IOWA'S GRAIN-ELEVATOR INDUSTRY: Factors Affecting Its Organization and Structural Adjustment

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SUMMARY

In December 1970, there were 1,178 grain elevators in Iowa. The total storage capacity of these elevators was in excess of 432 million bushels. In recent years, both the number and the storage capacity of elevators have been increasing. More than half the elevators had a storage capacity of 300,000 bushels or less. This group, however, accounted for only 21 percent of the total storage capacity. The current organization of the industry is typified by an elevator that receives corn and soybeans from a supply area with a radius of 5 to 7 miles.

A statistical cost function, derived from data from over 150 cooperative elevators, indicated that significant economies of scale exist in elevator operations. This cost function showed that an elevator with a capacity of 300,000 bushels would have an average cost of 11 cents per bushel of grain handled, compared with a cost of 7.9 cents for an elevator with a capacity of 2 million bushels. Since the statistical cost function was based on accounting data reflecting historical investment costs and interest rates, these estimates of elevator costs should be regarded as conservative.

An engineering cost function was developed that incorporated the current level of investment and operating costs of new elevator facilities. This function indicated a cost of 16 cents per bushel for storing and handling grain in a 300,000-bushel elevator compared with a cost of 9.5 cents per bushel in a facility of 2 million bushels storage capacity. Costs continued to decrease for larger sizes of elevators, but at a slower rate.

It seems that, if the current industry structure consisted of fewer and larger elevators, the over-all cost of assembling and storing grain in Iowa could be reduced. The magnitude of the costs savings could well be within a range of 1 to 4 cents per bushel, depending on the average size and location of the elevators in the adjusted structure and the rate at which old installations were phased out.

Projections of Iowa's demand for grain-handling services indicate that a substantial capacity expansion will be required in the future. Grain marketings are projected to increase by about 80 percent over recent levels, totaling about 1.2 billion bushels annually by 1980. In addition, grain receipts at elevators will tend to concentrate more in the fall harvest period, with a projected 150-percent increase in fall grain movements. Thus, not only will elevators have to expand storage capacity, but the elevators also must be prepared to receive, condition, and store a larger volume of grain in a shorter time.

Given the projected 1980 grain movements, an elevator structure with considerably fewer elevators of a much larger size than currently exists would result in substantial savings in marketing costs. Most economies can be achieved in an average trade area with a radius of 11 to 12 miles from the elevator in all crop reporting districts in the state. Under this criterion, 210 elevators of an average storage capacity of 3.5 million bushels would be required in Iowa in 1980. This more nearly least-cost industry organization would require a marked reduction in the number of elevators and an expansion in average size to almost 10 times the present average.

Variations exist in grain-marketing density and in elevator turnover rates by district in the state. As a result, the estimated average elevator sizes to achieve available economies range from about 1.5 million bushels in some districts to over 5 million bushels of storage capacity in others. Moreover, such factors as total grain sales, seasonal distribution of sales, elevator turnover rates, and transportation facilities vary within districts and must be considered in determining the number, size, and specific location within a district.

This study concentrated on grain handling and storage. Analysis of the multiproduct aspects of elevator operations seems desirable to ascertain the size of facility and trade area that would efficiently provide, not only elevator services, but feed, fertilizer, and other farm supplies as well. Moreover, this study has not attempted to ascertain possible economies in the out-shipment of grain from the elevator. Thus, an extension of the analysis would incorporate a cost function for outbound grain shipment in the model.

The results, based on a least-cost approach that assumes that each elevator has a 100-percent market share in its supply area, provide generalized guidelines for future adjustment of the elevator industry in Iowa that could lead to substantial cost savings to the industry and to farmers. The optimum number and size of facilities in a particular geographic area of the state must be determined by considering the factors included in this analysis, market-share patterns, and a detailed examination of current and future transportation facilities in the area. Similarly, the time pattern by which existing facilities should be phased out and new facilities built requires intensive analysis of each area.

Iowa's Grain-Elevator Industry: Factors Affecting Its Organization and Structural Adjustment[1]

by Richard J. Mikes,[2] Lehman B. Fletcher,[3] and Gene A. Futrell[3]

In 1970, Iowa produced 859 million bushels of corn and 187 million bushels of soybeans. This production of over a billion bushels of grain annually places Iowa among the leading grain-producing states in the nation. Grain production and marketing are thus of great importance in Iowa's agricultural economy.

Grain production has been increasing for many years, leading to a larger movement of grain off farms to elevators. The increased grain production has been accomplished by a dramatic shift in corn-harvesting technology. In 1960, only 10 percent of the corn crop was harvested as shelled corn by picker-shellers and corn combines. The rest was harvested as ear corn by mechanical pickers. By 1970, 54.2 percent of the corn was harvested shelled. Field shelling has been encouraged by the ability to handle a larger volume of grain with a given labor supply, reductions in risk of excessive field losses due to severe weather, improved field-shelling equipment, and other factors. The shift to field shelling has not been uniform throughout the state. But, it is likely to be a continuing trend in all areas.

Field shelling of corn results in large quantities of high-moisture corn moving to elevators in a short period in the fall. In 1970, over 20 percent of the crop moved to elevators at harvest time. Moreover, high-moisture corn is a perishable product and requires specialized drying and conditioning. As more high-moisture corn flows to elevators, additional investment in grain-drying equipment, storage facilities, and high-speed receiving facilities is required.

Grain-storage capacity at elevators in Iowa rose from about 350 million bushels in the late 50's to about 443 million bushels as of Jan. 1, 1971. The industry was faced with excess storage capacity in the mid-60's as a result of smaller Commodity Credit Corporation grain stocks associated with shifts in government farm programs. As production increased and field shelling was adopted in the late 60's, demand for elevator storage increased, again leading to rapid expansion in capacity.

The elevator historically was located close to the farms it served. Grain moved from farm to elevator by horse and wagon. Thus, a proliferation of elevators and small towns emerged in Iowa, dependent on and serving farmers in the local trade area. The need for a large number of small elevators scattered throughout rural communities is now questionable in light of modern transportation equipment, the road system available, and elevator technology. The farmer can now transport his grain longer distances in a shorter time. The low additional cost per bushel to haul grain beyond traditional trading boundaries creates an incentive for larger elevators located further apart to take advantage of economies of scale in elevator operations.

Economies of scale in elevator operations reduce costs per bushel and encourage the development of fewer and larger installations. Assembly costs, or costs of moving corn from farms to elevators, tend to raise costs per bushel as elevators become larger. This "tradeoff" between scale economies and transportation costs has an important influence on the number, size, and location of country elevators that will minimize marketing costs.

This study analyzes, as an over-all objective, the relative magnitude of these opposing cost factors and investigates adjustments in size and location of elevators needed to reduce costs under present and projected levels of grain marketings. The size, number, location, and operation of grain-storage facilities are of primary importance in determining the costs of marketing grain. Transportation costs and charges for handling grain in fixed facilities account for a large proportion of marketing costs. The costs of moving grain from farms and of conditioning, handling, and storing grain at elevators are the focus of this study.

The specific objectives of the study were: (1) Determine the number and size distribution of country elevators. (2) Estimate economies of scale in elevator operations, based on an analysis of costs in the current system and on an engineering cost simulation of model elevators. (3) Estimate an optimum number and size of elevators in terms of a least-cost system of grain assembly and grain handling. (4) Compare the optimum organization with the current industry structure, and project the optimum structure for the elevator industry for conditions expected to prevail in 1980.

As a first step in the study, trends in the number, size, and utilization of existing elevators are described. Subsequently, movements of grain from farms to elevators and estimated 1980 movements on the basis of projected production and marketing patterns are presented. Next, costs of transporting and handling grain are estimated. Finally, possibilities for cost reductions in grain marketings under current conditions and 1980 projections are evaluated.

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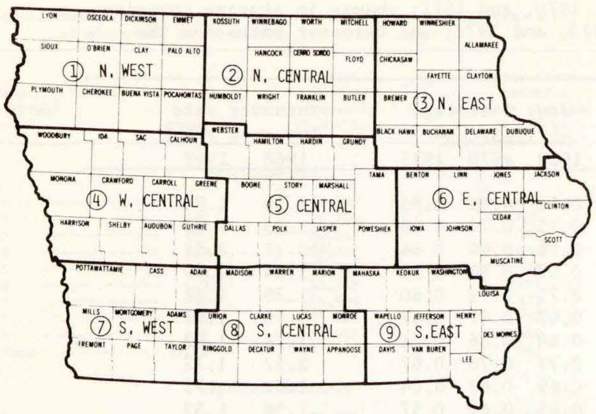

Fig. 1. Iowa's counties grouped into nine crop reporting districts.

The study focuses on the nine crop reporting districts in Iowa, as delineated by the USDA Statistical Reporting Service. This breakdown is convenient because of the availability of data on a district basis. The districts are shown in fig. 1. These districts do not constitute homogeneous economic regions; nevertheless, the organization and needed adjustment of the elevator industry are sufficiently different between regions to make the districts useful for purposes of this study.

THE IOWA ELEVATOR INDUSTRY

Country elevators are elevators that receive most of their grain directly from farmers. Another class of elevators is the terminal (and subterminal) and processing group. Terminal elevators and processors receive most of their grain from other elevators, not directly from the farm.

In Iowa, country elevators are the primary outlet for feed grains moving off the farm. There is only minor movement directly from the farm to subterminal and processing outlets. Soybeans follow a similar marketing channel. As the primary receivers of feed grains and soybeans from farms, country elevators are important in the total grain-marketing system.

Because the country elevator is the primary outlet for grain sold off farms in Iowa, the various functions of the country elevator are of direct interest and importance to producers. The country elevator provides facilities for receiving grain directly from farmers, and drying, storing, and reloading the grain for rail, truck, or, in some instances, barge shipment. The storage capacities of country elevators in Iowa vary from a few thousand bushels to more than 4 million bushels.

The country elevator may be operated as an independent business, as a branch owned by a firm owning several grain elevators, or as a cooperative owned and operated by farmers. Most country elevators in Iowa engage in many activities other than grain handling. The other activities often include feed mixing and retailing, fertilizer blending and retailing, and retailing other farm supplies. In many instances, the other activities of the elevator dwarf the grain-handling activity. These other activities are often complementary to the elevator's grain business because of better seasonal utilization of labor force, management, and facilities. There also is a relationship between the grain and other activities in terms of attracting patrons.

Trends in Elevator Grain-Storage Capacity and Utilization

Data indicate that a major expansion in elevator storage capacity occurred in the late 1950's (table 1). In 1951, storage capacity of elevators in Iowa was about 90.7 million bushels. By 1957, capacity had more than doubled to over 200 million bushels. In the 4 years from 1957 to 1961, storage capacity rose to about 350 million bushels and remained at about that level until 1968. Since 1968, capacity has increased each year.

The expansion in elevator capacity in Iowa has not been uniform across districts. Table 2 shows the off-farm storage capacity by districts and for Iowa as of Jan. 1 for 1969-71. (Data were not available for any year before 1969 for individual districts.) District 5 (central Iowa) has nearly one-fourth of the total capacity in the state with a storage capacity of 92.6 million bushels on Jan. 1, 1969, and 101.9 million bushels on Jan. 1, 1971. Over the last 3 years, the most rapid growth in storage capacity was in District 1 (northwestern Iowa). Both District 3 (northeastern Iowa) and District 8 (south-central Iowa) have relatively low storage capacities.

Storage utilization, measured as the proportion of total off-farm storage capacity occupied by corn and soybean stocks on Jan. 1, varies between districts and within districts by year. Utilization was 0.65 or higher in 1969 and 1970, but dropped to 0.57 in 1971 for the state as a whole (table 2). District 1 (northwestern Iowa) had a utilization rate of 0.73 in 1970 compared with only 0.53 in 1971. District 6 (east-central Iowa) consistently had the lowest utilization of any district.

Table 1. Elevator storage capacity in Iowa, Jan. 1, 1951-71, in thousands of bushels

Crop year	Capacity
1951	90,729
1954	122,846
1957	213,546
1961	343,400
1962	343,400
1963	359,800
1964	348,300
1965	351,800
1966	359,000
1967	359,500
1968	370,700
1969	404,050
1970	437,600
1971	442,600

Source: Dale Awtry. Personal communication. Iowa State Department of Agriculture, Des Moines. 1971.

Table 2. Off-farm storage capacity in Iowa, Jan. 1, 1969, 1970, and 1971; change in storage capacity, 1969-1971; storage utilization, Jan. 1, 1969, 1970, and 1971; and turnover rates for the 1968 and 1969 crop years.

Crop reporting district	Jan. 1 capacity (1,000 bu)			Percentage change	Jan. 1 storage utilization[a]			Turnover rate for crop year[b]	
	1969	1970	1971	1969-1971	1969	1970	1971	1968	1969
1	52,950	57,700	61,000	15	0.61	0.73	0.53	1.50	1.95
2	56,300	63,600	63,800	13	0.73	0.70	0.58	2.03	1.73
3	17,200	18,500	18,500	8	0.76	0.64	0.64	3.17	2.55
4	76,100	79,400	79,800	5	0.59	0.68	0.55	1.04	1.17
5	92,600	101,500	101,900	10	0.71	0.71	0.60	1.39	1.18
6	37,200	38,200	38,500	3	0.47	0.47	0.47	1.70	1.68
7	32,500	36,300	36,400	12	0.60	0.66	0.51	1.14	1.42
8	12,600	13,800	14,000	11	0.77	0.70	0.67	2.52	1.72
9	26,600	28,600	28,700	8	0.69	0.67	0.64	1.87	1.73
Iowa	404,500	437,600	442,600	10	0.65	0.67	0.57	1.58	1.53

Source: Jack Aschwege. Personal communication. Iowa Crop Reporting Board, Des Moines. 1971.

[a]Ratio of corn and soybean stocks on Jan. 1 to off-farm storage capacity.

[b]Ratio of grain sales to storage capacity. Sales data for the 1970 crop year were not available when these data were obtained.

Stocks in storage on a given date represent one measure of utilization. Another measure of utilization is the turnover rate. The turnover rate is defined as the total annual grain sales in a district divided by total storage capacity within the district. The average turnover rate of the state for both 1968 and 1969 crop years was slightly above 1.5. Thus, on the average, elevators in the state handled a volume of grain equal to 1.5 times their storage capacity. Turnover rates for districts range from a low of nearly 1 to more than 3. The actual turnover rates experienced by elevators in the crop reporting districts would tend to be higher than those shown in the table, however, because of the subsequent shipment of grain from country elevators to terminal facilities and processors. The grain-sales figures used to calculate turnover do not measure the total flow through all elevators, but, instead, the initial flow of grain from farms to elevators. Preliminary data indicated that the turnover rate declined to about 1.4 in 1970 for Iowa.

Total grain sales in 1969 and 1970 were about equal, but storage capacity in elevators had increased about 10 percent. As noted previously, the actual flow through the elevator facilities would be higher than these turnover figures indicate. Since most grain moves through the local or country elevator and then on through the terminal or processing elevator, the farm-sales data would not be equal to total volume through all the elevator facilities.

Number, Capacity, and Ownership of Elevators

Published data on storage capacity by county were not available from any source. Therefore, a complete inventory of elevators licensed by the Warehouse Division of the Iowa Commerce Commission and by the Transportation and Warehouse Division of the U.S. Department of Agriculture was conducted for August 1969 and December 1970. In addition, a limited number of unlicensed grain-processing elevators was added to both lists.

The inventory for August 1969 showed 1,136 elevators, representing over 394 million bushels of storage capacity. The inventory for December 1970 showed 1,178 elevators with a total capacity of over 432 million bushels.

Size data on all elevators and on country elevators by districts in 1969 are shown in table 3.

Table 3. Number, total storage capacity, and average storage capacity of elevators, August 1969.

Crop reporting district	Number	Total storage capacity (1,000 bu.)	Average storage capacity per elevator (1,000 bu.)
	All elevators		
1	161	52,953	328
2	143	56,871	397
3	85	15,853	186
4	176	74,214	421
5	210	93,322	444
6	115	29,126	253
7	100	33,735	337
8	49	14,232	290
9	97	24,139	248
Iowa	1,136	394,445	347
	Country elevators		
1	160	51,232	320
2	141	54,061	383
3	83	14,318	172
4	172	63,126	367
5	201	72,471	360
6	103	14,935	145
7	95	22,523	237
8	47	12,245	260
9	94	21,007	223
Iowa	1,096	325,918	297

Source: Unpublished data obtained from Warehouse Division, Iowa Commerce Commission, Des Moines, Iowa, and Transportation and Warehouse Division, U.S. Dep. Agric., Omaha, Nebraska.

Table 4. Number, total storage capacity, and average storage capacity of elevators, December 1970.

Crop reporting district	Number	Total storage capacity (1,000 bu.)	Average storage capacity per elevator (1,000 bu.)
		All elevators	
1	175	63,100	360
2	144	61,144	424
3	102	18,149	177
4	180	79,119	439
5	211	99,255	470
6	119	34,255	287
7	97	36,678	378
8	51	14,820	290
9	99	25,971	262
Iowa	1,178	432,491	367
		Country elevators	
1	174	61,379	352
2	142	58,334	410
3	100	16,614	166
4	176	68,031	386
5	202	78,118	386
6	107	18,815	175
7	92	25,592	278
8	49	12,833	261
9	96	22,839	237
Iowa	1,138	362,555	319

Source: Unpublished data obtained from Warehouse Division, Iowa Commerce Commission, Des Moines, Iowa, and Transportation and Warehouse Division, U.S. Dep. Agric., Omaha, Nebraska.

The largest average size for country elevators in the state was 383,000 bushels in District 2 (north-central Iowa). District 6 (east-central Iowa) had the smallest average size, with an average capacity of 145,000 bushels. The average capacity of all country elevators in Iowa was slightly under 300,000 bushels in August 1969.

Size data for all elevators and country elevators for December 1970 are given in table 4. Between August 1969 and December 1970, the average size of country elevator in Iowa increased from 297,000 to 319,000 bushels. District 3 (northwestern Iowa) experienced a decrease in average size of country elevator from 172,000 bushels to 166,000 bushels. The average size increased in all other districts.

Because the number of elevators increased between the two inventory dates, the data do not reveal how much of the growth in capacity was due to new elevators and how much to expansion of existing elevators. It would be useful to know, for example, if the new country elevators tended to be larger or smaller than average.

A more detailed examination of the elevator size distribution in December 1970 is presented in table 5. The largest size category, 2 million bushels and over, included 15 elevators with a total storage capacity of 48.7 million bushels. This size group represented slightly over 1 percent of the total elevators, but more than 11 percent of the total storage capacity in the state. There were 122 elevators with capacity of less than 50,000 bushels in 1970. Although this group represented 10.4 percent of the total elevators, it accounted for less than 1 percent of the total storage capacity. Over half the elevators had a capacity of under 300,000 bushels, but this group included only 21 percent of the total storage capacity.

Figure 2 depicts elevator storage capacity by districts for December 1970. The shaded area in each bar represents the storage capacity of country elevators, and the unshaded portion of the bar is the terminal and processing storage capacity. Districts 4 (west-central Iowa) and 5 (central Iowa) had the largest capacity, followed closely by districts 1 (northwestern Iowa) and 2 (north-central Iowa). (Data on the number and storage capacities of country elevators by county are given in Appendix fig. A-1.)

Table 5. Size distribution of grain elevators in Iowa, December 1970.

Capacity class (1,000 bu.)	No. of elevators	Total capacity (1,000 bu.)	Percentage of Elevators	Percentage of Capacity	Cumulative percentage Elevators	Cumulative percentage Capacity
2,000 & over	15	48,696	1.27	11.26	99.99	99.99
1,800-1,999	2	3,616	0.17	0.84	98.72	88.73
1,700-1,799	6	10,494	0.51	2.43	98.55	87.90
1,600-1,699	3	4,855	0.25	1.12	98.04	85.47
1,500-1,599	1	1,501	0.08	0.35	97.78	84.35
1,400-1,499	5	7,274	0.42	1.68	97.70	84.00
1,300-1,399	4	5,359	0.34	1.24	97.28	82.32
1,200-1,299	9	11,281	0.76	2.61	96.94	81.08
1,100-1,199	9	10,452	0.76	2.42	96.17	78.47
1,000-1,099	14	14,643	1.19	3.39	95.41	76.06
900- 999	11	10,478	0.93	2.42	94.22	72.67
800- 899	20	16,620	1.70	3.84	93.29	70.25
700- 799	40	29,709	3.40	6.87	91.59	66.41
600- 699	41	26,268	3.48	6.07	88.20	59.54
500- 599	82	44,495	6.96	10.29	84.72	53.46
400- 499	97	43,152	8.23	9.98	77.76	43.18
300- 399	151	52,121	12.82	12.05	69.52	33.20
200- 299	183	45,721	15.53	10.57	56.70	21.15
100- 199	219	31,664	18.59	7.32	41.17	10.58
50- 99	144	10,499	12.22	2.43	22.58	3.26
0- 49	122	3,593	10.36	0.83	10.36	0.83

Source: Unpublished data obtained from Warehouse Division, Iowa Commerce Commission, Des Moines, Iowa, and Transportation and Warehouse Division, U.S. Dep. Agric., Omaha, Nebraska.

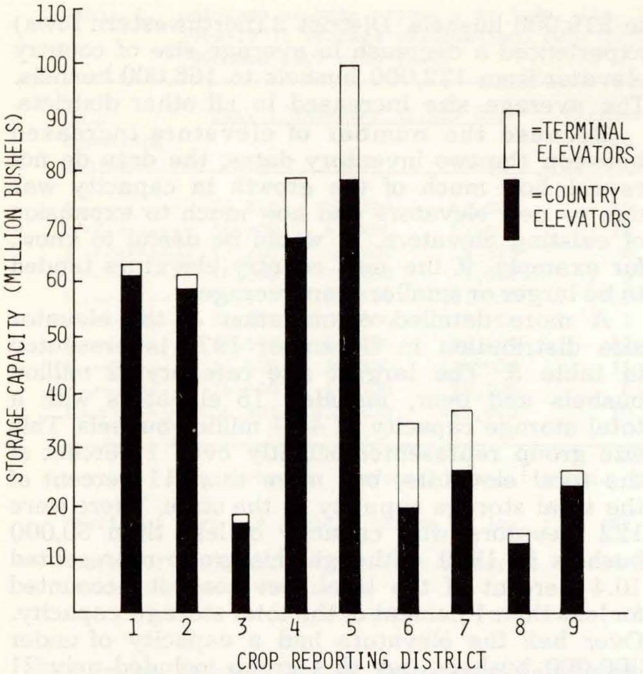

Fig. 2. Storage capacity of country and terminal elevators by crop reporting district in Iowa, December 1970.

Another aspect of the organization of the elevator industry is the type of ownership. All cooperatively owned elevators were grouped for comparison with other ownership forms. In August 1967, there were 400 cooperative elevators, representing 36 percent of the total elevators in Iowa (table 6). The cooperative elevators had a combined storage capacity of 187 million bushels. The heaviest concentration of cooperative ownership was in District 2, with 82 elevators representing almost three-fourths of the total storage capacity in that area. Cooperatives in districts 6, 7, and 9 represented only about one-sixth of the total number of elevators. Cooperatives accounted for more than half the storage volume in districts 1, 2, 4, and 5.

Cooperative country elevators also account for about 36 percent of all country elevators in the state. The cooperative group, however, includes more than 50 percent of the total storage capacity of country elevators. This means that, on the average, cooperative country elevators are larger than country elevators under other forms of ownership.

Table 6. Number, total storage capacity, and average storage capacity of cooperative elevators, August 1969.

Crop reporting district	Number	Storage capacity (1,000 bu.)	Average storage capacity (1,000 bu.)
		All cooperative elevators	
1	78	36,006	461
2	83	40,775	491
3	31	6,795	219
4	61	34,908	572
5	83	49,137	592
6	19	4,892	257
7	17	4,494	264
8	18	4,819	370
9	15	5,464	364
Iowa	400	187,290	468
		Cooperative country elevators	
1	77	34,285	445
2	82	39,615	483
3	30	6,285	209
4	61	34,908	572
5	82	40,797	497
6	18	4,422	245
7	17	4,494	264
8	13	4,819	370
9	14	4,994	356
Iowa	394	174,619	443

Source: Cooperative elevators identified by information obtained from Farmers Grain Dealers Association, Des Moines, 1971.

GRAIN MARKETINGS AND MOVEMENTS

The increasing production of corn and soybeans in Iowa has resulted in an increased flow of grain from farms to local elevators. Corn production in Iowa rose from 754.7 million bushels in 1964 to 922.8 million bushels in 1969, while off-farm sales of corn increased from 316.7 million bushels to 424.5 million bushels (table 7). Thus, Iowa has experienced, not only a growth in corn production, but also an increase in the share of the corn crop that moves off farms. In 1964, it was estimated that about 42 percent of the crop was sold off the farm, compared with 46 percent in 1969.

The increase in soybean production in Iowa has been especially dramatic. Soybean sales rose more than 50 million bushels between 1964 and 1969 (table 7). Historically, almost 98 percent of the soybean crop has been sold off the farm, with the remainder being used mainly for seed and a very limited amount for livestock feeding.

Oat production and marketings have declined since 1964. Usually, oats are fed on the farm where produced or saved for seed; only about 28 percent of the oats produced are sold off the farm.

In 1964, total corn, soybean, and oat sales were just over 465 million bushels. By 1969, total sales had increased by a third (155 million bushels). Total grain sales in both 1968 and 1969 amounted to about 620 million bushels. These grain sales represented total off-farm movements of grain estimated by the Statistical Reporting Service, based on a sampling procedure. The sample used for this estimate is largely composed of general livestock farms and is not a cross section of all types of farms. More grain would tend to be fed on farms with livestock than on specialized cash-grain farms. Thus, these estimates probably understate off-farm movements of grain.

The trend to field shelling of corn in Iowa and other Corn Belt states also is significant for country elevators. In 1964, 81 percent of the corn left the field as ear corn (table 8). By 1970, less than half the corn was harvested as ear corn. Iowa, thus, is following the trend of Indiana and Illinois where, by 1970, less than one-fourth of the total corn crop was harvested as ear corn. In 1970, 45.6 percent of Iowa's 10 million acres of corn for grain was harvested with combines, up from only 12.7 percent in 1964. Field picker-shellers were used to harvest

Table 7. Grain production, grain sales, and share of production sold in Iowa by crop years, 1964-69.

Grain	1964	1965	1966	1967	1968	1969
	Crop year					
	Grain production and sales (1,000 bu.)					
Corn:						
Produced	754,695	814,506	901,748	986,332	912,144	922,768
Sold	316,742	333,947	396,769	433,986	410,465	424,473
Soybeans:						
Produced	121,239	126,100	147,382	144,265	177,952	174,339
Sold	118,141	122,910	144,090	140,976	174,847	171,205
Oats:						
Produced	112,714	104,948	106,866	101,370	106,436	92,000
Sold	30,433	28,336	29,922	28,384	35,124	24,840
Total sold	465,316	485,193	570,781	603,346	620,436	620,518
	Share of production sold					
Corn	0.42	0.41	0.44	0.44	0.45	0.46
Soybeans	0.97	0.98	0.98	0.98	0.98	0.98
Oats	0.27	0.27	0.28	0.28	0.33	0.27

Source: Iowa Crop and Livestock Service. Annual Crop Summary. Agricultural Statistician's Office, Federal Building, Des Moines, 1969.

Table 8. Percentage of corn acreage harvested by designated methods, 1964, 1967, and 1970.

Crop reporting district and state	Mechanical picker			Field picker-sheller			Corn head on combine		
	1964	1967	1970	1964	1967	1970	1964	1967	1970
1	88.6	73.5	63.5	4.3	5.6	6.7	7.1	20.9	29.7
2	84.2	55.7	46.6	5.5	9.3	8.1	10.3	34.8	45.3
3	82.3	62.4	40.3	9.9	11.3	9.3	7.5	25.7	50.0
4	83.3	66.3	59.1	5.3	4.2	5.7	11.4	29.5	35.2
5	77.4	51.2	32.7	6.9	7.2	8.2	15.6	41.6	59.0
6	84.8	57.5	39.6	5.2	8.9	15.0	9.7	33.3	45.3
7	78.7	65.9	48.0	5.2	10.7	8.0	16.1	23.4	43.6
8	74.8	69.0	39.2	9.2	7.1	3.7	16.0	23.7	57.0
9	66.6	45.1	30.5	4.7	6.6	10.1	28.4	48.1	59.3
Iowa	81.2	60.5	45.8	6.0	7.7	8.4	12.7	31.5	45.6
Illinois	55.0	36.0	24.0	7.0	8.0	7.5	38.0	56.0	68.5
Indiana	47.2	28.8	22.7	7.0	8.7	7.3	45.1	62.2	69.0
Minnesota	--[a]	58.4	40.5	--[a]	9.4	8.8	--[a]	31.4	50.5

Source: Iowa Crop and Livestock Reporting Service. Corn for grain: harvesting, handling, and drying methods. Agricultural Statistician's Office, Federal Building, Des Moines. Annual issues, 1964-70.

[a]Not available.

8.4 percent of the corn acreage in 1970, compared with 6.0 percent in 1964.

The shift to field shelling and the use of corn combines has not been uniform across the state (table 8). All districts have shown increases in field shelling and combining from 1964 to 1970; the rate of adoption of these practices, however, has varied. It seems likely that the proportion of corn harvested as ear corn will continue to decrease in all districts.

The implications of field shelling on corn marketing can be summarized briefly as: (1) an increasing flow of high-moisture corn requiring drying and specialized handling and (2) an increasing proportion of corn moving to elevators during the fall harvest period.

Since high-moisture corn is a perishable commodity, the elevators must be prepared to condition and store the corn within a few days after delivery. The long line of farm trucks and wagons waiting to unload at country elevators points up a possible gap between the greatly expanded harvest capacity and the drying and storage capacity at the elevator. Many elevators are not equipped to receive and handle high-moisture corn as rapidly as farmers can deliver it. As a result, Iowa elevators have been faced with the need for major adjustments in services and facilities over the past few years.

Table 9. Methods of handling corn at harvest, 1964, 1967, and 1970, in percentages.

Crop reporting district and state	Marketed direct from field 1964	1967	1970	Stored by producer off farm 1964	1967	1970
1	5.2	6.6	10.8	0.6	7.6	6.9
2	4.8	8.3	13.4	1.2	12.0	7.0
3	7.2	7.3	10.6	0.6	6.1	4.7
4	10.2	6.1	11.7	2.2	6.6	10.2
5	9.6	6.1	17.3	0.5	12.9	12.1
6	9.1	7.7	11.2	0.7	6.1	4.2
7	11.8	4.0	9.8	0.7	8.1	5.9
8	10.7	9.6	17.7	2.3	10.1	4.5
9	14.3	9.3	16.2	2.3	19.0	11.8
Iowa	8.7	7.0	13.1	1.1	9.7	7.8
Illinois	24.0	17.5	21.5	4.0	14.0	13.5
Indiana	24.0	31.4	29.3	5.5	12.8	12.3
Minnesota	--[a]	11.5	18.4	--[a]	5.0	5.0

Source: Iowa Crop and Livestock Reporting Service. Corn for grain: harvesting, handling, and drying methods. Agricultural Statistician's Office, Federal Building, Des Moines. Annual issues, 1964-70.

[a]Not available.

Table 11. Stocks of grain in selected positions on Jan. 1, storage capacity, and capacity utilization, 1965-70, in thousands of bushels.

Iowa	1965	1966	1967	1968	1969	1970
Corn stocks:						
On farms	751,281	781,926	757,468	838,382	820,930	848,947
Off farms[a]	331,991	226,456	136,128	170,969	203,280	202,879
Soybean stocks:						
On farms	44,858	65,572	84,008	86,559	112,110	94,143
Off farms[a]	55,837	50,925	58,729	68,400	105,239	144,146
Total corn and soybeans:						
On farms	796,139	847,498	841,476	924,941	933,040	943,090
Elevators	228,035	170,509	170,439	216,470	261,945	295,725
CCC bin sites	159,793	106,872	24,418	22,899	46,574	51,300
Storage capacity:						
Elevators	351,800	359,000	359,500	370,000	404,500	437,600
CCC bin sites	285,644	--	198,032	--	107,920	--

Source: U.S.Dep. Agric., Statistical Reporting Service. Stocks of grains in all positions. Crop Reporting Board Quarterly Reports 1963-71; and Dale Awtry, Iowa Dep. Agric., Des Moines, private communication, 1971.

[a]Includes stocks at elevators, terminals, processors, and CCC bin sites.

Iowa farmers marketed 13 percent of their corn crop directly from the field in 1970 and stored about 8 percent of it off their farms (table 9). In 1964, the combined total of corn marketed directly from farms and stored off the farm by producers was less than 10 percent. The fall movement of new-crop corn is defined for the purpose of this analysis as the sum of the corn marketed directly from fields plus the corn stored by producers off farms (table 9).

In 1969, almost 200 million bushels of corn moved to the elevators during the fall harvest (table 10). This fall movement of corn was equivalent to 46.7 percent of the total corn sold during the 1969 crop year. This was double the share of the crop that moved in the fall in 1964. Thus, elevators received an additional 125 million bushels of corn during the fall period in 1969 compared with 1964.

The amount of soybeans moved to elevators during the fall harvest season was estimated by considering soybean production and changes in farm stocks of soybeans between Sept. 1 and Jan. 1. Fall movement of soybeans was defined as equal to Sept. 1 farm stocks, plus production, less Jan. 1 farm stocks, which are shown in table 11. The share of the fall movement was defined as the ratio of fall movement to production for the crop year. Fall movement of soybeans increased from about 82 million bushels in 1964 to 112 million bushels in 1969 (table 12). The share moved in the fall ranged from slightly over 46 percent to slightly over 67 percent. The average over the 1964-69 period was 55.7 percent.

The increasing fall movement of corn, coupled with increasing soybean production, has resulted in almost a doubling of fall grain receipts at grain elevators from 1964 to 1969. The total fall movement of corn and soybeans increased from 155.6 million bushels in 1964 to 310.6 million bushels in 1969 (table 12).

The ability of the country elevator system to ship grain received in the fall to terminal and processing points influences the rate at which grain can be received. Estimates of the amount of grain shipped out of country and terminal elevators were derived by adding the fall movement to the elevator stocks at the beginning of harvest and then subtracting Jan. 1 elevator stocks. Elevator shipments of soybeans during the fall were equivalent to 15.6 percent of the soybeans received in 1966 and 44.2 percent of the soybeans received in 1969 during the fall. A larger share of the corn received, as compared with soybeans received, was shipped from the elevators during the fall. In 1964, elevators shipped 45.9 million bushels of corn during the fall, or 62 percent of the total fall receipts. By 1969, 104 million bushels were shipped, slightly over half the total receipts. The combined elevator shipments of corn and soybeans during the fall quarter rose from 77.7 million bushels in 1964 to 153.8 million bushels in 1969 (table 12).

Table 10. Corn-harvesting method, fall movement of corn, and share of crop moved in fall by crop year, 1964-69.

Iowa	1964	1965	1966	1967	1968	1969
Percentage ear corn[a]	81.2	75.2	66.2	60.5	56.6	51.1
Fall movement:[b]						
Percentage of crop	9.8	10.4	15.7	16.7	18.1	21.5
Bushels (1,000)	73,960	84,709	141,574	164,717	165,098	198,395
Percentage of sales[c]	23.3	25.3	35.6	37.9	40.2	46.7

Source: Iowa Crop and Livestock Reporting Service. Corn for grain: harvesting, handling, and drying methods. Agricultural Statistician's Office, Federal Building, Des Moines. Annual issues, 1964-70.

[a]Corn reported as harvested by mechanical picker.

[b]Fall movement is the corn marketed direct from field plus corn stored off farm by producers.

[c]Fall movement of corn as percentage of corn sales.

Table 12. Estimated fall movements of grain in Iowa, 1964-69, in thousands of bushels.

Grain	1964	1965	1966	1967	1968	1969
Soybeans:						
Production --	121,239	126,100	147,382	144,265	177,952	174,339
Fall movements[a] --	81,680	64,771	68,081	76,866	91,810	112,227
Share, fall movements[b] --	0.674	0.514	0.462	0.533	0.516	0.644
Fall shipments[c] --	31,854	18,907	10,613	20,847	19,259	49,643
Share shipped[d] --	0.390	0.292	0.156	0.271	0.210	0.442
Corn:						
Production --	754,695	814,506	901,748	986,332	912,144	922,768
Fall movements --	73,960	84,709	141,574	164,717	165,098	198,395
Share, fall movements[e] --	0.233	0.253	0.356	0.379	0.402	0.467
Fall shipments[c] --	45,886	53,657	88,597	54,422	72,396	104,127
Share shipped[d] --	0.620	0.633	0.626	0.330	0.439	0.525
Total corn and soybeans:						
Fall movements --	155,640	149,480	209,655	241,583	256,908	310,622
Fall shipments[c] --	77,740	72,564	99,210	75,269	91,655	153,770
Share shipped[d] --	0.499	0.485	0.473	0.312	0.357	0.495

Source: Iowa Crop and Livestock Reporting Service. Annual crop summary, 1969; and U.S. Dep. Agric. Statistical Reporting Service. Stocks of grains in all positions, 1963-71.

[a]Fall movements of soybeans equals Sept. 1 farm stocks, plus production, less Jan. 1 farm stocks.

[b]Ratio of fall movement of soybeans to soybean production.

[c]Fall movements plus elevator stocks (Sept. 1 for soybeans, Oct. 1 for corn) less Jan. 1 stocks in elevators; elevator stocks include stocks in CCC bin sites.

[d]Ratio of fall shipments to fall receipts.

[e]Ratio of fall corn movements to corn sales.

Estimation Model for Corn Sales by District

Corn sales are defined as sales of corn off the farm. Once received by the elevator, corn either flows back to the same farm, or another farm in the area, or is shipped out. Estimates of total sales of corn off farms are available on an annual basis for Iowa as a whole. County and district data on corn sales, however, are available only once every 5 years in the U.S. Census of Agriculture (5). Since the latest census available at the time of this study was for 1964, it was necessary to develop a method to estimate district corn sales for more recent years for use in the analysis.

To identify and quantify relevant variables to predict corn sales, county data for 1959 and 1964 were examined by using least-squares regression techniques. Since no *a priori* basis for choosing the relevant variables was evident, a stepwise regression technique was used.[4]

[4]In stepwise regression, alternative independent variables are examined to ascertain which variable has the highest correlation with the dependent variable; in this instance, corn sales. This independent variable is selected, and a least-squares regression is completed, based on the one variable. An F-test for the significance of regression is then calculated; i.e., the ratio of the mean square due to regression to the mean square due to residual variation. If the F-test value is greater than a predetermined level, the variable with the highest partial correlation to the dependent variable is selected as the next one to enter the equation. This variable is included in the equation if the calculated partial F-test value exceeds the predetermined level. The process is repeated until the partial F-test of the last variable to enter the equation is below the predetermined level.

A group of 12 independent variables was identified for possible inclusion in the equation. The variables that entered most frequently in the equations were corn production, soybean production, fed cattle marketed, pigs born, milk cows on farms, percentage of farms reporting sows farrowed, and percentage of farms with livestock. The four variables selected for the final estimates were corn production, soybean production, fed cattle marketed, and pigs born.

Three different models were estimated. The first model was based on one regression equation for the state incorporating observations from each of the 99 counties for 1959 and 1964. Corn sales by county were hypothesized to be a function of the county's corn production, soybean production, fed cattle marketings, pigs born, and a dummy variable for the 2 years. The second model was identical to the first with the exception that, in addition to a dummy variable for year, another dummy variable was included for each of the crop reporting districts. The third model incorporated the same independent variables as the state model, with the exception of the dummy variable for district. A separate equation was developed for each district by using observations for 1959 and 1964 for each county within the crop reporting district.

Table 13 shows the results of the analysis by individual crop reporting districts for 1964 and 1968 compared with the 1964 Census of Agriculture and unpublished estimates by district obtained from the U.S. Dept. Agr. Statistical Reporting Service. Additionally, information on the percentage of the corn crop sold in the state of Iowa by years, 1964 through 1968, is shown in comparison with published data.

The results of the three estimation models are similar. Each of the three models showed variation among districts in the proportion of the crop sold. The aggregated state total estimates are quite comparable for various years in each of the three alternative models. The state total estimated by these models is higher, however, than the state figure reported by the Statistical Reporting Service. As previously noted, the reported total is based on a sampling of general livestock farms and does not encompass all farms. Thus, the slightly higher figures obtained through the model estimation procedures could be more representative of all farms, including cash-grain operations.

For the purpose of this study, the first regression model was selected. This model showed a closer correlation with the 1964 census data than did the other two (Appendix table A-1). With this model, the equation for estimating corn sales in a county was:

$$\text{Corn sales (bushels)} = -318{,}470 + 718.260\ (\text{corn production}) + 0.629\ (\text{soybean production}) - 19.667\ (\text{fed cattle}) - 9.04\ (\text{pigs born}).$$

Table 13. Proportions of corn sold, crop reporting district, and state totals by selected reports and alternative estimation models.

Source	Crop reporting district 1	2	3	4	5	6	7	8	9
Stat. Rep. Serv.									
(1969)[a] --	0.40	0.53	0.31	0.49	0.58	0.38	0.45	0.30	0.45
Census of Agric.									
(1964) --	0.396	0.549	0.360	0.396	0.549	0.360	0.333	0.396	0.414
State model[b]									
(1964) --	0.474	0.552	0.279	0.467	0.565	0.346	0.393	0.423	0.411
(1968) --	0.435	0.614	0.400	0.445	0.605	0.396	0.375	0.444	0.456
State-CRD[c]									
(1964) --	0.467	0.546	0.253	0.484	0.563	0.335	0.425	0.422	0.432
(1968) --	0.419	0.609	0.387	0.451	0.598	0.385	0.398	0.440	0.472
CRD[d]									
(1964) --	0.447	0.529	0.261	0.492	0.558	0.341	0.429	0.410	0.470
(1968) --	0.384	0.593	0.344	0.457	0.592	0.404	0.397	0.412	0.550

	State total by year 1964	1965	1966	1967	1968
Stat. Rep. Serv. ---	0.42	0.41	0.44	0.44	0.45
Census of Agric. ---	0.44	--	--	--	--
State model ---	0.453	0.488	0.494	0.496	0.481
State-CRD ---	0.454	0.487	0.495	0.496	0.477
CRD ---	0.453	0.484	0.488	0.491	0.466

[a]Data by district are unpublished data based on sample survey uniformly adjusted by statewide survey and Census of Agric. for 1964. Data by year is published. Personal communication with Roger Sutherland, Statistical Reporting Service, Federal Building, Des Moines, 1970.

[b]State model is regression equation with the following independent variables: corn production, soybean production, fed cattle marketed, pigs born, and dummy variable for year. Based on 99 observations (1 per county) for years 1959 and 1964.

[c]Same as for state model, but contains an additional dummy variable for crop reporting district.

[d]Same independent variables as state model, but separate equation developed for each crop reporting district for 1959 and 1964 data.

The positive coefficient for soybeans probably reflects the correlation of soybean production with cash-grain farming. Thus, high corn sales occur in conjunction with high production of soybeans. The negative coefficients on the livestock feeding reflect the feeding of corn on farms. County estimates were aggregated to district estimates for the 1964-69 period (Appendix table A-2).

Estimates of Grain Sales by District

The statewide average percentage of soybeans sold and oats sold for the particular crop year was used for each district. The variation in percentage of oats sold among districts probably is greater than the variation for soybeans. But since oats represent only 3 to 4 percent of the total grain marketings, any change in percentage sold among different districts would result in insignificant changes in the total grain sales estimated for that district. Soybean and oat sales were added to the estimates of corn sales to give district totals for grain marketings.

Table 14. Estimated total sales of corn, oats, and soybeans,[a] crop years 1964-69, in thousands of bushels.

Crop reporting district	1964	1965	1966	1967	1968	1969
1 ----------	78,133	71,390	95,253	86,155	79,436	112,511
2 ----------	79,718	85,814	102,236	111,499	114,049	109,860
3 ----------	28,675	41,884	45,558	53,549	54,436	47,238
4 ----------	73,062	73,342	86,694	85,289	79,101	93,017
5 ----------	100,673	101,358	113,364	1,240,083	129,120	119,782
6 ----------	45,189	55,271	53,661	69,968	63,011	64,142
7 ----------	31,767	41,393	47,936	47,257	36,928	51,522
8 ----------	25,068	26,816	30,804	21,079	31,736	23,721
9 ----------	38,075	46,468	44,079	52,578	49,839	49,536
Iowa --------	500,360	543,735	619,615	651,456	637,654	671,329

[a]Estimates for corn, soybeans, and oats are given separately in Appendix Table A-2.

Estimated total sales of corn, oats, and soybeans were slightly over 500 million bushels in 1964 in Iowa, compared with over 671 million bushels in 1969 (table 14). A general upward trend in grain sales occurred in most districts over the 6-year period 1964-69. District 1 (northwestern Iowa), District 2 (north-central Iowa), District 4 (west-central Iowa), and District 5 (central Iowa) are the largest grain-marketing areas. District 8 (south-central Iowa) has the smallest grain marketings.

Although total grain marketings in an area are of interest, the geographical size of each area varies. Thus, another measure, marketing density, was calculated to make more useful comparisons. The grain-marketing density in a district is defined as the total grain sales divided by the number of square miles in that district. Estimated grain-marketing densities by district for the 6 years are given in table 15. Grain-marketing densities in

Table 15. Estimated grain-marketing density, crop years 1964-69, in thousands of bushels per square mile.

Crop reporting district	1964	1965	1966	1967	1968	1969
1 ------------	11.5	10.5	14.0	12.6	11.6	16.5
2 ------------	13.1	14.1	16.8	18.3	18.8	18.1
3 ------------	4.4	6.4	6.9	8.2	8.3	7.2
4 ------------	10.0	10.0	11.8	11.6	10.8	12.7
5 ------------	14.9	15.0	16.8	18.4	19.2	17.8
6 ------------	7.5	9.2	8.9	11.6	10.4	10.6
7 ------------	6.4	8.4	9.7	9.5	7.4	10.4
8 ------------	4.5	4.8	5.6	3.8	5.7	4.3
9 ------------	7.1	8.7	8.2	9.8	9.3	9.2
Iowa ----------	9.0	9.8	11.2	11.8	11.5	12.1

1969 varied from a low of 4,300 bushels per square mile in District 8 to a high of 18,100 bushels per square mile in District 2. The highest marketing densities occur in the districts of most intensive grain production, as would be expected.

Grain-marketing densities increase directly with marketings. The grain-marketing density for the state was 9,000 bushels per square mile in 1964, rising to 12,100 bushels per square mile in 1969. The density of grain production in an area had a direct influence on the number and size of facilities required for efficient grain marketing. The higher the density, the less assembly costs will increase to offset economies of large-scale elevator operations. Thus, larger elevators would tend to be more economical in high-density areas.

Fall Movements of Corn and Soybeans by District

Estimated fall movements of corn and soybeans by district are given in table 16. The fall movement of corn for each district was defined as the new-crop corn sold directly from the field or stored off farms by farmers. The fall movement of soybeans by district was estimated by using the overall proportion of beans moved in the fall for the state. Fall movements increased in all districts between 1964 and 1969. District 5, for example, went from a fall movement of 28.5 percent in 1964 to almost 59 percent in 1969. These district estimates clearly reflect the tendency for grain marketings to be concentrated more in the fall, along with the growing total volume of grain moving to elevators.

Table 16. Estimated fall movements of corn and soybeans and fall movements as a proportion of total grain movements for the crop years 1964-69.

Crop reporting district	1964	1965	1966	1967	1968	1969
	Fall movements (1,000 bu.)					
1	21,646	14,482	30,354	30,788	36,152	43,741
2	19,207	19,455	30,452	41,301	43,126	50,337
3	8,389	10,513	12,898	17,094	16,328	16,218
4	25,483	20,010	34,400	27,253	35,441	43,651
5	28,670	27,881	41,105	44,730	45,164	70,221
6	13,884	15,413	16,932	22,865	23,023	26,293
7	12,490	12,585	14,260	15,027	12,772	22,684
8	10,083	7,544	9,897	10,912	14,201	10,925
9	17,256	20,183	18,078	29,244	25,352	27,174
Iowa[a]	156,926	148,065	208,376	239,214	251,558	311,245
	Fall movements as proportion of total grain movements					
1	0.275	0.203	0.319	0.357	0.455	0.389
2	0.241	0.227	0.298	0.370	0.378	0.458
3	0.293	0.251	0.283	0.319	0.300	0.343
4	0.349	0.273	0.397	0.320	0.448	0.469
5	0.285	0.275	0.363	0.360	0.350	0.586
6	0.307	0.279	0.316	0.327	0.365	0.410
7	0.393	0.304	0.297	0.318	0.346	0.440
8	0.402	0.281	0.321	0.518	0.447	0.461
9	0.453	0.434	0.410	0.556	0.509	0.549
Iowa	0.314	0.272	0.336	0.367	0.395	0.464

[a]State totals not identical to data reported in table 12 because of estimation errors.

Projected 1980 Grain Movements by District

Projected 1980 grain sales by district were obtained on the basis of projected levels of grain and livestock production in each district.[5] The projected 1980 corn sales were derived by using the corn-sales estimation model (Appendix table A-3) applied to the 1980 projections. It was assumed that the historical relationships between the variables would remain the same in 1980 as in the 1964-69 period. Various structural changes in Iowa agriculture between now and 1980 could alter the relationships assumed. One possible influence would be a higher degree of specialization in cash-grain farming, in which case the model could underestimate corn sales.

It was assumed that 98 percent of the soybean crop would be sold off farms in 1980. This is close to the average for the 1964 through 1969 crop years. The share of oats sold off farms was assumed to be 28.3 percent, the average percentage sold over the 1964-to-1969 period.

By applying these factors to the 1980 levels of production projected for each district, total grain marketing of about 1.2 billion bushels was estimated for 1980. This represents almost an 80-percent increase over the 1967-69 average sales of 653 million bushels. Grain sales and marketing densities in each district derived from the projections are shown in table 17. Marketing densities ranged from 8,700 bushels per square mile in District 8 to almost 32,000 bushels per square mile in districts 2 and 5. The average grain-marketing density in Iowa in 1980 is projected at 21,100 bushels per square mile, compared with 12,100 bushels per square mile in 1969.

To estimate the magnitude of the fall corn movements in 1980, stepwise regression techniques were

[5]Detailed production projections were developed and are available on request from the authors, Department of Economics, Iowa State University, Ames, Iowa 50010.

Table 17. Projected 1980 grain sales and grain-marketing densities.

Crop reporting district	Grain sales by type (1,000 bu.)				Density (1,000 bu. per sq. mi.)	
	corn	beans	oats	total	1980	1969
1	108,509	39,619	10,064	158,192	23.2	16.5
2	140,381	44,801	7,743	192,925	31.7	18.1
3	74,213	14,677	7,225	96,115	14.6	7.2
4	105,594	36,448	8,623	150,665	20.5	12.7
5	155,367	48,791	9,433	213,591	31.7	17.8
6	97,363	23,439	7,097	127,899	21.2	10.6
7	59,852	24,297	4,698	88,848	17.9	10.4
8	31,658	12,705	3,562	47,925	8.7	4.3
9	69,085	19,821	4,497	93,403	17.4	9.2
Iowa	842,022	264,599	62,943	1,169,562	21.1	12.1

used to identify relevant variables influencing fall movement in the 1964-69 period (Appendix table A-4). Various independent variables were considered, including percentage of corn field shelled, average corn production per farm, average number of various classes of livestock per farm, and percentage of farms with livestock. Regressions were run on individual-district data over time, state totals over time, and pooled district data over time. The percentage of field-shelled corn was the only variable that entered the stepwise regression model. Thus, it was selected as the variable to use in the 1980 projections.

Because the independent variable used in projecting fall movements was the percentage of field-shelled corn, it was necessary to estimate the level of field shelling in 1980. Alternative models of predicting the level of field shelling based on historical data were examined. Various regressions on different independent variables indicated that a strong time trend was the most important influence. When the time-trend variable was used in a prediction equation, however, the 1980 level of field shelling was consistently over 100 percent. This is, of course, a physical impossibility.

An examination of technological change in agriculture with reference to adoption of hybrid corn was conducted by Griliches (1) in1957. He found that the time trend in the data was so strong that it left nothing of significance for other variables to explain in the adoption of hybrid corn. He estimated the rate of adoption by using a logistic growth curve:

$$P = K/1 + e^{-(A+BI)}$$

where P is the percentage planted to hybrid seed, K is the ceiling or equilibrium value, T is the time variable, B is the rate of adoption coefficient, and A is the constant of integration that positions the curve on the time scale. Griliches points out that the curve is asymptotic to 0 and K and symmetric around the inflection point. This means the rate of adoption is proportional to the growth already achieved and to the remaining distance from the ceiling percentage.

The logistic curve was fitted to historical data on the percentage of corn field shelled and combined by district, assuming an equilibrium ceiling of 0.95. The function was transformed by dividing both sides by K—P and taking the logarithm to obtain

$$\log_e [P/(K-P)] = a + bt$$

Data by year on field shelling and combining in each respective crop reporting district were used to estimate the parameters directly by least squares. The estimated coefficients for the nine districts were used to project the 1980 level of field shelling by district.[6]

The projected 1980 level of field shelling and combining and associated fall grain movements by district are shown in table 18. Fall movements of corn and soybeans are projected at 658 million bushels in 1980. This represents an increase of 146 percent over the 1967-1969 average (table 19). The share of fall movements of corn is projected at 0.603 compared with 0.467 in 1969 (table 12), indicating a greater concentration of corn movement during the fall harvest. District grain sales are projected to increase from 71 to 96 percent, and fall movements of corn and soybeans by district are projected to increase from 105 to 236 percent (table 19).

These projections show that the demand for elevator services in Iowa will increase substantially by 1980. Elevators will have to be capable of receiving, conditioning, storing, and merchandising larger quantities of grain at harvest time. How will these adjustments take place? Will new and expanded elevators be of the scale and so located to provide an efficient marketing system in 1980? Or will decisions by individual elevators lead to excess capacity in some districts and shortages elsewhere, incorrect locations, and uneconomic sizes? The need for guidelines to assist in this decision process is the main justification for this study.

COSTS OF TRANSPORTING AND HANDLING GRAIN

This analysis is concerned not only with the costs of handling grain in elevators, but also with the cost of moving grain from farms to elevators. Consideration of optimum-sized facilities requires that assembly costs, as well as in-plant costs, be included in the analysis. In this study, the optimum-sized, grain-handling plant depends upon both grain assembly and in-plant handling costs.

Figure 3 shows a hypothetical example of the three cost curves relevant to this study. Average costs per bushel, in cents, are measured on the vertical axis, and volume, in bushels, is shown on the horizontal axis. Curve AA represents the average assembly costs incurred as volume increases. This curve typically increases at a decreasing rate. Curve APC represents the average processing costs for plants of different sizes. This is, by definition, a long-run average cost curve that shows costs per unit as size of elevator increases. This curve typically decreases at a decreasing rate as plant size is expanded. Implicit assumptions in the shape of the APC curve are a given state of technology and constant prices for all inputs used in the processing operation.

Combined average costs (CAC) is a summation of average processing costs and average assembly costs. They are derived by the addition of AA and APC for each volume. Combined average costs, at relatively low volumes, decrease; as volume expands, however, a point may be reached at which they start to increase. This point will occur when the AA curve is increasing at a more rapid rate than the APC curve is decreasing. Such a minimum point on the combined average cost curve indicates an optimum elevator size, taking both assembly and plant costs into account.

[6]Results of the estimation of the logistic curves for each district are given in Appendix table A-5.

Table 18. Projected share of corn field-shelled and combined in 1980; projected share of fall movements of corn in 1980; and projected fall movements of corn and soybeans and share fall movements in 1980.

Crop reporting district	Share of corn field-shelled and combined	Share fall movements of corn[a]	Fall movements of corn and soybeans (1,000 bu.) corn	soybeans	total	Share fall movements[b]
1	------ 0.874	0.645	70,050	22,518	92,568	0.585
2	------ 0.927	0.536	75,245	25,463	100,708	0.522
3	------ 0.928	0.636	47,176	8,342	55,518	0.578
4	------ 0.825	0.616	65,020	20,716	85,736	0.569
5	------ 0.936	0.559	86,824	27,731	114,555	0.536
6	------ 0.922	0.629	61,282	13,322	74,604	0.583
7	------ 0.896	0.580	34,689	13,810	48,499	0.546
8	------ 0.923	0.715	22,620	7,221	29,841	0.623
9	------ 0.924	0.645	44,528	11,266	55,794	0.597
Iowa	------ --	0.603	507,433	150,389	657,823	0.562

[a]Ratio of fall movements of corn to corn sales.

[b]Ratio of total fall movements of corn and soybeans to total sales of corn and soybeans.

Table 19. Projected increase in total grain sales and fall movements from 1967-69 average to 1980, in percentages.

Crop reporting district	Increases in total grain sales, 1980 compared with 1967-69	Increases in fall movements, 1980 over 1967-69
1	------------------ 71	151
2	------------------ 73	124
3	------------------ 86	236
4	------------------ 76	142
5	------------------ 72	115
6	------------------ 95	210
7	------------------ 96	188
8	------------------ 88	148
9	------------------ 84	105
Iowa	------------------ 79	146

Elevator Trade Areas and Assembly Costs

Three factors determine the volume of business attained by an elevator: (a) the size of the area served, (b) the demand density for elevator services in the area served, and (c) the plant's share of the total market.

This analysis assumes that all elevator trade areas are served by an east-west, north-south grid, road network with grid intervals of 1 mile and that farmsteads are located adjacent to the road. This pattern of road network and farmstead location is prevalent throughout Iowa. The analysis also assumes a homogeneous marketing density and a given elevator market share throughout the trade area served. The marketing density and market share, together, determine the amount of grain for which the elevator will need to provide marketing service in the given area.

Assembly costs are then assumed a function of miles traveled and of the volume in the area. The cost function used in the analysis was linear and included a fixed-cost component and a variable-cost component that varied with distance from the plant. The cost per bushel of grain (C_i) in the i-th mileage increment can be defined as

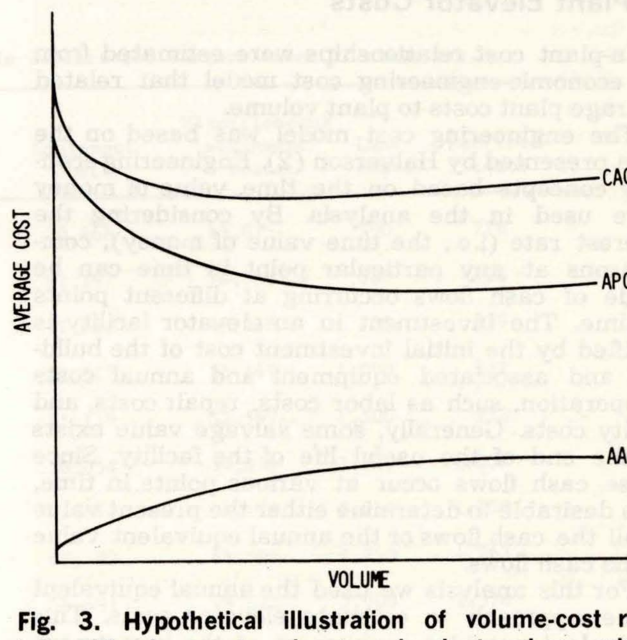

Fig. 3. Hypothetical illustration of volume-cost relationships in country elevators, in-plant and assembly costs.

$C_i = A + B$ (i miles). The total cost of assembly (TAC) for any volume is obtained by multiplying the cost per bushel times volume (V_i) in the i th mileage increment and then summing over the mileage increments (n) needed to obtain the given volume

$$TAC^n = \sum_{i=1}^{n} V_i C_i$$

After the total cost of assembly for a specified trade-area size is obtained, it is divided by the total volume to obtain the average assembly cost (AAC). Doubling production density doubles volume and, hence, total assembly cost. But average assembly cost remains the same as with the lower density. As density increases, however, combined cost for any given volume decreases since the plant can obtain the volume from a smaller trade area. Whether costs are paid by farmers or the elevator is immaterial. If the marketing system is poorly organized so that costs are much higher than necessary, someone must pay these higher costs either through lower prices to farmers, lower profits to elevators, higher prices to buyers, or some combination of all.

Most grain arrives at elevators in trucks. An average load of 300 bushels per truck was assumed. Representative rates being charged by truck operators, as filed with the Iowa Commerce Commission, were used to estimate a truck cost function. The grain-assembly cost function developed was $AC_i = 2.585 + 0.1327i$, where AC_i is the average cost in cents per bushel for the i-th mileage increment, and i is mileage in whole miles. The R^2 for the equation was 0.983, which suggests a good fit.

In-Plant Elevator Costs

In-plant cost relationships were estimated from an economic-engineering cost model that related average plant costs to plant volume.

The engineering cost model was based on the data presented by Halverson (2). Engineering economy concepts based on the time value of money were used in the analysis. By considering the interest rate (i.e., the time value of money), comparisons at any particular point in time can be made of cash flows occurring at different points in time. The investment in an elevator facility is typified by the initial investment cost of the building and associated equipment and annual costs of operation, such as labor costs, repair costs, and utility costs. Generally, some salvage value exists at the end of the useful life of the facility. Since these cash flows occur at various points in time, it is desirable to determine either the present value of all the cash flows or the annual equivalent value of the cash flows.

For this analysis we used the annual equivalent value approach to estimate elevator costs. This equivalent provides repayment of the investment and a return on the investment during its life. These two elements are referred to as capital recovery.

The basic formulation used in the analysis is described by Smith (4, p. 100). The general model has the form—

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

where

AEC = annual equivalent cost
B = first cost of the facility
V = salvage value
i = interest rate (or rate of return)
n = years of facility life

$$(a/p)_n^i = [i(1+i)^n]/[(1+i)^n - 1]$$
= annual equivalent of a present sum

$$(a/f)_n^i = i/[(1+i)^n - 1]$$
= annual equivalent of a future sum

This analysis assumed a before-tax rate of return of 10 percent. No provision was made in the analysis for the effect of income taxes. The 10-percent rate of return can be viewed as an opportunity cost of capital. This rate seems representative of the expectations of various firms and individuals. Halverson included an interest charge on the railroad siding and on the land where the facility was located, but no interest charge was made on the rest of the investment. Annual costs for taxes and insurance were assumed equal to 3.1 percent of the total cost of the plant and equipment.

The annual operating costs included labor, repairs, and utilities. These variable costs were assumed the same as those reported by Halverson.

It was assumed that the equipment in the building would be replaced twice during the life of the plant structure. Thus, replacements at one-third and two-thirds of the plant life were discounted to a present equivalent to ascertain the total present equivalent cost of the equipment. This present equivalent cost was then expressed in annual terms over the life of the elevator. A similar procedure was followed for the dryer and aeration equipment, with an initial installation cost, plus five replacements over the life of the plant assumed. It was further assumed that the only salvage value occurring to the firm would be the salvage value of the land. Thus, the salvage value of the land was discounted to a present equivalent and subtracted from the present cost of the land. This land cost was then converted to annual terms over the period of the investment. The railroad-siding cost was assumed to be the same as in the Halverson model and also was prorated over the life of the elevator.

The basic data in the Halverson model for investment costs were used in this analysis. Because elevator investment costs have been increasing since the time the original investment costs were gathered, however, an upward adjustment was made. It was assumed that costs for construction and all equipment utilized in the plant were 15 percent above those reported by Halverson. Estimates of total plant and equipment investment costs ranged from

$431,082 for the smallest elevator considered to almost $3 million for the 4-million-bushel elevator (table 20).

Table 20. Selected investment costs in dollars for various sizes of elevators.

Model size (bu.)	Construction cost	Equipment cost	Total investment cost[a]
350,000	266,857	83,887	431,082
500,000	387,193	95,530	583,200
1,000,000	656,010	134,343	901,802
1,500,000	924,818	173,155	1,252,500
2,000,000	1,193,630	244,737	1,638,674
2,500,000	1,462,443	283,550	1,969,248
3,000,000	1,731,255	327,537	2,324,082
3,500,000	2,000,067	366,350	2,639,898
4,000,000	2,268,880	420,687	2,994,470

Source: Halverson, Duane A. Economies of scale in country grain elevators. M.S. thesis. Iowa State University Library, Ames. 1969.

[a]Total includes costs of construction, equipment, and miscellaneous including: dryer equipment, aeration equipment, and heat-detection equipment.

The annual equivalent costs for investments required for elevators of various sizes are given in table 21. It was assumed that the elevator plant life would be 50 years. The selection of a 40-year period, however, would not significantly change the costs on an annual basis.

The resulting costs for elevators operating at a 1.5 turnover rate are shown in table 22. The costs ranged from 15.2 cents per bushel in the smallest plant to 8.5 cents per bushel in the largest. Most of the economies of size are realized in the change from a 500,000-bushel elevator to one with a capacity of 1 million bushels. The average total cost for the half-million-bushel elevator was 14.1 cents compared with 10.6 cents in the million-bushel facility.

The next step in the analysis was to determine turnover rates. It was assumed that the cost classified as "fixed cost" was, in fact, fixed and not related to changes in the elevator utilization rate. Labor costs, repair costs, and utility costs were regarded as variable costs. A 1.5 turnover rate was assumed to be the base utlization rate, and variable costs were adjusted in accordance with differences from this base rate. When the turnover rate was less than the 1.5 base rate, variable costs were decreased less than proportionally. For example, if the plant was operating at 80 percent of the base rate, variable costs were set at 90 percent of variable costs at the base rate. The reason for not reducing variable cost by the same percentage as utilization is that there are some costs in the variable category that have "fixed" characteristics. For example, a certain amount of power and fuel will be required to light and heat the elevator facilities regardless of the level of utilization. Similarly, the labor force required to perform the various functions may not be fully flexible.

For utilization rates greater than the base rate, it was assumed that variable costs would increase in the same proportion as the increase in utilization rate. Thus, if the utilization rate were increased 10 percent, variable costs also increased by 10 percent.

Alternative turnover rates varying from 1.0 to 4.0 were analyzed. Average costs per bushel with selected turnover rates in the model elevators are

Table 21. Annual equivalent investment costs in dollars for various sizes of elevators.

Model size (bu.)	Taxes and insurance costs	Construction costs	Equipment costs	Miscellaneous equipment costs	Land costs	Railroad costs
350,000	13,364	26,915	10,666	13,075	500	726
500,000	18,079	39,052	12,147	16,352	500	726
1,000,000	27,956	66,165	17,082	18,138	750	839
1,500,000	38,827	93,276	22,017	25,149	1,000	952
2,000,000	50,799	120,389	31,119	32,599	1,500	952
2,500,000	61,047	147,501	36,054	36,334	1,750	1,037
3,000,000	72,047	174,613	41,647	43,175	2,250	1,150
3,500,000	81,837	201,725	46,582	44,508	2,750	1,263
4,000,000	92,829	228,837	53,491	49,622	3,000	1,376

Table 22. In-plant costs in dollars for elevators of different sizes operated at a 1.5 turnover rate.

Model size (bu.)	Fixed cost[a]	Variable cost[b]	Total cost	Average cost per bushel fixed	variable	total
350,000	65,246	14,591	79,837	0.124	0.028	0.152
500,000	86,856	18,750	105,606	0.116	0.025	0.141
1,000,000	130,929	28,083	159,012	0.087	0.019	0.106
1,500,000	181,221	38,496	219,717	0.081	0.017	0.098
2,000,000	237,357	46,789	284,146	0.079	0.016	0.095
2,500,000	283,722	55,931	339,653	0.076	0.015	0.091
3,000,000	334,881	65,264	400,145	0.074	0.015	0.089
3,500,000	378,665	73,424	452,089	0.072	0.014	0.086
4,000,000	429,154	82,507	511,661	0.072	0.014	0.085

[a]Total annual equivalent investment costs.

[b]Includes labor, repairs, and utilities.

shown in table 23. Costs per bushel decreased as the turnover rate increased for all model elevator sizes. For example, in the smallest model size, the average total cost was 21.4 cents per bushel at a turnover rate of 1.0, compared with 7.4 cents per bushel at a turnover rate of 4.0. This decrease is due primarily to the spreading of fixed costs over a larger volume of grain.

Table 23. Average total cost per bushel for various sizes of elevators with selected turnover rates.

Model size (bu.)	Turnover rate 1.0	2.0	3.0	4.0
350,000	21.4 ¢	12.1 ¢	9.0 ¢	7.4 ¢
500,000	19.9	11.2	8.3	6.8
1,000,000	15.0	8.4	6.2	5.1
1,500,000	13.8	7.8	5.7	4.7
2,000,000	13.4	7.5	5.5	4.5
2,500,000	12.8	7.2	5.3	4.3
3,000,000	12.6	7.0	5.2	4.2
3,500,000	12.2	6.8	5.0	4.1
4,000,000	12.1	6.7	5.0	4.1

The next step of the procedure was to fit a cost function to the nine observations of model plant sizes under alternative turnover rates. A least-squares regression equation was used for the variables in logarithms. For example, at a 1.5 turnover rate, the following relationship was obtained

$$\text{Log ATC} = 1.280186 - 0.242579 \text{ (log volume)}$$

where

ATC = average total cost

The logarithmic equation was then converted to give the cost equation:

$$\text{ATC} = 3.597307 \text{ (volume)}^{-0.242579}$$

The R^2 statistic for these equations was consistently greater than 0.95. An over-all cost surface incorporating both volume and turnover variables could be expressed in a multiple-regression equation. Because the subsequent analysis of combined costs holds the turnover rate constant, however, separate equations were estimated for selected turnover rates.

Combined Costs and Optimum-Sized Elevators

Assembly costs and in-plant costs were summed to obtain the combined cost curve. The three cost curves associated with a marketing density of 12,000 bushels per square mile and a turnover rate of 1.5 are drawn in fig. 4. This density is close to the average marketing density for Iowa. The combined cost curve shows decreasing costs throughout the range of volumes; it tends to flatten out in the 3- to 5-million-bushel range, however, and declines very little thereafter. These curves assume that the elevator receives a 100-percent market share in the trade area. The costs are long-run costs because the size of the elevator varies along the in-plant cost curve.

The combined cost curve in fig. 4 never reaches a minimum point. This implies that costs per bushel could be decreased indefinitely by building a larger and larger elevator to serve a wider and wider trade area. The multiproduct organization of elevators, convenience, and other factors limit the extent to which elevators can extend their trade areas. For this reason, it seems more relevant to think in terms of the size of elevators and trade areas where most of the available cost savings are achieved.

Combined average costs with various marketing densities and a 1.5 turnover rate are shown in fig. 5. Most economies of size are achieved in the 2- to 3-million-bushel volume range. This corresponds to elevators with a minimum storage capacity of 1.5 to 2.0 million bushels that would result in costs approaching their minimum. The size of trade area required to obtain the required volume is shown on the horizontal scales in fig. 5. The market areas give the miles from the elevator necessary to attain the volume under the four indicated marketing-density levels. An elevator, for example, that requires a volume of 2 million bushels needs a trade area with a radius of 7 miles in all directions from the plant if this marketing density is 20,000 bushels. If the marketing density in a trade area is only 10,000 bushels per square mile, a trade area that extends 10 miles from the plant would be necessary to attain the same volume. Similar figures could be drawn for higher turnover rates, but the results would be about the same as for the 1.5 turnover rate.

The differences in marketing densities could also be interpreted as market-share differences. That is, an elevator that attains a 25-percent market share in an area with a marketing density of 40,000 could be viewed as operating along the curve cor-

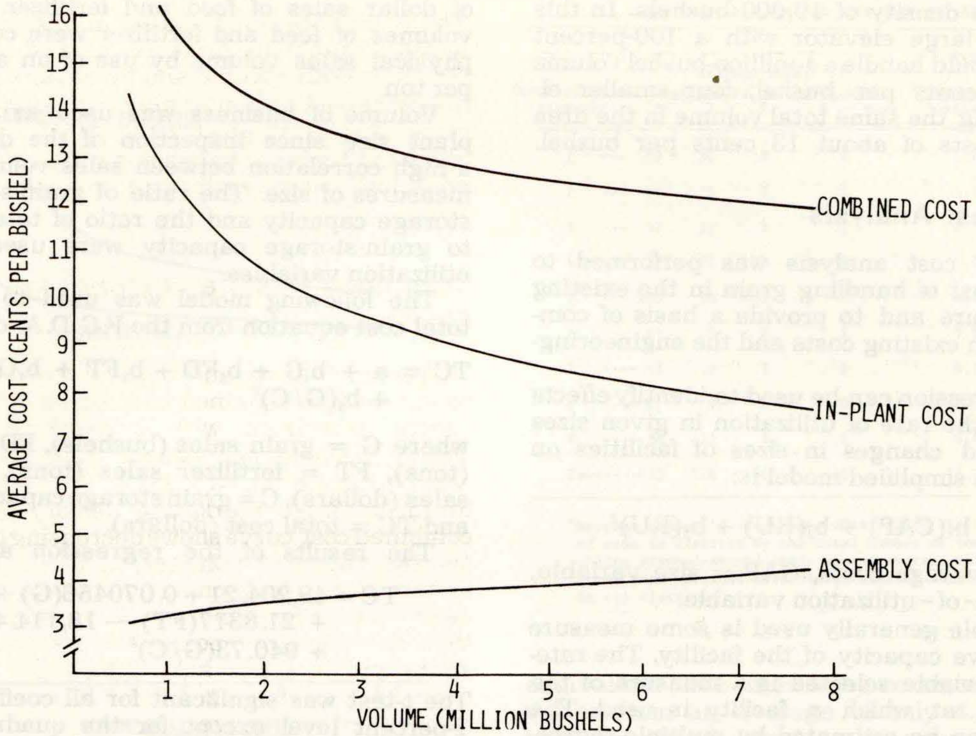

Fig. 4. Average assembly costs, in-plant costs, and combined costs of grain marketing in an area of 12,000 bushels per square mile marketing density and an elevator turnover rate of 1.5.

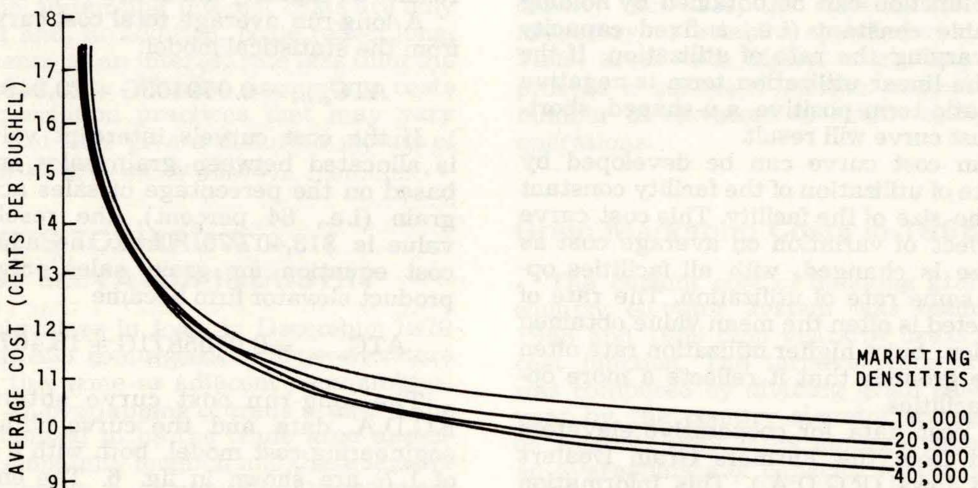

Fig. 5. Combined elevator handling and assembly costs under alternative marketing densities and trade-area sizes required to attain given volumes, assuming a turnover rate of 1.5.

responding to a density of 10,000 bushels. In this situation, one large elevator with a 100-percent market share could handle a 4-million-bushel volume for about 10 cents per bushel; four smaller elevators handling the same total volume in the area would have costs of about 13 cents per bushel.

Statistical Cost Analysis

A statistical cost analysis was performed to estimate the cost of handling grain in the existing industry structure and to provide a basis of comparison between existing costs and the engineering-cost model.

Multiple regression can be used to identify effects of changes in the rate of utilization in given sizes of facilities and changes in sizes of facilities on average cost. A simplified model is:

$$AC = a + b_1(CAP) + b_2(RU) + b_3(RU)^2$$

where AC = average costs, CAP = size variable, and RU = rate-of-utilization variable.

The size variable generally used is some measure of the productive capacity of the facility. The rate-of-utilization variable selected is a measure of the extent or rate at which a facility is used. The b coefficients can be estimated by multiple-regression techniques from the accounting data, giving an estimated cost function (6).

Once the cost function is obtained, long-run and short-run relationships can be derived from it. The short-run cost function can be obtained by holding the size variable constant (i.e., a fixed capacity facility) and varying the rate of utilization. If the coefficient of the linear utilization term is negative and the quadratic term positive, a u-shaped, short-run average cost curve will result.

The long-run cost curve can be developed by holding the rate of utilization of the facility constant and varying the size of the facility. This cost curve reflects the effect of variation on average cost as the facility size is changed, with all facilities operated at the same rate of utilization. The rate of utilization selected is often the mean value obtained in the regression, but a higher utilization rate often is used on the grounds that it reflects a more optimum use of facilities.

Accounting cost data for cooperative elevators were obtained from the Farmers Grain Dealers Association of Iowa (F.G.D.A.). This information was provided for 179 elevators that handled grain. Another selection criteria was introduced that specified that the ratio of the total bushels of grain sales to the total dollar sales of a particular cooperative had to be at least 0.25. As a result of the selection criteria, 168 elevators remained for analysis. These elevators represented 15.3 percent of the total elevators in Iowa as of August 1969 and accounted for 32.2 percent of the total grain-storage capacity. Cost data pertained to each elevator's fiscal year ending in 1969.

Generally, the elevators provided a full line of farm supplies and services as well as grain-marketing operations. Sales data were reported in terms of dollar sales of feed and fertilizer. Dollar sales volumes of feed and fertilizer were converted into physical sales volume by use of an average price per ton.

Volume of business was used as a measure of plant size since inspection of the data revealed a high correlation between sales volume and other measures of size. The ratio of grain sales to grain-storage capacity and the ratio of total dollar sales to grain-storage capacity were used as rate-of-utilization variables.

The following model was used to estimate the total cost equation from the F.G.D.A. data

$$TC = a + b_1G + b_2FD + b_3FT + b_4OT + b_5(G/C) + b_6(G/C)^2$$

where G = grain sales (bushels), FD = feed sales (tons), FT = fertilizer sales (tons), OT = other sales (dollars), C = grain storage capacity (bushels), and TC = total cost (dollars).

The results of the regression analysis were

$$TC = 48{,}204.21 + 0.070456(G) + 20.9295(FD) + 21.8317(FT) - 18{,}114.41(G/C) + 940.73(G/C)^2 \qquad R^2 = 0.92$$

The t-test was significant for all coefficients at the 1-percent level except for the quadratic term for the rate of utilization, which was significant at the 5-percent level. Since the linear utilization term has a negative coefficient and the quadratic term has a positive coefficient, a u-shaped cost curve results as capacity utilization (i.e., turnover) varies.

A long-run average total cost curve was derived from the statistical model:

$$ATC_{grain} = 0.070405G + 20{,}949.53$$

If the cost curve's intercept value of $20,949 is allocated between grain sales and other sales, based on the percentage of sales accounted for by grain (i.e., 64 percent), the resulting intercept value is $13,407.70. Thus, the adjusted long-run cost equation for grain sales only in the multiproduct elevator firm became

$$ATC_{grain} = 0.0705871G + 13{,}407.70$$

The long-run cost curve obtained from the F.G.D.A. data and the curve obtained from the engineering cost model, both with a utilization rate of 1.7, are shown in fig. 6. The engineering cost model shows greater economies of scale than does the statistical cost model. The statistical cost curve tends to flatten out at a lower volume level. The higher level of costs in the engineering model could be caused by several factors. One factor is that the engineering model is based largely on a specialized grain-handling operation, whereas the statistical cost curve is from multiproduct firms. Kaldenberg (3) found that multiproduct grain firms had a lower long-run average cost curve than did specialized grain firms. Another reason that the statistical cost model could tend to be lower is that it reflects facilities acquired at a cost substantially less than that of prevailing investment cost

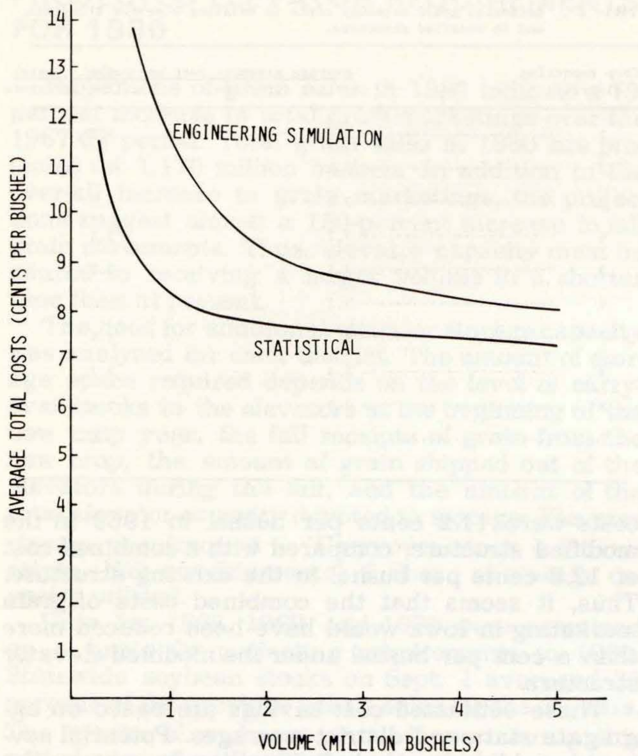

Fig. 6. Long-run average total cost curves for the engineering simulation and statistical cost models.

levels. Also, the accounting interest costs are only on debt capital and, in addition, could reflect long-term commitments at an interest rate less than the prevailing market rate. Finally, accounting costs depend on depreciation practices that may vary between firms and thus give a distorted picture of the costs of operating older facilities.

ADJUSTMENTS TOWARD A LOWER-COST ELEVATOR INDUSTRY

The 1,178 elevators in Iowa in December 1970 were located in 853 communities. Some elevators are located in the same or adjacent communities, which leads to an overlapping of trade areas. If the trade area is defined to be the trade area associated with one community location and there is more than one elevator in a community, the relevant measure of potential volume is no longer the grain-marketing density in the area. Rather, the relevant density is that based on the elevator's share of the grain volume; i.e., the elevator's market share.

The distribution of elevators in communities is shown in table 24. For example, there were 174 communities in Iowa with two elevators and 46 with three elevators. The average community trade area in each district was obtained by dividing the total square miles in the district by the number of communities with elevators. After the total number of square miles in an average trade area was determined, this was converted to a mileage radius

Table 24. Average number of elevators per community, average community trade area, and average effective elevator trade area, 1970.

Crop reporting district	Average number of elevators per community: 1	2	3	4 or more	Average trade area[a]: Community (miles)	Effective elevator (miles)
1 ---	69	30	10	4	5.4	4.4
2 ---	99	15	5	0	5.1	4.6
3 ---	47	18	3	2	6.8	5.7
4 ---	89	22	10	4	5.4	4.5
5 ---	123	30	6	4	4.6	4.0
6 ---	61	19	4	2	5.9	5.0
7 ---	42	19	3	2	6.1	5.0
8 ---	27	9	2	0	8.5	7.4
9 ---	58	12	3	2	6.0	5.2
Iowa----	615	174	46	18	5.7	4.9

[a]Average community trade area obtained by dividing square miles of area in district by the total number of communities and assuming diamond-shaped trade areas; average effective elevator trade area obtained by dividing area by total number of elevators in the district.

equivalent. The size of the community trade area varied from an average of only 4.6 miles in District 5 (central Iowa) to an average of 8.5 miles in District 8 (south-central Iowa).

Comparison of average trade area sizes with the grain-marketing densities by district given in table 15 shows an inverse relationship. As the marketing density increases, the distance from the elevator necessary to attain a specified volume decreases. Thus, areas with higher marketing densities can provide a sufficient volume of grain for a larger number of elevators to attain economic scales of operations.

Grain Marketing Costs in 1968-69

The current cost of handling grain through the country elevator system was estimated for the 1968 and 1969 crop years by use of the statistical cost function. The turnover rate in each district was computed by dividing grain sales in each crop year by the country elevator storage capacity as of August 1969. This storage capacity could be an overestimate of capacity for the 1968 crop year and, conversely, an underestimate for the 1969 crop year. It was assumed that the grain-marketing density was homogenous throughout each crop reporting district.

The volume of grain through an individual elevator was defined to be equal to the storage capacity of that elevator times the average turnover rate of the district in which it was located. The total cost of handling grain in each individual elevator was calculated by using the utilization rate corresponding to the data analyzed in the section on costs. Thus

$$\text{Total cost} = 0.070405\ (\text{grain volume}) + \$13{,}407.70$$

The estimated total country elevator cost of marketing grain in Iowa was $58.4 million for the 1968 crop year and $60.8 million for the 1969 crop year. This is an average cost per bushel of 9.2 cents for 1968 and 9.1 cents for 1969. These calculations do not include assembly costs.

Potential for Cost Reductions Under Current Conditions

Potential cost reduction achieved by using fewer and larger elevators to handle present volumes can now be examined. In 1969, the average size of country elevators was 297,000 bushels of storage capacity. The economies of scale exhibited by both the engineering cost function and the statistical cost function indicate that costs decrease as elevator sizes reach at least 3 to 5 times that capacity. The statistical cost function indicates a cost of slightly more than 11 cents per bushel for an elevator of 297,000 bushels storage capacity, compared with 8.5 cents per bushel in an elevator 3 times that size. Thus, elevators of a larger size could achieve lower costs than the smaller elevators in the existing structure.

To estimate the potential cost savings, a modified elevator structure was simulated. The modified structure assumed that all elevators in a district with capacity less than 3 times the average storage capacity per elevator in that district were replaced by elevators 3 times the average storage capacity in that district. The total amount of storage capacity in a district was held constant; only the number of elevators was changed. Costs in elevators that were greater than the assumed minimum size were calculated as before by using the statistical cost function. The same cost function was used in calculating costs in the larger replacement elevators. Costs in both the larger existing facilities and the replacement facilities were aggregated to obtain the total in-plant elevator costs of marketing grain in Iowa for the 1968 and 1969 crop years.

Assembly costs in the existing structure were calculated based on the assembly cost function developed previously. The average community trade area in each district was used to determine assembly costs for the existing structure. Such estimates understate actual costs since no cross-hauling from one elevator's trade area to a neighboring elevator is considered. In the modified structure, it was assumed that the square miles in each district's average-size trade area would be doubled; thus, the radius of trade area was increased by about 40 percent. Doubling the size of the trade area would increase average assembly costs; thus, the average cost of assembly for the state rose from 3.2 cents per bushel in the existing structure to 3.4 cents per bushel in the modified structure (table 25).

The total in-plant costs for marketing grain in 1969 in the modified structure were $52.3 million. This represents an estimated savings of almost $8.5 million, or 1.4 cents per bushel, in 1969 compared with the existing structure. The combined costs were 11.2 cents per bushel in 1969 in the modified structure, compared with a combined cost of 12.3 cents per bushel in the existing structure. Thus, it seems that the combined costs of grain marketing in Iowa would have been reduced more than a cent per bushel under the modified elevator structure.

Table 25. Estimated grain assembly costs in existing elevator structure and in modified structure.

Crop reporting district	Average assembly cost per bushel (cents) existing structure	modified structure
1	3.1	3.3
2	3.1	3.3
3	3.2	3.5
4	3.1	3.3
5	3.1	3.2
6	3.2	3.4
7	3.2	3.4
8	3.4	3.7
9	3.2	3.4
Iowa	3.2	3.4

These estimated cost savings are based on aggregate state and district averages. Potential savings would vary in individual trade areas. For example, in an area where the elevators have 200,000-bushel average storage capacity, the costs would be about 11 cents per bushel for annual volumes of 350,000 bushels. The costs in an elevator 3 times this size would be about 8.5 cents per bushel. This would indicate a potential savings of 2.5 cents per bushel in that particular area, considerably more than the average for the state.

It seems that using the statistical cost function results in a conservative estimate of cost savings in a structure with fewer and larger elevators. If the cost calculations in both the existing and modified structure were based on the engineering cost function, the cost savings on an aggregate basis in a modified structure would have been greater. For example, in a facility of 297,000-bushel storage capacity, the cost would be about 16 cents per bushel compared with 11 cents per bushel in an elevator 3 times that size. This suggests a cost reduction of 5 cents per bushel, whereas the statistical cost function indicates a 1.8-cents-per-bushel savings by going from an average-size facility to one 3 times larger.

As old facilities are replaced and capacity is expanded to meet demand, attainment of cost savings in the future are definitely possible with larger elevators. Existing elevators could have lower costs than new facilities because they were acquired with lower initial capital outlays or because capital costs have been largely depreciated. Replacement or expansion of existing elevators with new elevators of the present small average size rather than with larger elevators, however, will result in increased costs in the future. This conclusion has important implications for industry adjustments and investment decisions over time.

PROJECTED ELEVATOR REQUIREMENTS FOR 1980

Projections of grain sales in 1980 indicate a 79-percent increase in total grain marketings over the 1967-69 period. Total grain sales in 1980 are projected at 1,170 million bushels. In addition to the over-all increase in grain marketings, the projections suggest almost a 150-percent increase in fall grain movements. Thus, elevator capacity must be geared to receiving a larger volume in a shorter time than at present.

The need for additional elevator storage capacity was analyzed for each district. The amount of storage space required depends on the level of carryover stocks in the elevators at the beginning of the new crop year, the fall receipts of grain from the new crop, the amount of grain shipped out of the elevators during the fall, and the amount of the total elevator capacity devoted to storage: Elevator storage requirement = (Carryover stock + Fall receipts—Fall out-shipments) / Share of storage capacity utilized.

Data for 1968, 1969, and 1970 were examined as a basis for projecting requirements in 1980. Statewide soybean stocks on Sept. 1 averaged 36 percent of the previous year's sales for the 3 years. The stocks of soybeans carried over during this period seemed rather high and probably would not be representative of the 1980 situation. The 1967-69 average carryover as a share of soybean sales was determined for each district. It was assumed that the 1980 carryover would be equal to one-third the historical share times the projected 1980 soybean sales. The maximum carryover percentage, however, was limited to 12 percent.

Iowa carryover stocks of corn on Oct. 1 ranged from 65.4 to 86.1 million bushels during 1967-69, averaging 16.6 percent of the corn sales over the 3 years. For each district, it was assumed that the same relation of sales to carryover would be experienced in 1980 as in the historical 3-year period analyzed. Corn and soybeans carryover stocks for 1967-69 and the 1980 projected carryover by district are given in table 26.

The fall grain movements of corn projected earlier were used in the computations. The share of the fall receipts shipped from the elevators was examined by district for the 1968 and 1969 crop years, the only years for which data were available. The average share shipped for the 2 years is presented in table 27. It was assumed that the share shipped in 1980 would be equal to 90 percent of the historical average in each district, with a minimum of 40 percent shipped in any district. The lower shipping rate reflects the possibility of transportation facilities not being fully capable of handling the increased grain flow, plus the desirability of retaining more grain in elevators to earn increased storage revenues. Total shipments were projected by multiplying the projected fall receipts by the share expected to be shipped.

The 1980 storage utilization rate in each district was projected as follows. The average storage utilization rates for January 1969, 1970, and 1971 were computed for each district. The highest observed utilization rate was 0.71 in District 8. Raising this rate to 0.80 would represent a more efficient utilization of storage facilities. But this efficient rate might not be feasible in all districts. Therefore, the 1980 storage utilization rate by district was projected by multiplying the observed rate for each district by the ratio of the highest observed rate for District 8 (0.71) to the selected "efficient" rate (0.80). For example, in District 1, the historical average rate was 0.62 and, when multiplied by 0.80/0.71, gave a projected rate of 0.70 for 1980. In other words, 70 percent of the elevators' capacity would be utilized for storage on Jan. 1. The historical information on storage utilization and the 1980 projected utilization are shown in table 27.

Table 26. Historical average levels of carryover stocks of corn and soybeans as a share of sales of corn and soybeans and projected 1980 levels as a share of sales.

Crop reporting district	Corn[a] 1967-69 average	Corn[a] Projected 1980	Soybeans[b] 1967-69 average	Soybeans[b] Projected 1980
1	0.123	0.123	0.321	0.107
2	0.142	0.142	0.300	0.100
3	0.094	0.094	0.295	0.098
4	0.230	0.230	0.495	0.120
5	0.231	0.231	0.502	0.120
6	0.124	0.124	0.234	0.078
7	0.222	0.222	0.421	0.120
8	0.134	0.134	0.269	0.090
9	0.122	0.122	0.190	0.063

[a] 1967-69 average computed by adding Oct. 1 carryover stocks of corn and dividing by the sum of the corn sales for the 3 crop years; 1980 projection assumed same as historical average ratio.

[b] 1967-69 average computed by adding Sept. 1 carryover stocks of soybeans and dividing by the sum of the soybean sales for the 3 crop years; 1980 projection assumed to be one-third of 1967-69 average ratio with a maximum of 0.12 times projected 1980 soybean sales.

Table 27. Historical and 1980 projected fall shipment rates and storage utilization rates by district.

Crop reporting district	Fall shipment rate[a] 1968-69 average	Fall shipment rate[a] projected 1980	Storage utilization rate[b] 1969-71 average	Storage utilization rate[b] projected 1980
1	0.454	0.409	0.62	0.70
2	0.508	0.457	0.67	0.75
3	0.612	0.551	0.68	0.76
4	0.356	0.400	0.61	0.68
5	0.414	0.400	0.67	0.76
6	0.624	0.562	0.47	0.60
7	0.413	0.400	0.59	0.66
8	0.590	0.531	0.71	0.80
9	0.549	0.494	0.67	0.76

[a] Projected 1980 shipment rate assumed to be equivalent to 0.90 times the average rate with a minimum of 0.4.

[b] 1969-71 storage utilization is ratio of grain stocks in all elevators to capacity of all elevators; 1980 projection assumed to be ratio of average district rate to the historical rate in District 8 times 0.80. If calculated ratio was less than 0.60, it was adjusted upward to that level.

Total storage requirements by area were determined by adding the carryover stocks to the fall receipts, less fall shipments, and dividing by the storage utilization. The average turnover rate for each area was computed by dividing the total grain sales by the storage requirement. Total Iowa storage needs in 1980 were projected at 735.8 million bushels, an increase of 70 percent over the 1970 total capacity of 432.5 million bushels. The projected percentage increase in storage capacity by district ranged from 46 percent to 142 percent (table 28).

To estimate the optimum elevator size in each district, the average marketing density and average turnover rate were considered. The engineering elevator cost and the assembly cost curve previously developed were used to determine costs in each district for elevators serving alternative-sized trade areas. The size of facility and associated trade-area size that achieved most of the economies of scale varied with each district. As noted earlier, as the turnover rate is increased, most available economies of scale can be achieved in smaller elevators. Also, as the marketing density increases, the size of trade area required to attain a volume to capture the economies of scale decreases.

Grain-marketing costs for each crop reporting district with its associated marketing density and elevator turnover rate for trade areas of various sizes are presented in table 29. For example, in District 1 (northwest Iowa), the average combined costs of grain marketing are 15.2 cents per bushel for an elevator serving a 5-mile trade area and an associated volume of 1,159,999 bushels. If the trade area is extended to 10 miles, the volume increases to 4,639,994 bushels, and the combined costs drop to 12.2 cents per bushel.

An optimum-sized trade area would be one in which the combined costs are at a minimum. As noted earlier, however, the combined cost functions in this study did not increase even for trade areas that extended 28 miles from the elevator. The costs dropped rapidly as the size increased up to 6 to 8 miles; thereafter, the costs decreased less rapidly, and after 11 to 14 miles, they dropped only slightly. Thus, it was assumed that the relevant criterion was the selection of a trade area and associated facility size that captured most of the potential economies. The size of trade area beyond which the combined costs did not decrease at least 0.3 cent per bushel when the size of the trade area was increased another mile was assumed to be the size that would achieve most of the economies and was termed the "economic" trade area.

The size of the "economic area" ranged from 11 to 13 miles from the elevator in the nine districts. The storage capacity of the elevator was determined by dividing the grain-marketing volume by the elevator turnover rate estimated for each district. For example, in District 1 (northwest Iowa), the volume of grain assumed to capture the economies was 5,614,393 bushels in a trade area extending 11 miles from the elevator (see table 29). This would require an elevator of about 3,743,000 bushels storage capacity for a 1.5 turnover rate (table 30). The distance from the elevator in a trade area that achieves most of the economies, the number of elevators required to handle the projected 1980 grain sales, and the storage capacity of the elevators are shown by district in table 30.

It was estimated that 210 elevators in Iowa with an average storage capacity of 3.5 million bushels

Table 28. Projected 1980 stocks and storage requirements, change in storage requirements, and turnover rate.

Crop reporting district	Carryover stocks (1,000 bu.) corn	Carryover stocks (1,000 bu.) beans	New crop stocks (1,000 bu.)	Total stocks (1,000 bu.)	Storage requirement 1980 (1,000 bu.)	Percentage increase over 1970[a]	Turnover rate[b]
1	13,347	4,239	54,744	72,330	103,330	64	1.5
2	19,934	4,480	54,664	79,078	105,438	72	1.8
3	6,976	1,438	24,939	33,353	43,885	142	2.2
4	24,287	4,374	51,444	80,105	117,801	49	1.3
5	35,890	5,853	68,733	110,478	145,366	46	1.5
6	12,073	1,828	32,706	46,607	77,679	127	1.7
7	13,287	2,916	29,099	45,302	68,639	87	1.3
8	4,242	1,143	13,995	19,380	24,227	63	2.0
9	8,428	1,249	28,226	37,903	49,873	92	1.9
Iowa	138,464	27,522	358,550	524,536	735,803	70	1.6

[a]Percentage change from December 1970 capacity of all elevators.

[b]Ratio of total grain sales to storage capacity.

Table 29. Elevator in-plant costs, assembly costs, and combined costs by district under projected 1980 turnover rate and grain-marketing density.

Miles from elevator	Elevator volume (bu.)	Average cost per bushel (dollars) Assembly	In-plant	Combined
		District 1:		
5	1,159,999	0.031	0.122	0.152
6	1,670,398	0.032	0.111	0.143
7	2,273,597	0.033	0.103	0.136
8	2,969,596	0.034	0.097	0.130
9	3,758,395	0.034	0.091	0.126
10	4,639,994	0.035	0.087	0.122
11	5,614,393	0.036	0.083	0.119
12	6,681,592	0.037	0.080	0.117
13	7,841,591	0.038	0.076	0.114
14	9,094,390	0.039	0.074	0.113
15	10,439,980	0.040	0.071	0.111
		District 2:		
5	1,584,999	0.031	0.101	0.132
6	2,282,398	0.032	0.093	0.125
7	3,106,597	0.033	0.086	0.119
8	4,057,596	0.034	0.081	0.114
9	5,135,395	0.034	0.076	0.111
10	6,339,994	0.035	0.072	0.108
11	7,671,393	0.036	0.069	0.105
12	9,129,592	0.037	0.066	0.103
13	10,714,590	0.038	0.064	0.102
14	12,426,390	0.039	0.061	0.100
15	14,264,980	0.040	0.059	0.099
		District 3:		
5	730,000	0.031	0.113	0.144
6	1,051,200	0.032	0.104	0.135
7	1,430,800	0.033	0.096	0.129
8	1,868,800	0.034	0.090	0.123
9	2,365,200	0.034	0.085	0.119
10	2,920,000	0.035	0.081	0.116
11	3,533,200	0.036	0.077	0.113
12	4,204,800	0.037	0.074	0.111
13	4,934,800	0.038	0.071	0.109
14	5,723,200	0.039	0.068	0.107
15	6,570,000	0.040	0.066	0.106
		District 4:		
5	1,025,000	0.031	0.136	0.167
6	1,476,000	0.032	0.125	0.156
7	2,009,000	0.033	0.116	0.148
8	2,624,000	0.034	0.108	0.142
9	3,321,000	0.034	0.102	0.137
10	4,100,000	0.035	0.097	0.133
11	4,961,000	0.036	0.093	0.129
12	5,904,000	0.037	0.089	0.126
13	6,929,000	0.038	0.086	0.124
14	8,036,000	0.039	0.083	0.122
15	9,225,000	0.040	0.080	0.120
		District 5:		
5	1,584,999	0.031	0.113	0.144
6	2,282,398	0.032	0.103	0.135
7	3,106,597	0.033	0.096	0.128
8	4,057,596	0.034	0.090	0.123
9	5,135,395	0.034	0.085	0.119
10	6,339,994	0.035	0.081	0.116

Table 29. Cont'd.

Miles from elevator	Elevator volume (bu.)	Average cost per bushel (dollars) Assembly	In-plant	Combined
		District 5:		
11	7,671,393	0.036	0.077	0.113
12	9,129,592	0.037	0.074	0.111
13	10,714,590	0.038	0.071	0.109
14	12,426,390	0.039	0.068	0.107
15	14,264,980	0.040	0.066	0.106
		District 6:		
5	1,059,999	0.031	0.120	0.151
6	1,526,398	0.032	0.110	0.141
7	2,077,597	0.033	0.102	0.134
8	2,713,596	0.034	0.095	0.129
9	3,434,395	0.034	0.090	0.125
10	4,239,994	0.035	0.086	0.121
11	5,130,393	0.036	0.082	0.118
12	6,105,592	0.037	0.078	0.115
13	7,165,591	0.038	0.075	0.113
14	8,310,390	0.039	0.073	0.112
15	9,539,989	0.040	0.070	0.110
		District 7:		
5	894,999	0.031	0.141	0.172
6	1,288,799	0.032	0.129	0.161
7	1,754,198	0.033	0.120	0.152
8	2,291,197	0.034	0.112	0.146
9	2,899,796	0.034	0.106	0.140
10	3,579,995	0.035	0.101	0.136
11	4,331,794	0.036	0.096	0.132
12	5,155,193	0.037	0.092	0.129
13	6,050,192	0.038	0.089	0.127
14	7,016,791	0.039	0.085	0.124
15	8,054,990	0.040	0.083	0.122
		District 8:		
5	435,000	0.031	0.132	0.163
6	626,400	0.032	0.121	0.152
7	852,599	0.033	0.112	0.144
8	1,113,599	0.034	0.105	0.138
9	1,409,398	0.034	0.099	0.133
10	1,739,997	0.035	0.094	0.129
11	2,105,396	0.036	0.089	0.126
12	2,505,595	0.037	0.086	0.123
13	2,940,594	0.038	0.082	0.120
14	3,410,393	0.039	0.079	0.118
15	3,914,992	0.040	0.077	0.117
		District 9:		
5	869,999	0.031	0.117	0.148
6	1,252,799	0.032	0.107	0.139
7	1,705,198	0.033	0.100	0.132
8	2,227,195	0.034	0.093	0.127
9	2,818,796	0.034	0.088	0.123
10	3,479,995	0.035	0.084	0.119
11	4,210,794	0.036	0.080	0.116
12	5,011,193	0.037	0.077	0.114
13	5,881,192	0.038	0.074	0.112
14	6,820,791	0.039	0.071	0.110
15	6,820,791	0.039	0.071	0.110

Table 30. Projected trade area size, number of elevators, and average storage capacity to achieve most of the economies of scale in grain marketing.

Crop reporting district	Trade area (miles from elevator)	Number of elevators	Storage capacity per elevator (1,000 bu.)
1	11	28	3,743
2	11	25	4,262
3	11	27	1,606
4	12	26	4,542
5	11	28	5,114
6	12	21	3,592
7	12	17	3,965
8	13	16	1,471
9	11	22	2,216
Iowa	--	210	3,503

would achieve most of the economies. This compares with almost 1,200 elevators currently in Iowa with an average capacity of only 432,000 bushels. These are generalized estimates for crop reporting districts, and the different factors estimated would vary within the districts. Thus, all elevators and trade areas would not be of the same size in each district.

Although the average size of elevator needed to reduce marketing costs in 1980 for each area is far in excess of the current average size, a number of elevators of this size are now being operated in Iowa. The estimated number and size of elevators by district are guidelines, which indicate possible costs savings by increasing elevator and trade area size by 1980. Determination of the number and size of facilities in a specific geographic area within a district would require further intensive investigation, considering, not only the factors of marketing density, turnover rate, etc., but also the transportation facilities for shipments of grain out of an area. The current availability and likely future availability of grain-transportation services in a specific location are particularly important to an elevator that ships grain out of the local area.

It seems that substantial cost reductions in grain marketing are possible if the current industry structure is adjusted to a more optimum structure between now and 1980. The continued proliferation of many small elevators located close together is a costly alternative to a structure designed to achieve the economies inherent in a modern grain-marketing system incorporating the latest technology and elevators of sufficient size to realize economies of scale. This fact should be considered carefully when firms in the industry are deciding to merge, expand, or replace existing elevators or to build new elevators.

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APPENDIX

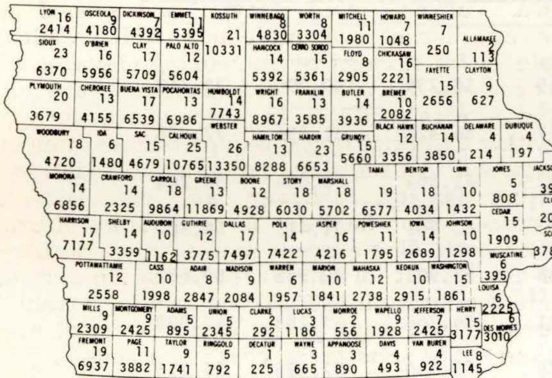

Fig. A-1. Country elevator capacity in thousands of bushels by county, 1970. First figure = number of elevators; second figure = total storage capacity.

Table A-1. Corn sales estimation model, analysis of variance, and information on estimated coefficients.

Source	DF	Sum of squares	Mean square	F ratio
		Analysis of variance		
Variation due to				
Total -------	197	869,371,227.868215		
Regression -------	5	845,044,158.208935	169,008,831.641787	
Residual -------	192	24,327,069.659280	126,703.487809	1,333.8925

Multiple R^2 = 0.97202

Information on estimated coefficients

Variable	Coefficient	t-value	Standard error	Standard coefficient
Year 1964 ----------	9,463914	0.1437	65.843940	0.002258
Corn ----------	0.718260	43.1503	0.016646	1.103900
Beans ----------	0.000629	10.9526	0.000057	0.222455
Cattle ----------	-0.019667	-13.3680	0.001471	-0.227530
Pigs ----------	-0.009040	-20.3524	0.000444	-0.382480
Intercept ----------	-327.933972	-4.0065	81.850568	-0.382480

Table A-2. Estimated corn, soybean, and oat sales, crop years 1964-69, in thousands of bushels.

Crop reporting district	1964	1965	1966	1967	1968	1969
			Corn			
1 --------	47,671	51,836	64,669	58,739	50,795	79,143
2 --------	62,811	56,992	75,457	84,328	81,396	77,978
3 --------	29,899	18,309	33,592	41,564	38,834	34,244
4 --------	53,347	52,280	63,001	62,701	51,411	66,880
5 --------	75,391	74,525	83,988	93,993	90,958	85,637
6 --------	43,054	34,510	41,391	56,366	45,188	47,992
7 --------	30,849	22,622	35,136	35,330	22,095	26,216
8 --------	17,455	16,171	20,379	12,743	18,555	13,642
9 --------	34,719	26,646	31,699	40,320	32,773	33,443
Iowa --------	395,196	353,890	449,310	486,084	432,005	475,176
			Soybeans			
1 --------	21,981	19,614	26,113	23,231	24,868	28,890
2 --------	18,896	19,471	23,409	23,966	28,656	29,087
3 --------	5,020	6,466	6,973	6,917	8,784	8,687
4 --------	17,056	16,797	20,058	19,225	23,675	22,882
5 --------	22,341	22,674	25,894	26,793	34,026	31,539
6 --------	6,260	7,967	8,080	9,453	12,480	12,461
7 --------	7,840	9,314	11,342	10,383	12,998	13,967
8 --------	7,541	8,168	8,865	6,910	11,003	8,915
9 --------	9,676	10,337	10,502	10,611	14,660	14,695
Iowa ---------	116,609	120,807	141,235	137,490	171,150	171,121
			Oats			
1 ----------	4,316	4,105	4,471	4,185	3,772	4,478
2 ----------	3,831	3,533	3,370	3,205	3,996	2,795
3 ----------	5,347	5,518	5,023	5,068	6,818	4,307
4 ----------	3,726	3,198	3,636	3,362	4,015	3,255
5 ----------	3,807	3,293	3,483	3,297	4,136	2,605
6 ----------	4,419	4,250	4,190	4,148	5,343	3,690
7 ----------	1,306	1,229	1,458	1,544	1,835	1,339
8 ----------	1,356	1,193	1,561	1,426	2,178	1,164
9 ----------	1,753	1,412	1,879	1,647	2,405	1,399
Iowa ----------	29,861	27,731	29,070	27,882	34,499	25,031

Table A-3. Estimated fall movement of corn, crop years 1964-69, in thousands of bushels.

Crop reporting district	1964	1965	1966	1967	1968	1969
1 ----------	6,253	4,141	18,019	18,114	23,098	24,795
2 ----------	6,131	9,190	19,394	28,227	28,083	31,262
3 ----------	4,915	7,104	9,604	13,320	11,717	10,521
4 ----------	13,681	11,155	24,925	16,765	23,014	28,645
5 ----------	13,210	15,927	28,873	30,113	27,303	49,538
6 ----------	9,553	11,213	13,115	17,708	16,472	18,122
7 ----------	7,065	7,675	8,902	9,363	5,949	13,525
8 ----------	4,865	3,239	5,709	7,142	8,425	5,079
9 ----------	10,561	14,733	13,117	23,455	17,657	17,538
Iowa ----------	76,233	84,378	141,657	164,206	161,718	199,023

Table A-4. Fall corn-movement estimation model, analysis of variance, and information on estimated coefficients.

Source	Analysis of variance: DF	Sum of squares	Mean square	F ratio
Variation due to				
Total ----------	53	0.187935		
Regression ----------	9	0.138588	0.015399	
Residual ----------	44	0.049348	0.001122	13.7299

Multiple $R^2 = 0.73742$

Variable	Information on Estimated Coefficients: Coefficient	t-value	Standard error	Standard coefficient
District 1 --------	-0.005098	-0.2265	0.022510	-0.027158
District 2 --------	-0.013422	-0.6633	0.020236	-0.071503
District 3 --------	-0.043165	-2.0423	0.021136	-0.229949
District 4 --------	0.007707	0.3633	0.021212	0.041056
District 5 --------	0.001529	0.0773	0.019773	0.008148
District 6 --------	-0.032935	-1.5878	0.020742	-0.175449
District 7 --------	-0.035408	-1.7111	0.020693	-0.188625
District 8 --------	-0.015320	-0.7418	0.020653	-0.081613
Percentage shelled -	0.342004	8.2196	0.041608	0.764575
Intercept --------	0.046574	1.8277	0.025483	

Table A-5. Statistical results of logistic growth function applied to field shelling of corn.[a]

Crop reporting district	Regression coefficients a	b	R^2	t value for b coefficient
1 -----------	-19.12	0.270	0.939	8.7
2 -----------	-21.30	0.312	0.906	7.0
3 -----------	-22.88	0.333	0.971	12.9
4 -----------	-14.05	0.199	0.876	5.9
5 -----------	-22.18	0.329	0.959	10.9
6 -----------	-21.04	0.307	0.862	5.6
7 -----------	-17.55	0.254	0.959	10.8
8 -----------	-20.86	0.305	0.874	5.9
9 -----------	-16.58	0.252	0.934	8.4

[a]The growth function used in the regression had the form $\log_e [P/(0.95-P)] = a + bt$, where P = percentage field shelled, and t = year.

Table A-6. Selected investment costs in dollars for various sizes of elevators.

Model size	Building construction cost	Building equipment cost	Dryer equipment cost	Land cost	Total building and all equipment cost[a]
350,000 ------------	232,050	72,945	59,944	5,000	374,854
500,000 ------------	336,690	83,070	71,989	5,000	507,131
1,000,000 ------------	570,444	116,820	71,989	7,500	784,186
1,500,000 ------------	804,190	150,570	101,129	10,000	1,089,131
2,000,000 ------------	1,037,940	212,815	131,933	15,000	1,424,935
2,500,000 ------------	1,271,690	246,565	143,978	17,500	1,712,391
3,000,000 ------------	1,505,440	284,815	173,118	22,500	2,020,942
3,500,000 ------------	1,739,190.	318,565	173,118	27,500	2,295,565
4,000,000 ------------	1,972,940	356,815	202,258	30,000	2,603,888

Source: Halverson, Duane A. Economies of scale in country grain elevators. Unpublished M.S. thesis. Iowa State University Library, Ames. 1969.

[a]Includes building, building equipment, dryer equipment, heat detection, and aeration.

Table A-7. Grain-marketing costs in an area with marketing density of 10,000, 20,000, 30,000, and 40,000 bushels per square mile with alternative elevator turnover rates and trade-area sizes.

Trade area size[a] (miles)	Plant volume[b] (1,000 bu.)	Average assembly cost (dollars per bu.)	Average combined assembly and in-plant costs[c] (turnover rate) (dollars per bu.)			
			1.5	2.0	2.5	3.0
		Density: 10,000				
4	320	0.030	0.196	0.172	0.156	0.147
5	500	0.031	0.180	0.158	0.144	0.135
6	720	0.032	0.168	0.148	0.135	0.127
7	980	0.033	0.159	0.141	0.129	0.121
8	1,280	0.034	0.152	0.135	0.123	0.116
9	1,620	0.034	0.147	0.130	0.119	0.112
10	2,000	0.035	0.142	0.126	0.116	0.109
11	2,420	0.036	0.138	0.123	0.113	0.107
12	2,880	0.037	0.135	0.120	0.111	0.105
13	3,380	0.038	0.132	0.118	0.109	0.103
14	3,920	0.039	0.129	0.116	0.107	0.102
15	4,500	0.040	0.127	0.114	0.106	0.100
16	5,120	0.041	0.125	0.113	0.104	0.099
17	5,780	0.042	0.124	0.111	0.103	0.098
18	6,480	0.042	0.123	0.110	0.103	0.098
19	7,220	0.043	0.121	0.109	0.102	0.097
20	8,000	0.044	0.120	0.109	0.101	0.097
		Density: 20,000				
4	640	0.030	0.170	0.150	0.136	0.128
5	1,000	0.031	0.157	0.138	0.126	0.119
6	1,440	0.032	0.147	0.130	0.119	0.112
7	1,960	0.033	0.140	0.124	0.114	0.107
8	2,560	0.034	0.134	0.119	0.109	0.103
9	3,240	0.034	0.129	0.115	0.106	0.100
10	4,000	0.035	0.125	0.112	0.103	0.098
11	4,840	0.036	0.122	0.109	0.101	0.096
12	5,760	0.037	0.120	0.107	0.099	0.094
13	6,760	0.038	0.117	0.105	0.098	0.093
14	7,840	0.039	0.115	0.104	0.096	0.092
15	9,000	0.040	0.114	0.102	0.095	0.091
16	10,240	0.041	0.112	0.101	0.094	0.090
17	11,560	0.042	0.111	0.100	0.094	0.089
18	12,960	0.042	0.110	0.100	0.093	0.089
19	14,440	0.043	0.109	0.099	0.093	0.089
20	16,000	0.044	0.109	0.098	0.092	0.088
		Density: 30,000				
4	960	0.030	0.157	0.139	0.126	0.119
5	1,500	0.031	0.145	0.128	0.117	0.110
6	2,160	0.032	0.136	0.121	0.111	0.104
7	2,940	0.033	0.130	0.115	0.106	0.100
		30,000: (cont'd)				
8	3,840	0.034	0.125	0.111	0.102	0.097
9	4,860	0.034	0.120	0.107	0.099	0.094
10	6,000	0.035	0.117	0.104	0.097	0.092
11	7,260	0.036	0.114	0.102	0.095	0.090
12	8,640	0.037	0.112	0.100	0.093	0.089
13	10,140	0.038	0.110	0.099	0.092	0.088
14	11,760	0.039	0.108	0.097	0.091	0.087
15	13,500	0.040	0.107	0.096	0.090	0.086
16	15,360	0.041	0.106	0.095	0.089	0.085
17	17,340	0.042	0.105	0.095	0.089	0.085
18	19,440	0.042	0.104	0.094	0.088	0.085
19	21,660	0.043	0.103	0.094	0.088	0.084
20	24,000	0.044	0.102	0.093	0.088	0.084
		Density: 40,000				
4	1,280	0.030	0.149	0.131	0.120	0.113
5	2,000	0.031	0.137	0.121	0.111	0.105
6	2,880	0.032	0.129	0.115	0.105	0.099
7	3,920	0.033	0.123	0.109	0.101	0.095
8	5,120	0.034	0.118	0.105	0.095	0.092
9	6,480	0.034	0.115	0.102	0.095	0.090
10	8,000	0.035	0.111	0.100	0.093	0.088
11	9,680	0.036	0.109	0.098	0.091	0.086
12	11,520	0.037	0.107	0.096	0.089	0.085
13	13,520	0.038	0.105	0.095	0.088	0.084
14	15,680	0.039	0.104	0.093	0.087	0.083
15	18,000	0.040	0.102	0.092	0.087	0.083
16	20,480	0.041	0.101	0.092	0.086	0.082
17	23,120	0.042	0.100	0.091	0.086	0.082
18	25,920	0.042	0.100	0.091	0.085	0.082
19	28,880	0.043	0.099	0.090	0.085	0.082
20	32,000	0.044	0.099	0.090	0.085	0.081

[a] Miles from plant to periphery of trade area, assuming grid road system.

[b] Volume of grain handled in specified size of trade area; elevator storage capacity is equal to grain volume divided by the turnover rate.

[c] Total of average assembly costs and in-plant costs; average assembly costs do not vary with elevator turnover rate or grain-marketing density.

Table A-8. Statistical cost models, analysis of variance, and information on estimated coefficients.

MODEL I

Analysis of Variance

Source	DF	Sum of squares	Mean square	F ratio
Variation due to				
Total	---- 167	3,336,538,742,866.995000		
Regression	---- 6	3,066,709,977,126.158000	511,118,329,521.026200	
Residual	---- 161	269,828,765,740.837900	1,675,955,066.713279	304.9714

Multiple R^2 = 0.91913

Information on estimated coefficients

Variable		Coefficient	t-value	Standard error	Standard coefficient
Grain sales (bu.)	--------	0.062660	6.8424	0.009158	0.235594
Feed sales (tons)	--------	22.599365	11.5864	1.950515	0.343457
Fertilizer sales (tons)	--------	22.087201	6.2885	3.512313	0.236833
Other sales (dollars)	--------	0.148977	11.7900	0.012636	0.353244
Grain sales / storage capacity	--------	-5491.892518	-2.3461	2340.822520	-0.129200
Grain sales / storage capacity^2	--------	114.498512	1.6816	68.087737	0.091175
Intercept	--------	40,672.097314	4.0571	10,024.959253	

MODEL II

Analysis of Variance

Source	DF	Sum of squares	Mean square	F ratio
Variation due to				
Total	----167	3,336,538,742,866.995000		
Regression	---- 6	3,076,080,441,607.761000	512,680,073,601.293500	
Residual	----161	260,458,301,259.234400	1,617,753,423.970400	316.9087

Multiple R^2 = 0.92194

Information on estimated coefficients

Variable		Coefficient	t-value	Standard error	Standard coefficient
Grain sales (bu.)	----	0.070456	7.9051	0.008913	0.264907
Feed sales (tons)	----	21.831654	11.4918	1.899765	0.331789
Fertilizer sales (tons)	----	20.929505	6.0459	3.461753	0.224420
Other sales (dollars)	----	0.144051	11.8695	0.012136	0.341565
Total sales / storage capacity	----	-18,118.409407	-3.2531	5,569.659299	-0.171654
Total sales / storage capacity^2	-----	940.728381	2.3414	401.780019	0.123717
Intercept	-----	48,204.209619	4.8079	10,025.981655	