded by the j-th destination, and X_{ij} is the amount of product shipped from origin i to destination J that minimizes total transportation costs. The cost of shipping X_{ij} unit of product from any origin i to any destination j is $C_{ij}X_{ij}$. The mathematical relationships of the transportation problem can be drawn from the tableau and may be stated as follows:

Minimize

$$C = \sum_{i=1}^{m} \sum_{j=1}^{n} C_{ij} X_{ij} \tag{1}$$

Subject to the constraints

$$\sum_{j=1}^{n} X_{ij} = a_i \qquad i=1,2,\ldots,m \tag{2}$$

$$\sum_{i=1}^{m} X_{ij} = b_j \qquad j=1,2,\ldots,n \tag{3}$$

$$X_{ij} \geq 0 \tag{4}$$

$$\sum_{i}^{m} a_i = \sum_{j}^{m} b_j . \tag{5}$$

		DESTINATIONS						Supply
	i \ j	1	2	...	j	...	n	
Origins	1	X_{11}	X_{12}	...	X_{1j}	...	X_{1n}	a_1
	2	X_{21}	X_{22}	...	X_{2j}	...	X_{2n}	a_2
	⋮	.	.	...	.	...	.	.
	i	X_{i1}	X_{i2}	...	X_{ij}	...	X_{in}	a_i
	⋮	.	.	...	.	...	.	.
	m	X_{m1}	X_{m2}	...	X_{mj}	...	X_{mn}	a_m
Demand		b_1	b_2	...	b_j	...	b_n	Total

Figure 3. Tableau Format of the Transportation Model

As stated before, problems other than those of transportation can be handled by the transportation method, but they must, as do transportation problems, satisfy certain assumptions.

Formal Assumptions of Transportation Models[16]

The formal assumptions of the transportation model are as follows:

1. The products being transported are homogeneous. In other words, the supply of product at each origin will equally satisfy the demands of any destination (Eq. 2 and Eq. 3).
2. The supplies of products at various origins and the demands of various destinations are known and total demand must equal total supply (Eq. 5). When discrepancies occur between supply and demand, a dummy origin or destination vector is used to produce equality. This dummy vector is comparable to the slack activities of the simplex method and can be used to signify current inventories and unsatisfied demands.
3. The costs of moving products from origins to destinations are known and are independent of the amount of product moved. That is, a constant per unit transportation rate regardless of the amount of produce moved between locations is assumed; however, the transportation model can be altered to consider rates that increase or decrease with the volume shipped.
4. There is an objective function to be maximized or minimized (Eq. 1). Generally with transportation problems, the objective is to minimize total transport costs.
5. The transport activities cannot be executed at negative levels (Eq. 4).

Development and Application of the Transportation Model

The transportation problem is a subclass of a linear programming problem for which computation procedures have been developed that take advantage of the special structure of the problem.

Hitchcock first formulated the transportation problem in 1941[17]. He applied the procedure to the problem of minimizing the cost of distributing a product from several factories to a number of cities. His procedure dealt with introducing and eliminating parameters in determining an optimum solution. He outlined a geometric method that was very similar to the simplex technique developed by Dantzig in 1947.

Dantzig formulated the problem as a special linear-programming problem and then developed a special form of the simplex technique for solving the transportation problem[18]. His solution procedure makes possible solving transportation type problems involving large numbers of restrictions and unknowns.

Koopmans made further revisions and application of Hitchcock's formulation[19]. He applied the theory of optimum resource allocation to the shipping industry to determine the most efficient use of transportation vehicles. Samuelson expanded Hitchcock and Koopman's work into a procedure to analyze problems involving spatial equilibrium[20]. Samuelson's model not only determined optimum product flows, but equilibrium prices as well.

Since its formulation, applications of the transportation model have been made to numerous economic problems in the agricultural sector. One such application was performed by Stemberger where he evaluated the competitive position of North Carolina egg marketing firms[21]. Stemberger's transportation model was also used to determine the best markets for North Carolina eggs, given regional production, regional consumption and transportation cost statistics.

A spatial equilibrium model of the beef cattle feeding industry was employed by Schrader and King to analyze regional adjustments to changing economic conditions[22]. Optimum locations for beef feeding activities given regional feedstuff supplies were determined along with optimum shipment patterns and equilibrium prices for beef.

More recent studies by Uhrig[23] and Wright[24] have employed the transportation model in analyzing the soybean processing industry of Iowa and the United States wheat-flour economy, respectively. Uhrig's analysis determined optimum flows of soybeans to existing processing plants in Iowa. The economic effects that changes in transportation rates and processing capacity have on soybean procurement were determined. Wright's study of the wheat-flour economy served to show the effects which changes in transportation rate differentials between wheat and flour have on the present location of facilities of the flour milling industry. Wright also developed an analytical framework to identify relationships between transportation rates and the different sectors and regions of the wheat-flour economy. Also, results obtained given alternative assumptions about transportation rates and valuations of flour were interpreted to show implications which each of these different assumptions yield for the different sectors of the wheat-flour economy.

As illustrated above, the transportation model has been applied to various types of distribution problems. Further refinement and development of the transportation model has resulted in the outgrowth of the transshipment model.

King and Logan made the first major application of the model in the field of agricultural economics in 1964[25]. In their study of cattle slaughtering facilities in California, the transshipment model of linear programming was utilized to consider simultaneously the costs of shipping raw materials, processing, and shipping final product. The problem concerned the optimum location, number and size of processing plants. An iterative procedure was used to incorporate economies of scale in processing in addition to transfer costs in obtaining the minimum cost solution.

More recently, the transshipment model has been used by Leath to evaluate the interregional aspects and competitive structure of the grain marketing industry[26]. An operational model was developed to analyze a multifactor, multiproduct, multiregion and multistate transshipment problem of the United States grain marketing system. The study determined: (1) efficient distribution patterns, (2) intermarket and shipping point price relationships, and, (3) the competitive position of flour mills in various regions. An extension of this study of the U.S. grain marketing system was made by Schnake[27]. In his study the possible effects of an alternative transportation rate structure were investigated by developing cost-of-service charges and comparing the resultant solutions with those of Leath[28].

While the studies by Leath and Schnake dealth with the United States grain marketing system, Copeland and Cramer utilized the transshipment model to evaluate the performance of the wheat marketing system in Montana[29]. Their model was used to determine the number, size and location of elevators which minimize the combined cost of transporting wheat from farms to elevators, storage at the elevator and transporting the wheat to the final destination.

Ladd and Halvorson[30] applied the approach developed by Stollsteimer[31] in an analysis of the turkey-processing industry in Minnesota, Iowa and Wisconsin. Their study was concerned with determining the least-cost number, size and location of turkey-processing plants in the three state area given 33 possible plant locations. An iterative-expansion approach was used to compare total combined processing and assembly costs as the number of locations considered increased. The least-cost solution consisted of that number of locations which yielded the lowest total combined costs.

Warrack and Fletcher also utilized Stollsteimer's general model in their study concerning the location and efficiency of the Iowa feed-manufacturing industry[32]. In their analysis both an iterative-elimination and an iterative-expansion approach was followed in the empirical solution. In their study, the computational requirement of the iterative-elimination approach ranged from computing minimized distribution and processing cost for 40 plants to be located at 40 possible locations to one plant to be located at 40 possible locations In the iterative-elimination approach, each conceivable combination represents a possible location pattern. The number of location patterns to be evaluated under this approach was exceedingly high. However, computational costs and the number of locational patterns associated with the iterative-expansion were a fraction of the alternatives in the iterative-elimination approach. By assuming that locations previously selected for inclusion in the model are retained, the number of possible location patterns become only the number of potential plant locations not yet selected. Therefore, computational costs for the iterative-expansion approach were relatively inexpensive compared to those of the iterative-elimination approach. The results obtained by Warrack and Fletcher showed little differences between the least-cost solution of the two approaches.

This study, like Warrack and Fletcher's, utilizes the iterative-expansion approach to solve for the optimum number, size and location of grain handling facilities in Oklahoma. By incorporating this approach, the number of locational possibilities are reduced when compared to those associated with the iterative-elimination approach.

Copeland and Cramer's work is somewhat analogous to this study in which a minimum cost solution is used to determine the optimum number, size and location of grain handling facilities. However, this study differs from their work in that the assembly costs were not included as a part of those costs incurred by the grain elevator industry. Costs of assembling grain from producers at local elevators were eliminated from this study because these costs were assumed to be incurred by the producing sector. Hence, this study considers elevator operating costs and transportation costs to final destination points. By eliminating from consideration the grain assembly function, the problem became one which can be solved using the general transportation model. The general transportation model, its data requirements and basic assumptions were discussed earlier. The following chapter will be devoted to presenting the basic data needed to implement this model.

FOOTNOTES

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CHAPTER III

BASIC DATA

Much of the basic data for this study was obtained from a livestock feed study conducted by Economic Services, Inc. (ESI) for the U.S. Army Corps of Engineers[1]. This livestock feed study analyzed possible feed grain flows, transportation costs and cost savings resulting from a proposed extension of the McClellan-Kerr Waterway to the vicinity of Oklahoma City, Oklahoma, and Wichita, Kansas. The ESI study covered the period 1990 to 2040. Only production and utilization data from the ESI study which pertained to Oklahoma for the year 1990 were incorporated in this study. These production and consumption data were used in this study because of the availability of the consumption data that were disaggregated for various areas in Oklahoma. These data include areal delineation, feed grain production and feed grain consumption. Data from the ESI study were selected for this study primarily due to its availability and disaggregation for various areas in Oklahoma. Also, the determination of the optimum size, number and location of grain handling facilities based on data projected for 1990 will help serve as a guide to the industry in planning future organizational patterns.

Other data such as transportation rates for truck and rail were obtained from various secondary sources. No surveys were conducted for the purpose of collecting transportation rate data; however, some of the secondary data sources are based on survey results.

In this study a survey of varying sizes of elevators was conducted in order to determine operating costs per unit of grain handled.

An explanation of the derivation of the data used in this study is given below.

Areal Delineation

The geographic area considered in this study is the state of Oklahoma. For pusposes of this study, the state of Oklahoma was partitioned into 57 sub-areas which correspond to those delineated in the ESI study for the U.S. Army Corps of Engineers. The sub-areas are depicted in Figure 4. Partitioning the state into sub-areas involved several subjective considerations as well as availability of disaggregated data.

Counties are the smallest geographical area for which much of the data are available. Therefore, all except 16 of the sub-areas consist of single counties. In those exceptions, four sub-areas consist of three counties and twelve sub-areas consist of two counties. In general, those sub-areas containing two or more counties are low feed grain producing and/or consuming areas.

Production and consumption were assumed to take place at a specific origin and destination point in each sub-area, and sub-area requirements and quantities available were determined. The selection of points representing grain origins and destinations was based on these criteria: (1) proximity to major rail lines, (2) proximity to major highways or that truck transportation may be readily accessible,

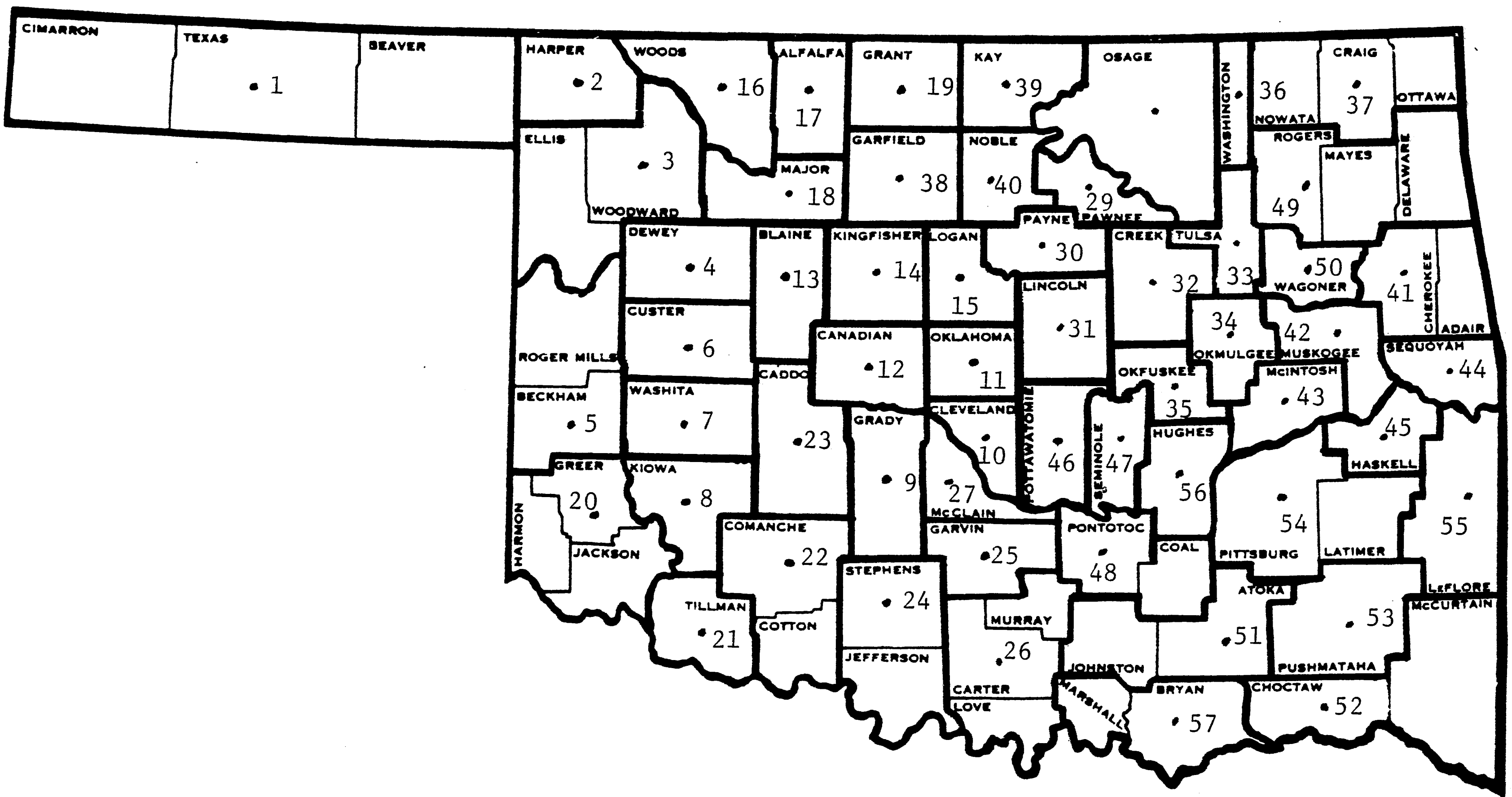


Figure 4. Oklahoma with Sub-Areas by Number as Used in the Analysis

and (3) proximity to the center of the sub-area's grain production area. The cities selected to represent production and consumption points are presented in Table III along with their sub-area code number. These code numbers will be used throughout the remainder of this study to facilitate presentation of sub-area data. For purposes of determining the optimum locations of grain handling facilities, the 57 production and consumption points listed in Table III are also used as possible locations of grain handling facilities. In addition to those 57 possible plant locations, Houston, Texas, was included in the model as an export facility to allow for disposal of surplus grain from the various sub-areas.

Once areal delination was decided, the next step toward implementation of the model was collecting or generating the various input data required. The transportation model discussed in Chapter II requires four types of sub-area data. They are: (1) supplies (production) of feed grain and wheat in each area, (2) demand for feed grain and wheat (consumption) in each area, (3) transportation rates between each possible location point and (4) elevator operating costs (handling charges) per unit of grain for each alternative size of elevator. The sources of these basic data are discussed below.

Feed Grain and Wheat Production

In addition to wheat, feed grain movements within and out of Oklahoma were considered. For purposes of this study, feed grains are defined to include corn, grain sorghum, and barley. Determining production levels of wheat and feed grains for the year 1990 involves a wide range of economic, social, and technological variables. An

TABLE III

BASING POINTS IN OKLAHOMA FOR GRAIN ORIGINS AND DESTINATIONS

Code	City	Code	City
1	Guymon	30	Stillwater
2	Buffalo	31	Chandler
3	Woodward	32	Bristow
4	Camargo	33	Tulsa
5	Elk City	34	Okmulgee
6	Clinton	35	Weleetka
7	Cordell	36	Bartlesville
8	Hobart	37	Vinita
9	Chickasha	38	Enid
10	Norman	39	Ponca City
11	Oklahoma City	40	Perry
12	El Reno	41	Tahlequah
13	Watonga	42	Muskogee
14	Kingfisher	43	Eufaula
15	Guthrie	44	Sallisaw
16	Alva	45	Stigler
17	Cherokee	46	Shawnee
18	Fairview	47	Wewoka
19	Medford	48	Ada
20	Altus	49	Claremore
21	Frederick	50	Wagoner
22	Lawton	51	Atoka
23	Anadarko	52	Hugo
24	Duncan	53	Antlers
25	Pauls Valley	54	McAlester
26	Ardmore	55	Poteau
27	Purcell	56	Holdenville
28	Pawhuska	57	Durant
29	Pawnee		

analysis of these variables and the resulting production projection is beyond the scope of this study and thus secondary sources of these data were used.

In the ESI study, estimates prepared by the Office of Business Economics, U.S. Department of Commerce and the Economic Research Service, U.S. Department of Agriculture were used in projecting grain production for the year 1990[2]. These estimates will hereafter be referred to as "OBERS" estimates. The OBERS projections are the results of a large scale coordination effort by many experienced groups in government to project the trend of key economic variables into the future. Thus, the OBERS projections were used as the source of grain production data in this study.

OBERS grain production estimates were projected for the years 1980, 2000, and 2020. Since 1990 is the year on which the ESI study was based, it was necessary that an interpolation of the data between the year 1980 and 2000 be made in order to obtain estimates for 1990. A procedure was developed for this interpolation in the ESI study by using regression analysis and fitting of a second degree polynomial to the OBERS estimates[3]. This procedure resulted in equations which were then used by ESI to calculate estimates for 1990. Projections by ESI for wheat and feed grain production in the United States for 1990 are as follows:

wheat - 1,670.0 million bushels

corn - 6,976.4 million bushels

grain sorghum - 1,320.4 million bushels, and

barley - 570.7 million bushels.

Since the attention of this analysis was focused on the wheat and feed grain aggregate, the above projections were converted to 1000-ton units to permit the summation of the four grains. To make this conversion, per bushel weights of 60, 56, 56 and 48 were used respectively for wheat, corn, grain sorghum and barley. The resulting data in 1000-ton units are as follows:

wheat - 50,100.0

corn - 195,337.8

grain sorghum - 36,969.8, and

barley - 13,696.8

Estimates of wheat and feed grain production are also presented by OBERS for the major producing states. Major producing states are those which produce one percent or more of the nation's supply of the various grains. OBERS state projections for the four grains were obtained and the same procedure of interpolation was used to determine estimates for 1990. These data were again converted to 1000-ton units for aggregation of the different grains. For the above calculations, the projected sum of the four grains produced in the state of Oklahoma in 1990 was 5,903,804 thousand tons.

Wheat and Feed Grain Production by Sub-Areas

As stated earlier, the state of Oklahoma was divided into 57 grain producing and consuming sub-areas. This necessitated the development of grain production estimates for each of the 57 sub-areas. ESI developed a procedure to determine estimated production for each individual sub-area[4]. Production trends were determined by analyzing county data for the most recent ten years. The estimated state production was then allocated to each sub-area on the basis of ten-year average production shares. Projections of grain production by sub-areas are presented in Columns 2 and 3 of Table XVII in Appendix A.

Wheat for Feed

Wheat is primarily used as a food grain; however, in the past ten years, a significant quantity of wheat has been used as a feed grain. USDA statistics show that wheat used for feed has ranged from over 20 million bushels in 1963-64 to 266 million bushels in 1971-72. Based on these statistics, the elimination of wheat as a source of feed would be unlikely[5, 6].

The inclusion of wheat as a feed source does, however, have an effect between the identified sub-areas. For instance, several of the sub-areas in Oklahoma are deficit in feed grain when only corn, grain sorghum and barley are considered, but are surplus when wheat is allowed to help satisfy feed demands. These changes in the feed grain supply of the state's sub-areas would be expected to alter the route and level of grain movement.

Feed Grain and Wheat Consumption

With wheat and feed grain production estimates established, estimates of wheat and feed grain consumption or utilization by area are needed in order to determine the net supply status of each area. Those areas which are surplus or deficit in their grain supplies must be identified to facilitate formulation of the transportation model. The ESI study was used as the source for feed grain utilization data since the development of such consumption or utilization data was beyond the scope of this study[7]. Estimates of feed grain utilization for the year 1990 were prepared by ESI for fed cattle, swine, dairy, broilers, laying hens, and turkeys. Also, requirements for industrial and food uses of feed grain were projected by ESI. Estimates of wheat utilization in 1990 were based on OBERS projections[8]. Wheat production was allocated between uses for seed, food, feed, and for meeting export requirements. A summary of the determination procedure and basic data for each use listed above is discussed next.

Fed Cattle

In estimating the utilization of grains for cattle feeding, a projection of fed cattle marketings for 1990 was made by fitting linear and curvilinear functions to annual data over the 13-year period, 1960-1972. Estimates for years between 1960 and 1973, as calculated by the linear and curvilinear function were developed based on available research, judgement and per capita beef consumption given available population projections. Allocation of the projected fed cattle marketings to the various areas was based on historical patterns of production. The resulting projection for each state or region was allocated to sub-state areas based on historical patterns plus giving consideration to resource availability.

With the projected number of fed cattle known, estimation of grain consumption was possible. Assuming a 400-pound weight gain of animals in feedlots at a conversion rate of 5.52 pounds of grain, estimates of grain requirements per animal were determined. The utilization data of grain for fed cattle for the 57 sub-areas are shown in column 3 of Table XVII in Appendix A.

Swine

Swine production esimates for 1990 were based on OBERS projections. Historical production patterns were the basis for allocating those estimates to sub-state or county levels. Grain consumption by this projected level of production was determined by applying the feed conversion ratio which could be expected in 1990. With allowances for improvements in technology and considering trends in the ratio of feed input to swine production, the ratio of 3.15:1 was employed. The grain use estimates for swine feeding for each of the sub-areas in this study are listed in Column 4 of Table XVII in Appendix A.

Dairy

Again, OBERS estimates were used in projecting milk production for the United States and major producing states. Projections for other states' milk production were allocated on historical production patterns. Given estimates of production, grain requirements were determined through the use of a conversion ratio. A ratio of .1577 pounds of grain per pound of milk produced was applied to the milk production estimates and an estimated 1755 pounds of grain per cow for maintenance needs were combined to determine total grains requirements for the dairy sector. These grain requirements are shown in Column 5 of Table XVII in Appendix A.

Poultry

The basis for 1990 utilization of grain for poultry feed was OBERS projections of poultry and egg production. Feed conversion estimates were obtained from commercial poultry firms and poultry scientists at Oklahoma State University. The feed grain requirements for poultry production were based on the following feed conversions:

Broilers - .65 tons of grain per 1000 pounds of live bird, assuming 2.0 pounds of feed per pound of bird would produce a four-pound bird.

Turkeys - 1.05 tons of grain per 1,000 pounds of live bird, assuming 3.0 pounds of feed per pound of bird would produce a 24-pound tom or 16-pound hen.

Eggs - 145.8 tons of grain per million eggs, assuming 4.0 pounds of feed would produce a dozen eggs.

For sub-state areas, OBERS projections were adjusted on the basis of percentage share that each sub-area had of state totals during the 1960-1972 period. In projecting the production for the sub-areas, consideration was given to possible growth potential in those areas. Grain utilization by broiler, turkey and laying operations in 1990 by sub-area are presented in Column 6, 7 and 8 of Table XVII in Appendix A.

Use of Feed Grains for Industrial and Food Purposes

Industrial and food uses of feed grains include wet process grinding, meal and grits, alcohol and distilled spirits, breakfast foods, and malt. Projection of total utilization of feed grains for the above purposes were based on per capita consumption projection and estimated United States population for 1990. Population estimates used were those made by the Office of Business Economics[9]. Allocation of the estimated industrial and food utilization of feed grains to the various areas defined in the study was made following a study by Leath and Blakley[10]. Industrial utilization of grains had been allocated to various regions of the United States based on utilization in the period July 1966-June 1967. Since it was assumed that no major changes would occur in industry location, the percentage shares in the 1966-67 period were used. The projections of industrial utilization of feed grains by sub-area for the year 1990 are shown in Column 9 of Table XVII in Appendix A.

Utilization of Wheat

The utilization and/or consumption of wheat was the total quantity of wheat used for seed, food, feed and exports. Requirements for seed, food and exports were calculated with the balance being allocated to feed use.

Seed use of wheat was based on crop data as reported in Field and Seed Crops, May, 1972[11]. As calculated from these data, seed use of wheat equaled 3.37 percent of total wheat production in Oklahoma. This percentage was then applied to the projected wheat production for 1990 to determine the state's total seed requirements. Sub-area seed requirements were based on each sub-area's share of total wheat production. Allocation of wheat for seed use by sub-area is shown in Column 10 of Table XVII in Appendix A.

Estimates of wheat for food uses were based on a projected annual human consumption of 525 million bushels as determined by considering per capita consumption trends and projected U.S. population. This consumption rate was distributed among the states according to data shown in Distribution of the Varieties and Classes of Wheat in the United States[12] and Utilization of Wheat for Food[13]. Sub-state area distribution was based on area percentages of production and the state's share of total U.S. consumption. Distribution of feed wheat by sub-areas for 1990 is listed in Column 11 of Table XVII in Appendix A.

Wheat export estimates by sub-areas were determined by first calculating the state's percentage share of total U.S. wheat exports based on the historical export pattern[14]. These percentage shares were then applied to projections of U.S. exports of wheat for 1990 as projected by OBERS[15]. Allocation of wheat for export to the various sub-areas in Oklahoma was made on the basis of each sub-area's percentage of Oklahoma production. Estimates of wheat available for export by sub-area are presented in Column 13 of Table XVII in Appendix A.

Given estimates of wheat utilization for seed, food and export for each sub-area, the balance of each sub-area's wheat production was assumed as available for feeding. These data are shown in Column 12 of Table XVII in Appendix A.

Grain Surpluses or Deficits by Area

In Appendix A estimates of production, utilization and net surplus (deficit) of feed grain and wheat for feed and food for the 57 identified sub-areas of Oklahoma for 1990 are recorded. The surplus-deficit status of each sub-area was determined by deducting from estimated production the estimates of grain utilization for the various purposes. The net surpluses are available for satisfying requirements in deficit areas and for meeting export demands. Table IV summarizes the surplus-deficit status of the 57 sub-areas. These data regarding surplus supplies and deficient supplies by sub-area are used in the remainder of this study to determine minimum cost flows of grain between sub-areas and to export points and thereby to determine the optimum size, number and location of grain handling facilities in Oklahoma.

Transportation Rates

Transportation rates for two modes, truck and rail, were utilized in developing the transportation cost matrix for the model. The development of rates for each of these modes will be discussed in the subsections below.

Truck Rates

Truck rates were based on point-to-point minimum distances between the 57 sub-areas determined from Oklahoma's Official State Highway Map, 1972[16]. Mileages used were approximate distances between town centers by the shortest route utilizing the state highway system. The truck cost function applied to these minimum distances was developed by Kansas State University from survey data on truck shipments. The survey consisted of 91 observations on one-way trips ranging from 100 to 350 miles. These observations were taken on

TABLE IV

PROJECTED GRAIN PRODUCTION, UTILIZATION AND NET SUPPLY STATUS BY SUB-AREA OF OKLAHOMA FOR 1990

Code	Feed Grain and Wheat Production (1000 tons)	Feed Grain and Wheat Utilization (1000 tons)	Net Surplus (1000 tons) Surplus	Deficit
1	1,021.738	911.877	139.135	
2	66.111	116.715		50.604
3	123.643	92.754	30.889	
4	104.651	66.087	38.564	
5	116.201	90.090	26.111	
6	164.662	96.712	67.950	
7	217.118	109.766	107.353	
8	191.391	128.227	63.164	
9	77.545	126.053	15.592	
10	9.512	16.328	.432	
11	29.033	28.194	.938	
12	191.405	182.970	8.433	
13	169.177	93.578	75.598	
14	233.117	208.262	24.855	
15	97.617	56.591	41.026	
16	161.775	132.655	29.120	
17	254.280	187.064	67.215	
18	150.336	91.693	59.264	
19	344.845	188.542	156.393	
20	251.955	168.252	83.703	
21	202.202	198.351	3.851	
22	162.284	91.110	71.173	
23	187.662	98.855	88.906	
24	32.652	27.764	4.888	
25	14.709	10.080	4.630	
26	9.275	18.464		9.188
27	14.364	29.385		15.022
28	43.031	28.342	14.689	
29	29.520	28.465	1.056	
30	21.320	21.524		.204
31	11.090	13.393		2.302
32	1.989	3.099		1.110
33	14.973	15.074		.100
34	4.342	3.797		.546
35	4.139	5.323		1.185
36	42.235	25.554	16.682	
37	91.580	78.836	12.744	
38	363.567	209.802	153.764	
39	346.826	184.303	162.535	
40	152.402	86.073	66.329	
41	2.431	62.944		60.513

TABLE IV (Continued)

Code	Feed Grain and Wheat Production (1000 tons)	Feed Grain and Wheat Utilization (1000 tons)	Net Surplus (1000 tons) Surplus	Deficit
42	14.510	11.051	3.458	
43	11.701	4.514	7.187	
44	4.238	8.759		4.521
45	2.095	3.885		1.790
46	11.018	67.341		50.323
47	23.387	9.447		4.929
48	4.630	13.496		8.865
49	55.277	87.696		32.416
50	22.280	13.999	8.280	
51	6.185	6.871		.686
52	2.562	36.862		34.300
53	.269	2.923		2.654
54	4.917	3.338	1.579	
55	5.142	45.506		40.364
56	10.038	4.568	5.471	
57	15.629	8.475	7.154	

shipments involving no backhaul. The truck transportation cost function which was applied to the point-to-point minimum distances is:

$$T_{ij} = 0.851 + 0.015354\ X_{ij} \qquad (6)$$

where X_{ij} is the number of miles from origin i to destination j, and T_{ij} is the cost in dollars per ton of shipping grain from origin i to destination j. R^2 for this equation is 0.627 with a standard deviation of 0.03.

<u>Rail Rates</u>

Rail rates used in this study were export carlot rates effective in Freight Tariff X-281-B during 1973 for bulk wheat, grain sorghum and corn. Only rail rates from the 57 sub-areas to Houston, Texas, were considered, since in all cases rates for in-state shipments of grain by rail were considerably higher than the corresponding truck rate. Rail rates to Houston used in this study are shown in Table V. In many cases this one transit privilege may be exercised by shipping the export grain through a terminal elevator such as that located at Enid, Oklahoma. Export carlot rates, from Freight Tariff X-281-13, used in this study provide for the use of a one transit privilege.

Operating Expenses

As stated earlier, one of the specific objectives of this study is to estimate operating costs per unit of grain for different sizes of grain handling facilities. These costs which are an expense to the grain elevator industry can, depending on their magnitude, affect

TABLE V

RAIL RATES FOR EXPORT GRAIN TO HOUSTON, TEXAS, FROM OKLAHOMA ORIGINS

Origin	¢/cwt.	Origin	¢/cwt.	Origin	¢/cwt.
1	48.5	20	35.5	39	42.5
2	46.0	21	35.5	40	38.0
3	46.0	22	33.0	41	N/A
4	41.5	23	34.5	42	36.5
5	36.5	24	32.0	43	36.5
6	36.5	25	32.0	44	41.5
7	36.5	26	30.5	45	36.5
8	35.5	27	32.0	46	36.5
9	33.0	28	41.5	47	36.5
10	32.0	29	38.0	48	33.0
11	36.5	30	38.0	49	38.0
12	36.5	31	36.5	50	38.0
13	36.5	32	36.5	51	33.0
14	36.5	33	38.0	52	30.5
15	38.0	34	36.5	53	30.5
16	42.5	35	36.5	54	36.5
17	42.5	36	42.5	55	36.5
18	39.5	37	40.5	56	36.5
19	42.5	38	38.0	57	30.5

Source: Enid Board of Trade, Bulk Wheat, Sorghums, and Corn Export Carlot Rates, Freight Tariff X-281-B.

the optimum (minimum-cost) size, number and location of grain handling facilities. Also, the direction and volume of grain flow can be affected by elevator operating costs.

Data for estimating elevator operating costs were obtained from annual reports and/or audits of 35 cooperative elevator associations. This data source was utilized primarily due to the availability of audits on file in the Department of Agricultural Economics at Oklahoma State University. Additional input data were obtained from personal interviews with cooperative grain elevator managers whose grain handling facilities corresponded to the sizes selected for this study.

The expenses considered in this analysis were extracted from the Detail of Expense Statements provided by the sample elevators. Selection of the expense categories was in part based on the study by Corley[17] as well as the Detail of Expense Statements from sample elevators. Annual expense budgets were developed from which operating costs per unit of grain were determined. A certain amount of subjectivity was involved in determining the expense line items to include in the estimated annual budgets. The primary basis upon which expenses were chosen was the amount of consistency with which the expenses appeared in the audits. Expenses that did not appear regularly in the audits were either included in the Miscellaneous Expense category or excluded from the analysis. Many of the sample elevators in addition to their grain handling function, provided various sideline activities. Therefore, in order to isolate the expense which could be attributed to the grain handling function of the elevators, adjustments were made in the total operating expenses. Several of the sample elevator audits and annual reports had departmentalized the accounting of expenses incurred by the elevator itself; however, most did not have such an accounting and adjustments were made according to the grain handling activity's percentage of gross sales. The resulting value was used as the grain elevator department's estimated total operating expense for each individual elevator. Inspection of the elevators' annual reports and audits resulted in 19 expense categories selected to constitute the annual expense budget. These expense categories are presented in Table VI.

Selection of Elevator Sizes

Five different sizes of elevators based on rated storage capacity were chosen for detailed analysis and for inclusion in the model. Operating cost data were developed for elevators with storage capacities of 100,000; 200,000; 400,000; 600,000; and 900,000 bushels. The selection of these five sizes of elevators was based on the percentage distribution of Oklahoma elevators according to rated storage capacity as shown in Table I, page 2, and the sizes for which cost data were available. Annual reports and/or audits from 35 cooperative elevator associations with storage capacities within a 50,000 bushel range of the selected size were selected as the sample for detailed cost analysis. For example, elevators in the sample group for estimating operating expenses of 100,000 bushel elevator ranged in grain storage capacity from 52,000 to 150,000 bushels. Table VII shows the number and storage capacity size range of elevators in the sample by elevator size selected for this study.

TABLE VI

ANNUAL GRAIN HANDLING DEPARTMENT EXPENSE COMPONENTS AND THEIR ASSOCIATED LOW, MEAN AND HIGH PERCENTAGES FOR 22 COOPERATIVE ELEVATORS IN OKLAHOMA, 1970

Expense	Low Percentage	Mean Percentage	High Percentage
Advertising	.69	.874	1.18
Annual Meeting	.54	.695	.84
Audit and Legal	.53	.689	.84
Depreciation	17.75	20.504	24.10
Director's Fee	.34	.460	.58
Fuel and Lubricants	.21	.352	.48
Insurance and Bonds	3.29	4.725	5.71
Interest on Capitol	3.27	5.350	8.24
Lease and Rental	.10	.375	.49
Miscellaneous Expense	.28	.824	1.59
Operating Supplies	1.02	1.323	1.99
Pest Control	.71	1.350	2.12
Repairs	2.87	4.240	6.17
Salaries	37.82	43.740	54.50
Taxes	6.10	7.906	8.83
Telephone and Telegraph	.40	.700	1.00
Testing Expense	.23	.447	.59
Truck Expense	1.64	2.144	2.53
Utilities	2.34	3.302	4.22
Total		100.00	

TABLE VII

NUMBER AND SIZE RANGE OF EXISTING OKLAHOMA ELEVATORS IN THE SAMPLE; 1970, BY SELECTED ELEVATOR GRAIN STORAGE CAPACITY

Selected Size of Grain Storage Facility in bu.	Number of Elevators	Range of Grain Storage Capacity in bu.
100,000	6	52,000 - 150,000
200,000	8	182,000 - 250,000
400,000	8	365,000 - 435,000
600,000	7	550,000 - 613,000
900,000	6	860,000 - 950,000

Operating Expense Per Unit

The average annual volume of grain handled in combination with the estimated annual operating expense for each size elevator was used to determine elevator operating expense per unit of grain.

Volume data of grain handled by each elevator in the sample were obtained either from the audits and annual reports or from personal interviews with the elevator manager. Given that grain production and thus volume handled by elevators can vary significantly from year to year, handling volume data for each of the sample elevators were obtained for the three-year period 1970-72. From these handling volume observations, the average quantity of grain handled by each of the five different size elevators was determined and is shown in Table VIII.

TABLE VIII

MEAN ANNUAL VOLUME OF GRAIN HANDLED BY ELEVATORS IN EACH OF THE FIVE STORAGE CAPACITY SIZES STUDIED IN OKLAHOMA, 1970

Grain Storage Capacity in Bu.	Volume of Grain Handled in Bu.
100,000	314,000
200,000	518,000
400,000	691,000
600,000	777,000
900,000	909,800

Individual total elevator expense observations by size group were averaged to determine the mean annual operating expense for the five different sizes of elevators. Annual expense budgets were developed by applying the percentage shares of each of 19 expense categories (Table VI) to the estimated average annual operating expense of the different size elevators. These budgets for elevators of 100,000; 200,000; 400,000; 600,000; and 900,000 bushels of grain storage capacity are presented in Tables XVIII, XIX, XX, XXI, and XXII, respectively, of Appendix B.

These handling volume and annual operating expense estimates were then used to determine annual elevator operating expense per unit of grain. The per unit operating expense for elevators in each size category are shown in Tables XVIII, XIX, XX, XXI, and XXII of Appendix B. Per unit operating expense estimates were then incorporated in the model to determine the optimum size and number of grain handling facilities for each of the 57 identified sub-areas of Oklahoma.

Relative Importance of Selected Expenses

In determining the relative importance of the selected expenses actual dollar amounts for each expense item from the sample elevators were used to calculate its percentage of the total grain handling department expense of the firm. In each of the different size groupings, little variation occurred in each expense item's percentage share of the total as shown in Table VI. Given only slight variation across the five size groupings, the percentage shares for each expense item were summed over all sample elevators and a mean percentage for each expense item was calculated. The individual expense percentage for the various size groupings showed no consistency as being above or below the calculated mean percentage for that expense category. Therefore, the mean percentage for each expense item was used in constructing the annual expense budgets for all five sizes of elevators. The calculated mean percentage for each expense item is shown in Table VI.

This chapter served to present all the basic data used in this study. The next chapter will describe the analytical procedure used to determine the optimum number, size and location of grain handling facilities in Oklahoma.

FOOTNOTES

[1]Economic Services, Inc., Livestock Feed Transportation and Extended Navigation into Oklahoma and Kansas, 1990-2040 (Stillwater, 1973).

[2]United States Water Resources Council, 1972 OBERS Projections, Regional Economic Activity in the United States, Vol 1-5 (Washington, 1972).

[3]Economic Services, Inc., 1973, pp. 10-11.

[4]Ibid, p. 13.

[5]United States Department of Agriculture, Food Grain Statistics Through 1967 (Washington, 1968).

[6]United States Department of Agriculture, Wheat Situation, ERS, WS-224 (Washington, May, 1973).

[7]Economic Services, Inc., 1972, pp. 20-42.

[8]United States Water Resources Council, 1972 OBERS Projections, Regional Economic Activity in the United States, Table 3, Bol. 5 (Washington, 1972), p. 824.

[9]United States Water Resources Council, Preliminary Report on Economic Projections of Selected Geographic Areas 1929-2020, Vol. 1 (Washington, 1968).

[10]Mack N. Leath and Leo V. Blakley, An Interregional Analysis of the United States Grain Marketing Industry, ERS in Cooperation with Oklahoma State University, USDA Technical Bulletin No. 1444 (Stillwater, November, 1971).

[11]United States Department of Agriculture, Field and Seed Crops, Crop Reporting Board, SRS (Washington, May, 1972)

[12]United States Department of Agriculture, Distribution of the Varieties and Classes of Wheat in the United States in 1969, Agricultural Research Service, Statistical Bulletin 475 (Washington, 1971)

[13]Robert O. Rogers, "Utilization of Wheat for Food," Agricultural Economics Review, Vol. XV, No. 2 (April, 1963), p. 232.

[14]Isaac F. Lemon, "United States Agricultural Export Shares by Region and States, 1970-71," Foreign Agricultural Trade of the United States, ERS-24, USDA (October, 1971), pg. 25.

[15]United States Water Resources Council, 1972 OBERS Projections, Regional Economic Activity in the United States, Vol. 1-5 (Washington, 1972).

[16]Oklahoma State Highway Commission, Official State Highway Map (Oklahoma City, 1972).

[17]Edward M. Corley, Estimated Effects of Variations in Wheat Production Upon Cost Levels of Country Elevators in Northwestern Oklahoma (Unpublished Ph.D. dissertation, Oklahoma State University, Stillwater, 1964).

CHAPTER IV

ANALYTICAL PROCEDURE

As stated earlier, the general transportation model was used in determining the minimum cost solution for the optimum number, size and location of Oklahoma's grain handling facilities based on wheat and feed grain production and consumption estimates for the year 1990. Several computation steps were used to develop data to meet the limitations of the model. These data were used in an iterative-expansion transportation model which minimized the total distribution and operating costs with respect to an optimum locational pattern for the number of locations in each iteration. Given the number of locations to be considered in each iteration, the least-cost number and size of elevators at each location were determined based on operating costs per unit of grain and the volume of grain to be handled at each location.

Presented in this chapter is a detailed explanation of the analytical procedures followed in this study.

The Iterative-Expansion Approach

The iterative-expansion approach utilizing the general transportation model is concerned with minimizing total distribution and operating costs for a varying number of locations. In the initial iteration only one out of the 57 possible locations of grain handling facilities was considered to serve the entire state of Oklahoma. In each successive iteration an additional location was included in the model. This process was followed until all 57 possible locations entered the model.

An important assumption was made regarding the supply of and demand for grain when one of the specified sub-areas was not included as a location point.[1] It was assumed that grain produced in the specified sub-areas would be assembled at the nearest location point being considered in the model, handled at this point, and then transported back to the specified sub-area to meet its grain demands. For example, with only one location point for the entire state being considered, all grain produced in the state would be transported to this point, handled, and then transported back to the various sub-areas in an amount which would satisfy their grain demands. Any surplus grain at the particular location would be shipped to Houston, Texas, for export. When two location points A and B are considered in the model, point A serves as the assembly point for all grain produced in the nearest specified sub-areas. This volume of grain was handled at point A, then distributed back to the sub-areas to meet their grain demands. The same procedure applies for point B. In essence, given two locations, the state is divided into two producing-consuming areas whose sub-areas are being served by grain handling facilities located at one of the assigned location points. Any surplus grain at point A or point B was transported to Houston, Texas, for export. In case a specific sub-area, say the one serviced by point B, after determination of total grain supply and demand in the area, was deficit in its grain requirements, then point A would supply the needed quantity to point B and ship the remainder to export.

In each successive iteration one additional location point was included in the model and total costs of: (1) transporting grain to the location points, (2) elevator operations at the various locations, (3) transporting grain to meet sub-area demand and (4) transporting grain to export were minimized with respect to the number of locations considered.

Cost Relationships

The logic of this model's solution stems from two factors: (1) the more widely distributed and greater the number of grain handling locations, the lower will be total distribution costs; and (2) total elevator operating costs will increase as the number of locations increase. The first factor decreases the total combined transportation and operating cost as more locations are added. The second factor, however, increases total combined costs as locations are added because more locations imply that facilities at each location must be smaller and therefore not able to benefit from economies of scale. The solution is obtained at the point where the sum of these two cost factors is at a minimum. A further discussion of the costs involved in this study is presented below.

Transporting to Location. The costs of transporting grain from the specified sub-areas to the assigned locations were determined by applying the truck rate formula presented in equation 6 to the minimum distance from the designated point in the sub-area to the assigned location. The resulting transportation charge per unit of grain was applied to the volume of grain to be transported from the sub-area to the location to determine transportation-to-location costs for each producing-consuming area. These costs were summed for each location point to arrive at the total costs of transporting grain to the various location points.

Since it is assumed that all production within each specified sub-area is concentrated at a specific point, transportation-to-location costs within a sub-area is zero. So, as the number of locations increase, one would suspect total transportation-to-location costs to decline.

Elevator Operation. An inverse relationship exists between elevator operating costs per unit of grain and elevator size as shown in the annual expense budgets in Tables XVIII, XIX, XX, XXI, and XXII in Appendix B. Thus, with a fixed quantity of grain being considered, as the number of locations increase, one would suspect that the size of grain handling facilities at each location would be smaller; hence increasing the total elevator operating cost over all locations.

Transporting to Demand. A truck rate specified in equation 6 was employed again to determine the cost of transporting grain from the assigned locations to the specified sub-areas to meet grain demands. These costs, as were transportation-to-location costs, were summed over all locations to arrive at total transportation-to-demand costs. Since it is assumed that all consumption within each specified sub-area is centered at a specific point, transportation-to-demand costs within a sub-area are zero. Thus as the number of locations increase, one would expect total transportation-to-demand costs to decrease.

Transporting to Export. All locations with a net surplus of grain either shipped their surplus grain to grain deficit locations or to Houston, Texas, for export. This option provided the foundation for use of the transportation model. Truck transportation rates were applied to shipments of surplus grain transported between locations in Oklahoma because those existing rail rates were more expensive. However, rail rates were lower for shipments of grain for export and those rates were used for grain shipped from locations in Oklahoma to Houston, Texas, for export. The total cost of transporting grain to export was determined via the transportation model. This cost may or may not decline with an increase in the number of locations. Its direction and magnitude of change is based on two considerations: (1) as locations increase and become more concentrated in the state, some locations will be nearer the export destination while others will be more distant from the export destination resulting in fluctuations in the total cost, and (2) with greater concentration of locations, the possibility exists that more sub-areas serviced by these elevator locations will be grain deficit areas resulting in a large volume of shipments between assigned locations. The distance-volume relationship between the surplus locations, deficit locations, and the export destination will determine the magnitude of change in total transportation to export costs.

Considering these four cost components, each were minimized with respect to location numbers. Each of the four costs, with the exception of transportation-to-export costs in each iteration, can be and were determined outside the transportation model. They are discussed in detail in the next chapter.

The Locational Pattern

As previously indicated, each iteration in the iterative-expansion approach was minimized with respect to an optimum locational pattern for each number of locations. The development of a locational pattern was necessary to keep the computations in a manageable proportion. To illustrate, say there are N demand points to be served from M possible supply points. In order to minimize a total transportation cost function with respect to location numbers (M) and plant locational patterns (L_K), where L_K is the K-th locational pattern out of all possible patterns, the cost for each possible combination of each assigned number of locations, J = 1, . . ., J must be computed. There are ${}_LC_J$ possible combinations of locations $L_K | J$. For example, if there are eight potential location sites, four plants can be arranged in

$$\frac{8!}{4!4!} = 70 \text{ ways}$$

So with location numbers varying in this study from 1 to 57, the computation requirements to consider all possible combinations of locations is astronomical. Instead of computing all possible combinations, a modification to a procedure developed by Stollsteimer was employed[2]. Stolsteimer's model was developed initially as a raw material assembly model applied to determine the optimum number, size, and location of pear processing plants with respect to assembling pear production. However, he states that procedures set forth in the model can be equally adapted to problems in processing and distribution.

The model was not used in its entirety, but only to develop a locational pattern to follow in this study.

The Stollsteimer Model. Given the problem of minimizing total transportation costs between (I) origins and (J) possible plant locations for each locational pattern (L_K), the first step is to obtain a minimized transportation-cost function with respect to plant locations and varying numbers of plants, J[3]. There are $\binom{L}{J}$ possible combinations of locations given J, which can be written as $L_K | J$. For each possible locational pattern L_K, there is a sub-matrix, $C^*_{ij} | L_K$ of the transportation-cost matrix C_{ij}. This sub-matrix will be I x J in dimension with the entries in each of the J columns representing transportation costs from each origin to a specific plant location. A(1 x I) vector $\overline{C_{ij}} | L_K$ is obtained by scanning $C^*_{ij} | L_K$ by rows and selecting the minimum C_{ij} in each row. The minimum total transportation cost with J plants at a specified set of locations L_K is equal to the vector X', whose entries X_i represent the quantities of material produced at each of the I origins, multiplied by the vector $C_{ij} | L_K$. The minimum value over L_K is a point on the transportation-cost function minimized with respect to plant location. Algebraically, this is stated as:

$$\overline{TTC} | J = \overset{\min}{L_K} (X_i') \, \overline{C_{ij}} | L_K.$$

where

$\overline{TTC}$ = total transportation cost minimized with respect to plant location for each value of J = 1 . . . L,

(X_i') = a (1 x I) vector whose entries, X_i, represent the quantities of raw material produced at each of the I origins, and

$\overline{C_{ij}}\Big| L_K$ = a vector whose entries C_{ij}, represent minimized unit transportation costs between each origin and a specific set of locations, L_K, for J plants.

The procedure described above may be illustrated as follows. Assume there are four points of origins, each of which produced one unit of raw material. Also, assume that four potential plant locations are being considered. The matrix shown below represents transportation costs between each origin and plant location.

Transportation Costs: C_{ij}

Origin	Potential Plant Location 1	2	3	4
1	1	4	4	2
2	3	1	3	5
3	2	3	1	4
4	4	5	5	1

In this illustration the vector X' would be

$$X' = (1, 1, 1, 1).$$

With the number of locations, J, equal to one, there are four possible plant locations. The vector $\overline{C_{ij}}$ for each L_K is one of the columns of the C_{ij} matrix. The total transportation cost for each potential plant location, L_K is determined by multiplying the vector X' by the appropriate column of the matrix C_{ij}. For a single plant in the entire area, i.e., where J = 1, situated at location number 1, total transportation cost is,

$$TTC = \overset{\min}{L_K} (X') \ \overline{C_{ij}} \Big| L_K = (1,\ 1,\ 1,\ 1) \begin{pmatrix} 1 \\ 3 \\ 2 \\ 4 \end{pmatrix} = 10$$

For a single plant in the entire area, i.e., where J = 1, situated at location number 2, TTC = 13; likewise, for location number 3, TTC = 13; and similarly for location number 4, TTC = 12. So, in this example, total transportation costs with one plant location being considered are minimized by locating the plant at location number 1, i.e., where TTC with J = 1 in $\overline{C_{ij}}$ is 10 units.

If two locations are being considered, there are six possible combinations of locations, and thus K = 2 and L = 6 in L_K. If locations numbered 1 and 2 are considered, a vector of minimized unit transportation costs is obtained by scanning the first two columns of C_{ij} and selecting the minimum value in each row. The following vector results:

$$\frac{\min}{C_{ij}} \Big| L_K = \begin{pmatrix} 1 \\ 1 \\ 2 \\ 4 \end{pmatrix}$$

Multiplying this vector by (X)' results in minimum total costs given two plants located at 1 and 2 of eight units. Total costs with other combinations of locations with two or more plants may be determined similarly. The minimum cost solution when two locations are considered is obtained by locating the plants at locations 1 and 4. When three locations are considered, the optimum locations are at points 1, 4, and 2. Of course, with four locations being considered, plants will be located at all four of the possible locations.

By comparing the results of each iteration in the example above, a definite pattern is observed. When each possible combination is ranked by cost in each iteration, the following results:

- with one location considered the order of four possible locations ranked from lowest cost to highest cost is 1, 4, 2, 3;
- with two locations considered the order of six sets of possible locations ranked from lowest cost to highest cost is 1 and 4, 2 and 4, 3 and 4, 1 and 2, 1 and 3, 2 and 3;
- with three locations considered the order of four sets of possible locations ranked from lowest cost to highest cost is 1, 2 and 4; 2, 3 and 4; 1, 3 and 4; 1, 2 and 3.

The order of the combinations when one location is considered corresponds to the locations which enter the solution as additional location possibilities are considered.

Several other examples of the problem above were computed and, with few exceptions, the "order of entry" as determined by considering one location at a time held true as additional numbers of locations were considered. For purposes of this study, it was assumed that the ranking of each possible combination by transportation cost, as determined by considering one location at a time would constitute the order in which each location would enter the model.

The Calculated "Order of Entry". The procedure described above was applied to the data used in this study to determine the order of entry into the model. This procedure implies that once a particular location is selected it is retained in the model, thus determining a specific locational pattern. The retention of a particular location once it enters the model greatly reduces the possible location combinations. This procedure limits the number of possible location combinations to only the number of potential locations not yet selected.

Number and Size of Elevators at Each Location

Several steps were involved in determining the optimum number and size of elevators at each location for each iteration. Elevator number, size and location determinations in this study are for country elevators. Also, it is assumed that existing terminal elevator facilities may be operational in conjunction with the optimum number, size and location of country elevators determined in this study. The determination of the optimum number and size of elevators at each location was made outside the transportation model since the volume of grain to be handled at each location in each iteration is given. The operating cost data discussed earlier were used to calculate the least-cost size or combination of sizes of elevators required to accomodate a given volume of grain. A constraint however was placed on determining the least-cost combination of elevators, i.e., the size elevator selected would be that size which just meets the storage capacity requirements of a particular location. For example, if location 1 requires a storage capacity of 100,000 bushels, the 100,000 bushel elevator was selected for this location even though, as the model is structured, a lower per unit operating cost could be obtained by selecting a 900,000 bushel elevator. This constraint was added in order to keep excess storage capacity for the total system at a minimum.

The first step in calculating the number and size of elevators at each location is to determine the volume of grain to be handled at each location. This was accomplished by summing the grain production in all sub-areas to be served by a particular location to obtain the total grain supply at that location. This same summation technique was applied to grain demands of each sub-area to obtain the total grain requirements of a specific location. To illustrate, say that grain handling facilities are to be located in sub-area 14 and will service sub-areas 15, 30, and 40. Then to determine the total grain supply for location 14, grain production in sub-areas 14, 15, 30 and 40 are summed. The same method is used to determine total grain requirements for location 14. The higher of the two totals between grain supply and grain demand constitutes the total volume of grain to be handled at the elevator location. When total grain supply is the larger, total grain demands of the location and sub-areas will be met from this supply with the surplus being shipped to export or to deficit locations. When total grain demand of the location is the larger, all production of the sub-areas serviced by the location will be handled in addition to grain shipped to the location for meeting the balance of grain requirements.

Once the volume of grain to be handled at each location is obtained, the next step is to determine the combination of elevator sizes and numbers which provides for the lowest total operating cost for that specific volume. Each possible combination of elevator sizes and numbers that just met the storage capacity needed to handle a specific volume of grain was determined based on handling volumes of the various size elevators. The handling volumes of the five different size elevators as shown in Table VIII are assumed constant for each elevator size. That is, the rate of turnover in grain handled by each elevator, as determined by dividing the estimated average handling volume by the amount of grain storage capacity of the specific elevator, remains unchanged. In reference to Table VIII, page 49, the rates of turnover for each of the five sizes of elevators used in this study are 3, 14, 2.59, 1.73, 1.295, and 1.01 for elevators with 100,000; 200,000; 400,000; 600,000; and 900,000 bushels of storage capacity, respectively. The operating costs per unit were applied to the grain handled by each size elevator and summed to determine total elevator operating costs at each location. The combination of elevator sizes and numbers which yielded the lowest total operating cost was selected as the optimum size and number of elevators at each location. For example, if a certain location was to handle 30,000 tons (999,000 bushels of grain, there are five possible combinations of elevator sizes and numbers. These are shown in Table IX along with their corresponding total operating costs. In this specific example, total operating costs of handling 30,000 tons of grain are minimized by locating one 400,000-bushel elevator and one 200,000-bushel elevator at this particular location. Total storage capacity at this location is 600,000 bushels.

TABLE IX

EXAMPLE COMBINATIONS OF ELEVATOR SIZES AND NUMBERS THAT WILL HANDLE 999,000 BUSHELS OF GRAIN AND THEIR CORRESPONDING TOTAL OPERATING COSTS

Combination Number	Number of Elevators	Grain Storage Capacity in Bu.	Operating Cost Per Size and Number	Total of Combination
1	1	900,000	$ 96,893.70	
	1	100,000	$ 17,616.06	$114,509.76
2	1	600,000	$ 88,432.07	
	1	100,000	$ 43,402.17	$131,834.24
3	1	400,000	$ 74.496.09	
	1	200,000	$ 39,678.21	$114,174.30
4	2	200,000	$128,700.00	$128,700.00
5	4	100,000	$195,300.00	$195,300.00

This same procedure was used to determine the number and sizes of elevators at each location in each iteration of the model. The resulting storage capacity at each location can be summed to determine the total storage capacity for the state.

As an additional location is added in each iteration, the size and number of elevators at each location must be recalculated since the volume of grain handled changes in at least two of the locations. Handling volumes at more than two locations may change depending on the distance the added location is from other locations in the model.

To reiterate, as more locations are added to the model, total elevator operating costs are expected to increase, and total transportation costs are expected to decrease. Thus, it is expected that the number of locations at which the increase in operating costs are just offset by the decline in transportation costs will be the least-cost solution that determines the optimum number, size and location of grain handling facilities for the state.

The next chapter will report the results obtained from the model and associated calculation procedures that have been presented in this chapter.

FOOTNOTES

[1]The term sub-area is hereafter used to refer to that place where grain production and/or utilization occurs. The sub-area of production and utilization, and the location of grain handling facilities are the same only when all 57 possible locations of grain handling facilities are included in the transportation model.

[2]John F. Stollsteimer, "A Working Model for Plant Numbers and Locations," Journal of Farm Economics, Vol. XLIII (August, 1963), p. 634.

[3]Ibid, p. 634.

CHAPTER V

RESULTS

The objective of this study was to determine the optimum number, size and location of grain handling facilities in Oklahoma. This objective was accomplished based on existing data which projected feed grain and wheat production and utilization for the year 1990. For the purposes of this study, optimum refers to a least-cost solution for grain transportation and elevator operation. A crucial assumption of this study was that cost minimization is compatible with the fundamental objectives of the grain elevator industry, i.e., the goals of the grain elevator industry are advanced by the ability to produce with a low-cost structure. The costs minimized by the general transportation model introduced in Chapter II are transportation costs to deficit locations and the assigned export destination. Costs minimized outside the model through procedures outlined in Chapter IV were elevator operating costs and transportation costs to and from subareas and to designated locations. All costs were minimized subject to the number of locations.

An iterative-expansion approach was applied empirically to a set of 57 potential locations. Forty-seven iterations of the model were computed, each resulting in a minimized total cost statistic for a specific number of locations. Individual iterations were not made for some numbers of locations because of the flatness of the total combined cost function and consequently relatively small change in total costs with a larger number of locations considered. For example, a small change in total costs was noted when the number of locations considered in the model varied from 36 to 40; therefore, iterations considering 37, 38, and 39 locations were not computed. In each iteration operating costs data, developed in Chapter III, was used to determine the least-cost number and size of elevators at each location being considered.

In this chapter the results of the iterative analysis are reported in addition to an indepth look at the optimum solution for conditions predicted in 1990, and a comparison of that optimum solution with existing conditions in the grain elevator industry.

Least-Cost Number and Size of Elevators at Different Specified Numbers of Locations

Each iteration of the model was solved with respect to a specific number of locations which enter the model in a specific order. The results of the "order of entry" calculation procedures discussed in Chapter IV are shown in Table X.

In each iteration of the model, the number of locations being considered was predetermined. That is, the first iteration considered only one location, iteration number 2 considered two locations and so forth until all 57 possible locations were included. Through assumptions regarding assembly and delivery of grain within a given sub-area, it was possible to determine the volume of grain to be handled by each location being considered in the model. Given the volume of grain to be handled at each location, the operating cost and handling volume

TABLE X

ORDER OF ENTRY INTO THE ITERATIVE-EXPANSION MODEL FOR EACH OF THE 57 SPECIFIED SUB-AREAS OF OKLAHOMA

Order	Sub-Area Code	Specified City	Order	Sub-Area Code	Specified City
1	38	Enid	30	28	Pawhuska
2	14	Kingfisher	31	24	Duncan
3	13	Woodward	32	31	Chandler
4	18	Fairview	33	36	Bartlesville
5	12	El Reno	34	26	Ardmore
6	6	Clinton	35	25	Pauls Valley
7	17	Cherokee	36	49	Claremore
8	19	Medford	37	56	Holdenville
9	7	Cordell	38	37	Vinita
10	16	Alva	39	33	Tulsa
11	4	Camargo	40	48	Ada
12	3	Woodward	41	50	Wagoner
13	39	Ponca City	42	41	Tahlequah
14	15	Guthrie	43	43	Eufaula
15	23	Anadarko	44	42	Muskogee
16	5	Elk City	45	52	Hugo
17	8	Hobart	46	55	Poteau
18	40	Perry	47	57	Durant
19	9	Chickash	48	10	Norman
20	11	Okla. City	49	32	Bristow
21	2	Buffalo	50	47	Wewoka
22	1	Guymon	51	35	Weleetka
23	22	Lawton	52	34	Okmulgee
24	30	Stillwater	53	51	Atoka
25	46	Shawnee	54	54	McAlester
26	21	Fredrick	55	45	Stigler
27	20	Altus	56	53	Antlers
28	27	Prucell	57	44	Sallisaw
29	29	Pawnee			

data presented in Chapter III provided for the determination of the least-cost number and size of elevators at each location. It was assumed that operating costs were independent of plant location and that grain handling technology remained constant. The results of this determination are presented in Table XI. The number of elevators by categories of grain storage capacities are shown as well as the total number of elevators in the system required to handle the state's volume of grain production.

The most extreme case possible, as shown in Table XI is for one location to service the entire estimated Oklahoma grain production and to have 220 elevators located at this location. Even when one assumes that the number of grain elevators determined in a specific location are distributed throughout a given sub-area, the above case still seems unrealistic. It is more realistic to suppose that elevators at several locations would be established. Nevertheless, the case of one location for the entire state serves as a starting point toward determining the least-cost number and size of elevators required to handle the state's total grain production.

Inspection of Table XI reveals that a large number of elevators with a storage capacity of 900,000 bushels were selected in each solution. The low operating cost per unit of grain for this size elevator provided for its inclusion whenever possible. Selection of elevators in the remaining four size categories was brought about primarily by the constraint that only that size elevator which would just meet a location's storage requirement is allowed to be included. The number of 900,000 bushel elevators in each solution varies from a high of 222 when three and four locations are considered to a low of 153 for

TABLE XI

NUMBER AND SIZE DISTRIBUTION OF ELEVATORS BY NUMBER OF LOCATIONS REQUIRED TO HANDLE OKLAHOMA'S PREDICTED VOLUME OF GRAIN IN 1990

Number of Locations	Selected Elevator Sizes (1000 bu. storage capacity)					Total Number of Elevators
	100	200	400	600	900	
1	1				219	220
2		1		1	215	217
3	2	1			222	225
4	1		1		222	224
5	1	2	1	1	215	220
6	1	2	12	1	213	229
7		3	13		209	225
8	1	3	12		209	225
9	3	2	12		212	229
10	4	1	23	1	203	232
11	4	2	12	1	214	233
12	3	3	23	1	188	218
13	5	2	25	1	198	231
14	4	4	36	1	189	234
15	3	4	63	1	172	243
16	3	4	69	1	168	245
17	3	4	69	1	168	245
18	4	3	93	1	152	253
19	4	2	67	2	172	247
20	4	3	60	2	177	246
21	4	3	65	3	176	251
22	4	4	66	2	174	250
23	5	5	65	1	175	251
24	6	5	60	1	181	253
25	6	6	58	1	182	253
26	6	6	68	1	175	256
27	6	6	69	11	166	258
28	6	6	67	11	168	258
29	5	6	79	13	158	261
30	4	8	81	12	155	260
31	4	7	72	13	161	257
32	5	7	60	13	170	255
33	5	7	61	13	170	256
34	5	7	73	12	162	259
35	6	8	71	12	163	260
36	6	6	86	13	153	264
40	8	6	77	13	161	265

TABLE XI (Continued)

Number of Locations	Selected Elevator Sizes (1000 bu. storage capacity)					Total Number of Elevators
	100	200	400	600	900	
43	8	6	78	14	160	266
44	8	7	76	15	160	266
45	7	7	74	16	161	265
46	7	8	73	17	161	266
47	7	8	74	17	160	266
48	9	8	72	17	161	268
50	12	10	71	17	160	270
55	17	14	65	16	160	272
56	17	14	65	16	160	273
57	18	14	66	16	159	273

thirty-six locations. An erratic downward trend is noted as a relatively small number of locations is considered; but as the number of locations increase, the number of elevators with 900,000 bushels of storage capacity remains fairly steady. In general, the number of elevators included in the other four size categories follows an upward trend as the number of locations is increased.

With successive increases in the number of locations, the total number of elevators in the model, with few exceptions, increase at a consistent rate. Total numbers of elevators vary from a low of 217 when two locations are considered to a high of 283 with all 57 possible locations in the model. While the total number of elevators varies in each solution, the corresponding total storage capacity remains relatively stable throughout the range of locations as shown in Table XII. Maximum storage capacity (200.2 million bushels) occurs when three locations are considered and the minimum volume of total storage capacity (177.6 million bushels) occurs when the solution contains eighteen locations. Total storage capacity for the state varies due to: (1) the relationship of per unit operating costs among the selected size categories, and (2) the indivisibility of elevator size. Further consideration to total storage capacity and elevator numbers will be given later in this chapter when comparisons are made with existing conditions in the grain elevator industry.

Operating Cost in Relation to Number of Locations

Operating costs were computed on the volume of grain handled at each number of locations considered using the operating cost data

TABLE XII

TOTAL GRAIN STORAGE CAPACITY FOR EACH NUMBER OF LOCATIONS

Number of Locations	Storage Capacity (Mil. bu.)	Number of Locations	Storage Capacity (Mil. bu.)	Number of Locations	Storage Capacity (Mil. bu.)
1	197.2	17	180.5	33	187.1
2	194.3	18	177.6	34	184.1
3	200.2	19	183.6	35	184.5
4	200.1	20	185.5	36	181.9
5	195.0	21	187.2	40	185.7
6	197.6	22	185.4	43	185.8
7	193.9	23	185.6	44	185.8
8	193.6	24	189.1	45	186.4
9	196.3	25	189.4	46	186.6
10	193.1	26	187.1	47	186.3
11	196.4	27	185.4	48	186.6
12	179.9	28	186.4	50	186.0
13	189.7	29	183.3	55	184.3
14	186.3	30	181.1	56	184.3
15	181.5	31	183.3	57	183.9
16	180.5	32	186.7		

corresponding to the number and size of elevators presented above. Operating costs for all elevators at each individual location were summed to obtain total operating costs over all locations. In each successive iteration, operating costs were minimized with respect to location numbers. Total operating costs for each iteration are shown in Column 1 of Table XXIII in Appendix C.

Figure 5 is a graph of the numerical results in Column 1 of Table XXIII in Appendix C. Operating costs are at a minimum when only one location is included in the model. For one location the total operating costs were $20,958,504.20. Maximum total operating costs of $22,643,786.74 occurred when all 57 locations were contained in the solution. Throughout the range of location numbers, total operating costs increased as more locations were considered. Logically, as the number of locations increase, elevator sizes at each location will tend to be smaller assuming a fixed quantity of grain to be handled. So, given the elevator size operating cost relationship used in this study, a larger number of relatively small elevators resulted in increased operating costs for the system.

Several exceptions to the above statement were noted in the total operating cost data. Figure 5 shows several downward movements in total operating costs. In those isolated cases, the volume of grain handled at each location was such that a greater number of the larger elevators were selected with lower per unit costs than in the previous solution, resulting in lower total operating costs. As a larger number of locations were considered, deviations from the upward trend were not observed.

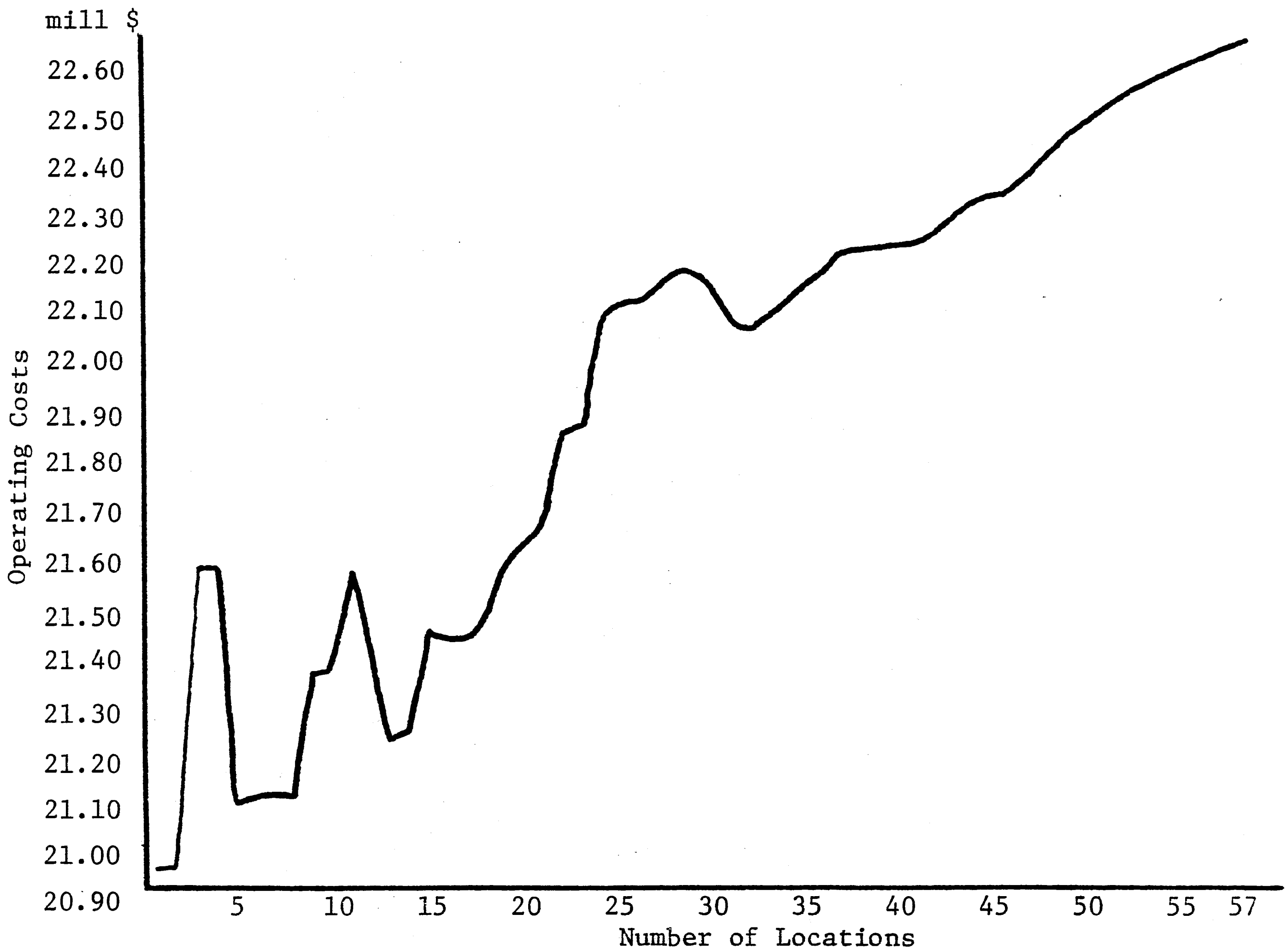


Figure 5. Operating Costs for Different Numbers of Country Elevator Locations

Transportation Costs with Respect to Location Numbers

Three individual transportation cost functions were calculated for each number of locations considered. These transportation costs included: (1) costs of transporting grain to the specified locations from sub-areas closer to the specified location than to any other location; (2) costs of transporting grain to meet areal demand, and, (3) costs of transporting grain to deficit locations and the export destination. The transportation cost results for each iteration are presented numerically in Columns 2, 3, 4, and 5 of Table XXIII in Appendix C. The three transportation cost functions and the total transportation cost function are plotted in Figure 6. A discussion of each of the transportation cost components is given below.

Transportation-to-Location Costs

These costs were computed by applying the truck rate formula in equation 6 to the volume of grain to be assembled at each location and then summed over all locations to obtain a total transportation-to-location cost for the state. The numerical results are shown in Column 2 of Table XXIII in Appendix C and by the solid line TL in Figure 6. Given the assumptions and procedures followed in the model, these costs are highest when only one location is in the model. The magnitude of these costs as additional locations are added become zero when all 57 possible locations are included in the model.

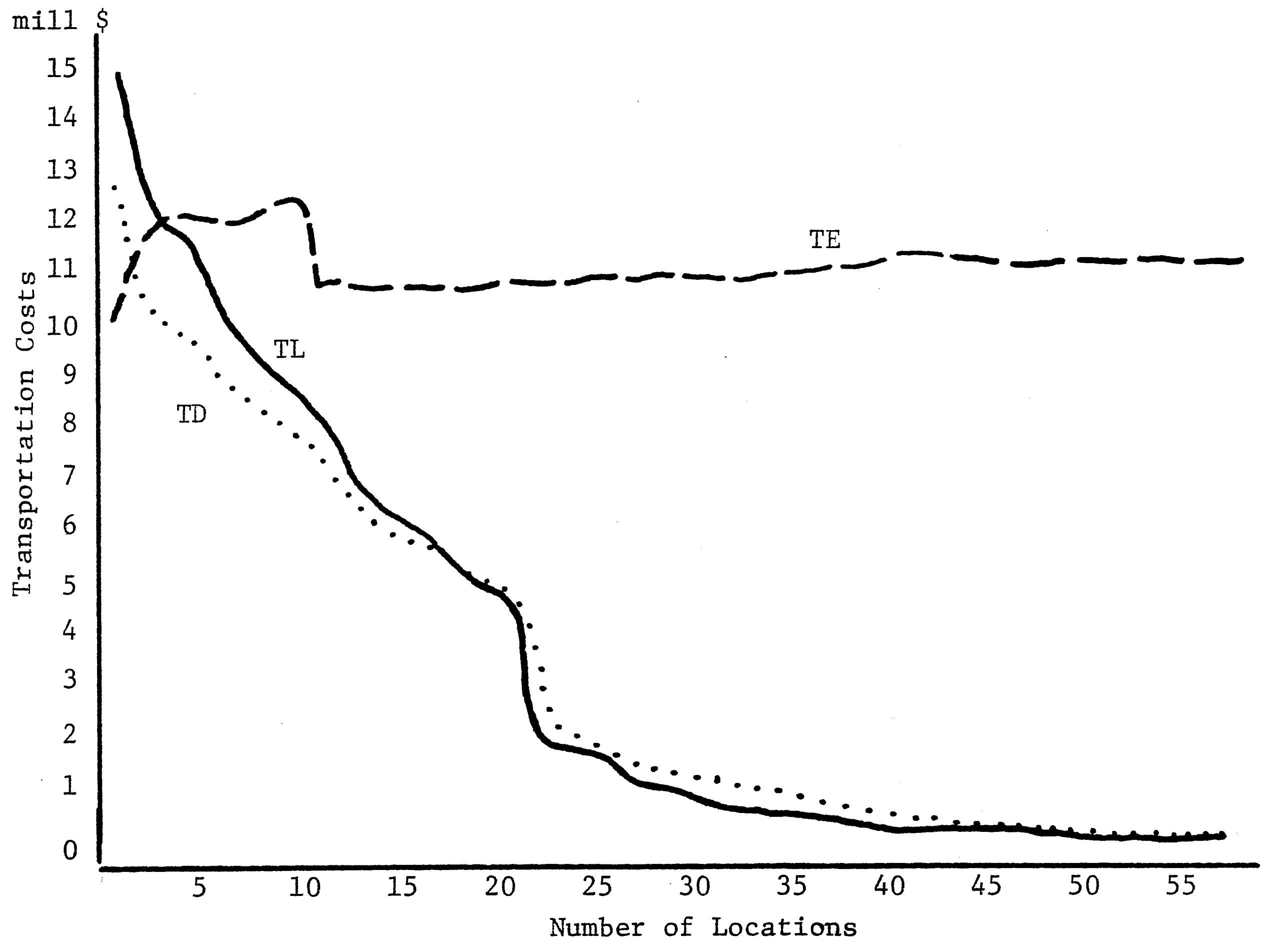


Figure 6. Transportation Costs for Different Numbers of Country Elevator Locations

Transportation-to-Demand Costs

Transportation-to-demand costs were computed by applying equation 6 to the volume of grain to be distributed from the specific location to the sub-areas in its service area. These costs follow the same pattern as do transportation-to-location costs. That is, they decline steadily throughout the range of location numbers. They are highest at one location and become equal to zero with 57 locations in the model. Transportation-to-demand costs are reported numerically in Column 3 of Table XXIII in Appendix C and are shown graphically by the dotted line TD in Figure 6.

Transportation-to-Export Costs

Transportation-to-export costs include the costs associated with the movement of grain to deficit locations as well as to Houston, Texas, for export. Column 4 of Table XXIII in Appendix C lists the results of these cost calculations as determined by the transportation model. This cost varies over the range of possible locations depending on the number and location of elevator locations which are deficit in their grain requirements. Variations also occur due to the combined distance that locations in the model are from the export destination. Transportation-to-export costs with respect to number of locations are illustrated by the dashed line TE in Figure 6. Maximum costs of $12,290,000 occur when nine locations are considered. Minimized transportation-to-export costs of $10,153,000 are noted when only one location is considered in the model. That cost represents the cost to transport grain to Houston, Texas, for export purposes.

Total Transportation Cost

Total transportation cost is obtained by summing each of the three transportation costs presented above for each number of locations. Numerical results of this summation are reported in Column 5 of Table XXIII in Appendix C. The total transportation cost function shown by the dotted line TTC in Figure 7 is a vertical summation of all three component cost functions shown in Figure 6. As in the case of transportation-to-location and transportation-to-demand costs, total transportation costs were highest with only one location in the model and were at a minimum with all 57 possible locations being considered. Therefore, the total transportation cost function was a decreasing cost function throughout the range of location numbers.

Total Combined Costs with Respect to Number of Locations

The total combined cost, shown by the solid line TTC in Figure 7, was obtained by separate summations of the minimized total transportation cost and the total operating cost, shown in Figure 7 by the dotted line TTC and the dashed line TOC, respectively, for each different number of locations. Each of the three cost functions varies with number of potential locations as shown in Figure 7. The solution for the model is the minimum point on the total combined cost function. The transportation cost function is negatively sloped, while the operating cost function has a positive slope. As long as the magnitude of change of the declining transportation cost function exceeds the magnitude of change of the inclining operating cost

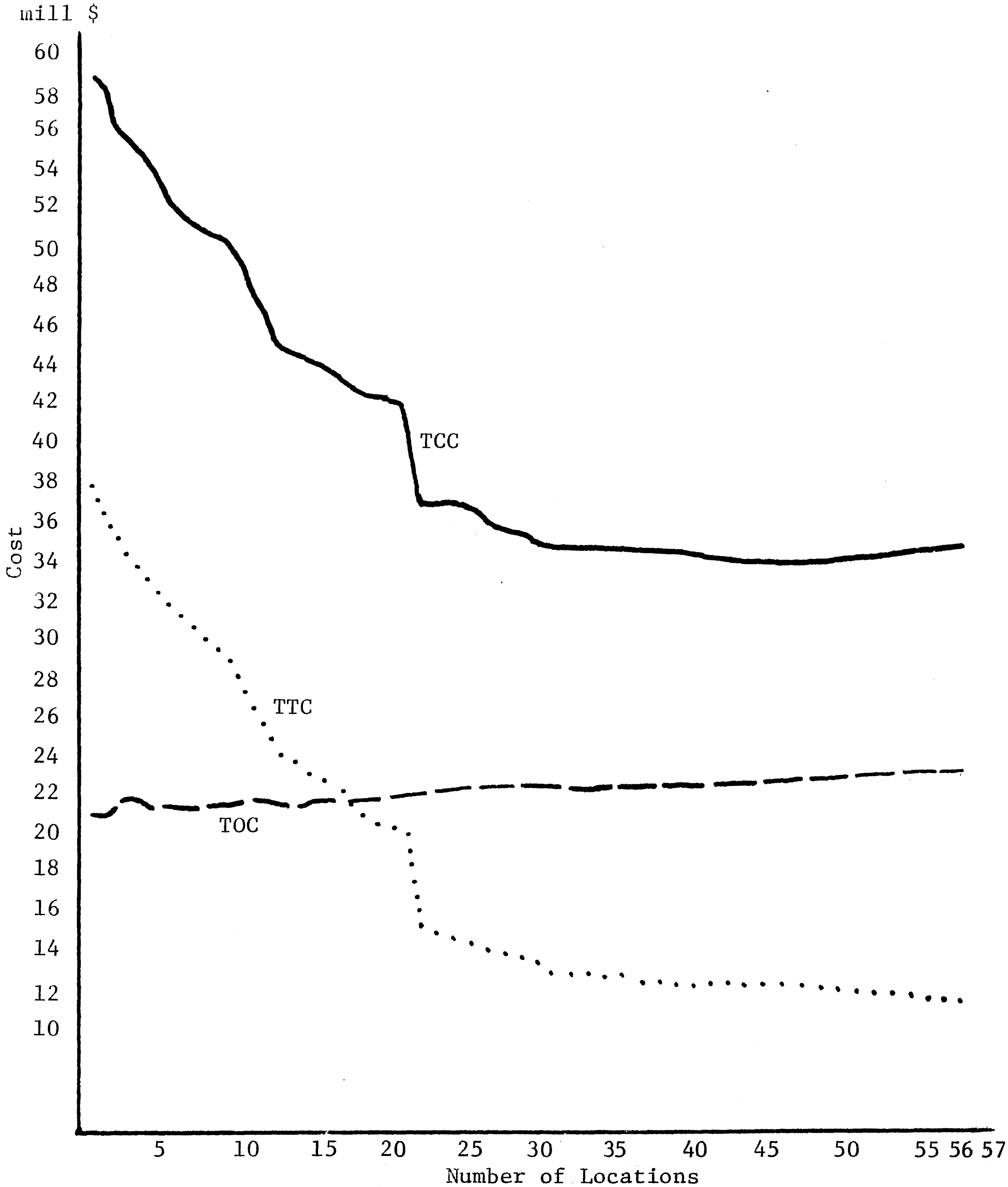


Figure 7. Total Combined Costs for Different Numbers of Country Elevator Locations

function, the combined cost function decreases with respect to location numbers. When the magnitude of change of the operating cost function exceeds that of the transportation cost function, total combined costs increase with additional location numbers. The minimum point on the total combined cost function occurs when 46 locations are included in the model. Therefore, given the assumptions of this study, the optimum solution is that in which elevators are located at 46 of the 57 possible locations.

The Optimum Solution

The optimum solution as determined by the iterative-expansion approach utilizing the transportation model contains 46 elevator locations. These locations and their corresponding sub-areas serviced are shown in Figure 8. A comparison of Figure 8 with Figure 9 reveals those sub-areas in the optimum solution which do not have grain handling facilities, but are serviced by facilities located in other sub-areas. For example, sub-area 10 is serviced by facilities in sub-area 11 in the optimum solution. Of the 46 locations in the solution, 35 were located in grain surplus areas while the remaining 11 were in grain deficit areas. The grain deficit locations were primarily in the eastern portion of the state, while the balance of deficit locations were dispersed throughout the central and western portions of Oklahoma which are the areas of intensive grain production. In the sub-sections to follow an indepth discussion of the optimum solution will be given, and in addition, a comparison will be made with existing industry conditions.

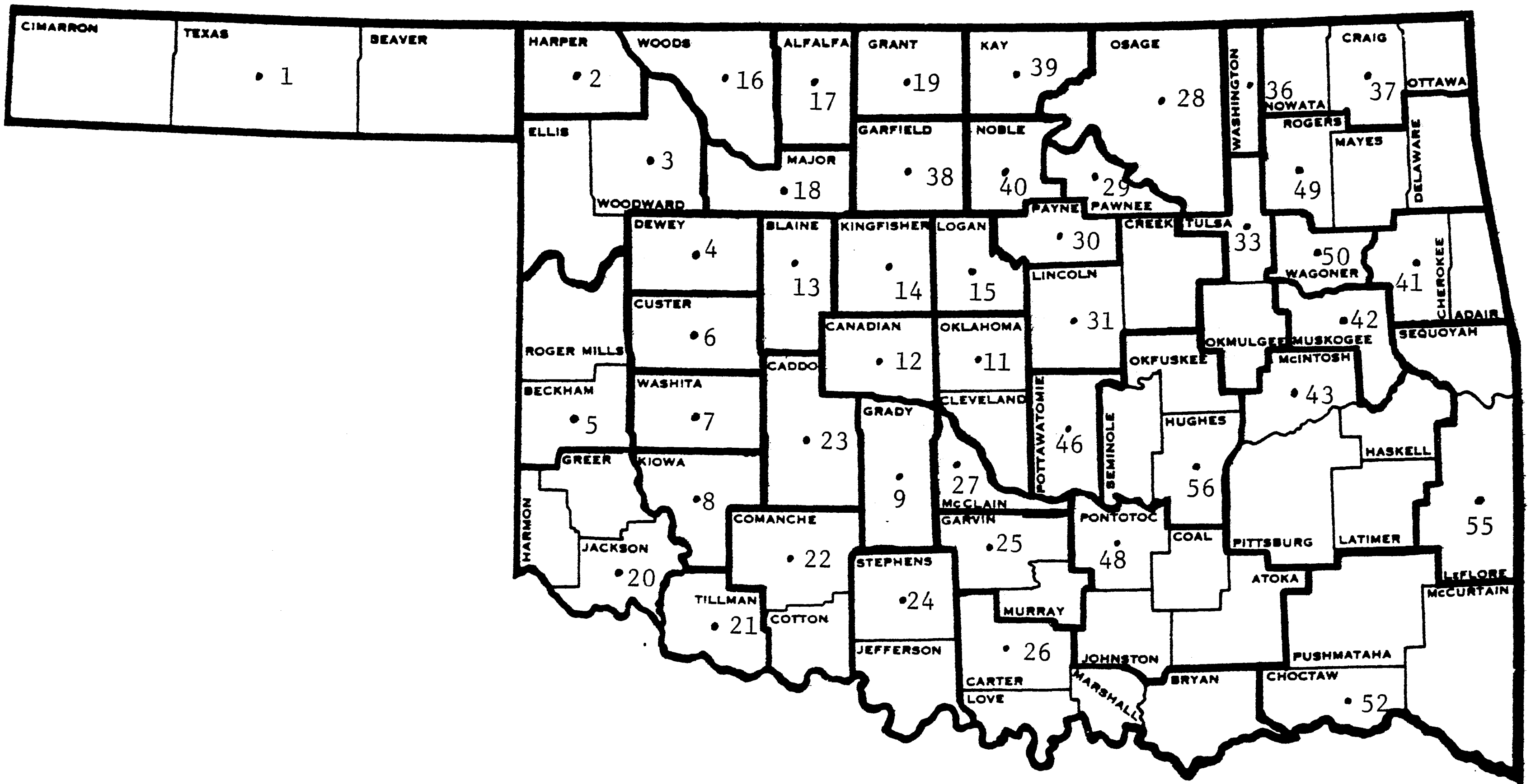
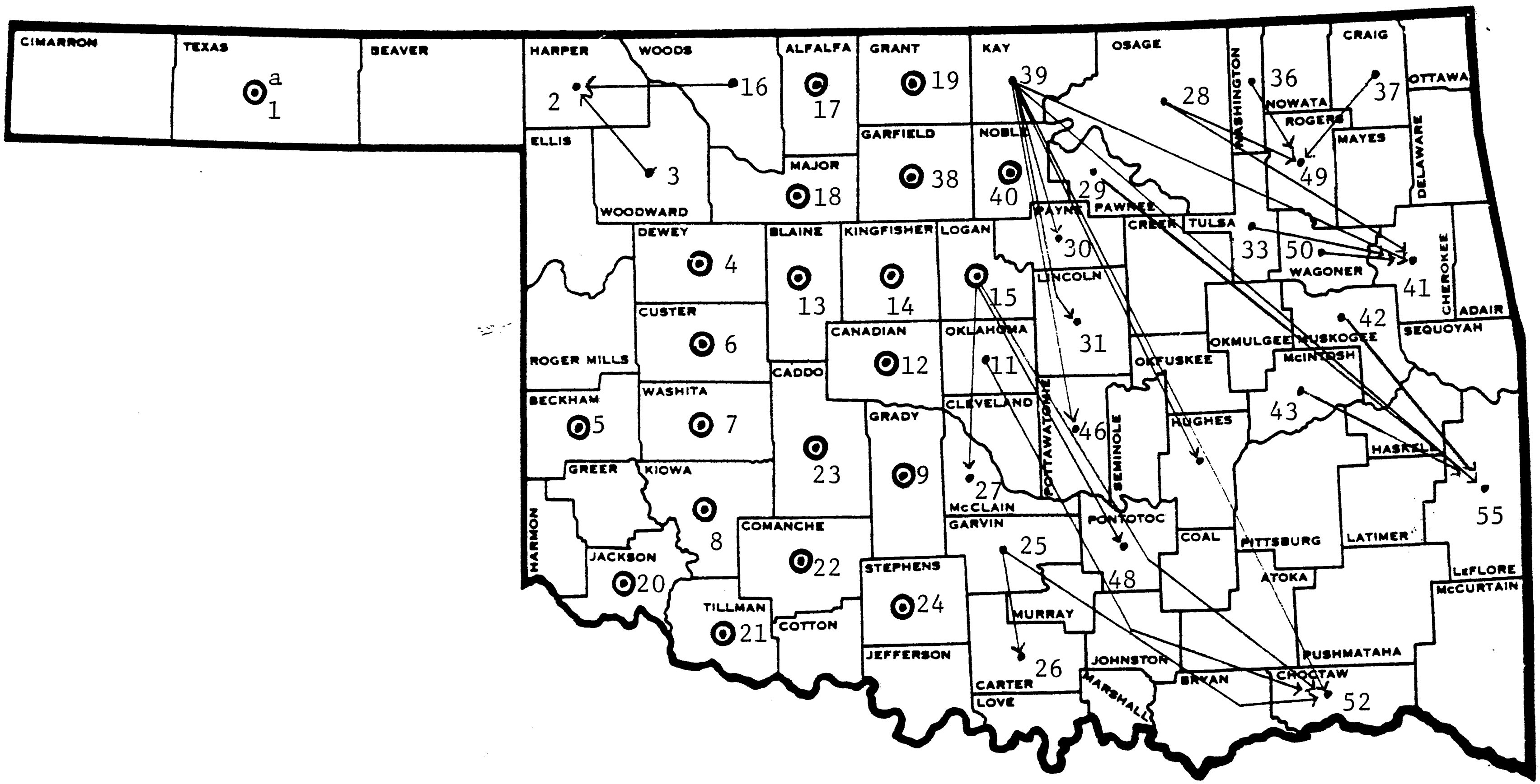


Figure 8. Locations of Country Elevators in the Optimum Solution with Designated Sub-Areas Serviced



[a]An encircled dot indicates those locations which ship grain to export.

Figure 9. Projected Grain Flows Within Oklahoma and to Export, 1990

Total Combined Costs

For 46 locations the minimized total transportation costs were $11,330,330, while the accompanying total operating costs were $22,385,400. The total combined costs were $33,715,730. By comparison total combined costs for one location were $58,702,900 and for 57 locations those combined costs were $33,879,400. In comparing the solution with those in the neighborhood of 46 locations, namely, 45 and 47 locations, slight differences in the total combined costs were observed. Total combined costs for 45 and 47 locations were $33,732,200 and $33,726,500, respectively. In relation to total combined costs of 46 locations, the total costs of 45 and 47 locations differed by less than .05 percent.

Number and Size of Elevators

In Table XI, page 72, the total number of elevators in 46 locations is shown to be 266. This total is distributed over the five size categories in the following manner: 7 elevators with 100,000 bushels of grain storage capacity each; 8 elevators with 200,000 bushels of grain storage capacity each; 73 elevators with 400,000 bushels of grain storage capacity each; 17 elevators with 600,000 bushels of grain storage capacity each; and 161 elevators with 900,000 bushels of grain storage capacity each. In comparing this solution with those of 45 and 47 locations of grain elevator facilities, little variation is noted in the total number of elevators and the number of elevators in each size category. However, when compared to the solutions with one and 57 locations, significant differences are observed. With one location in solution, all but one of the total number of elevators is of the 90,000 bushel size. Comparing the optimum solution with the solution considering all 57 possible locations, the number of 600,000 and 900,000 bushel elevators are practically the same, while the number of 100,000 and 200,000 bushel elevators is significantly higher and the number of 400,000 bushel elevators is relatively lower. As shown in Table XI the total number of elevators remains fairly stable in those solutions neighboring the optimum solution.

A breakdown of the number and size of elevators as well as their corresponding storage capacity for each of the 46 locations is presented in Table XIII. The location with the largest number of elevators is Location 1 (Guymon) with 38. In this solution ten different locations have only one elevator; however, of the ten, Locations 25 (Pauls Valley) and 42 (Muskogee) have the smallest amount of storage capacity with 200,000 bushels each. Locations with relatively large numbers of elevators were situated primarily in the western part of the state, while few elevators per location were characteristic of eastern Oklahoma.

Projected Grain Flows

To determine the optimum number, size and location of grain handling facilities in Oklahoma, estimates of feed grain and wheat production and utilization for the year 1990 were incorporated into the transportation model. In the optimum solution to this model, total operating and transportation costs of distributing grain from surplus areas to deficit areas and an export destination were minimized subject to the number of locations being considered. Thus, the optimum

TABLE XIII

NUMBER, SIZE AND LOCATION OF COUNTRY ELEVATORS AND TOTAL GRAIN STORAGE CAPACITY AT EACH OF 46 LOCATIONS IN THE OPTIMUM SOLUTION FOR OKLAHOMA, 1990

Code	Specified City	Selected Elevator Sizes (1000 bu. storage capacity)					Storage Capacity Per Location (1000 bu.)
		100	200	400	600	900	
1	Guymon		1			37	33,500
2	Buffalo			6			2,400
3	Woodward		1			4	3,800
4	Camargo				1	3	3,300
5	Elk City			6			2,400
6	Clinton	1				6	5,500
7	Cordell					8	7,200
8	Hobart	1				7	6,400
9	Chickasa			4			1,600
11	Okla. City			2			800
12	El Reno	1				7	6,400
13	Watonga			11			4,400
14	Kingfisher			12			4,800
15	Guthrie			1		3	3,100
16	Alva					6	5,400
17	Cherokee			12			4,800
18	Fairview		1			5	4,700
19	Medford			1		12	11,200
20	Altus			1	10		6,400
21	Frederick		1			7	6,500
22	Lawton					6	5,400
23	Anadarko					7	6,300
24	Duncan		1	1			600
25	Pauls Valley		1				200
26	Ardmore					1	900
27	Purcell	1				1	1,000
28	Pawhuska			1		1	1,300
29	Pawnee	1				1	1,000
30	Stillwater				1		600
31	Chandler			1			400
33	Tulsa			1			400
36	Bartlesville			1	1		1,000
37	Vinita		1			3	2,900
38	Enid	1				13	11,800
39	Ponca City			1		12	11,200
40	Perry			1		5	4,900
41	Tahlequah			1	2		1,600
42	Muskogee		1				200

TABLE XIII (Continued)

Code	Specified City	Selected Elevator Sizes (1000 bu. storage capacity) 100	200	400	600	900	Storage Capacity Per Location (1000 bu.)
43	Eufaula			1			400
46	Shawnee			6			2,400
48	Ada				1		600
49	Claremore	1				3	2,800
50	Wagoner				1		600
52	Hugo			1		1	1,300
55	Poteau					2	1,800
56	Holdenville			1			400
	Total	7	8	73	17	161	186,600

flow of grain as projected for 1990 was determined, given the assumptions and data used in this study. Table XIV shows the volume of grain shipped from the 35 surplus areas to the 11 deficit areas and the amount of grain shipped to Houston, Texas, for export in the optimum solution. The grain flows are illustrated in Figure 9, page 87. The arrows in Figure 9 indicate the movement of grain within Oklahoma, while encircled dots are used to depict those locations which ship grain to export. As illustrated in Figure 9, grain deficit areas are located primarily in the eastern half of Oklahoma and receive grain from locations in the western half of Oklahoma. The only exception is Location 2 (Buffalo) whose grain demands are met by Locations 3 (Woodward) and 16 (Alva). Practically all locations in western Oklahoma had surplus quantities of grain and shipped those surpluses to Houston, Texas, for export.

Comparison with Existing Conditions

A comparison with existing conditions in the grain elevator industry should serve to put the optimum solution in perspective regarding the number, size and location of country grain elevators projected for 1990 in Oklahoma. An indication as to adjustments required in existing conditions in order to conform with those specified in this study for the year 1990 can be obtained from the data presented in Table XV. Here a comparison is made between 1970 actual data and the 1990 model results of total storage capacity, total number of elevators, and the mean size country elevator by selected regions of Oklahoma[1].

TABLE XIV

PROJECTED FLOWS OF GRAIN BY LOCATION IN OKLAHOMA FOR 1990

Origin		Destination		Volume Shipped (1000 tons)
Code	City	Code	City	
1	Guymon	58	Houston	139.136
3	Woodward	2	Buffalo	30.889
4	Camargo	58	Houston	38.564
5	Elk City	58	Houston	26.111
6	Clinton	58	Houston	67.950
7	Cordell	58	Houston	107.352
8	Hobert	58	Houston	63.164
9	Chickasha	58	Houston	15.592
11	Okla. City	52	Hugo	1.270
12	El Reno	58	Houston	8.435
13	Watonga	58	Houston	75.599
14	Kingfisher	58	Houston	24.855
15	Guthrie	58	Houston	14.372
15	Guthrie	27	Purcell	15.021
15	Guthrie	58	Ada	9.552
15	Guthrie	52	Hugo	2.081
16	Alva	2	Buffalo	19.715
16	Alva	52	Hugo	9.405
17	Cherokee	58	Houston	67.216
18	Fairview	58	Houston	58.643
19	Medford	58	Houston	156.393
20	Altus	58	Houston	83.703
21	Fredrick	58	Houston	3.851
22	Lawton	58	Houston	71.172
23	Anadarko	58	Houston	88.807
24	Duncan	58	Houston	4.888
25	Pauls Valley	26	Ardmore	1.035
25	Pauls Valley	52	Hugo	3.594
28	Pawhuska	41	Tahlequah	11.698
28	Pawhuska	49	Claremore	2.991
29	Pawnee	55	Poteau	1.055
33	Tulsa	41	Tahlequah	.444
36	Bartlesville	49	Claremore	16.681
37	Vinita	49	Claremore	12.744
38	Enid	58	Houston	153.765
39	Ponca City	30	Stillwater	.204
39	Ponca City	31	Chandler	3.413
39	Ponca City	41	Tahlequah	40.090
39	Ponca City	49	Claremore	64.174
39	Ponca City	52	Hugo	20.604

TABLE XIV (Continued)

Origin		Destination		Volume Shipped (1000 tons)
Code	City	Code	City	
39	Ponca City	55	Poteau	33.395
39	Ponca City	56	Holdenville	.643
40	Perry	58	Houston	66.329
42	Muskogee	55	Poteau	3.459
43	Eufaula	55	Poteau	6.976
50	Wagoner	41	Tahlequah	8.281

TABLE XV

TOTAL GRAIN STORAGE CAPACITY, NUMBER AND AVERAGE SIZE OF OKLAHOMA'S COUNTRY ELEVATORS BY SELECTED REGIONS IN 1970 AND 1990

Region	1970	1990
	Total Grain Storage Capacity in thousands of bushels	
Western one-third of Okla.	53,762	93,500
Central one-third of Okla.	89,532	77,800
Eastern one-third of Okla.	14,493	15,300
Total	157,787	186,600
	Number of Elevators	
Western one-third of Okla.	167	125
Central one-third of Okla.	180	116
Eastern one-third of Okla.	22	25
Total	369	266
	Mean Size of Elevators bushels	
Western one-third of Okla.	321,928	748,000
Central one-third of Okla.	497,400	670,690
Eastern one-third of Okla.	658,773	612,000
State Mean	427,607	701,504

Several differences are noted in comparing the 1970 data to the 1990 model results. The storage capacity data show a large shift in total storage capacity between the western and central regions of the state. Storage capacity in the western region for 1990 is approximately double that of 1970, while storage capacity for the central region in 1990 is over 37 percent below the amount shown in 1970. Only a slight increase is noted in storage capacity for the eastern region. Total country elevator grain storage capacity for the state marked an increase of nearly 29 million bushels from that existing in 1970. This occurs because with this optimum organization of number, size and location the increase in storage capacity requirements of the western region and eastern region more than offset the reduction in needed storage capacity of the central region.

Regarding the change in the number of country elevators in each region, the western and central regions show fewer numbers of elevators for 1990, while the eastern region shows only a slight increase. Only moderate changes occur in elevator numbers for the western and eastern regions, but the number of elevators in the central region dropped nearly 36 percent from 180 in 1970 to 116 in 1990. With all regions except the eastern region showing declines in elevator numbers, the total number of elevators for the state totalled 103 less than were in existance in 1970.

In comparing the mean size elevator for the three regions of Oklahoma, changes similar to those in total storage capacity were observed. As in the case of storage capacity, the mean size elevator in the western region was over double the mean size elevator in that region in 1970. However, with declines in storage capacity and number of elevators, the central region showed an increase of 173,290 bushels in the mean size elevator for 1990. Unlike country elevator total grain storage capacity and total number of country elevators in the state which both exhibit marked decreases after 1970, the mean size country elevator for the state as a whole shows an increase of 64 percent from 427,607 to 701,504 bushels of grain storage capacity.

These comparisons made above indicate that several changes may be expected to occur in the structure and organization of the grain elevator industry between 1970 and 1990. A further comparison of the existing industry organization with that as developed in this analysis is made in Table XVI where the number of elevators and corresponding storage capacity for each of the 46 locations in the optimum solution are compared to similar statistics for 1970.

The comparison of the number of country elevators and corresponding grain storage capacity at each location in the 1990 model with conditions as they existed in 1970 gives a more detailed indication of possible changes. From Table XVI several observations were made regarding changes in the number of country elevators and associated grain storage capacities. The number of elevators at 34 of the 46 locations declined from 1970, while the number of elevators was higher at 7 of the locations. The remaining five locations experienced no change in elevator numbers from 1970 to 1990. The more pronounced changes in elevator numbers are expected to occur primarily at locations which are situated in the western half of the state.

As stated earlier, country elevator total grain storage capacity for the state increased by nearly 29 million bushels with 28 of the individual locations showing increases in storage capacity from 1970.

TABLE XVI

NUMBER OF COUNTRY ELEVATORS AND CORRESPONDING GRAIN STORAGE CAPACITY FOR EACH OF 46 OKLAHOMA LOCATIONS IN 1970 AND THE OPTIMUM SOLUTION FOR 1990

Location		Number of Elevators		Storage Capacity (1000 bu.)	
Code	City	1970	1990	1970	1990
1	Guymon	19	38	13,294	33,500
2	Buffalo	6	6	976	2,400
3	Woodward	11	5	3,792	3,800
4	Camargo	8	4	1,832	3,300
5	Elk City	8	6	1,653	2,400
6	Clinton	10	7	5,383	5,500
7	Cordell	10	8	2,598	7,200
8	Hobart	13	8	2,987	6,400
9	Chickasha	10	4	3,251	1,600
11[a]	Okla. City	9	2	2,788	800
12	El Reno	15	8	8,868	6,400
13	Watonga	14	11	6,529	4,400
14	Kingfisher	13	12	4,794	4,800
15	Guthrie	9	4	1,878	3,100
16	Alva	13	6	9,806	5,400
17	Cherokee	14	12	5,415	4,800
18	Fairview	7	6	2,810	4,700
19	Medford	17	13	5,651	11,200
20	Altus	20	11	5,094	6,400
21	Fredrick	13	8	4,762	6,500
22	Lawton	10	6	1,981	5,400
23	Anadarko	10	7	2,881	6,300
24	Duncan	4	2	588	600
25	Pauls Valley	2	1	611	200
26[b]	Ardmore	3	1	535	900
27	Purcell	1	2	80	1,000
28	Pawhuska	3	2	6,783	1,300
29	Pawnee	3	2	154	1,000
30	Stillwater	4	1	1,688	600
31[c]	Chandler	1	1	1,857	400
33[d]	Tulsa	3	1	630	400
36	Bartlesville	1	2	9	1,000
37	Vinita	6	4	1,983	2,900
38	Enid	31	14	23,645	11,800
39	Ponca City	21	13	8,377	11,200
40	Perry	6	6	2,972	4,900
41	Tahlequah	1	3	20	1,600

TABLE XVI (Continued)

Location		Number of Elevators		Storage Capacity (1000 bu.)	
Code	City	1970	1990	1970	1990
42	Muskogee	4	1	871	200
43[e]	Eufaula	6	1	857	400
46	Shawnee	2	6	3,080	2,400
48[f]	Ada	1	1	65	600
49	Claremore	5	4	2,176	2,800
50	Wagoner	1	1	10	600
52[g]	Hugo	0	2	0	1,300
55[h]	Poteau	1	2	1,000	1,800
56[i]	Holdenville	3	1	733	400

[a]This location serves sub-area 10 in the optimum solution.

[b]This location serves sub-area 57 in the optimum solution.

[c]This location serves sub-area 32 in the optimum solution.

[d]This location serves sub-area 34 in the optimum solution.

[e]This location serves sub-area 45 and 54 in the optimum solution.

[f]This location serves sub-area 51 in the optimum solution.

[g]This location serves sub-area 53 in the optimum solution.

[h]This location serves sub-area 44 in the optimum solution.

[i]This location serves sub-area 35 and 47 in the optimum solution.

However, all locations except seven posted increases in the mean size of their elevators. This comparison further indicates those adjustments in the current industry structure regarding an optimum number, size and location of grain handling facilities which may be expected to take place during the next 20 years.

FOOTNOTES

[1]Grain Storage capacity data for 1970 used in these comparisons exclude the storage capacity of existing terminal elevator facilities at Enid, Oklahoma.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Significant changes have occurred in the structure and organization of Oklahoma's country elevator industry over the past decade. Average size of country elevators had increased while the number of firms in the industry has declined. Both the decline in elevator numbers and increase in average size elevator have occurred at different rates in different parts of the state. The reduction in number of firms and corresponding increase in average firm size indicates that those firms exiting the industry have been the smaller, below average size firms.

This study was concerned with determining the optimum number, size and location of grain handling facilities in Oklahoma that minimized grain elevator handling and distribution costs to the grain marketing system. In accomplishing this primary objective several specific objectives were completed including: estimating operating costs per unit of grain for different sizes of grain handling facilities, determining the least-cost size combination and associated number of grain handling facilities at each location, and determining the optimum flow of grain within Oklahoma and to an export destination.

Theory relating to transportation costs and the location of economic activity was discussed. The works of Hoover[1] and Barlowe[2] were discussed in relation to firms locational decision. They approached the problem of determining the firm's location based on the quantities of each material used and their weight-loss weight-gain characteristics. Processing costs and their role in the locational decision were considered. Corley's study showed that grain elevator industry processing or in-plant costs do not dominate the cost structure so as to become a determining factor in the location decision[3].

A general transportation model was employed to determine the optimum number, size and location of grain handling facilities in Oklahoma's grain marketing system. The least-cost solution of the model also determined the optimum flow of grain both within and away from Oklahoma based on existing transportation rates. An iterative approach which utilized the transportation model was developed and used to determine the least-cost number and size of grain elevators for a given number of locations. That number of locations which yielded the least total combined costs, operating plus distribution costs, was considered optimum.

To facilitate the use of the basic model, the state of Oklahoma was delineated into 57 sub-areas. In addition, Houston, Texas, was included as a destination point for grain in excess of Oklahoma utilization requirements. Once the areal delination was made, existing data related to feed grain and wheat production and consumption for each of the state's sub-areas were obtained. These existing production and consumption estimates were based on projections for the year 1990. Transportation rates for shipments of grain were obtained from existing studies in the case of truck rates, and from effective rail rate schedules. Data were also obtained on elevator operating costs for five different sizes of elevators. Given the basic data and the operational model, iterative computations of the model were made. Each iteration resulted in a minimized total cost figure for a specific number of locations. That number of locations started at one and was increased by one with each iteration leading to the iterative-expansion name for this procedure. In each iteration, operating costs were minimized to determine the optimum number and size of elevators at each location being considered. Successive iterations together determined the optimum locational pattern subject to those individual locations having an optimum number and size of elevators.

Each iteration of the model was solved with respect to a specific number of locations. The first iteration was solved assuming only one location to service Oklahoma's entire estimated grain production or consumption, whichever was larger. This first solution revealed 220 as the total number of elevators with 197.2 million bushels of storage capacity. In successive iterations the total number of elevators in the system increased at a fairly consistent rate while the corresponding storage capacity remained relatively stable throughout the range of possible location numbers. Operating costs, computed on the volume of grain handled at each number of locations, increased steadily as the number of locations considered increased. Operating costs ranged from nearly 21 million dollars when one location was assumed to over 44.5 million dollars with all 57 possible locations of the country elevators in solution.

Total transportation costs were highest when only one location was considered and declined steadily with each successive iteration. Total costs of operation and distribution were obtained by a summation of the total operating cost function and the total transportation cost function for each iteration which involved a specified locational pattern. The minimum (least-cost) point on the total combined cost function occurred when 46 locations were included in the model.

Of the 46 country elevator locations in the optimum solution for the 1990 model, 35 were grain surplus and 11 were grain deficit. Under this optimum arrangement the heaviest concentration of elevator locations was in the central and western portions of Oklahoma. The total number of country elevators at the 46 locations was 266. Of the 266 elevators, 7 had a storage capacity of 100,000 bushels, 8 had a storage capacity of 200,000 bushels, 73 had a storage capacity of 400,000 bushels, 17 had a storage capacity of 600,000 bushels, and 161 has a storage capacity of 900,000 bushels. Total storage capacity of the 266 country elevators in the system was 186.6 million bushels. The single location with the largest amount of storage capacity was location number 1 (Guymon) with 33.5 million bushels[4]. The smallest amount of storage capacity at any of the 46 locations was 200,000 bushels at location numbers 25 (Pauls Valley) and 42 (Muskogee).

Optimum grain flows as determined in the least-cost solution consisted of shipments to 11 deficit locations and the export destination, Houston, Texas. All but one of the deficit locations were in the eastern one-third of the state and received grain from central Oklahoma locations. All but three locations in the western one-third of the state shipped all of their surplus grain to Houston for export.

By comparing the results of this study with existing conditions in the grain elevator industry, differences are evident. Based on existing estimates for production and consumption in 1990, the results of this study indicate an increase in total grain storage capacity of nearly 29 million bushels from that existing in 1970. Also, the total number of elevators in the system declined from 372 in 1970 to 266 in 1990, a reduction of 106 elevators. The mean size elevator for the state as a whole as determined in this study had 273,897 more bushels of storage capacity than the mean size elevator in 1970.

Regional comparisons more clearly illustrate the differences in existing conditions from those found in the results of this study. Comparisons of grain storage capacity on a regional basis showed the western one-third of Oklahoma with an increase of 39.74 million bushels, up from 53.76 million bushels in 1970. The central one-third of the state posted a decline of 11.73 million bushels, while storage capacity in the eastern one-third rose .81 million bushels from that of 1970. Regionally a reduction in the number of elevators of 42 and 64 from 1970 were noted for the western and central regions, respectively, while the number of elevators in the eastern region increased by 3 from that of 1970. The mean size elevator in each of the regions followed much the same pattern as did storage capacity. The mean size elevator increased from that of 1970 in the western and central regions and declined in the eastern region.

While the total storage capacity in the optimum solution increased by nearly 29 million bushels from that of 1970, 28 of the 46 locations in the optimum solution showed increases in storage capacity. In addition, all locations but seven posted increases in the mean size of their elevators.

Conclusions

Implications

The results presented in the preceding chapter were obtained by formulating a transportation model of the grain marketing system in Oklahoma and computing successive iterations of the model, each with a different number of locations, by use of linear programming procedures. The results were based on existing estimates of grain production and consumption for the year 1990. Total costs of elevator operation and grain transportation to the industry were minimized with respect to different numbers of locations. Since data on actual total industry costs were not available, comparison of the results with actual costs was not possible. However several conclusions can be drawn from those results obtained in this study.

The shape of estimated total combined cost function suggests that the degree of sensitivity may be low. In the neighborhood of the optimum solution the total combined cost function is very flat. This indicates that a small deviation in the number of locations from the optimum solution will raise costs only slightly. So a high degree of sensitivity in the optimum solution does not seem likely since a small deviation from the solution does not appear to raise costs sharply.

According to the model for 1990 used herein, an increase in total grain storage capacity of nearly 29 million bushels will be needed in Oklahoma. This increase can be explained by the data incorporated in the study. These data show an increase in Oklahoma's wheat and feed grain consumption. Because of the increased wheat and feed grain production as well as increased feed grain consumption by livestock in the western region of Oklahoma, the model for 1990 developed in this study indicates that expansion in grain handling facilities may be necessary. Furthermore, the storage capacity in the central region is expected to be reduced due to elimination of excess storage capacity and comparatively lower handling requirements.

The total number of country elevators in the state has been declining over the past 10 years. The results of this study indicate a continued reduction in total elevator numbers to the year 1990. However, as shown in Table XV, page 95, the mean size elevator in the state is expected to increase by 273,897 bushels of grain storage capacity. Therefore, the expected reduction in country elevator numbers and increase in the mean size elevator might lead one to suggest that those firms exiting the industry may be those small, below-average size firms. This same conclusion does not necessarily hold true in the case of mergers.

The reduction in number of country elevators and their adherence to an optimum locational pattern may serve to reduce total operating and transportation costs to the industry. With a relatively fewer number of country elevators of a large size, economies of scale could be achieved by those firms in the industry, thereby providing for a lower operating cost structure. Also, a reduction in the number of country elevators which must be served by the railroads could improve coordination and reduce railroad transportation costs. The adherence of country elevators to an optimum locational pattern could result in a reorganization of the existing rail rate structure. And too, an optimum location pattern for country elevators could provide for more adequately coordinated grain shipments within Oklahoma. This also would allow for the possibility of reduced transportation costs and for a possible increase in profits to the industry.

A substantial reduction in the number of elevators may have effects on other than the grain elevator industry. Social and economic conditions of some areas could be affected by the elimination of the local elevator, since in some small towns the local elevator may be the main activity holding a community together.

As shown in the results, total operating costs varied by $1,685,000 from a high of over $22,644,000 to a low of $20,959,000 over the range of 1 to 57 location numbers, while total transportation costs varied by $26,508,000 over this same range of 1 to 57 location numbers. This would tend to indicate that transportation costs play a vital role in the grain elevator industry's cost structure and may be a dominant factor in location decision.

The need for strong public policy measures to ensure a more efficient locational pattern for Oklahoma's grain elevator industry need not be interpreted from the results of this study. However, public policy could emphasize inclusion of information and projections to encourage the location of grain elevators at points more consistent with over-all efficiency in the industry. Such information would also serve to reduce the unexpectedness of possible future changes in the organization and structure of the grain handling industry. The results of this study may provide some guidance not only to the future development of the Oklahoma grain elevator industry, but also lend support to the elevator industry in their arguments against railroad abandonment and for retaining adequate railroad facilities and services by which Oklahoma produced grain is shipped to export terminals.

Limitations

Although the model used and results of the analysis have provided some indication as to expected adjustments in Oklahoma's grain elevator industry, there were some notable limitations which should be pointed out.

First, only Oklahoma grain supplies and demand, except in the case of export demand at Houston, Texas, were considered in this study. The existence of "border effects" is likely, i.e., grain produced near the state boundary and marketed through Oklahoma elevators and vice versa. The arbitrary delineation of state boundaries is a limitation of this study.

Second, the results may be somewhat biased toward the specific locations considered in the analysis. Only 57 possible elevator locations in 57 of Oklahoma's 77 counties were considered in this study. The grain handling requirements of those 20 counties not considered for a possible elevator location were assumed to be serviced by the nearest elevator location. The inclusion of more possible elevator locations could provide for a more definite evaluation of the optimum number of Oklahoma elevator locations.

Third, the results may be limited by the selection of only five different size elevators to be considered in determining the optimum number and size of elevators at each location. By considering elevators of more different sizes a different distribution of elevator sizes over all elevator locations could have been obtained. Also, with more alternative size elevators being considered, excess storage capacity could be further reduced.

Fourth, the 1990 wheat and feed grain production and consumption data used in this analysis were extracted from existing studies as it was beyond the scope of this study to project such estimates. Projecting future production and consumption patterns for wheat and feed grains would entail a separate study in itself. The problems involved in projecting the 1990 data do tend to limit their validity. However, it is hoped that the use of such wheat and feed grain projections does not severely distort the results obtained in the analysis.

Finally, the results are based on the assumption that one of the fundamental objectives of the country grain elevator industry is cost minimization. Certain conditions of competition, social considerations and physical limitations may exist that prevent firms within the industry from utilizing cost minimization practices. While only those costs of grain transportation and elevator operation were considered in this study, these other factors may play an integral role in determining the optimum number, size and location of grain handling facilities.

Need for Further Study

The iterative-expansion approach using the general transportation model used in this study was formulated to determine the optimum number, size and location of grain handling facilities in Oklahoma. The model as formulated has several limitations and may need refinement in a few areas. An expansion of the model to include various sideline activities of country elevators could provide valuable information concerning overall adjustments in the operations of the grain elevator industry. Also, the model could be revised to evaluate new investment requirements to meet pollution control standards as well as changes in transportation rates, operating costs, grain supplies and grain demands and their effect on the optimum industry organization.

In this study, only the operating costs associated with the grain handling function of elevators were considered. The additional consideration of costs associated with other functions performed by grain elevators could give an indication as to the relative importance of the grain handling function in total elevator activities and provide insights into the dependency of grain elevators on their grain handling activities.

In light of changes in the grain production and marketing industry, continued research is needed in projecting future grain production, consumption and marketing patterns in order to provide continually updated, useful information to decision makers and to increase the awareness of possible changes.

Many problems concerning spatial equilibrium lend thenselves to the iterative-expansion approach utilizing the general transportation model. Formulations similar to the one used in this study could be applied to other agricultural commodities or commodity industries. An optimal solution to a problem concerning the structure and organization of an industry could be beneficial to firms entering the industry and to firms in the industry who may be considering expansion by indicating those areas in which facilities should be located.

FOOTNOTES

[1]Edgar M. Hoover, The Location of Economic Activity (New York, 1948), p. 36.

[2]Raleigh Barlow, Land Resource Economics (Englewood Cliffs, 1958), pp. 249-253.

[3]Edward M. Corley, Estimated Effects of Variations of Wheat Production Upon Cost Levels of Country Elevators in Northwestern Oklahoma (Unpublished Ph.D. dissertation, Oklahoma State University, 1964).

[4]Guymon is the selected city which serves the grain handling requirements in Texas, Cimmaron and Beaver counties of Oklahoma.

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APPENDIX A

TABLE XVII

PROJECTED FEED GRAIN AND WHEAT PRODUCTION, UTILIZATION AND SURPLUS-DEFICIT STATUS BY SUB-AREA OF OKLAHOMA, 1990

	Oklahoma Projected Grain Production for 1990		Utilization of Oklahoma's Feed Grains (Excluding Wheat) 1990							Utilization of Oklahoma's Wheat Production 1990				Surplus and Deficit Status 1990				
	Feed Grain	Wheat												Feed Grain (1000 tons)		Wheat (1000 tons)	Net (1000 tons)	
Area Code	Production (1000 tons)	Production (1000 tons)	Fed Beef (1000 tons)	Swine (1000 tons)	Dairy (1000 tons)	Turkeys (1000 tons)	Broilers (1000 tons)	Layers (1000 tons)	Industrial (1000 tons)	Seed (1000 tons)	Food (1000 tons)	Feed (1000 tons)	Exports (1000 tons)	Surplus	Deficit		Surplus	Deficit
1	659.180	362.558	664.736	17.407	2.824	-0-	-0-	-0-	-0-	12.230	59.688	115.717	144.922		5.787	144.922	139.135	
2	9.517	56.594	79.046	2.191	1.506	-0-	-0-	-0-	-0-	1.909	14.000	18.063	22.622		73.226	22.622		50.604
3	16.105	107.538	12.365	10.014	5.822	-0-	-0-	-0-	-0-	3.628	26.602	34.323	42.985		12.096	42.985	30.889	
4	15.187	89.464	8.280	2.939	1.165	-0-	-0-	-0-	-0-	3.018	22.131	28.554	35.761	2.803		35.761	38.564	
5	38.513	77.688	27.379	7.920	8.156	-0-	-0-	-0-	-0-	2.621	19.218	24.796	31.053		4.942	31.053	26.111	
6	26.066	138.596	4.085	6.814	2.617	-0-	-0-	-0-	-0-	4.675	34.285	44.236	55.400	12.550		55.400	67.950	
7	52.511	164.607	-0-	6.621	1.855	-0-	-0-	2.479	-0-	5.553	40.720	52.538	65.797	41.556		65.797	107.353	
8	9.185	183.206	17.001	1.365	.487	-0-	-0-	-0-	-0-	6.146	45.073	58.155	72.832		9.668	72.832	63.164	
9	13.445	64.100	8.942	7.647	6.886	-0-	-0-	-0-	-0-	2.162	15.857	20.450	25.622		10.030	25.622	15.502	
10	2.265	7.247	-0-	2.325	2.405	-0-	-0-	-0-	-0-	.245	1.793	2.313	2.897		2.465	2.897	.432	
11	7.379	21.654	5.299	3.092	2.431	-0-	-0-	4.374	-0-	.730	5.357	6.911	8.656		7.817	8.656	.938	
12	32.923	158.482	74.520	9.135	4.183	-0-	-0-	-0-	-0-	5.346	39.204	50.582	63.348		54.915	63.349	8.433	
13	32.954	136.223	5.630	4.029	2.148	-0-	-0-	-0-	-0-	4.595	33.698	43.489	54.451	21.147		54.451	75.598	
14	35.425	197.692	74.851	9.641	5.100	-0-	-0-	-0-	-0-	6.669	48.904	63.097	79.022		54.167	79.022	24.855	
15	13.761	83.856	-0-	4.694	1.560	-0-	-0-	-0-	-0-	2.829	20.744	26.764	33.519	7.507		33.519	42.026	
16	7.823	153.952	33.893	5.424	.924	-0-	-0-	-0-	-0-	5.193	38.084	49.137	61.538		32.418	61.538	29.120	
17	14.616	239.664	29.035	12.630	1.534	-0-	-0-	-0-	-0-	8.085	59.287	76.493	95.798		28.583	95.798	67.215	
18	10.230	140.105	-0-	4.917	2.673	-0-	-0-	-0-	-0-	4.726	34.659	44.718	56.624	2.640		56.624	59.264	
19	58.339	286.506	3.864	11.979	.661	-0-	-0-	-0-	-0-	9.668	70.897	91.473	114.558	41.835		114.558	156.393	
20	32.479	219.476	28.152	7.399	.954	-0-	-0-	-0-	-0-	7.404	54.293	70.050	87.729		4.026	87.729	83.703	
21	33.540	168.662	88.541	8.151	.415	-0-	-0-	-0-	-0-	5.689	41.723	53.832	67.418		63.567	67.418	3.851	
22	23.817	138.467	-0-	4.976	3.016	-0-	-0-	-0-	-0-	4.671	34.253	44.194	55.348	15.825		55.348	71.173	
23	65.069	122.593	17.554	6.419	1.293	-0-	-0-	-0-	-0-	4.135	30.326	39.128	49.003	39.803		59.003	88.906	
24	5.131	27.521	2.981	6.617	1.646	-0-	-0-	-0-	-0-	.928	6.808	8.784	11,001		6.113	11.001	4.888	
25	9.533	5.176	-0-	4.910	2.062	-0-	-0-	-0-	-0-	.175	1.281	1.652	2.069	2.561		2.069	4.630	
26	5.954	3.321	-0-	5.180	4.437	-0-	-0-	6.853	-0-	.112	.822	1.060	1,328		10.516	1.328		9.188
27	4.054	10.310	9.936	8.735	4.526	-0-	-0-	-0-	-0-	.348	2.550	3.290	4.121		19.143	4.121		15.022
28	9.169	33.862	-0-	5.815	2.200	-0-	-0-	-0-	-0-	1.142	8.377	10.808	13.535	1.154		13.535	14.689	
29	6.054	23.466	8.832	4.369	1.177	-0-	-0-	-0-	-0-	.792	5.805	7.490	9.380		8.324	9.380	1.056	
30	5.273	16.047	1.766	5.448	4.677	-0-	-0-	-0-	-0-	.541	3.970	5.122	6.414		6.618	6.414		.204
31	3.326	7.764	-0-	2.993	5.739	-0-	-0-	-0-	-0-	.262	1.921	2.478	3.104		5.406	3.104		2.302
32	1.299	.690	-0-	1.512	1.173	-0-	-0-	-0-	-0-	.023	.171	.220	.276		1.386	.276		1.110
33	5.052	9.921	4.416	.991	3.711	-0-	-0-	-0-	-0-	.335	2.454	3.167	3.966		4.066	3.966		.100
34	3.911	.431	-0-	2.023	1.514	-0-	-0-	-0-	-0-	.015	.107	.138	.172	.374		.172		.546
35	2.629	1.910	-0-	3.341	1.076	-0-	-0-	-0-	-0-	.051	.373	.482	.603		1.788	.603		1.185
36	20.840	21.395	2.760	5.424	4.526	-0-	-0-	-0-	-0-	.722	5.293	6.829	8.552	8.130		8.533	16.682	
37	60.350	31.230	40.186	10.036	5.557	2.415	-0-	1.895	-0-	1.053	7.726	9.968	12.483	.261		12.483	12.744	
38	34.094	329.473	3.533	6.545	1.949	-0-	-0-	-0-	-0-	11.114	81.503	105.158	131.697	22.067		31.697	153.764	
39	69.978	276.848	4.306	11.763	2.035	-0-	-0-	-0-	-0-	9.339	68.485	88.375	110.661	51.874		110.661	162.535	
40	26.272	126.130	-0-	9.031	1.329	-0-	-0-	-0-	-0-	4.255	31.201	40.257	50.417	15.912		50.417	66.329	

TABLE XVII (Continued)

Area Code	Oklahoma Projected Grain Production for 1990: Feed Grain Production (1000 tons)	Oklahoma Projected Grain Production for 1990: Wheat Production (1000 tons)	Utilization of Oklahoma's Feed Grains (Excluding Wheat) 1990 (1000 tons): Fed Beef	Swine	Dairy	Turkeys	Broilers	Layers	Industrial	Utilization of Oklahoma's Wheat Production 1990 (1000 tons): Seed	Food	Feed	Exports	Surplus and Deficit Status 1990: Feed Grain (1000 tons) Surplus	Feed Grain (1000 tons) Deficit	Wheat (1000 tons)	Net (1000 tons) Surplus	Net (1000 tons) Deficit
41	2.043	.388	-0-	6.899	6.421	4.830	35.230	9.331	-0-	.013	.096	.124	.155		60.668	.155		60.513
42	9.549	4.961	-0-	3.805	4.269	-0-	-0-	-0-	-0-	.167	1.227	1.583	1.983	1.475		1.983	3.458	
43	10.752	.949	1.325	1.800	.819	-0-	-0-	-0-	-0-	.032	.235	.303	.379	6.808		.379	7.187	
44	.744	3.494	-0-	.987	.636	2.415	-0-	2.624	-0-	.118	.864	1.115	1.397		5.918	1.397		4.521
45	.887	1.208	-0-	2.381	.779	-0-	-0-	-0-	-0-	.041	.299	.385	.483		2.273	.483		1.790
46	3.167	7.851	1.766	8.477	4.785	-0-	-0-	-0-	47.600	.265	1.942	2.506	3.138		59.461	3.138		56.323
47	3.310	1.208	-0-	1.948	1.963	-0-	-0-	4.811	-0-	.041	.299	.385	.483		5.412	.483		4.929
48	2.344	2.286	4.416	3.133	4.574	-0-	-0-	-0-	-0-	.077	.566	.730	.914		9.779	.914		8.865
49	30.215	25.062	8.280	15.345	12.315	8.452	22.425	5.832	-0-	.847	6.200	7.999	10.018		42.434	10.018		32.416
50	8.045	14.235	-0-	3.309	2.146	-0-	-0-	-0-	-0-	.480	3.521	4.543	5.690	2.590		5.690	8.280	
51	5.495	.690	-0-	3.751	2.706	-0-	-0-	-0-	-0-	.023	.171	.220	.276		.962	.276		.686
52	2.217	.345	1.766	3.106	1.932	2.174	12.805	14.872	-0-	.012	.085	.110	.138		34.438	.138		34.300
53	.269	-0-	-0-	2.532	.391	-0-	-0-	-0-	-0-	-0-	-0-	-0-	-0-		2.654	-0-		2.654
54	4.529	.388	-0-	2.037	1.068	-0-	-0-	-0-	-0-	.013	.096	.124	.155	1.424		.155	1.579	
55	1.346	3.796	8.722	1.344	1.270	1.208	21.060	9.623	-0-	.128	.939	1.212	1.517		41.881	1.517		40.364
56	9.391	.647	-0-	3.406	.773	-0-	-0-	-0-	-0-	.022	.160	.207	.259	5.212		.259	5.471	
57	12.653	2.976	-0-	4.509	2.180	-0-	-0-	-0-	-0-	.100	.736	.950	1.190	5.964		1.190	7.154	

APPENDIX B

TABLE XVIII

ANNUAL EXPENSE BUDGET FOR A GRAIN ELEVATOR WITH RATED GRAIN STORAGE CAPACITY OF 100,000 BUSHELS AND HANDLING VOLUME OF 314,000 BUSHELS OF GRAIN

Expense	Dollars
Advertising	536
Annual Meeting	426
Audit & Legal	422
Depreciation	12,568
Directors Fee	282
Fuel & Lub	216
Insurance & Bonds	2,895
Interest on Capital	3,279
Lease & Rental	230
Miscellaneous Expense	505
Operating Supplies	811
Pest Control	827
Repairs	2,599
Salaries	26,810
Taxes	4,846
Telephone & Telegraph	429
Testing Expense	274
Truck & Tractor	1,314
Utilities	2,024
Total Cost	61,293
Per Unit Cost	.1952

TABLE XIX

ANNUAL EXPENSE BUDGET FOR A GRAIN ELEVATOR WITH RATED GRAIN STORAGE CAPACITY OF 200,000 BUSHELS AND HANDLING VOLUME OF 518,000 BUSHELS OF GRAIN

Expense	Dollars
Advertising	583
Annual Meeting	464
Audit & Legal	460
Depreciation	13,678
Directors Fee	307
Fuel & Lub	235
Insurance & Bonds	3,152
Interest on Capital	3,569
Lease & Rental	250
Miscellaneous Expense	550
Operating Supplies	883
Pest Control	900
Repairs	2,828
Salaries	29,179
Taxes	5,274
Telephone & Telegraph	467
Testing Expense	298
Truck & Tractor	1,430
Utilities	2,203
Total Cost	66,710
Per Unit Cost	.1288

TABLE XX

ANNUAL EXPENSE BUDGET FOR A GRAIN ELEVATOR WITH RATED GRAIN STORAGE CAPACITY OF 400,000 BUSHELS AND HANDLING VOLUME OF 691,000 BUSHELS OF GRAIN

Elevator	Dollars
Advertising	651
Annual Meetings	517
Audit & Legal	513
Depreciation	15,263
Directors Fee	342
Fuel & Lub	262
Insurance & Bonds	3,517
Interest on Capital	3,982
Lease & Rental	280
Miscellaneous Expense	613
Operating Supplies	985
Pest Control	1,005
Repairs	3,156
Salaries	32,560
Taxes	5,885
Telephone & Telegraph	521
Testing Expense	333
Truck & Tractor	1,596
Utilities	2,458
Total Cost	74,439
Per Unit Cost	.1077

TABLE XXI

ANNUAL EXPENSE BUDGET FOR A GRAIN ELEVATOR WITH RATED GRAIN STORAGE CAPACITY OF 600,000 BUSHELS AND HANDLING VOLUME OF 777,000 BUSHELS OF GRAIN

Expense	Dollars
Advertising	772
Annual Meeting	641
Audit & Legal	609
Depreciation	18,114
Directors Fee	406
Fuel & Lub	311
Insurance & Bonds	4,175
Interest on Capital	4,726
Lease & Rental	331
Miscellaneous Expense	728
Operating Supplies	1,170
Pest Control	1,193
Repairs	3,746
Salaries	38,641
Taxes	6,984
Telephone & Telegraph	618
Testing Expense	395
Truck & Tractor	1,894
Utilities	2,917
Total Cost	88,343
Per Unit Cost	.1039

TABLE XXII

ANNUAL EXPENSE BUDGET FOR A GRAIN ELEVATOR WITH RATED GRAIN STORAGE CAPACITY OF 900,000 BUSHELS AND HANDLING VOLUME OF 908,800 BUSHELS OF GRAIN

Expense	Dollars
Advertising	846
Annual Meeting	673
Audit & Legal	667
Depreciation	19,851
Directors Fee	445
Fuel & Lub	341
Insurance & Bonds	4,575
Interest on Capital	5,180
Lease & Rental	363
Miscellaneous Expense	798
Operating Supplies	1,280
Pest Control	1,307
Repairs	4,105
Salaries	42,348
Taxes	7,654
Telephone & Telegraph	678
Testing Expense	433
Truck & Tractor	2,076
Utilities	3,197
Total Cost	96,817
Per Unit Cost	.1064

APPENDIX C

TABLE XXIII

OPERATING AND TRANSPORTATION COSTS FOR EACH ITERATION, IN THOUSANDS OF DOLLARS

Number of Locations	Operating Cost	Transportation to Location Cost	Transportation to Demand Cost	Transportation to Export Cost	Total Transportation Cost	Total Combined Cost
1	20,959	14,959	12,633	10,153	37,744	58,703
2	20,959	13,348	10,934	11,697	35,979	56,938
3	21,580	12,125	10,056	12,071	34,252	55,832
4	21,580	11,727	9,762	12,189	33,679	55,259
5	21,104	11,343	9,717	11,958	33,020	54,124
6	21,124	10,274	9,003	11,965	31,242	52,366
7	21,124	9,816	8,639	12,012	30,468	51,592
8	21,124	9,358	8,388	12,260	30,006	51,130
9	21,376	8,951	8,141	12,290	29,383	50,759
10	21,399	8,559	7,792	12,370	38,721	50,120
11	21,581	8,236	7,503	10,726	26,465	48,046
12	21,427	7,579	6,936	10,785	25,300	46,727
13	21,231	6,754	6,380	10,687	23,821	45,052
14	21,249	6,620	6,029	10,694	23,343	44,592
15	21,449	6,170	5,903	10,678	22,801	44,251
16	21,434	6,021	5,788	10,678	22,487	43,921
17	21,430	5,796	5,632	10,648	22,076	43,507
18	21,482	5,192	5,230	10,570	21,092	42,574
19	21,600	5,067	5,106	10,698	20,871	42,472
20	21,643	5,002	5,001	10,744	20,748	42,391
21	21,665	4,798	4,742	10,749	20,289	41,954
22	21,849	2,029	2,350	10,760	15,139	36,988
23	21,868	1,785	2,210	10,769	14,765	36,632
24	22,105	1,736	2,028	10,759	14,523	36,628

TABLE XXIII (Continued)

Number of Locations	Operating Cost	Transportation to Location Cost	Transportation to Demand Cost	Transportation to Export Cost	Total Transportation Cost	Total Combined Cost
25	22,120	1,675	1,957	10,924	14,556	36,676
26	22,124	1,360	1,648	10,925	13,933	36,057
27	22,174	1,015	1,417	10,925	13,358	35,532
28	22,192	983	1,364	10,951	13,298	35,489
29	22,191	923	1,286	10,954	13,164	35,355
30	22,086	763	1,162	10,889	12,814	34,899
31	22,058	717	1,123	10,885	12,725	34,783
32	22,060	699	1,102	10,888	12,689	34,749
33	22,112	578	987	10,925	12,489	34,601
34	22,136	543	925	10,970	12,438	34,574
35	22,168	543	913	10,973	12,411	34,579
36	22,225	379	660	11,061	12,100	34,325
40	22,227	188	469	11,339	11,955	34,273
43	22,332	112	260	11,138	11,511	33,843
44	22,347	96	256	11,138	11,491	33,838
45	22,349	51	141	11,191	11,384	33,732
46	22,385	41	57	11,231	11,330	33,716
47	22,435	14	42	11,235	11,291	33,726
50	22,520	35	46	11,238	11,319	33,839
55	22,610	6	15	11,238	11,259	33,869
56	22,617	6	12	11,237	11,255	33,873
57	22,644	-	-	11,236	11,236	33,879

VITA

Travis Dean Justice

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