STATISTICAL COST ANALYSIS OF THE EXISTING NORTH DAKOTA COUNTRY ELEVATOR INDUSTRY

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AN OVERVIEW

North Dakota Grain Handling, Transportation, and Merchandising Study

North Dakota's branchline system was developed in the late 1800s and early 1900s primarily for the purpose of moving farm commodities to markets outside the state and to bring freight such as farm inputs and other needed goods to the state's communities. The only other form of surface transportation available for moving bulk freight when the rail network was being developed (excluding some minor river transportation) was the horse-drawn freight wagon. The limited distance that a team of horses and wagon could travel influenced the design of the early branchline railroad network. This development pattern resulted in branchlines that were no further apart than 10 to 20 miles, and even the most remote producing areas were accessible to rail transportation.

Development of the country grain merchandising system was also influenced by the limited distance a team of horses and wagon could travel, the relative density of the branchline network, and available technology at that time. This resulted in a large number of country elevators spaced only a few miles apart on grain gathering rail lines. Although much of what existed in the past still exists today in the form of the branchline network, economic and technological forces that influenced its development have changed since the turn of the century. Other factors are currently at work that may influence rationalization of the railroad network and the country grain merchandising system.

Factors which will influence the future grain handling transportation and merchandising system include branchline abandonment, implementation of multiple car and unit train grain rates, and capital replacement decisions. Other factors include differing rates of cost increases in the two modes, thereby shifting their competitive relationship. Competition between producing regions will also influence the future system. Efficiencies gained as a result of changes in marketing systems by competing producing regions will possibly influence a move to obtain those same efficiencies by other producing regions. The changing technology of farm trucks and the improved quality of our highway system makes it possible for producers to move grain much further today than previously. These forces may very well influence changes in the state's traditional grain merchandising system. Government policies such as railroad deregulation may also have some impact on the system.

As a result of these impending changes that could alter a rather traditional grain handling, transportation, and merchandising system, many private and public decisions will have to be made. These include decisions regarding location, economic viability, size of plant, investment in grain facilities, investment in transportation equipment and infrastructure, efficiencies of merchandising, purchases of farm production equipment, and storage capacity. If such decisions are to be made on an informed basis, it is important that basic information about the industry be developed and published. It was for this reason that the Upper Great Plains Transportation Institute and the Department of Agricultural Economics of North Dakota State University have undertaken a study entitled "North Dakota Grain Handling, Transportation, and Merchandising Study." Cooperators in the study include Burlington Northern Railroad, Farm Bureau, Farmers Union, Grain Terminal Association, North Dakota Agricultural Experiment Station, North Dakota Department of Agriculture, North Dakota Grain Dealers Association, North Dakota Highway Department, North Dakota Public Service Commission, St. Paul Bank for Cooperatives, and the Soo Line Railroad Company. The purpose of this study is to provide relevant information to decision makers in meeting the challenge of a changing business environment in handling, transportation, and merchandising grain in North Dakota.

The study is composed of a number of research projects that will result in thirteen separate publications of which this is one. The publications planned for release at varied time intervals are:

- Description of the Existing Country Elevator System
- Cost Analysis of Existing Country and Farm Storage System
- Cost Analysis of Subterminal Elevators
- Existing and Past Patterns of North Dakota Grain Movements
- Description of Rail Rate Structure, Multiple Car Movements, and Rates and Analysis of Shipper Owned Equipment
- Description and Analysis of Exempt Carrier Industry
- Economics of Branchline Operation
- Farm Truck Costs
- Seasonal Behavior of Marketing Patterns for Grain from North Dakota
- Grain Merchandising
- Marketing Using Delayed Pricing Controls
- Analytical Model for Analyzing Economic Efficiencies of Subterminals
- North Dakota Grain Handling, Transportation, and Merchandising Study: Summary, Conclusions, and Policy Implications

These reports, as they are completed, will be available upon request from the Department of Agricultural Economics or the Upper Great Plains Transportation Institute, North Dakota State University.

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The grain elevator industry is an essential and integrated part of the marketing system in North Dakota. The majority of the grain produced in this area is shipped out of state, so the local country elevator provides a vital link between the producer and the ultimate consumer. For example, over 2.1 billion bushels of grain was produced in North Dakota between 1974 and 1978, while 1.6 billion bushels (77 percent of total grain produced) was shipped out of state (Table 1).[1]

A need exists to review the elevator industry's overall efficiency since a more efficient system can benefit society either in the form of increasing producer income through higher grain prices, reducing consumer expenditures through lower retail prices, or both. The marketing system in North Dakota is currently moving through an adjustment period as a result of institutional and technological changes. For instance, increased yields due to technological advances have allowed the producer to grow a larger crop, which in turn forces the elevator manager to provide a faster and more efficient method for merchandising the larger supply of grain. Also, many elevator managers are forced to view the possibility of rail branch line abandonment and make major financial and marketing adjustments. The management may wish to make adjustments in receiving and loadout capacities to allow for shipments by 26 or 52 multiple car units, if continued rail services are expected. A comparison should be made between the costs and benefits associated with each alternative. Then sound decisions on the size and location of an elevator under the existing and alternative systems can be attained.

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[1]Gene C. Griffin and Ken Casavant, "An Evaluation of North Dakota Grain Movements," North Dakota State University, Ag. Econ. Report No. 145, August 1981.

TABLE 1. PRODUCTION AND OUT-OF-STATE SHIPMENTS OF SELECTED CROPS, NORTH DAKOTA, 1974-78[a]

Year	Production[b]	Out of State Shipments[c]	
		Number	Percent
	(thousand bushels)	(thousand bushels)	
1974	319,466	276,687	87
1975	415,485	303,534	73
1976	430,210	292,857	68
1977	441,460	341,206	77
1978	542,326	434,571	80
Total	2,148,947	1,648,855	77

SOURCE:

[a]Crops include spring wheat, durum, barley, oat, and sunflower.

[b]Hundredweight of sunflower were converted into bushels at a 30 lb. per bushel rate. All production data were received from North Dakota Agricultural Statistics (Fargo: North Dakota Crop and Livestock Reporting Service, May 1981).

[c]Shipment data were received from Gene C. Griffin and Ken Casavant, "An Evaluation of North Dakota Grain Movements," p. 4.

Objectives

The purpose of this study was to analyze the cost characteristics of the existing country elevator industry. Characteristics such as size of elevator, age and type of construction, location, facility utilization, and type of merchandising activities were analyzed. Specific objectives were to: 1) determine the average total, fixed and variable handling costs of a sample of existing facilities during the period 1978-79; 2) identify model(s) used to analyze the relationships between average total and average variable costs and the above characteristics; 3) review facility utilization rates--determining relative efficiency and existence of economies of size of the industry during the 1978-79 period; and 4) use results as inputs into other sections of the overall grain merchandising study.

It is important to be aware of the capabilities of each type of elevator to interpret its possible influence on the industry. For instance, the 363 cooperative elevators in North Dakota had 87,888,000 bushels of licensed storage capacity or 82 percent of the total capacity within the amended population (Table 2). This percentage taken in conjunction with the number of cooperatives (78 percent of the total) indicates that a representative sample may be received without the use of the private sector. Once the assumption is made that the cooperative sector is representative of the industry, a sample can be taken from the revised population consisting of cooperatively owned elevators only.

Elevator Population and Subsequent Revisions

During the 1978-79 fiscal year North Dakota had 587 licensed and bonded elevators in operation of which 568 actively traded grain. Of the 568, 373 (66 percent) were cooperative and 195 (34 percent) privately owned.[2] Difficulty in definition arises with the term privately owned. It may be defined as any noncooperatively owned elevator as indicated by the numbers above, or it may be interpreted as those elevators that are individually owned. For purposes of this study, the first definition was used. Thus, companies such as Cargill,

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[2]The number of licensed and bonded elevators used was received from the 1979 Directory of Licensed and Bonded Country Elevators in North Dakota (Fargo: North Dakota Grain Dealers Association, 1980), p. 202. The number of elevators actively trading was received from the Upper Great Plains Transportation Institute as determined by the Public Service Commission of North Dakota. It should be noted that although an elevator may be given a license it does not have to move grain, thus a discrepency exists between the two numbers.

TABLE 2. NUMBER AND LICENSED STORAGE CAPACITY OF COOPERATIVELY AND PRIVATELY-OWNED GRAIN ELEVATORS BY CROP REPORTING DISTRICT, AMENDED POPULATION, NORTH DAKOTA, 1978-79

Crop Reporting District	Cooperatives Number	Cooperatives Licensed Storage Capacity	Private Number	Private Licensed Storage Capacity	Total Number	Total Licensed Storage Capacity
		(thousand bushels)		(thousand bushels)		(thousand bushels)
1	52	12,074	9	924	61	12,998
2	42	8,020	4	530	46	8,550
3	75	17,996	21	3,188	96	21,184
4	19	5,371	3	626	22	5,997
5	30	7,138	14	3,515	44	10,653
6	56	16,546	14	4,774	70	21,320
7	22	6,050	6	1,633	27	7,683
8	20	4,473	4	617	22	5,090
9	47	10,220	19	3,375	66	13,595
Total	363	87,888	100	19,182	463	107,070

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Peavey, Pillsbury, etc. (see Table 3 for a complete listing) were deleted from the population. Additional restrictions were also made. For instance, those companies that did not merchandise at least two of the five grains (hard red spring wheat, durum, barley, oats, and sunflower) were labeled as specialty companies. They were assumed to have a significantly different operating cost structure and their inclusion would result in less precise estimates and poor modeling results. Elevators with small grain movements (less than 50,000 bushels per year) and those no longer in business also were deleted from the population. The above restrictions affected 95 (40 percent) of the elevators in the private sector. Of the 373 cooperatives, 10 were no longer in business, leaving a total of 363. The amended population consisted of 363 (78 percent) cooperative and 100 (22 percent) privately owned elevators, for a total of 463.

One hundred ninety elevators (41 percent) had a licensed storage capacity between 101,000 and 200,000 bushels, while 437 elevators had capacities between 51,000 and 800,000 bushels (Table 4). Three hundred twenty-three (70 percent) of the elevators were located on branch lines (Table 5). The highest concentration of elevators (20 percent) were located in CRD 3, followed by CRD 6 with 16 percent of the elevators (Table 6).

TABLE 4. NUMBER OF COOPERATIVELY AND PRIVATELY-OWNED GRAIN ELEVATORS BY SIZE STRATIFICATION, AMENDED POPULATION, NORTH DAKOTA, 1978-79

Type of Ownership	Licensed Storage Capacity (thousands of bushels)								
	0-50	51-100	101-200	201-300	301-400	401-800	801-1600	1600-5000	Total
	(number of elevators)								
Cooperative	9	23	147	96	48	35	5	0	363
Private	9	22	43	14	4	5	3	0	100
Total	18	45	190	110	52	40	8	0	463

TABLE 5. LOCATION OF ELEVATORS BY TYPE OF LINE, (BRANCH VERSUS MAIN LINE), AMENDED POPULATION, NORTH DAKOTA, 1978-79

Type of Ownership	Branch	Main	Total
	(number of elevators)		
Cooperative	258	105	363
Private	65	35	100
Total	323	140	463

TABLE 3. NUMBER, TYPE, AND LICENSED STORAGE CAPACITY OF COMPANIES AFFECTED BY RESTRICTIONS MADE ON THE ORIGINAL GRAIN ELEVATOR POPULATION, NORTH DAKOTA, 1978-79

	Number	Total Licensed Storage Capacity[a]
		(thousand bushels)
<u>Company</u>		
Cargill, Inc.	10	6,431
Coast Trading Company, Inc.	7	1,070
International Multifoods	2	1,050
Peavey Company	31	5,938
Pillsbury	2	7,403
Porr Corporation	2	7,438
Wickes Agriculture	4	479
Total	58	29,809
<u>Specialists</u>		
Bean Companies	10	1,802
Sunflower Companies	5	1,980
Barley or Wheat Companies	7	7,195
Total	22	10,977
<u>Miscellaneous</u>		
Bought or Out of Business	9	1,664
Family Owned or Small Movements	6	377
Total	15	2,041
All Groups	95	42,827

[a] <u>1979 Directory of Licensed and Bonded Country Elevators in North Dakota</u> (Fargo: North Dakota Grain Dealers Association, 1979).

TABLE 6. NUMBER OF COOPERATIVELY AND PRIVATELY-OWNED GRAIN ELEVATORS BY SIZE STRATIFICATION AND CROP REPORTING DISTRICT, AMENDED POPULATION, NORTH DAKOTA, 1978-79[a]

Crop Reporting District	Licensed Storage Capacity (thousands of bushels)								
	0-50	51-100	101-200	201-300	301-400	401-800	801-1600	1600-5000	Total
					(number of elevators)				
1	2-2	7-4	21-2	11-1	7-0	2-0	2-0	0-0	52-9
2	2-0	8-1	14-2	12-1	5-0	1-0	0-0	0-0	42-4
3	3-2	5-8	26-6	21-3	12-1	8-1	0-0	0-0	75-21
4	0-0	0-0	8-1	4-2	3-0	4-0	0-0	0-0	19-3
5	0-0	1-3	9-8	13-2	5-0	2-1	0-1	0-0	30-15
6	0-1	0-3	24-10	15-1	5-1	10-1	2-2	0-0	56-19
7	1-0	0-0	11-4	4-0	2-0	3-1	1-0	0-0	22-5
8	0-0	2-2	9-1	5-2	2-0	2-0	0-0	0-0	20-5
9	1-4	0-1	25-9	11-2	7-2	3-1	0-0	0-0	47-19
Total	9-9	23-22	147-43	96-14	48-4	35-5	5-3	0-0	363-100

[a]Under licensed storage capacity the first number denotes number of cooperative and the second number denotes the number of privately-owned elevators.

Sampling Procedure

The optimal strategy in determining elevator efficiencies would be to analyze the entire population. However, time, cost constraints, and availability of data required a sampling of elevators from the population. Theoretically, the sample from the population, as previously defined, would have 78 percent cooperative and 22 percent privately owned elevators consisting of 70 percent branch line and 30 percent main line locations. The respective percentages within each strata would exist as presented in Tables 4 and 6.

Data Source

Data consisted of accounting records from grain elevators sampled from the revised population. Data from 212 cooperative audit statements were received for the calendar years 1978 and 1979. Several of the accounting records were consolidated statements. For example, a cooperative may have several elevators or satellites grouped into one accounting system or audit statement. If a cooperative is composed of three elevators (i.e., 50,000, 130,000, and 350,000 bushels of licensed storage capacity) the company would be represented as a 530,000 bushel capacity elevator. With the elevators classified in this manner, the sample consisted of 239 elevators, or 66 percent of the revised population of 363 cooperatives.

A comparison between the revised population and the sample drawn is presented in Table 7. Except for the smallest size group (less than 50,000 bushel capacity) the sample contained at least 35 percent of the population in each size group. For instance, 61 percent of the revised population in the 101-800 thousand bushel range was received.

TABLE 7. PROPORTION OF REVISED COUNTRY ELEVATOR POPULATION AND OF SAMPLE BY SIZE STRATIFICATION, NORTH DAKOTA, 1978-79

Licensed Capacity in Thousand Bushels	Revised Country Elevator Population	Sample Drawn from Revised Population	% of Sample Drawn from Revised Population
0- 50	9	0	0
51- 100	23	8	35
101- 200	147	87	59
201- 300	96	60	63
301- 400	48	27	56
401- 800	35	25	71
801-1,600	5	5	100
Totals	363	212	58

Related Works

Several studies have reviewed various aspects of the grain marketing system. Velde and Taylor examined the organization of country markets for grain in North Dakota.[3] Egediusen further analyzed the marketing channels while Anderson emphasized cooperative elevators in his analysis.[4] While these studies allow the reader to obtain a better understanding of the marketing system and how it works, they fail to analyze the operating cost structure of the elevator industry and its effect on the overall marketing system.

Special attention has been paid to the operating cost structure within the industry. For instance, Zasada and Tangri used regression analysis to analyze the cost of handling and storing grain from a sample of country elevators in Manitoba.[5] The study indicated the effects on average total costs of the size of the elevator, amount of grain handled, degree of utilization, and annex to capacity ratio. The single most important factor affecting costs was turnover.

Trock used an economic-engineering method in deriving a cost function of country elevators operating in Montana and North Dakota.[6] The results indicated that economies of size existed and there appeared to be no evidence of rising average total costs as grain storage and merchandising increased.

Sorenson and Keyes concluded that economies of size exist with respect to grain merchandising.[7] Factors affecting utilization were found to be more important in determining cost than plant size. This indicates that the long run average cost curve had very little negative slope.

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[3] Paul D. Velde and Fred R. Taylor, "The Organization of Country Markets for Grain in North Dakota," North Dakota State University, Ag. Econ Report No. 49, 1966.

[4] Stephen H. Egediuson, "An Analysis of Marketing Channels of North Dakota Grain" (Master of Science Thesis, North Dakota State University, 1968) and Floyd Anderson, "An Analysis of North Dakota Cooperative Elevators" (Master of Science Thesis, North Dakota State University, 1966).

[5] Don Zasada and Om P. Tangri, "An Analysis of Factors Affecting the Cost of Handling and Storing Grain in Manitoba Country Elevators," University of Manitoba, Agricultural Economics Report No. 13, July 1967.

[6] Warren L. Trock, "Costs of Grain Elevator Operation in the Spring Wheat Area," Montana State University, Agricultural Experiment Station Bulletin No. 593, February 1965.

[7] V. L. Sorenson and C. S. Keyes, "Cost Relationships in Grain Plants," Michigan Agricultural Experiment Station, Technical Bulletin No. 292, July 1965.

Fuller analyzed the efficiency of the existing country elevator market structure in Kansas by the use of an economic-engineering approach.[8] Economies of size were found to exist throughout the range of plant size included in the study and were much more evident in small plant size ranges than large plant size ranges. This behavior could lead to an L-shaped long run average cost curve as depicted by earlier empirical studies.[9]

Method of Presentation

In any analysis, it is essential to review areas relating to the primary objective. One of this study's objectives as previously defined was to determine relative efficiency and existence of economies of size and discuss its implications for the industry.

The following section describes the economic concepts involved and relates them to the concepts of efficiency and economies of size. The model to be analyzed with inferences to theory and economies of size also is included. Individual relationships between average total cost and defined characteristics are detailed. Three methods of analyses are presented in the third section. The intent is to describe each of the methodologies and discuss their strengths and weaknesses. A discussion of their implications on economies of size and reasoning behind the method chosen is included. The last two sections discuss the analyses and results and summarize the implications for the grain elevator industry. The intent is to summarize the reasoning behind the existence of economies of size and its effect on the concept of efficiency.

Economic Analysis

Short Run Versus Long Run Costs

Internal operating costs include those costs associated with merchandising, handling, storage and drying of grain within the country elevator. For purposes of this study, these activities were grouped into one item and referred

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[8] Stephen W. Fuller, "Optimum Number and Size of Country Grain Elevators in Spatial Equilibrium" (Ph.D. dissertation, Kansas State University, 1970).

[9] For further references to empirical studies, see J. Johnston, Statistical Cost Analysis (New York: McGraw-Hill Book Company, Inc., 1960).

to as handling costs. However, a discussion covering the economic theory of short and long run costs is reviewed before covering empirical results.

The short run can be defined as that period in time where certain inputs (e.g., plant size) are fixed in nature while others (e.g., labor and machinery) are variable. Changes in output in the short run may occur only by changing the amount of variable inputs used. Costs associated with these inputs are referred to as variable costs. Fixed costs are those costs associated with the use of fixed inputs. The summation of the fixed and variable cost components at any level of output is the total cost of handling that output.

The long run occurs when all inputs, including plant size, are variable and is commonly referred to as the "planning horizon."[10] Under this situation a manager can alter plant size to any changes in input or output levels that may occur due to outside influences. No distinction is made between total variable cost and total cost, contrary to the situation in the short run.

Average or Per Unit Cost[11]

Average cost is the total cost at a specific output level divided by that output. The average cost curve (AC) is generally U-shaped, declining at first until a minimum point is reached, then rising (Figure 1). In the short run, average cost can be subdivided into two components, fixed and variable, just as total cost was divided into fixed and variable cost. Average fixed cost (AFC = TFC/Q) and average variable cost (AVC = TVC/Q) are derived by dividing each by total output. Since total fixed cost (TFC) is constant, dividing it by output gives a steadily decreasing AFC curve (Figure 2). TFC drops lower and lower, approaching the horizontal axis as the constant fixed cost gets spread over more and more units of output. Average variable cost at first declines, reaches a minimum, then ultimately rises. This is similar to the analogy of AC in Figure 1. The U-shaped behavior is a result of the relationship of the marginal cost curve to average cost.

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[10]This term is used in a majority of economic texts. For an example, see Edwin Mansfield, Principles of Microeconomics, 2nd Ed. (New York: W. W. Norton and Company, Inc., 1977), p. 195.

[11]For an excellent introductory discussion on average and marginal costs, see Paul A. Samuelson, Economics 9th Ed. (New York: McGraw-Hill Book Company, 1973), pp. 463-480.

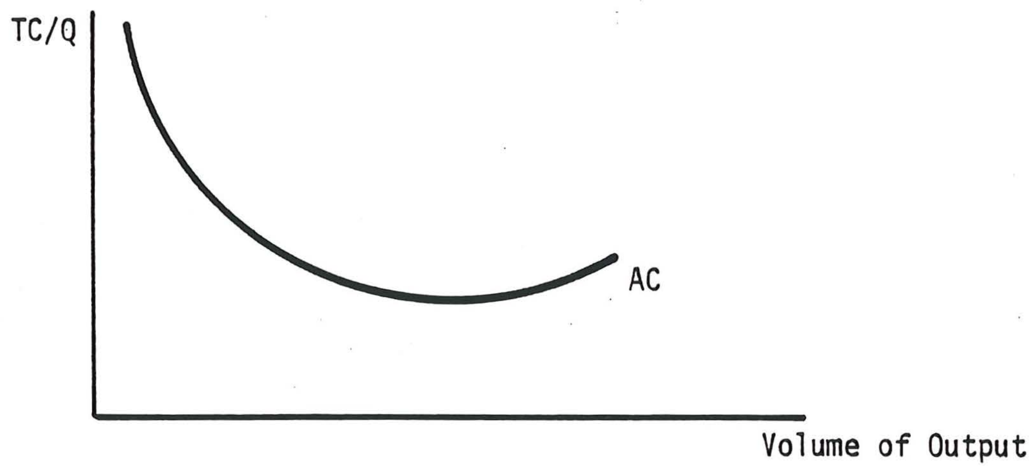

Figure 1. Average Cost Curve

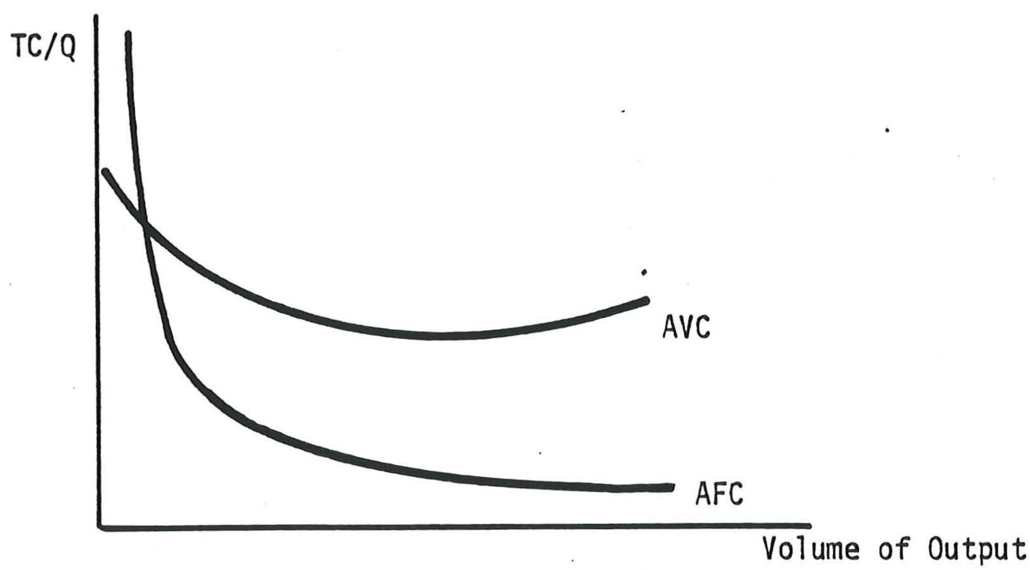

Figure 2. Average Variable and Fixed Costs

Marginal Cost

Marginal cost may be defined as the increment to total cost that results from producing one additional unit of output. As with the AC and AVC curves, the MC curve first falls, reaches a minimum, then ultimately rises.[12] This may be due to the economies associated with using some or all of the inputs on a larger scale forcing MC to decline to a minimum positive number. The cost of each additional unit of production eventually becomes more expensive, causing the marginal cost curve to rise (Figure 3). The marginal cost curve intersects the AC and AVC curves at their respective minimum points. This phenomenon is explained by the following circumstances.

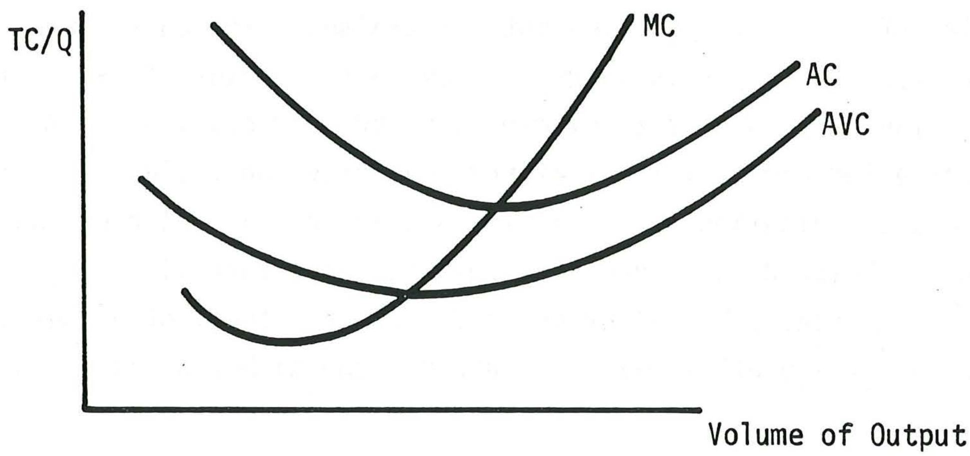

Figure 3. Comparison Between Average and Marginal Costs

Average cost curves are pulled downward when marginal costs are below average costs (i.e., the last increment of cost is less than the average of all previous ones). When MC is equal to AC, AC is no longer pulled down; instead it begins to rise as MC becomes larger than AC. Thus, the minimum point of the AC curve is where AC = MC.

Economies of Size

The long run average cost curve (LRAC) shows the minimum average cost of producing each level of output when all plant sizes are considered. If an expansion of plant size causes a decrease in per unit costs (LRAC), economies of size are occurring. The term economies of size (i.e., all inputs need not

[12] The marginal cost curve will be U-shaped unless diminishing returns are encountered immediately.

increase in the same proportion) is used in this study rather than economies of scale.[13]

Economies of size can be subdivided into two parts, internal and external. External economies result when the industry as a whole incurs growth. They are independent of plant size due to the equal availability of resources, technology, etc., to small and large firms alike. Internal economies accrue to an individual firm and may occur from: 1) specialization of labor (subdividing tasks) or other inputs; 2) purchasing discounts in the acquisition of inputs; and 3) merchandising the product. Elevators will obtain a competitive advantage, and therefore internal economies, if they can receive higher prices for their products or lower transportation rates by multiple car shipments.

Economies of size will continue until a minimum point on the LRAC is located (Figure 4). If output is increased beyond this point, diseconomies of size occur. Diseconomies of size (increasing per unit cost) are normally a result of decreasing managerial efficiency, capacity constraints (bottlenecks), disadvantageous coordination of activities and increased "red tape" as plant size increases. Point B in Figure 4 is the most efficient size of plant. It is the least cost point for a plant designed for that level of output and plants designed for any other level of output incur higher average costs.

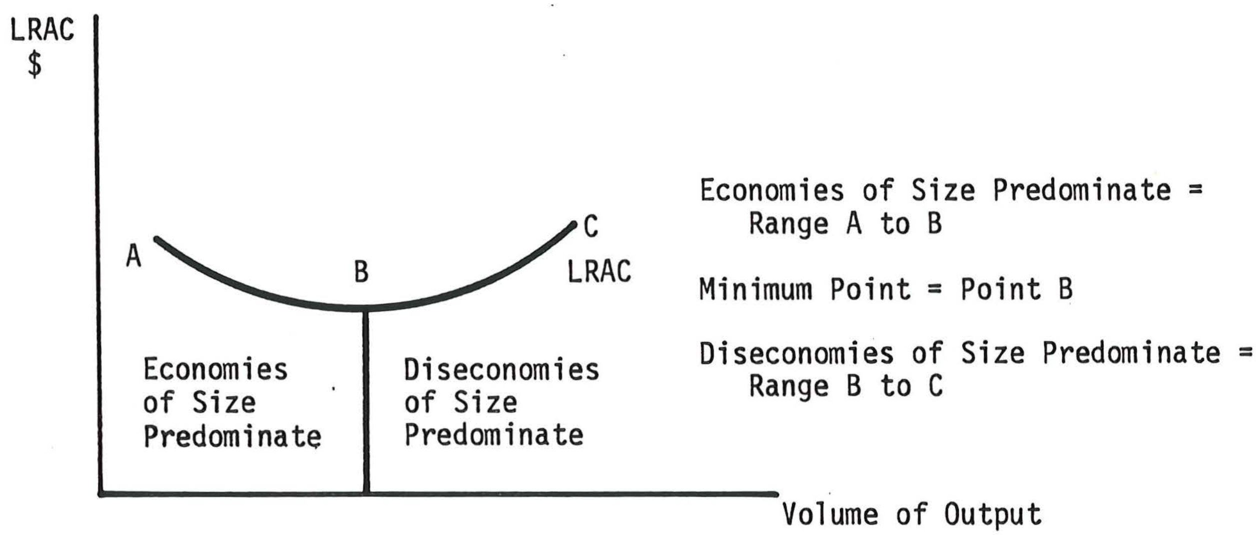

Figure 4. Theoretical Economies and Diseconomies of Size

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[13]For a good discussion on economies of size and scale, see R. G. Bressler, "Research Determination of Economies of Size," Journal of Farm Economics, Vol. 27, No. 3 (August 1945), pp. 528-29 and F. Larry Leistritz, "Alternative Research Procedures for Determining Economies of Size" (unpublished paper, North Dakota State University, November 1972), pp. 1-2.

Determining Economies of Size

It is traditionally assumed that cross-section data covering many firms typify a long run situation. Cross-section data taken from a sample of firms of one size that incur a wide range of output typify the short run.[14]

Two types of analyses were made for estimating economies of size. The first uses the size of the firm and volume of grain handled as a continuous variable to estimate the LRAC curve. Prior to estimation, the ability to choose and adjust to the optimum size of plant must be made available to all firms. The second analysis stratifies the industry by volume of grain handled or turnover ratio. Individual short run cost functions were estimated for each strata. An envelope curve connecting the short run functions was then used as an estimate for the long run cost curve.

Both methods were utilized due to differences of opinion concerning which method is more nearly correct. The second approach was added because an envelope curve may be a better method for determining economies of size unless every plant in the sample is efficiently organized and operated at capacity.[15] Since it is unrealistic to believe that all firms operate at capacity, both methods were used to estimate the LRAC curve and the results were compared.

Existence of economies of size were determined by analyzing the following functional relationship:

$$ATC = f(U, S_L, S_A, V, G, M, T_E)$$

where: ATC = average total cost

U = plant utilization (i.e., turnover)

S_L = licensed storage capacity

S_A = actual storage capacity

V = annual volume of grain handled

G = determined by grain contribution margin $(0 \leqq G \leqq 1)$[16]

M = gross margin per bushel

T_E = type of elevator (i.e., age of facility, number of annexes, and major type of annex).

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[14] J. R. Meyer, Some Methodological Aspects of Statistical Costing as Illustrated by the Determination of Rail Passenger Costs," American Economic Review, Vol. 28, No. 2 (May 1958), pp. 212.

[15] R. G. Bressler, "Research Determination of Economies of Scale," pp. 528-29.

[16] Grain contribution margin is defined as grain trading margin divided by gross margin. Larger grain ratios lead to trade classification as grain merchandisers.

The expected results of the above relationships were that all variables were to be inversely related to average total costs, meaning an increase in utilization, capacity, grain handled, or other characeristics would result in a decrease in per unit cost. Characteristics such as differences due to geographic and rail line location were also analyzed. Geographic differences take into account differences due to weather, terrain, wages and other factor prices. Rail line location was analyzed as differences in utilization and other factors due solely to main or branch line location.

The following section introduces the three common procedures for evaluating existence of economies of size. The results section will follow with a detailed review of the functional relationships and how they actually relate to economies of size.

Methods of Determining Economies of Size

The grain elevator industry of North Dakota consists of a wide variation of plant sizes. Licensed storage capacity ranges from a low of 25,000 to a high of approximately one million bushels. This variability may be due to the nature of the agricultural industry. A local elevator must be large enough to handle the harvest peak demand within its region, while being small enough where underutilization is not felt at off-peak times. A second reason for this variability is that all elevators are not in a position to use the resources (land, labor, machinery) available to them efficiently. Elevators throughout the state do not have identical resources at their disposal.

In addition to reviewing the variability of sizes within an industry at one particular point in time, changes in elevator size over time need to be determined. During the 1968-69 crop year, 696 licensed and bonded elevators were located in North Dakota with an average storage capacity of 178,493 bushels.[17] Ten years later, 587 elevators with an average capacity of 243,874 bushels were in existence in North Dakota, a decline of 15.7 percent while average total capacity increased by 36.6 percent. One possible explanation for this occurrence is that larger elevators are able to receive a price or cost advantage on a per bushel basis (economies of size). A need exists to analyze these advantages.

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[17] 1981 Directory of Licensed and Bonded Country Elevators in North Dakota, p. 212.

Three procedures have been employed in various studies to determine the existence of economies of size. They are: 1) survivorship technique, 2) economic-engineering approach, and 3) statistical analysis of actual firm costs. A brief description of each will be made, followed by a discussion of their respective advantages and disadvantages.

Survivorship Technique

The survivorship technique is based on the assumption that competition forces firms toward the size which provides the lowest per unit cost available to the industry.[18] This is represented by the minimum point on the industry long run average cost curve (point B in Figure 4). The firm that moves toward this minimum, in addition to receiving a cost or price advantage, will be able to withstand competition from any other size firm for an indefinite period of time. This is due to the firm's ability to produce more efficiently, introduce technology at a competitive rate, adapt to changes in consumer tastes and governmental regulations, and adapt to changes in geographic market demands.

The technique analyzes changes in the share of an industry held by each size strata of firms over a period of time. The share is calculated as a percentage of the industry's capacity. For example, assume an elevator handled a volume of 100 million bushels of grain. The industry handled two billion bushels during this same period. The elevator's share would be 5 percent (100 million/2 billion). If its share remained the same or increased over time, it is considered cost-efficient. The opposite is true when shares decline, and in general, the faster the decline the more inefficient the group.

All size stratifications within the industry are analyzed. Each group is considered equally efficient if the distribution of the groups remain the same since no firm can increase profits or decrease costs by moving from one group to another. However, if an inefficient strata exists, those firms in that strata would either become more efficient, thus moving to a more efficient group or be forced to leave the industry over the long run as a result of being at a cost or price disadvantage.

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[18] For a review of the survivorship technique and how it relates to economies of size, see George J. Stigler, "The Economies of Scale," Journal of Law and Economics, Vol. I (April 1958): pp. 54-71 and George J. Stigler, The Theory of Price, 3rd Ed. (New York: MacMillan Company, 1966) p. 158.

The theory behind this technique is somewhat basic. It is based on survival and implicitly all judgment on economies of size is based on or empirically verified by the experience of survival.

Economic-Engineering Technique

The economic-engineering or synthetic-firm approach determines the average cost per unit attainable by firms of various sizes using modern technology and efficient use of all resources to produce a given level of output. For this reason, it closely resembles the theoretical concept of the long run average cost curve.[19]

Cost information on plant design and construction of the building and equipment is provided by architects, contractors, and engineers. Job analyses indicate the number of employees and the skill level required in the various sections of the plant. Other variable and fixed costs are projected on the basis of known data. All information concerning plant operation is broken down into stages. These stages are synthesized into hypothetical plant models of different sizes. The models are aggregated and a cost function estimated. Costs are referred to as "synthetic" because they are not attained from actual operations.

Statistical Costing

Statistical costing involves the determination of economies of size directly from a sample of actual firm records. The estimation of a long run average cost function requires collection of cost data from a large number of firms reflecting different sizes and levels of operation. From this data, an equation (possibly linear) is estimated which relates total cost as a function of the various operating characteristics (i.e., plant utilization, storage capacity, etc.). The usual method of estimating such an equation is that of least squares.[20] For a relevant LRAC curve to be determined by this procedure, it is necessary to assume that each firm in the sample adjusts all factor inputs so as to minimize costs. The long run average cost curve

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[19]F. Larry Leistritz, "Alternative Research Procedures for Determining Economies of Size" (unpublished paper, North Dakota State University, November 1972), p. 8.

[20]For a detailed explanation of least squares estimation see N. R. Draper and H. Smith, Applied Regression Analysis (New York: John Wiley and Sons, Inc., 1966), pp. 7-13.

also may be approximated by averaging the costs of the firms sampled in each of several size classes and fitting an envelope curve to the points representing average costs of each size class.

Comparison of Methods

Most comparisons of procedures are confined to differentiating between the statistical costing and economic-engineering approach, since the survivorship technique does not analyze any cost-output relationships. Instead, it determines the minimum cost size of an elevator by reviewing changes in the share of industry's capacity only. This technique has been criticized for leaving a number of additional questions unanswered. For instance, is the decline in number of small firms within an industry a result of movement caused by inefficiency or by ordinary growth? Second, if a decrease is due to inefficiency, is the strata itself (all firms) inherently inefficient? Factors other than size may be causing the inefficiency. Factors such as the quality of management, plant utilization and location may vary significantly among firms within a given size group. Third, firm size is measured as a percentage of industry capacity and if industry capacity changes, the boundaries of the size strata also change.

Finally, the survivorship technique uses historical data which may be an imperfect guide for predicting future group distributions. This is especially true for industries that incur rapid technological changes. This technique is useful as a guide to examining economies of size, but does not identify which characteristics significantly affect size and to what extent.

The economic engineering approach is appropriate for determining the average cost per unit of output a firm could potentially achieve given modern technology and efficient resource use. In addition, it locates the differences in average cost per unit attributable solely to differences in size between firms and not to management practices or use of substandard technologies. Technology and management practices can be assumed to remain at a constant level since the plants are hypothetical. Other advantages of this approach are: 1) a large sample is not required, and 2) contractors and equipment manufacturing firms are much less reluctant to share engineering and accounting data than are specific firms. There are three main disadvantages associated with the economic-engineering procedure. Joint costs are incurred if a firm produces more than one product. Allocation of these costs becomes extremely difficult without a complete understanding of what they consist of. Second, no evaluation can be made of managerial ability at various output levels since management practices are assumed to be constant. Finally, a high level of knowledge of technical relationships is required if the results are to be realistic.

The statistical costing method has been described as having both the appeal of reflecting "real" plant operations, while problems with data collection and usage are inherent with the procedure. The most serious disadvantage is the time and expense involved in obtaining and analyzing firm records. First, it is often difficult to receive the cooperation needed to obtain accounting data from a sufficiently large number of each size of plant. Many firms have a tendency (with justification) to be reluctant to release cost data associated with their operations. Differences in accounting procedures among firms often occur and may cause wide variation in costs. A method of allocating the joint costs is required when labor and machinery are used for several products. Arbitrary weights for allocating these costs must be avoided. Instead, they should be determined by empirical analysis.

A second criticism of the statistical costing method is that cost-size relationships may be obscurred by differences in technological factors, varying degrees of management proficiency and plant utilization, geographic differences, and variation in age, type and cost of equipment.

It is difficult to separate plant utilization relationships from actual economies of size. To alleviate this problem, it is necessary to obtain observations of a given size of firm for a wide range of output. In addition, differences in the level of technology on utilization between firms of different sizes may distort the long run average cost curve to the extent that it would be an unreliable indicator of the economies of size existing in the industry. Third, statistical costs based on historic data are to be used with caution if the purpose of the study is to make inferences about the future since historical cost data may not be applicable in the future.

Choosing a Method

Since the purpose of this study was to analyze the existing cost structure of the grain elevator industry, the concern is with "what is" rather than "what could be." For this reason, the statistical approach was determined to be an appropriate method to use due to its focus on "real" plant operations. Most of the criticisms of the statistical costing approach can be resolved through various strategies which will be discussed throughout the empirical results section.

Empirical Results

Average Total Cost

Existence of economies of size was determined by analyzing the following functional relationship.

$$ATC = f(U, S_L, S_A, V, G, M, T_E)$$

Where: ATC = Average total cost

U = Plant utilization (i.e., turnover)

S_L = Licensed storage capacity

S_A = Actual storage capacity

V = Annual volume of grain handled

G = Grain contribution margin ($0 \leqq T_T \leqq 1$)

M = Gross margin per bushel

T_E = Type of elevator (i.e., age of facility, number of annexes, and majority type of annex)

A number of the above independent (explanatory) variables were not significant in determining average total cost. For instance, actual storage capacity was found to be a better explanatory variable than licensed storage capacity.

Type of elevator (T_E) as defined here is characterized by age of the facility, number of annexes, and majority type of annex (i.e., flat or upright storage). Age of facility and number of annexes were introduced into the regression equation as continuous variables. The sample data indicated that most annexes were of the upright type. In fact, so few of the flat storage type existed that it was not possible to perform any meaningful analysis on type of annex. Consequently, majority type of annex was no longer considered. Thus, the new functional relationship became:

$$ATC = f(NOA, AGE, AGM, CON, ACT, GRH, TUR)$$

Where: ATC = Average total cost

NOA = Number of annexes

AGE = Age of facility

AGM = Average gross margin (i.e., gross margin/grain handled)

CON = Grain contribution margin (i.e., grain trading margin/gross margin)

ACT = Actual storage capacity

GRH = Annual volume of grain handled

TUR = Turnover ratio (i.e., grain handled/actual storage capacity)

The following factors were also considered: 1) the existence of differences between cost structures of elevators due to branch versus main line location and 2) differences among three types of cooperative elevators. Types of elevators were subdivided into affiliated elevators (both single and multiple plant sites), independent cooperatives, and line elevators. These elevators are referred to as types I, II, and III to preserve revealing their identity.

It is advantageous to begin with the simplest form of a relationship and review its performance when analyzing functional relationships. This relationship was a linear combination of the previously mentioned variables. Plots of ATC versus all independent variables were obtained. Plots of ATC against grain handled (GRH) and turnover (TUR) indicated a lack of linear fit, suggesting the existence of a nonlinear relationship. Consequently, nonlinear terms were introduced into the model for GRH and TUR. A quadratic equation (i.e., squaring GRH and TUR) was utilized and resulted in a better fit. However, with this type of model a problem arises when interpreting the estimates. Figure 5 presents a graphic example of the problem. The graph clearly defines the existence of a nonlinear relationship. The question remains, however, is this a direct or inverse relationship or both. In order to answer this question, it is clear that the value of m must be known. Unfortunately, with equations involving several independent variables, such values cannot be easily obtained. Therefore, to aid in interpretation an alternative model was sought. The elected alternative was to redefine GRH and TUR in terms of exponentials. This resulted in the following model.

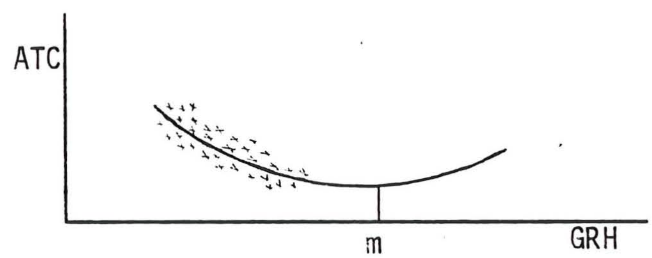

Figure 5. ATC as a Quadratic Function of Grain Handled.

$$ATC = b_0 + b_1 \, NOA + b_2 \, AGE + b_3 \, AGM + b_4 \, CON + b_5 \, ACT + b_6 \, X + b_7 \, Y + E$$

Where: b_0 = intercept term

$b_1, b_2, \ldots, b_7$ = parameters

$X = e^{a_1 GRH}$

$Y = e^{a_2 TUR}$

e = base of the natural logarithm (2.71828)

E = error term

and other variables are as previously defined.

The fact that the unknown parameters a_1 and a_2 appear as exponents makes this model nonlinear in the parameters. Consequently, it was necessary to employ nonlinear least squares estimation. SAS PROC NLIN was used for this purpose.[21] As with most nonlinear routines, parameter estimates are obtained iteratively using numerical analysis techniques. The iterative procedure continues until subsequent iterations produce only minimal changes in the parameter estimates. At such a point, the method is said to converge. In many cases convergence is very slow, requiring a large number of iterations and consequently a large amount of computer time. Such was the case when attempting to fit the above model using the three methods available in PROC NLIN.

The iterative procedure involved selection of initial values for a_1 and a_2. Careful selection of the initial values reduced the amount of computer time to reach acceptable parameter estimates. Successive iterations provided estimates of each parameter (b_0, b_1, b_2, ..., b_7, a_1, and a_2). The final iteration provided useable parameter estimates for a_1 and a_2.

Using the estimates of a_1 and a_2 obtained in the above manner, the following transformations were made.

$$X = e^{-1.12\ GRH}$$
$$Y = e^{-1.0\ TUR}$$

This led to the following model:

$$ATC = b_0 + b_1\ NOA + b_2\ AGE + b_3\ AGM + b_4\ CON + b_5\ ACT + b_6 X + b_7 Y + e$$

The above is linear in the parameters and can be analyzed as a linear model. The model was fit to each of the three types of elevators for both branch and main line locations. Data for 186 of the sampled elevators were available for this analysis (a decrease of 26 from the original 212 observations) due to missing values of the independent variables. The breakdown of the six populations (i.e., three elevator types at two locations) are presented below. The elevator types are not presented in any particular order and should not be viewed as such.

	Type I	Type II	Type III
Main Line	28	10	12
Branch	76	16	44

The parameter estimates and their standard errors (in parentheses) were tabulated for each population modeled independently.

[21]For those interested in the three methods available, see SAS Users Guide, 1979 Edition, SAS Institute, pp. 317-329.

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		Intercept	NOA	AGE	PRO	CON	ACT	X (GRHAND)	Y (TURN)
TYPE I	Branch	11.7*(2.4)	.22(.15)	-.02 (.01)	25* (5)	- 8* (1.8)	.24(.34)	9.3*(3.2)	22.4*(9.8)
	Main	14.9*(4.5)	.27(.24)	-.04 (.02)	41* (10)	-13* (4.2)	.35(.45)	9.2*(4.4)	7 (9.2)
TYPE II	Branch	27* (7.4)	1.4*(.57)	-.04 (.04)	26* (12.5)	-23* (5)	-.61(2.3)	1.7 (9)	76* (32)
	Main	20 (16)	1.9 (1.2)	-.08 (.05)	16 (23)	-13 (11)	.15(1.6)	9.2 (12)	17.6 (27)
TYPE III	Branch	10.8*(3.1)	.22(.22)	-.03 (.02)	26.3*(5.7)	- 9.6*(2.7)	-24 (.36)	14.8*(4.8)	2.4 (19)
	Main	9.5 (12)	.75(.53)	-.09*(.03)	41.5*(21)	- 8.8 (12.4)	.47(1)	9.6 (8.1)	11.1 (42)

*Indicates significance at the .05 level.

Actual storage capacity was not significant in any of the populations. Signs on the estimates between the populations tended to be the same with the exception of ACT. The estimates for this variable should not be regarded as meaningful since they were not significant. Large standard errors occurred within Types I and II main line location populations and were largely a consequence of small sample sizes.

The next step was testing for differences among the six populations Table 8). This was accomplished using the TEST statement in SAS PROC REG.

TABLE 8. RESULTS FOR THE HYPOTHESES TESTED FOR ATC

Hypothesis Tested	Calculated F-Stat[a]	d.f.[b]	Table F-Value[c]
1) Differences between line locations	.9395	24,138	1.58
2) Differences between elevator types	1.6600	32,138	1.54
3) Differences between parameters	1.0339	39,138	1.48

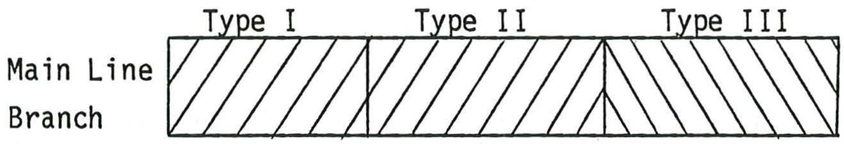
[a]The F-statistic is used to test hypotheses about linear combinations of the unknown parameters. For a further explanation see S. R. Searle, Linear Models (New York: John Wiley and Sons, Inc., 1971) pp. 110-123.

[b]Degrees of freedom. Hypothesis testing is accomplished by comparing the tabled F-value with the calculated F-stat. The tabled value is partially determined by the degrees of freedom.

[c]Approximate Table F-value at the 5 percent level.

Differences between elevators located on main versus branch lines were found to be insignificant (Hypothesis 1, Table 8) since the calculated F was less than the associated Table F-values. On the basis of this sample information there was insufficient evidence to distinquish between main line and branch line elevators. Hence, the number of populations was reduced from six to three.

Attention was also paid to whether elevator type, disregarding elevator location, affected the cost structure (Hypothesis 2, Table 8). Differences in elevator type were found to be significant (i.e., significant differences in cost structure occurred). Subsequent tests indicated that this difference appeared to be between Types I and III and Types II and III. However, Types I and II were not found to differ significantly. The two distinct populations with their corresponding equations are shown below.



Population 1 (Types I and II):

$$ATC = b_0 + b_1\ NOA + b_2\ AGE + b_3\ AGM + b_4\ CON + b_5\ ACT + b_6X + b_7Y + E_1$$

Population 2 (Type III):

$$ATC = c_0 + c_1\ NOA + c_2\ AGE + c_3\ AGM + c_4\ CON + c_5\ ACT + c_6X + c_7Y + E_2$$

Testing also was completed (Hypothesis 3, Table 8) on the supposition that some parameters were equal in the models (i.e., $b_0 = c_0$, $b_1 = c_1$, $b_2 = c_2$, $b_3 = c_3$, $b_5 = c_5$, $b_6 = c_6$, $b_7 = c_7$). No significant differences between estimates were found. However, if $b_4 = c_4$ (the parameter for CON) is included, the calculated F increased to 1.648 and revealed that differences exist between the b_4 and c_4 estimates resulting in the following equations.

Population 1:

$$ATC = b_0 + b_1\ NOA + b_2\ AGE + b_3\ AGM + b_4\ CON + b_5\ ACT + b_6X + b_7Y + E_1$$

Population 2:

$$ATC = b_0 + b_1\ NOA + b_2\ AGE + b_3\ AGM + c_4\ CON + b_5\ ACT + b_6X + b_7Y + E_2$$

Testing whether all the parameter estimates were significant (i.e., non-zero) showed b_5 (ACT) was not significant and it was dropped from the model. This resulted in the final model as shown below.

	Intercept	NOA	AGE	AGM	CON	X^b	Y^c
Population 1[a]	14.2 (1.26)	.31 (.09)	-.03 (.0078)	27.2 (3.05)	-9.8 (1.22)	9.0 (1.04)	19.5 (3.40)
Population 2[a]	Same as Population 1				-12.1 (1.36)	Same	

[a] All estimates were significant at the .001 level.

$X^b = e^{-.12\ GRH}$

$Y^c = e^{-1.0\ TUR}$

Analysis Assumptions

The previous analysis involved the following assumptions: 1) the variables were independent (i.e., uncorrelated), and 2) the error terms were normally distributed with a mean of zero and constant variance. Multicollinearity was present but did not seem to pose any serious problems. The assumption of normality was necessary for testing hypotheses about the parameters.[22] Residual plots indicated a potential problem with nonconstant error variance but did not confirm it.

Model Adequacy

The model resulted in an R^2 of .74 (i.e., 74 percent of the variation in ATC was explained by the independent variables). The standard error of ATC was reduced from 4.1 cents in the raw data to 2.1 cents. In other words, if the information contained in the independent variables is disregarded, and the sample mean of ATC is used to estimate ATC for every elevator, then the standard deviation of the residuals[23] is about 4.1 cents. On the other hand, by utilizing the information contained in the independent variables to adjust the mean of ATC for each elevator, the standard deviation of the residuals is only about 2.1 cents. Residual plots indicated some important independent variables were possibly missing from the analysis. For example, geographic location or type and amount of different varieties of grain were not considered. Geographic location was dismissed as a possible explanatory variable due to minimal numbers of observations from some areas of the state. Valid tests could not be obtained with the small number of sample observations within such populations. Costs associated with the movement of various types of grain would require further allocation of joint costs. The process would be arbitrary and controversial. Load out capacity (bushels per hour) was considered but was found to be insignificant.

Points of Interest

The signs associated with the parameter estimates are of interest since they dictate the nature of the relationship with the given independent variables and ATC. For example, a minus sign on contribution margin (CON) indicates that

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[22]For those interested in the validity of such an assumption, see John Neter and William Wasserman, Applied Linear Statistical Models (Homewood, Illinois: Richard D. Irwin, Inc., 1974), pp. 47-48.

[23]A residual is defined to be the difference between what is observed and what is predicted.

if all other independent variables were held constant, ATC would decrease as CON increases. The coefficients on X and Y were positive implying a positive relationship between X, Y, and ATC. However, the minus sign associated with the exponentials translates into a negative relationship (i.e., as grain handled (GRH) and turnover (TUR) increase ATC decreases). These relationships support the theory of economies of size. All significant variables in the model, with the exception of average gross margin (AGM), were related to ATC as expected. Average gross margin (AGM) resulted in a positive relationship with ATC indicating that as AGM increases, ATC increases. The reason for this occurrence is not known. A possible explanation may be that the relationship of AGM with the other characteristics was more influential than its relationship with ATC (i.e., actual storage capacity and number of annexes influencing average gross margin into a positive relationship with ATC). A second explanation is that competitive forces within a region may have caused various elevators to increase or decrease relative margins on grain and nongrain merchandise resulting in a positive relationship of average gross margin with actual storage capacity.

An effective method for interpreting the model is to standardize the estimates. This technique expresses the equation in terms of standard deviations of the variables and eliminates the problem of inconsistent units. Each variable was transformed by dividing its value by the standard deviation of the values of that variable. Each of the transformed variables are denoted by appending an asterisk as a superscript, for example,

$$NOA^* = \frac{NOA}{s_{NOA}}$$

The standardized equation for the model is:

$$ATC^* = .003 + .141\ NOA^* - .157\ AGE^* + .371\ AGM^* - \begin{matrix} .991\ CON^*_b \\ (-1.090\ CON^*_c) \end{matrix} + .415\ X^* + .267\ Y^*$$

Where: CON^*_b = Contribution margin for Type I and II cooperative elevators (measured in standard deviations)

CON^*_c = Contribution margin for Type III cooperative elevators (measured in standard deviations)

ATC^* is cents per bushel (measured in standard deviations)

The above equation implies that a one standard deviation increase in NOA while holding all other variables constant results in a .141 standard deviation increase in ATC. Similarly a one standard deviation increase in CON_b results in a decrease of ATC by .991 standard deviations.

Joint Cost Allocation

As previously mentioned, one problem with using accounting data is in the allocation of joint costs. For example, wages paid to a support group for the day-to-day operation of an elevator can be identified from accounting records. However, these wages cannot be specified between grain and nongrain related operations. An allocation must be made by the investigator. The first step of the allocation process was to classify joint costs into fixed and variable components (Table 9). One of the objectives of the study was to estimate the average variable operating costs of the existing elevator industry and use these estimates as inputs in the network flow model. Joint fixed cost components were ignored.

TABLE 9. LISTING OF JOINT COSTS RELEVANT TO THE GRAIN ELEVATOR INDUSTRY BY CLASSIFICATION

Variable[a]	
Interest Expense	Light, Heat, and Power
Salaries	Telephone
Repairs	Special Meeting
Payroll Taxes	Travel
Unemployment Compensation	Convention
Workmen's Compensation	Legal Fees
Bookkeeping	Rodent Control
Office Supplies	Tax and Dividend Work
Subscriptions	Data Processing
Advertising	Residence Expense
Fixed	
Director's Fees	Dues
Site Rental	Annual Meeting
Property Taxes	Warehouse License
General Insurance	Lease Rental
Bonds	Depreciation
Warehouse Bonds	

[a]It is realized that most of the cost categories in this classification are a mixture of variable and fixed components. For purposes of this study, these categories are assumed to be variable only with the exception of salaries.

A regression analysis similar to the allocation process within the railroad industry was used to allocate joint variable costs.[24] The objective of the regression analysis was to measure the variation of the individual cost components with changes in the relevant outputs. The cost components may be viewed as a function of grain and nongrain activity. For example,

$$E_i = f(Q_G, Q_m)$$
$$= a + b_G Q_G + b_m Q_m + e$$

Where: E_i = individual cost component

a = fixed cost independent of grain and nongrain merchandising

b_G = allocation factor for grain merchandising where $0 \leq b_G \leq 1$

Q_G = quantity of grain handled

b_m = allocation factor for nongrain merchandising where $0 \leq b_m \leq 1$

Q_m = quantity of nongrain merchandise handled

e = error term, minimized by the statistical model; $b_G + b_m = 1$

However, one problem exists with the above functional relationship. While grain activity is easily measured in bushel throughput, nongrain activity cannot be readily determined since no common denominator exists (tons of fertilizer, gallons of gas, barrels of oil, etc.). Thus, an allocation process using one variable, grain activity (simple linear regression model using log transformations), was used. The estimates received may be interpreted as the percentage of that cost component attributable to grain merchandising. These estimates are presented in Table 10. Estimates for interest and residence expenses were found to be insignificant (i.e., equal to zero) and were deleted from the allocation process.

Estimation of the average variable cost for each individual elevator for the two-year period 1978-79 was achieved through a three step process. First, each of the individual cost components was multiplied by the allocation

[24]For a thorough discussion on the allocation process used by the railroad industry, see George H. Borts, "The Estimation of Rail Cost Functions," Econometrica 28, No. 1 (January 1960): pp. 108-131 and John R. Meyer and Gerald Kraft, "The Evaluation of Statistical Cost and Techniques as Applied in the Transportation Industry," American Economic Review 51, No. 2 (May 1961): pp. 313-334.

factor presented in Table 10. The multiplication process determines the portion of each individual cost component to be allocated to grain merchandising. However, salaries were allocated in a slightly different manner.

TABLE 10. INDIVIDUAL COST COMPONENTS AND THEIR RESPECTIVE TWO-YEAR AVERAGE ALLOCATION FACTORS FOR 1978 AND 1979

Item	1978-79
Salaries[a]	0.488
Maintenance[b]	0.344
Taxes[c]	0.605
Supplies[d]	0.453
Light, Heat, and Power	0.588
Marketing[e]	0.481
Meetings[f]	0.302

[a]Salaries, bookkeeping, legal fees, and tax and dividend work.
[b]Repairs and rodent control.
[c]Payroll and unemployment compensation taxes.
[d]Office supplies and subscriptions.
[e]Telephone, data processing, and advertising.
[f]Special meeting, travel, and convention expenses.

Salary levels were reduced by an arbitrary fixed component which increased in a direct relationship with storage capacity as follows:

1. If storage capacity was less than 100,000 bushels, fixed salaries were $17,500.
2. If storage capacity was between 101,000 and 300,000 bushels, fixed salaries were $20,000.
3. If storage capacity was between 301,000 and 800,000 bushels, fixed salaries were $22,500.
4. If storage capacity was greater than 800,000 bushels, fixed salaries were $25,000.

The residual (total salaries less fixed salaries) was multiplied by the allocation factor. Payroll taxes were reduced by multiplying 6.65 percent by the fixed salary component. Second, all amounts allocated to grain merchandising were added to the directly assignable costs (100 percent allocable) associated with grain merchandising (i.e., elevator supplies, scale inspection and repair, dryer expense, and protein tests) achieving a total variable cost figure. Third, total variable costs were divided by the respective amount of grain handled (two-year average) to achieve an average variable operating cost per bushel for each elevator for the 1978-79 period.

Average Variable Cost

Analysis of AVC followed the same procedures as ATC. The independent variables used were number of annexes (NOA), AGE, average gross margin (AGM), contribution margin (CON), actual storage capacity (ACT), grain handled (GRH), and turnover (TUR). Elevator type and line location also were used as classifying variables. Plots of GRH and TUR against AVC indicated that a linear regression model was adequate.

The first step in the analysis was to determine the existence of differences due to line location (i.e., branch versus main line). The associated F-statistic (Hypothesis 1, Table 11) showed there were differences between

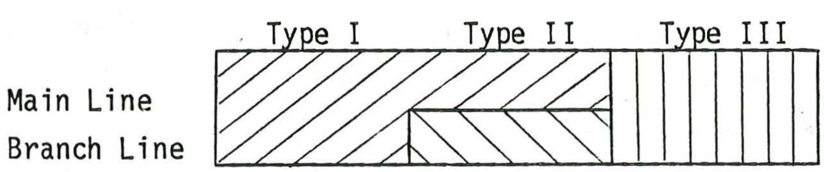
TABLE 11. RESULTS FOR THE HYPOTHESES TESTED FOR AVC

Hypothesis Tested	Calculated F-Stat	d.f.	Table F-Stat
(1) Differences Between Line Location	1.587	24,138	1.58
(2) Differences Between Elevator Types	4.120	32,138	1.54

line locations whereas no differences occurred in the case for ATC. Secondly, testing for differences between elevator types indicated differences existed (Hypothesis 2) between elevator types. The next step was to identify the actual number of unique populations from which the sample was drawn. The following notation was used.

	Type I	Type II	Type III
Main Line	U	W	Y
Branch Line	V	X	Z

Various hypotheses were tested. The hypothesis that U = V = W and Y = Z resulted in an F value of $1.03_{24,138\ d.f.}$ indicating the potential existence of only three populations (i.e., U = V = W, Y = Z, and X).



Population 1 includes all Type I and main line Type II elevators while Population 2 includes only branch line Type II elevators. Both main and branch line Type III elevators were represented by the third population. Additional tests revealed that the above three populations were significantly different at the .05 level.

Assuming the above three populations, the model can be written in terms of the standardized variables as follows:

Population 1;

$$AVC^* = a_o + a_1NOA^* + a_2AGE^* + a_3AGM^* + a_4CON^* + a_5ACT^* + a_6GRH^* + a_7TUR^* + E_1$$

Population 2;

$$AVC^* = b_o + b_1NOA^* + b_2AGE^* + b_3AGM^* + b_4CON^* + b_5ACT^* + b_6GRH^* + b_7TUR^* + E_2$$

Population 3;

$$AVC^* = c_o + c_1NOA^* + c_2AGE^* + c_3AGM^* + c_5CON^* + c_5ACT^* + c_6GRH^* + c_7TUR^* + E_3$$

The above model features 24 unknown parameters (a_0, a_1, ..., a_7, b_0, b_1, ..., b_7, c_0, c_1, ..., c_7). The obvious question is whether or not the three populations can be adequately described by less than 24 parameters. This may happen in two ways. As an example of the first, it may be that $a_0 = b_0 = c_0$ in which case we could get by with estimating 22 parameters as opposed to 24. The other way in which the number of parameters might be reduced is if one or more parameters are zero. Since the parameters themselves are unknown, one has no way of knowing the answers to the above questions.

However, by following the principles of hypothesis testing, it is possible to make inferences about the unknown parameters. In particular, if the sample data do not provide sufficient evidence to reject a given hypothesis, then one may proceed as if the hypothesis were true. In terms of the above model, what this means is that if we were unable to reject the hypothesis that $a_0 = b_0 = c_0$, then we would conclude that the three populations could be represented by 22 parameters.

Using the above principle, one may search out the minimum set of parameters necessary to adequately model AVC^*. One shortcoming of this approach is that the minimal sufficient set may not be unique. Such was the case with the above model. The following three joint hypotheses failed to reach significance at the 5 percent level.

(1) $b_1 = c_1$, $a_2 = b_2 = c_2$, $a_3 = b_3 = c_3$, $a_4 = b_4 = c_4$, $a_7 = c_7$
$b_0 = 0$, $a_5 = a_6 = c_5 = c_6 = 0$

(2) $a_1 = b_1 = c_1$, $a_2 = b_2 = c_2$, $a_3 = b_3 = c_3$, $a_4 = b_4 = c_4$, $a_7 = c_7$
$b_0 = 0$, $a_6 = c_6 = 0$

(3) $a_0 = c_0$, $a_1 = b_1 = c_1$, $a_2 = b_2 = c_2$, $a_3 = b_3\ c_3$, $a_4 = b_4 = c_4$,
$a_6 = c_6$, $a_7 = c_7$, $b_0 = 0$, $a_5 = 0$

A closer look at the first hypothesis reveals that 11 parameters (a_0, c_0, a_1, b_1, a_2, a_3, a_4, b_5, b_6, a_7, b_7) are sufficient to describe the three populations. Similarily, hypothesis (2) states that 12 parameters (a_0, c_0, a_1, a_2, a_3, a_4, a_5, b_5, c_5, b_6, a_7, b_7) are sufficient whereas hypothesis (3) requires only 11 (a_0, a_1, a_2, a_3, a_4, b_5, c_5, a_6, b_6, a_7, b_7). It should be noted that the sufficient set of 11 parameters as dictated by hypothesis (1) is a different set than that dictated by hypothesis (3). In addition, further attempts to reduce the number of parameters were unsuccessful.

The above findings suggest that their may not be a single "best" model for AVC^*. This is in opposition to ATC where a singel "best" model was found. In terms of model adequacy, such as R^2 and the standard deviation of the residuals, the three suggested models for AVC were very comparable. Given the preceeding remarks, it was deemed appropriate that all three models be recognized. Discussion of each of the models follows. All equations are in terms of the standardized variables (i.e., the variable value divided by the standard deviation of that variable).

Model 1.

The standardized results for Model 1 are listed below.

Population 1;

$$AVC^* = 2.30 + .174NOA^* - .122AGE^* + .379AGM^* - .420CON^* - .170TUR^*$$

Population 2;

$$AVC^* = .125NOA^* - .122AGE^* + .379AGM^* - .420CON^* + 1.367ACT^* - 1.278GRH^* + 1.166TUR^*$$

Population 3;

$$AVC^* = 1.69 + .125NOA^* - .122AGE^* + .379AGM^* - .420CON^* - .170TUR^*$$

Model 1 resulted in an R^2 of .614 with the regression relationship causing a reduction in the standard error of the residuals from 1.34 cents to .85 cents. The equation associated with the second population differed substantially from the other two. No intercept term existed, two additional independent variables (actual storage capacity and grain handled) were significant and one estimate (turnover rate) changed sign. The reasoning behind the dramatic changes may be due to the small number of observations (i.e., 16) composing the sample. All of the significant parameter estimates were related to AVC^* as expected, with the exception of AGM^* and ACT^* and TUR^* in the second equation. Actual storage capacity was not significant in the first and third equations when estimating AVC^*, but was significant when estimating ATC. Volume of grain handled also was not significant in the first two equations. This may be due to the use of the amount of grain handled in the joint cost allocation process previously mentioned.

Model 2

The equations used to estimate AVC^* in Model 2 are listed below for the three populations:

Population 1;

$$AVC^* = 1.238 + .138NOA^* - .141AGE^* + .350AGM^* - .408CON^* + .243ACT^* - .175TUR^*$$

Population 2;

$$AVC^* = .138NOA^* - .141AGE^* + .350AGM^* - .408CON^* + 1.387ACT^* - 1.296GRH^* + 1.184TUR^*$$

Population 3;

$$AVC^* = 5.91 + .138NOA^* - .141AGE^* + .350AGM^* - .408CON^* - .288ACT^* - .175TUR^*$$

Model 2 produced an R^2 of .614 with an accompanying reduction in the standard error of the residuals from 1.34 to .86. Estimates of NOA^*, AGE^*, AGM^*, and CON^* were identical in all three populations as was the case in the first model. The only difference between the first and third populations was the parameter estimates for actual storage capacity and the intercept. The estimate for actual storage capacity was expected to be negative (i.e., as actual storage capacity increases AVC^* decreases). However, the estimate for actual storage capacity in Population 3 was positive and may be due to the extreme variability that occurred within the sample data. Grain handled was present in equation 2 and turnover produced a positive sign as with the first model.

Model 3

The following equations were utilized to estimate AVC^* in the third model:

Population 1;

$$AVC^* = 1.331 + .146NOA^* - .138AGE^* + .353AGM^* - .413CON^* + .273GRH^* - .381TUR^*$$

Population 2;

$$AVC^* = .146NOA^* - .138AGE^* + .353AGM^* - .413CON^* + 1.390ACT^* - 1.300GRH^* + 1.187TUR^*$$

Population 3;

$$AVC^* = 1.331 + .146NOA^* - .138AGE^* + .353AGM^* - .413CON^* - .519ACT^* + .273GRH^* - .381TUR^*$$

The above model yielded an R^2 of .617 and standard deviation of residuals of .85. All parameter estimates were identical for the first and third populations. In addition, actual storage capacity was present in the third equation. All estimates with the exception of average gross margin and grain handled in the first and third equations received the expected relationship with AVC^*. Population 2 included some discrepencies as was the case with the two previous models. No intercept term was significant, while actual storage capacity and turnover received unexpected signs.

Model Adequacy

The previous models appear to define the AVC cost structure adequately, given the limitations of the data. AVC was more variable than ATC within the populations. This variability may have given rise to the differences observed between the three models. The assumptions made for the analysis of AVC were the same as for ATC.

Network Flow Model

One of the objectives of the study was to calculate AVC as an input for the network flow model which analyzes grain movement in two crop reporting districts in North Dakota.[25] AVC was estimated as a function of licensed storage capacity and volume of grain handled:

[25]Transshipment of grain movement are accomplished through network flow models. Research is currently in progress with publications forthcoming.

$$AVC = 2.65 + .00419\ STO - .00000059\ GRH$$

Where: AVC = Average variable cost

STO = Licensed storage capacity (100,000 bu.)

GRH = Annual volume of grain handled (bushels)

Both STO and GRH were found to be significant in estimating AVC at the 10 percent level. AVC was obtained by averaging the sample data for 1978 and 1979, reducing problems that may occur due to yearly fluctuations in volume of grain handled and individual cost accounts. The sample consisted of 51 au it statements representing 58 of the 121 existing elevators within CRD 3. The model yielded an F-value of $5.225_{2,48\ d.f.}$.

A more precise model could have been achieved involving additional independent variables [i.e., contribution margin (CON) and average gross margin (AGM)] provided the data were available for all elevators. The above is the "best" model, based on available information. It was constructed under the assumption that AVC is invariant with respect to elevator type (i.e., Types I, II, and III). While this assumption may or may not be totally realistic, it is necessary because the sample data do not include all of the three types of elevators in sufficient numbers to allow for a meaningful analysis of type differences.

Analysis by Stratification

The purpose of this analysis was to substantiate the previous indications of the existence of economies of size; that is, the cost per bushel declines as the quantity of grain handled or turnover ratio increases. Short run average fixed, average variable and average total cost functions were estimated by stratifying the sample using two different variables, volume of grain handled, and turnover ratio. Linear regression models were estimated and found to be deficient in goodness of fit. Instead, logrithms were used since they allow for a continuously decreasing function.

Stratification by Grain Handled

The sample, stratified by grain handled, contained four categories: less than 600,000 bushels, 600,001 to 900,000, 900,001 to 1,400,000, and over 1,400,000 bushels of grain handled. The equations computed through stratification by grain handled (GRH) are presented in Table 12. The sample sizes for strata 1 through 4 were 50, 49, 56, and 50 respectively. The parameter estimates and standard errors (in parentheses) were tabulated for each

TABLE 12. FUNCTIONAL RELATIONSHIPS OF ATC, AVC, AND AFC USING THE LOGRITHM OF VOLUME OF GRAIN HANDLED BY STRATIFICATION

Strata	1	2
	0 - 600,000	600,001 - 900,000
	ATC = 21.8* - 4.24 LOG (GRH)* (2.00)	ATC = 8.3 + 2.55 LOG (GRH) (4.07)
	AVC = 3.1* + .26 LOG (GRH) (.78)	AVC = 2.5 + .39 LOG (GRH) (1.47)
	AFC = 18.8* - 4.51 LOG (GRH)* (1.32)	AFC = 5.7 + 2.15 LOG (GRH) (2.87)
	3	4
	900,001 - 1,400,000	1,400,000 and over
	ATC = 41.1* - 12.05 LOG (GRH)* (3.74)	ATC = 16.5* - 1.89 LOG (GRH) (1.47)
	AVC = 12.2* - 3.62 LOG (GRH)* (1.45)	AVC = 3.6* - .10 LOG (GRH) (.56)
	AFC = 29.0* - 8.44 LOG (GRH)* (2.44)	AFC = 12.9* - 1.78 LOG (GRH) (.99)

*Indicates significance at the .10 level.

stratification modeled independently. A function with one independent variable was utilized, allowing for illustration of possible economies of size by a two-dimensional graph (Figure 6).

The parameter estimates for LOG(GRH) were significantly related to ATC in strata 1 and 3. LOG(GRH) was an adequate estimator of AFC in the first, third, and fourth stratifications while the estimates explaining the variation in AVC were significant in the third stratum only. No relationship was found between the volume of grain handled and any of the cost components in the second stratum. Thus, the parameter estimates in this stratification are meaningless and may be ignored. The insignificance was due to the enormous variability within this stratification.

The equations in stratum 3 resulted in a steeper downward slope for each function and incurred a section of lower costs relative to stratum 4, indicating that diseconomies may be incurred with larger grain volumes in strata 4. This occurrence may be a result of relative efficiencies within the third stratum or due to noncost characteristics (i.e., AGE, NOA, AGM, etc.), which were not taken into account. These characteristics may have a relatively greater influence on ATC, AFC, and AVC in stratum 3 and are not fully realized in stratum 4, making a section of the third stratum appear more efficient when in actuality it may not be.

A continuously decreasing function was defined when the second stratum and all insignificant parameter estimates were ignored. The decreasing ATC function emphasizes the existence of economies of size and the lack of any diseconomies infers the underutilization of industry-wide capacity.

Stratification by Turnover Ratio

Turnover ratio was stratified into four categories: less than 2.75, 2.76 to 3.5, 3.51 to 5.5, and over 5.5 times. The respective sample sizes for the strata were 52, 46, 57, and 49. The parameter estimates and standard errors (in parentheses) were computed independently for each stratification and are presented in Table 13 while the two-dimensional graphics are illustrated in Figure 7. Turnover ratio (TUR) was significantly related to ATC and AFC in strata 1, 2, and 4 while AVC was significantly related to TUR in the second stratification. The latter function resulted in a peculiar form. The intercept was negative and the function was continuously increasing, contrary to the other estimates. The reasoning for this occurrence is not known but may be somewhat suspect due to the large variability found in AVC.

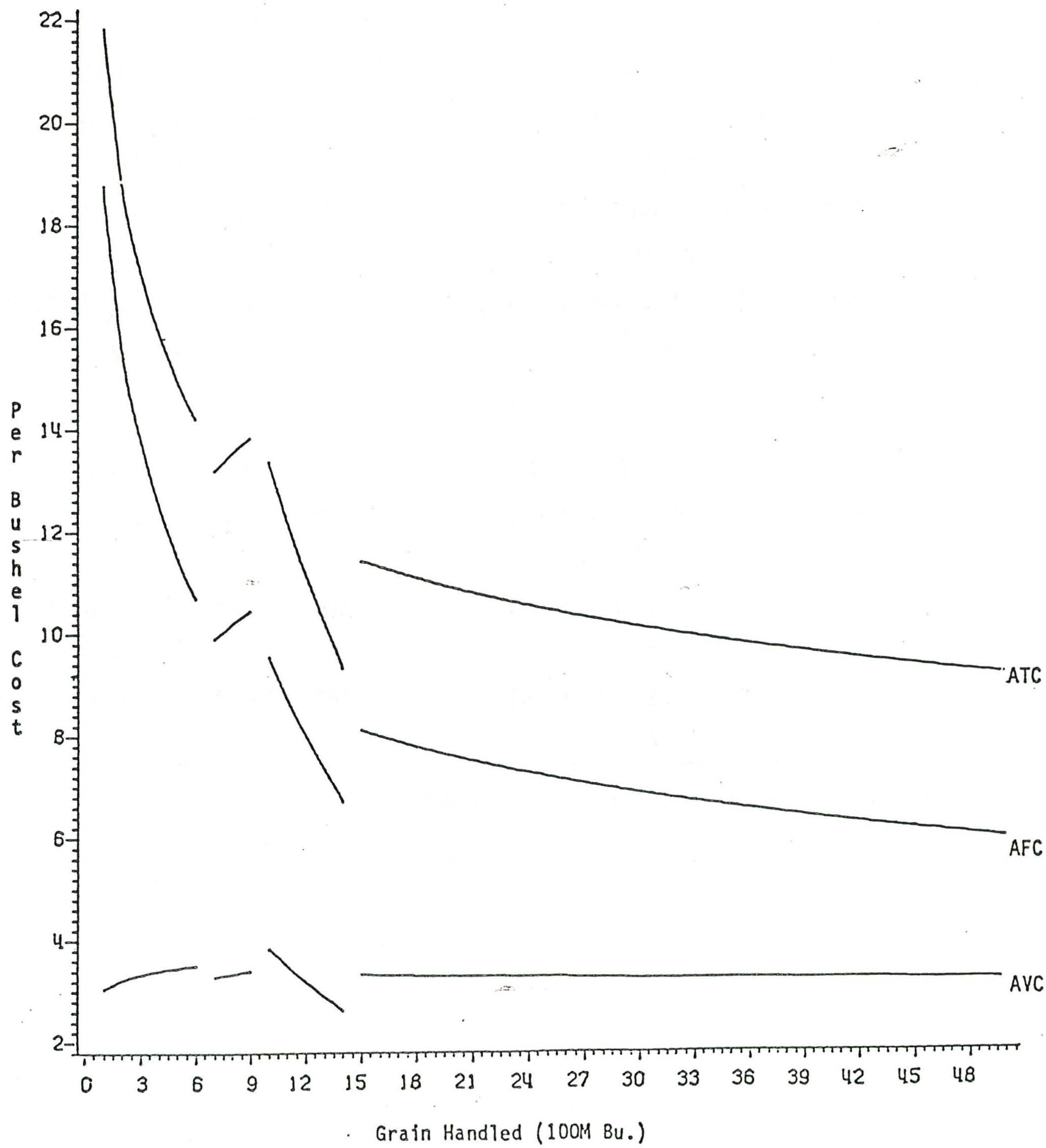


Figure 6. Cost Structure for North Dakota Grain Elevators, 1978-79

TABLE 13. FUNCTIONAL RELATIONSHIPS OF ATC, AVC, AND AFC WITH THE LOGRITHM OF TURNOVER RATIO

Strata	1	2
	0 - 2.75	2.76 - 3.50
	ATC = 20.2* - 4.90 LOG (TUR)*	ATC = 1.7 + 10.49 LOG (TUR)
	(2.82)	(8.41)
	AVC = 4.7* - .80 LOG (TUR)	AVC = -4.7 + 7.07 LOG (TUR)*
	(1.17)	(3.18)
	AFC = 15.6* - 4.10 LOG (TUR)*	AFC = 6.4 + 3.42 LOG (TUR)
	(2.03)	(6.08)
	3	4
	3.51 - 5.50	5.51 and over
	ATC = 19.1* - 5.28 LOG (TUR)*	ATC = 19.9* - 4.62 LOG (TUR)*
	(2.33)	(1.93)
	AVC = 4.7* - 1.16 LOG (TUR)	AVC = 4.4* - .67 LOG (TUR)
	(.92)	(.71)
	AFC = 14.4* - 4.12 LOG (TUR)*	AFC = 15.4* - 3.95 LOG (TUR)*
	(1.75)	(1.38)

*Indicates significance at the .10 level.

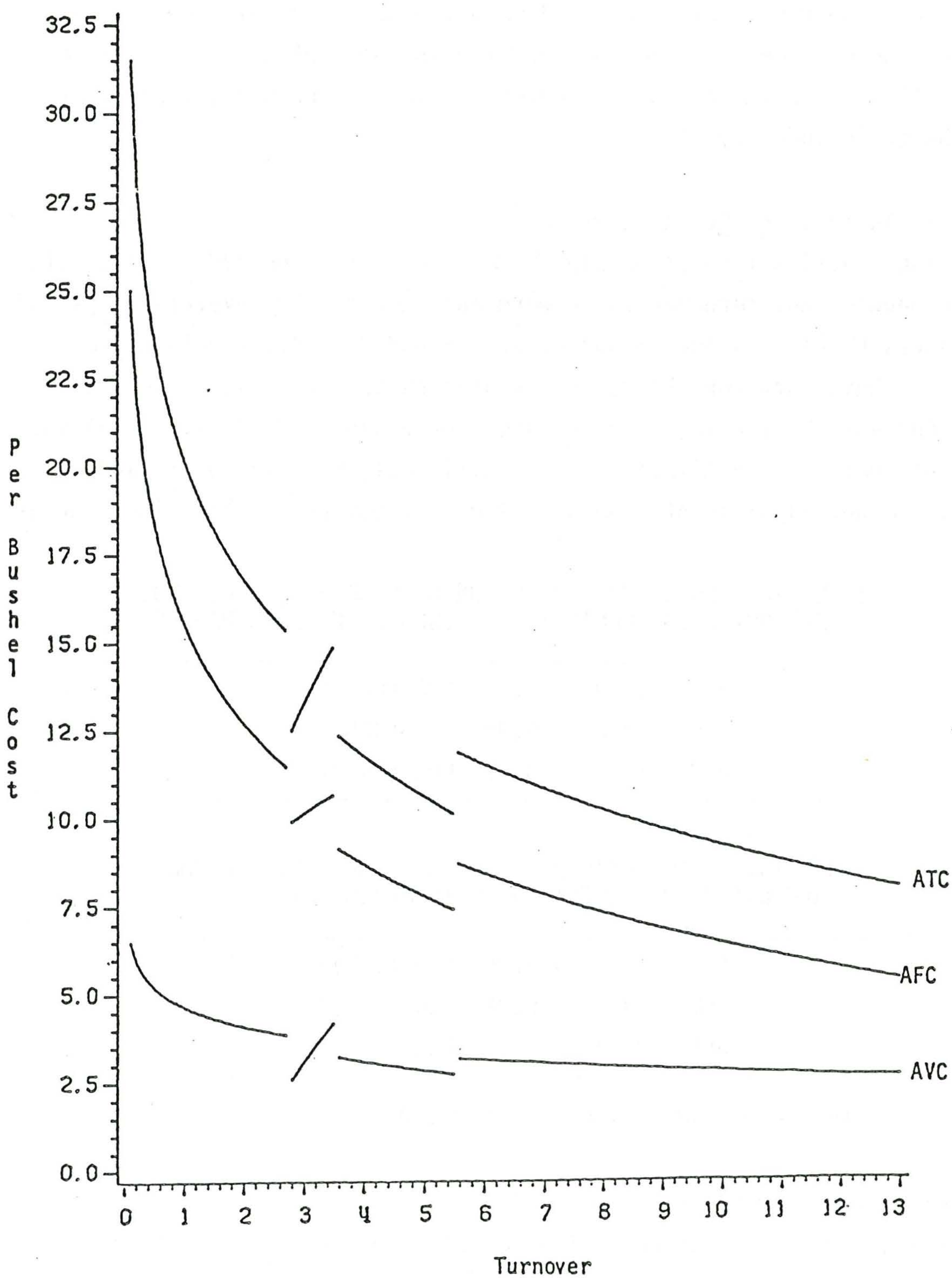


Figure 7. Cost Structure for North Dakota Grain Elevators, 1978-79

The equations in stratum 3 resulted in a steeper downward slope for each function and incurred a section of lower costs relative to stratum 4 as in the grain handled example. The reasons for this occurrence were stated previously.

The same result also occurred when the second stratification was ignored. A continuously decreasing function with no apparent minimum point was defined, indicating the existence of economies of size and underutilization of capacity by the grain industry.

Graphic Analysis of Overall Sample

The functional relationships between ATC, AFC and AVC and the volume of grain handled and turnover ratio were analyzed for the overall sample of 205 elevators (Tables 14 and 15 and Figures 8 and 9). All functions were expressed in logrithmic form for the reasons mentioned in the previous section.

Analysis by the logrithm of volume of grain handled (Table 14) indicated that all parameter estimates were significantly related to ATC and AFC. LOG (GRH) did not significantly measure the enormous variability inherent with AVC.

TABLE 14. FUNCTIONAL RELATIONSHIPS OF ATC, AVC, AND AFC USING THE LOGARITHM OF VOLUME OF GRAIN HANDLED

ATC	=	20.0*	-	3.15	LOG (GRH)*
AVC	=	3.6*	-	0.08	LOG (GRH)
AFC	=	16.5*	-	3.07	LOG (GRH)

TABLE 15. FUNCTIONAL RELATIONSHIPS OF ATC, AVC, AND AFC USING THE LOGARITHM OF TURNOVER RATIO

ATC	=	19.7*	-	4.96	LOG (TUR)*
AVC	=	4.6*	-	0.91	LOG (TUR)*
AFC	=	15.1*	-	4.05	LOG (TUR)*

*Indicates significance at the .10 level.

All parameters for LOG (TUR) were significant in estimating the variability in each of the cost components (Table 15). The functional relationships for ATC and AFC were continuously decreasing. Average variable cost remained relatively constant, indicating AVC did not change significantly with increases in size.

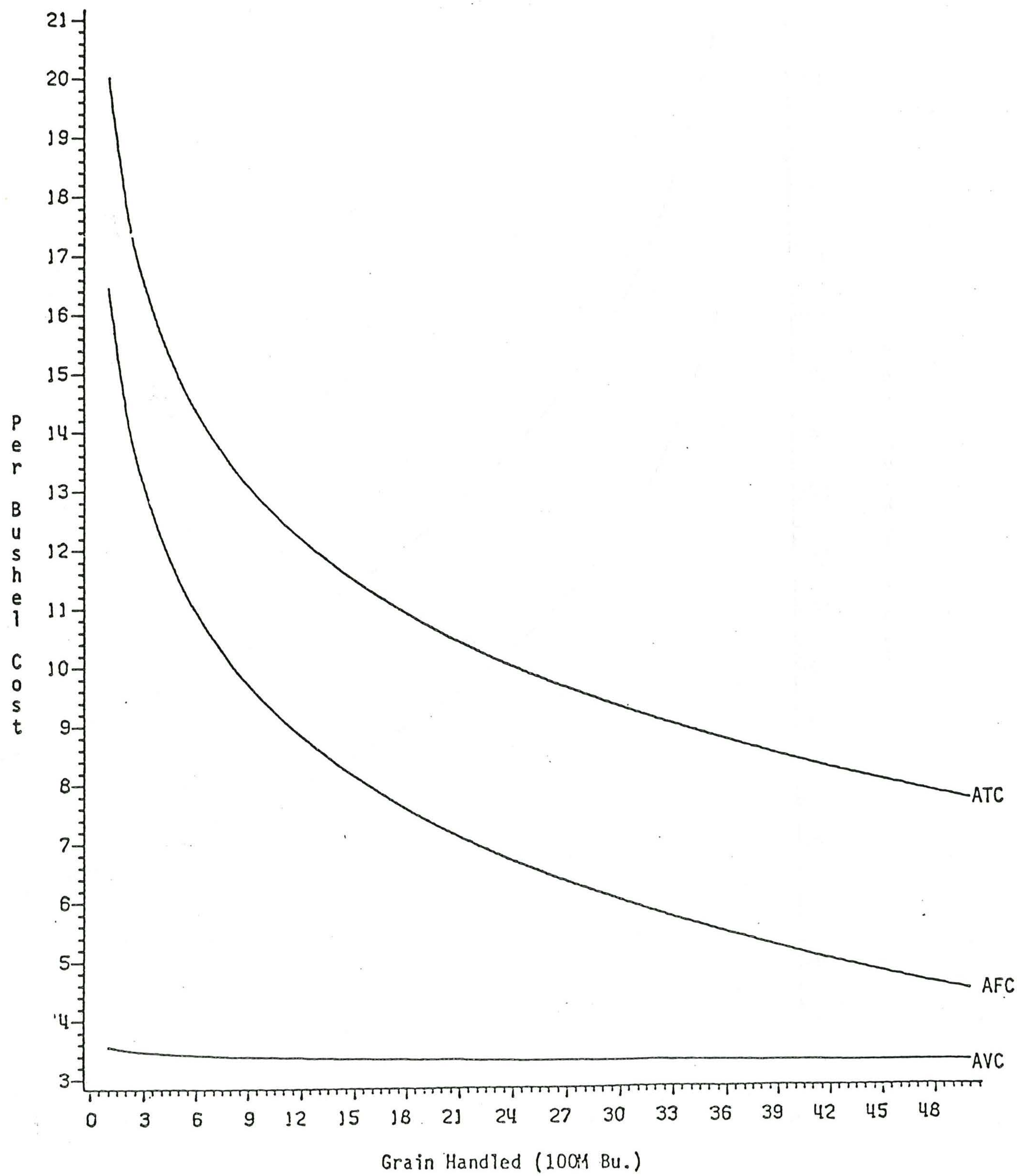


Figure 8. Cost Structure for North Dakota Grain Elevators, 1978-79

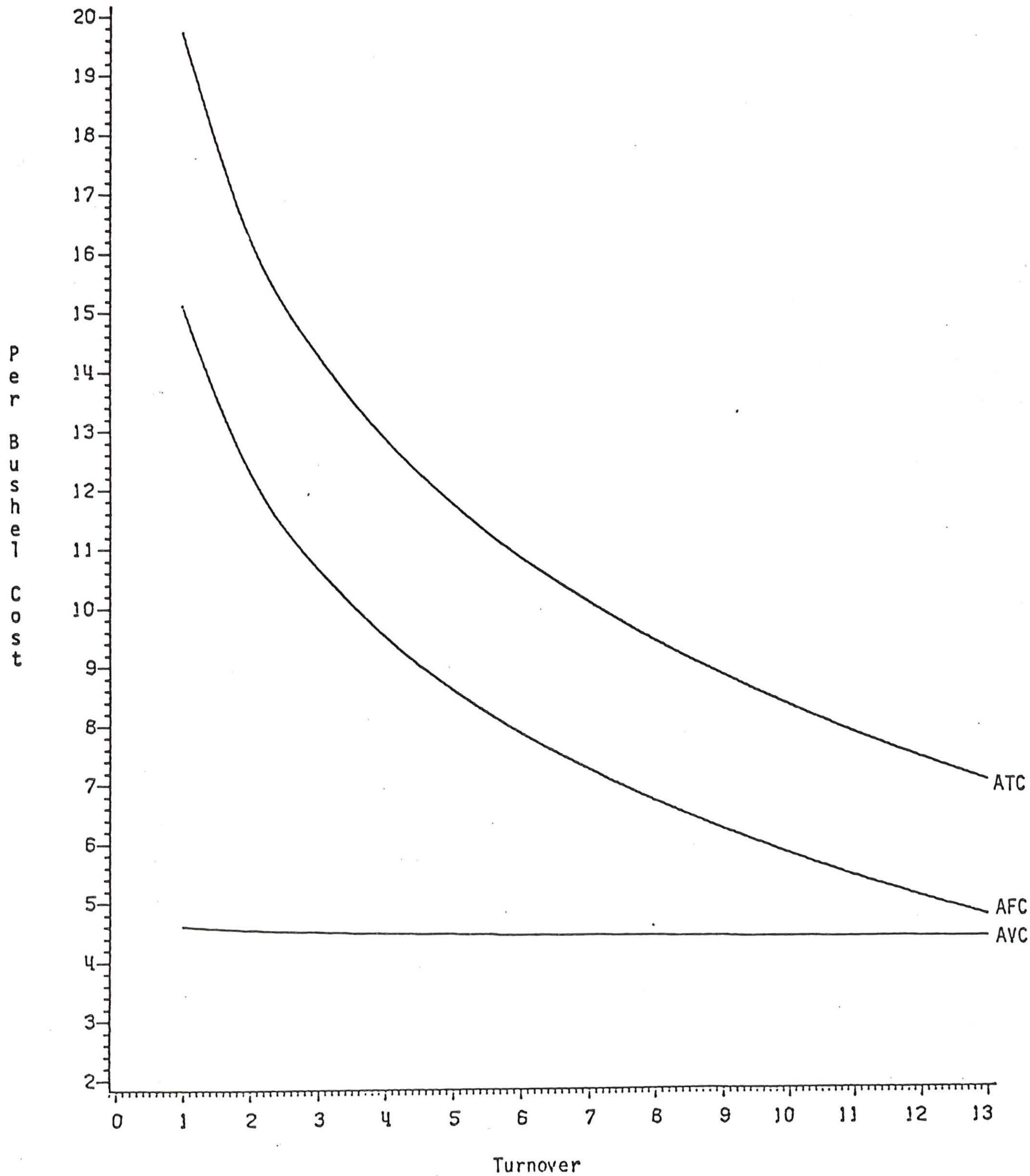


Figure 9. Cost Structure for North Dakota Grain Elevators, 1978-79

The results of this section of the study indicate that economies of size exist in the grain elevator industry in North Dakota as shown by the continuously decreasing functions. A lack of a minimum ATC point indicates the industry is characterized by underutilized plants.

Analysis of Average Values

The objective of this analysis was to further determine if economies of size were in existence in the elevator industry during the 1978 to 1979 period. Average values were computed for average total cost, average variable cost, and each of the seven previously mentioned elevator charateristics. These values were calculated by two methods. The first stratified the sample by the volume of grain handled (Table 16) and turnover ratio (Table 17) as in the previous section. Each stratification had approximately the same number of observations. The second method averaged all values over the sample of 205 elevators (Table 18).

Analyses of average values were used only for substantiating prior results since averaging does not take into consideration variability, estimating significance or skewness of the data. Care must be taken when making recommendations or conclusions concerning average values.

Stratification by Grain Handled

Storage capacity increased from 169,000 to 453,000 bushels as volume of grain handled increased, indicating the larger facilities, on the average, handled more grain (Table 16). The larger throughput facilities also tended to be newer, ranging from 45 years of age for the 0 - 600,000 bushel throughput elevators to 29 years of age for elevators which handled over 1.4 million bushels of grain. Turnover ratio (i.e., grain handled/storage capacity) doubled from the smallest to largest size category. This indicates volume of grain handled increased at a more rapid rate than the increase in storage capacity, inferring marketing efficiencies and the possible existence of economies of size. The existence of economies of size was substantiated when average total cost decreased from 15.8 to 10.9 cents per bushel as grain handling capacity increased. The decrease in ATC was attributable to the fixed cost portion of ATC being distributed over a larger number of bushels of grain, hence, the fixed cost per bushel decreased as volume of grain handled increased. AVC was invariant with size and remained around 3.4 cents per bushel. Average gross margin, (gross margin/volume of grain

TABLE 16. AVERAGE VALUE OF CHARACTERISTICS ASSOCIATED WITH THE EXISTING GRAIN ELEVATOR SYSTEM, STRATIFIED BY VOLUME OF GRAIN HANDLED[a]

	Grain Handled (bushels)			
Item	0 - 600,000	600,001 - 900,000	900,001 - 1,400,000	1,400,000 and Over
Number of Annexes (NOA)	2.2	2.6	2.9	2.7
Age of Facility (AGE), years	45	40	35	29
Average Gross Margin (AGM), cents/bu.	.156	.158	.157	.152
Contribution Margin (CON), decimal fraction	.86	.82	.86	.83
Storage Capacity (ACT), bu.	169,170	220,898	265,054	453,286
Grain Handled (GRH), bu.	431,541	753,635	1,110,745	2,115,107
Turnover Ratio (TUR), rate	2.79	3.95	5.00	5.55
Average Variable Cost, cents/bu.	.034	.033	.035	.033
Average Total Cost, cents/bu.	.158	.134	.122	.109
Number of Observations in Strata	50	49	56	50

[a]Characteristic values represent an average of the two-year period 1978-79. These values were sorted according to stratification and a mean value determined.

TABLE 17. AVERAGE VALUE OF CHARACTERISTICS ASSOCIATED WITH THE EXISTING GRAIN ELEVATOR SYSTEM, STRATIFIED BY TURNOVER RATIO[a]

Item Name	Turnover Ratio 0 - 2.75	2.76 - 3.50	3.51 - 5.50	5.51 and Over
Number of Annexes (NOA)	3.1	2.6	2.3	2.4
Age of Facility, years	43	37	35	32
Average Gross Margin, cents/bu.	.176	.161	.147	.142
Contribution Margin, decimal fraction	.85	.85	.83	.84
Storage Capacity, bu.	333,078	291,630	279,018	200,357
Grain Handled, bu.	729,838	944,551	1,218,735	1,474,042
Turnover Ratio, rate	2.17	3.21	4.41	7.33
Average Variable Cost, cents/bu.	.040	.036	.030	.030
Average Total Cost, cents/bu.	.164	.139	.113	.107
Number of Observations in Strata	52	46	57	49

[a]Characteristic values represent an average of the two-year period 1978-79. These values were sorted according to stratification and a mean value determined.

TABLE 18. CHARACTERISTICS OF THE EXISTING ELEVATOR SYSTEM[a]

Item Name	Average Value	Minimum Value	Maximum Value
Number of Annexes (NOA)	2.6	0	11
Age of Facility, years	37	1	93
Average Gross Margin, cents/bu.	15.6	0.0	35.6
Contribution Margin, decimal fraction	.84	.34	1.00
Storage Capacity, bu.	276,159	74,000	1,059,000
Grain Handled, bu.	1,104,694	145,653	4,189,727
Turnover Ratio, rate	4.34	1.29	15.80
Average Variable Cost, cents/bu.	.034	.011	.077
Average Total Cost, cents/bu.	.130	.048	.284

[a]Characteristic values represent an average of the two-year period 1978-79. The sample consisted of 205 elevators.

handled), number of annexes and contribution margin remained relatively constant when stratified by volume of grain handled, indicating no economies of size existed for these variables.

Stratification by Turnover Ratio

The same variables analyzed by the volume of grain handled also were analyzed by turnover ratio. The results, presented in Table 15, may at first glance seem somewhat inconsistent and puzzling when compared to the previous table. Facilities which averaged 200,000 bushels of storage incurred an average turnover ratio of 7.33 while the 333,000 bushel facilities, on the average, had a turnover ratio of 2.17. This seems to contradict the previous table where storage capacity, grain handled and turnover increased simultaneously. However, this occurrence was due to the relative ease of turning over 200,000 bushels versus 333,000 bushels. Storage capacity also was relatively more variable when stratified by turnover compared to grain handled. This causes some unreliability when comparing storage capacity to the other characteristics and costs between Tables 16 and 17. Average gross margin decreased by 3.4 cents per bushel from the lowest to highest turnover categories. This may have been due to the averaging process discussed earlier. Average variable cost remained relatively constant, dropping one cent per bushel over the range of elevators. ATC decreased from 16.4 to 10.7 cents per bushel as turnover increased from 2.17 to 7.33. Taking this decrease in conjunction with the increase in volume of grain handled indicates economies of size are in existence. Number of annexes and contribution margin remained relatively constant as they did in the previous analysis.

Analysis of Overall Sample

The previous comment on the lack of consideration of variability for average values is readily apparent in Table 18. For example, the sample consisted of elevators whose storage facilities ranged in capacity from 74,000 to 1,059,000 bushels and whose age ranged from 1 to 93 years. The average values for these characteristics were 276,000 bushels and 37 years, respectively. Annual volume of grain handled varied within a 4 million bushel range (averaged 1.1 million) while the range in turnover ratio was 11.5 (averaged 4.34). Average variable cost ranged from 1.1 to 7.7 cents per bushel. Average total cost differed 23.6 cents per bushel from a low of 4.8 to a high of 28.4 cents per bushel.

The characteristics of the sample consisted of a wide range of values and indicated the wide array of sizes, age, costs, etc. of the grain elevator industry in North Dakota.

Summary and Conclusions

Summary

The country elevator in North Dakota is a vital link between the producer and ultimate consumer of grain. The industry consisted of 568 licensed and bonded elevators which were actively involved in grain merchandising during the 1978-79 period. Cooperatively owned elevators and elevators located on branch lines constituted 373 and 323 elevators, respectively.

The data base for this study consisted of accounting records from 212 cooperatives representing 239 elevators (42 percent of total). The sample consisted of a wide range of sizes and was found to contain an adequate number of observations within each size category.

It is traditionally assumed that cross-section data covering many firms typify a long run situation whereas cross-section data taken from a sample of firms of one size that incur a wide range of output typifies the short run. Both types of analyses were made for estimating economies of size.

The statistical costing method was used for determining economies of size since the major concern of the study was with "what is" rather than "what could be" in the elevator industry. The statistical approach was determined appropriate due to its focus on existing plant operations.

Empirical Results

Regression analysis was used in modeling average total and average variable cost characteristics. Average fixed cost was calculated by subtracting average variable cost from average total cost. Seven characteristics were used to define the cost components, number of annexes, age of facility, average gross margin, contribution margin, actual storage capacity, volume of grain handled, and turnover ratio. Linear relationships were analyzed and found to be inadequate in some cases. Volume of grain handled and turnover ratio were transformed exponentially allowing for continuously decreasing functions.

Average Total Cost

The sample was restructured into six populations, taking into account elevator types and line locations. No significant differences were found between the average total cost structure of elevators located on main versus branch lines. Two distinct populations were found when testing for differences between elevator types. The first population consisted of Type I and II elevators while the second population was Type III elevators only. Type III elevators had a slightly more negative parameter estimate for contribution margin than Type I and II elevators.

All significant variables in the model, except average gross margin, were related to average total cost as expected. Actual storage capacity was not significant, possibly because turnover ratio (i.e., volume of grain handled/ actual storage capacity) incorporated actual storage capacity into the model.

Joint Costs

Joint costs were allocated by a regression analysis similar to the allocation process used in the railroad industry. The objective was to measure the variation of the individual cost components with changes in volume of grain handled. All estimates, except interest and residence expense, were significant.

Average Variable Cost

Modeling results for average variable cost were dramatically different from those found for average total cost. Differences existed between both elevator types and line locations. Hypothesis testing resulted in the identification of three distinct populations. Three separate models were used to analyze the three populations and provided comparable results. The equations within each model shared some parameter estimates.

Model differences occurred on a frequent basis and could have been a result of the number of observations in one of the populations. Another reason for the differences might be due to the joint cost allocation process. Large amounts of variability occurred within the sample data which may have led to some of the inconsistencies present in the results. However, the models appeared to define the cost structure adequately, given the data limitations.

Network Flow Model

Average variable cost of elevators in Crop Reporting District 3 was used as an input for the network flow model of grain movements. The sample of elevators from this area consisted of 51 observations.

Average variable cost was estimated as a function of licensed storage capacity and volume of grain handled. Both estimates were significant at the 10 percent level. A more precise model could have been achieved involving additional independent variables provided the data were available for all elevators.

Analysis by Stratification

The sample of 205 observations was stratified by volume of grain handled with each stratification containing approximately the same number of observations. Functions were derived utilizing numerous dependent variables and one independent variable, LOG(GRH), to determine possible economies of size. Significance levels associated with ATC, AFC, and AVC varied between stratifications. A continuously decreasing function was defined when the second stratum and all insignificant parameter estimates were ignored.

Turnover ratio was stratified into four categories with approximately the same number of observations in each category. A function with the independent variable, LOG(TUR), was utilized in the same manner as the previous analysis. Similar results occurred with a continuously decreasing function being defined.

Graphic Analysis of Overall Sample

The functional relationships between ATC, AFC, and AVC of grain handled and turnover ratio were analyzed for the overall sample of 205 elevators with all functions expressed in logrithmic form. The functional relationships for ATC and AFC were continuously decreasing when independently compared to LOG (GRH) and LOG(TUR). LOG(GRH) did not significantly measure the variability inherent with AVC while LOG(TUR) related AVC as relatively constant, indicating AVC did not change significantly with increases in elevator size.

Analysis of Average Values

Average values were determined for average total cost, average variable cost and each of the seven previously mentioned elevator characteristics. Stratification by volume of grain handled was categorized in the same manner previously described. Storage capacity and turnover ratio increased while ATC declined as volume of grain handled increased.

Average values received from stratification by turnover ratio were somewhat different than stratification by volume of grain handled. Storage capacity decreased with increases in turnover ratio and volume of grain handled. Average variable cost remained constant while average total cost decreased continuously as turnover ratio increased.

Average values of the cost components associated with the overall sample of 205 elevators revealed that considerable variability in costs existed within the sample. All other characteristics of the sample consisted of a wide range of values, indicating a wide array of sizes, age, throughput, etc. of the grain elevator industry in North Dakota.

Conclusions

All conclusions on efficiency were based on the results received through empirical analyses. The analyses revealed that no minimum point was attained suggesting that few elevators within the sample were operating near the minimum cost point. The reason for elevators not operating near the minimum cost point might be due to the nature of the agricultural industry. A local elevator must be large enough to handle the harvest peak demand within its region while being small enough where underutilization is not significant at off peak times. Another reason may be due to the inability of the elevator managers to use the available resources (i.e., land, labor, and machinery) as efficiently as possible.

The number of elevators in North Dakota has been declining in North Dakota at a rate of 12 per year during the 1964 to 1980 period. Several factors will determine the fate of the elevators in North Dakota: branch line abandonment; deregulation of rail rates; amount of remodeling of existing facilities within a competitive region; the potential of elevator mergers; and the factor, elevator management. Changes within the elevator industry are occurring and will continue to occur. Elevator management must be fully aware of these changes and possibly alter operations to remain competitive within this region.

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