2

WESTERN AGRICULTURAL ECONOMICS ASSOCIATION

PROCEEDINGS

1969

Forty-second Annual Meeting
July 20, 21, 22, 1969
Oregon State University
Corvallis, Oregon

EFFECT OF ASSEMBLY COSTS ON OPTIMUM GRAIN ELEVATOR SIZE IN PLAINS AND CORN BELT LOCATIONS

by Ahmed A. Araji and Richard G. Walsh*
University of Idaho and Colorado State University

This study is an extension of earlier work on factors affecting least-cost grain elevator size. In the earlier studies, various aspects of plant economies of size were considered such as in receiving, handling, storage, and loading grain. Assembly cost factors such as grain sales density and the costs of hauling grain from farm to elevator were not considered.

Consideration of assembly costs is of interest from at least three standpoints. First, the goals of cooperatives are usually stated in terms of benefits to farmer-members. Consequently, the owner of the cooperative elevator should consider assembly as well as plant costs in determining the size of operation that would return the highest net-farm price. Second, the fact that owners of these elevators may not have to consider assembly cost factors does not in any way eliminate these costs. If all costs are considered, the focus is placed on total cost to the economy, regardless of the incidence of any particular cost. Third, many developing countries are expanding their grain production and in the process of organizing their grain elevator industry. Consideration of both plant operating costs and assembly costs will provide these countries with a framework for policy decision as to the number of grain elevators that could most economically serve their needs today, in the next decade, as well as volume and location.

Optimum size and location of a plant is a function of plant operation cost and assembly cost. Long-run average cost of plant operation, F, is a function of the quantity of the product handled, X.

(1.1) $$F = g(X)$$

Long-run average cost of assembly, L, is a function of the quantity of the product handled, X, density of grain sales off farm, D, and transportation cost per bushel mile, C. This function is specified in the equation

(1.2) $$L = (X, D, C)$$

Long-run average total cost of the plant is the summation of equations (1.1) and (1.2). With AC_t denoting the long-run average total cost of the plant, this function is specified in the equation

(1.3) $$AC_t = g(X) + h(X, D, C)$$

The primary objective of this paper is to determine the effect of varying grain sales densities and assembly truck cost per mile on total marketing cost for grain, consequently, the optimum size and location of grain elevators.

PROCEDURE

Elevator operating cost data were obtained from earlier studies for use in this analysis. Yager studied volume cost relationships for small cooperative elevators in the northern plains [6]. Sorenson and Keyes combined engineering and economic data to show the effect of plant size and plant utilization on unit costs of medium to large size grain elevators in the Midwest [5]. These data were combined and adjusted to assure comparability of five model plants with annual volume handled as shown in Figure I.

Long-Run Average Cost Function

The long-run average operating cost function was derived from the short-run average cost functions shown in Figure I. In fitting the observations several forms consistent with our restriction on function

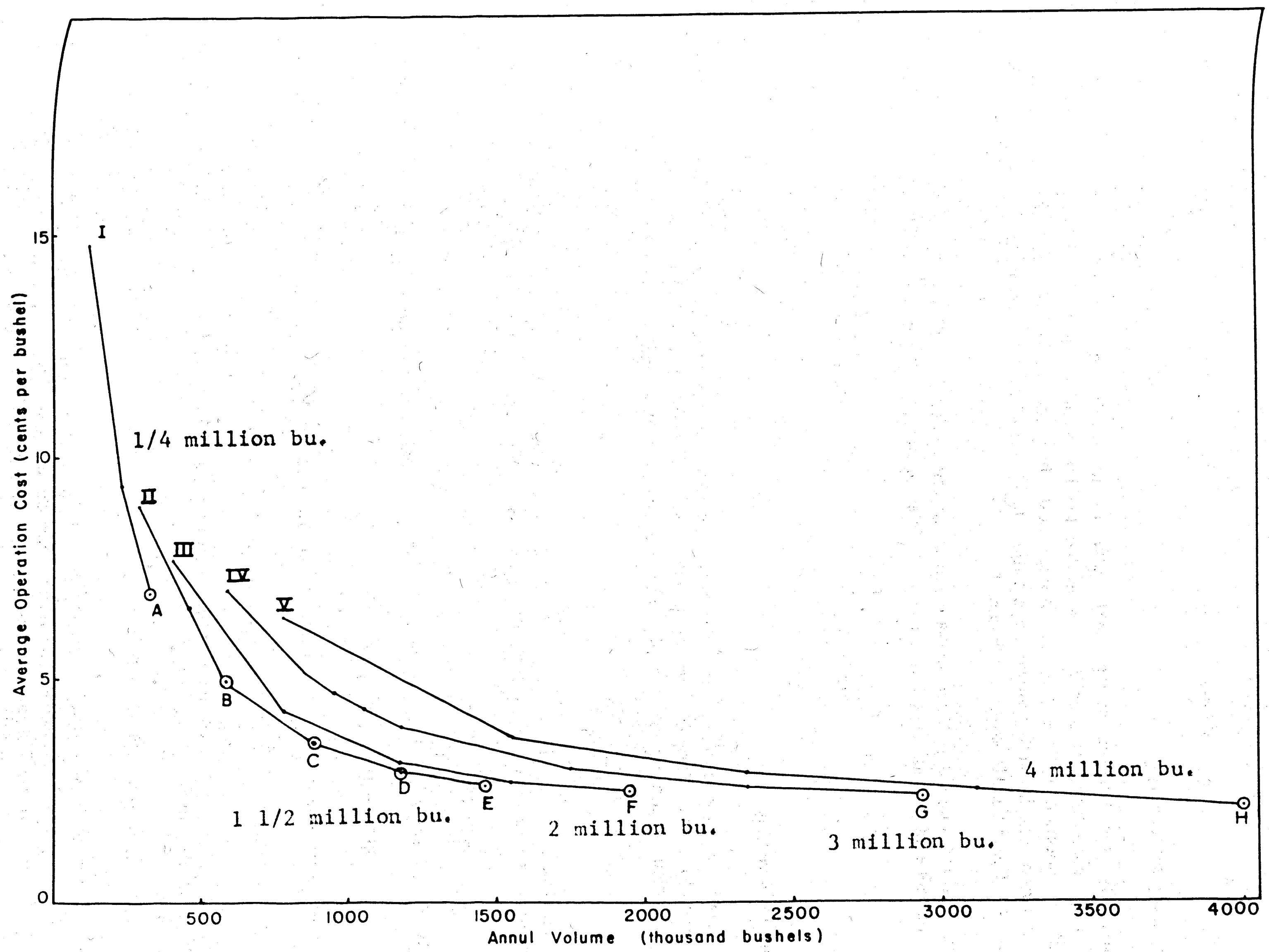

FIGURE I. Comparison of Average Operation Cost for Five Model Grain Elevators of Various Sizes and Operating Rates.

(1.1) were tried. On the basis of the standard measure of fit, a hyperbolic function with the general equation

(2.1) $$F = a + B \left(\frac{1}{x}\right)$$

seemed the most satisfactory.

Theoretically, the long-run average cost curve is the lowest envelope of the set of all possible short-run average cost curves. It is fairly obvious that the lowest observations shown on Figure I tell much more about the location of the long-run average cost than the higher observations do. Therefore, a curvilinear function of the form shown in equation (2.1) was fitted by regression through the circled observations (A,B,C,D,E,F,G,H) shown on Figure I.

Estimate of the long-run average operating cost function used in calculating the optimum size plant, along with the value of the associated coefficient of determination, is shown in the following equation:

(2.2) $$F = 1.590 + \underset{(59)}{18 \times 10^5} \left(\frac{1}{x}\right) \qquad (R^2 = 0.989)$$

(Fig. 2)

Average Cost of Assembly

The long-run average cost of assembly was determined by calculating the total cost function of assembling grain [3]. The marginal cost of hauling grain (C) was estimated at 1/2 cent per bushel-mile under the assemption of contract hauling [4]. The marginal cost of assembling grain is:

(3.1) $$MC_a = CS$$

where S is the distance from the grain elevator. Volume of grain hauled off farm to the grain elevator is equal to the grain sales density per square mile times πS^2 as specified in the equation

(3.2) $$X = D \pi S^2$$

By solving for S and substituting in equation (3.1) the marginal cost function is specified in the equation

(3.3) $$MC_a = CX^{1/2} (\pi D)^{-1/2}$$

The total cost of assembling grain is the integral of equation (3.3)

(3.4) $$TC_a = \int CX^{1/2}(\pi D)^{-1/2}\, dx = 2/3CX^{3/2} (\pi D)^{-1/2}$$

The average cost of assembly can be determined by dividing equation (3.4) by volume hauled off farms to the grain elevator in the following equation:

(3.5) $$L = 2/3C\, X^{1/2} (\pi D)^{-1/2}$$

Sales density was varied from 4,000 to 16,000 bushels per square mile. The lower sales density was typical of the Western Plains Wheat area. The higher sales density was typical of Corn belt agriculture [2]. Figure 2 illustrates the effect of grain sales density on assembly cost and consequently on average total cost.

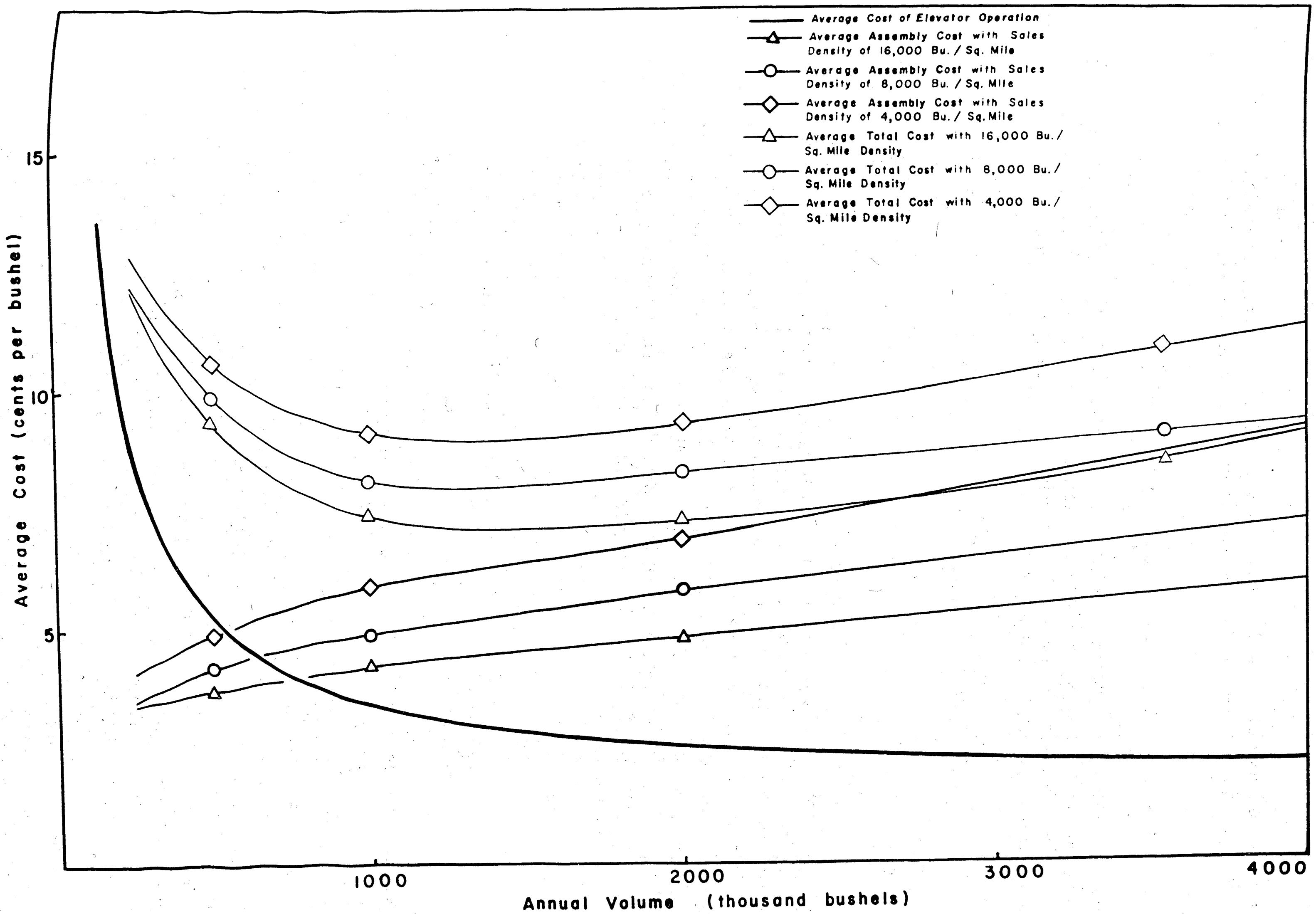

Figure 2. Average Total Cost, Average Cost of Elevator Operation, and Average Assembly Cost

OPTIMUM SIZE AND LOCATION OF GRAIN ELEVATORS

Optimum size and location of grain elevator is a function of the long-run average cost of operation and long-run average cost of assembly. The long-run average total cost function, AC_t, is specified in the equation

$$AC_t = 1.590 + 18 \times 10^5 \left(\frac{1}{X}\right) + 2/3C\, X^{1/2} (\pi D)^{-1/2} \quad (4.1)$$

Since our goal is least-cost grain elevator size and location rather than profit, the objective here is to find the volume of grain handled that will minimize the average total cost function. This can be determined by setting the first derivative, with respect to X, of equation (4.1) equal to zero and solving for X which gives, after rearrangement of terms, the following equation:

$$X = \left[(18 \times 10^5)^{2/3}\right]\left[\frac{(\pi D)^{1/3}}{(\frac{C}{3})^{2/3}}\right] \quad (4.2)$$

Plant and Assembly Costs

The addition of assembly factors establishes a least-cost size of plant beyond which in-plant economies gained by expansion will not offset the accompanying diseconomies due to increasing average length of haul (Fig. 2). When all combinations of levels of factors considered were analyzed, substantial differences in the least-cost size plant were found, Table I shows that when grain sales density was increased to 16,000 bushels per square mile, as is typical of the Corn Belt, the optimum size plant increased to 2 million bushels. This was twice the size of the optimum plant for a typical Plains farming area with a density of 4,000 bushels per square mile. The optimum Plains elevator required a market area of 250 miles compared to 125 miles for an optimum Corn Belt elevator. Market area needed is a function of volume handled and sales density. With MAN denoting market areas needed in square miles, this function can be specified in the equation

$$MAN = \frac{X}{D} \quad (4.3)$$

Maximum distance from elevator needed to deliver grain, S, is specified in the following equation:

$$S = \sqrt{\frac{X}{\pi D}} \quad (4.4)$$

The shortest distance between elevators, S_s, is specified in equation (4.5)

$$S_s = \sqrt{\frac{X}{D}} \quad (4.5)$$

CONCLUSION

The results of the study indicate that assembly factors influence the least-cost size and relative location of grain elevators. Under a range of assembly conditions, least-cost size of plant was 25 to 50 percent of the size where only plant economies of size were considered. Where total costs to the economy are of interest and in many other cases, as well, assembly costs should not be overlooked.

In the long-run, increased grain sales density should result in additional cost savings. Where very high grain production and sales densities are achieved with improved farming practices, the least-cost sizes of grain elevators may become larger and average total costs may become less than those considered in this study.

Table 1. Size of Market Area, Cost of Elevator Operation and Assembly with Grain Sales Densities of 4,000, 8,000 and 16,000 bushels per Square Mile, Central United States, 1960.

	I Annual Volume 250,000 (Bu.)[a] Density[b]			II Annual Volume 500,000 (Bu.)[a] Density[b]			III Annual Volume 1,000,000 (Bu.)[a] Density[b]			IV Annual Volume 2,000,000 (Bu.)[a] Density[b]			V Annual Volume 4,000,000 (Bu.)[a] Density[b]		
	4,000	8,000	16,000	4,000	8,000	16,000	4,000	8,000	16,000	4,000	8,000	16,000	4,000	8,000	16,000
Market Area Needed (Square Mile)	62.5	31.25	15.62	125	62.5	31.25	250	125	62.5	500	250	125	1000	500	250
Maximum Distance from Elev. Needed to Deliver Grain (Miles)	5.56	3.95	2.8	7.93	5.56	3.95	11.18	7.93	5.56	15.81	11.18	7.93	22.36	15.81	11.18
Shortest Distance Between Elevators (miles)	7.93	5.56	3.95	11.18	7.93	5.56	15.80	11.18	7.93	22.06	15.81	11.18	31.86	22.36	15.81
Average Cost of Elev. Operation (Cents per Bu.)	8.79¢	8.79¢	8.79¢	5.20¢	5.20¢	5.20¢	3.39¢	3.39¢	3.39¢	2.49¢	2.49¢	2.49¢	2.10¢	2.10¢	2.10¢
Average Cost of Assembly (Cents per Bu.)[c]	4.1¢	3.5¢	3.4¢	4.9¢	4.2¢	3.7¢	5.9¢	4.9¢	4.2¢	6.8¢	5.8¢	4.8¢	9.2¢	7.2¢	5.9¢
Average Costs Total (per Bu.)	12.85¢	12.20¢	12.15¢	10.60¢	9.90¢	9.40¢	9.10¢	8.10¢	7.40¢	9.28¢	8.28¢	7.28¢	11.35¢	9.35¢	8.05¢

[a]Plant utilization at 100 percent capacity.
[b]"Density" refers to the amount of grain marketed per square mile.
[c]Custom rate for truck transportation is used; 0.5 cents per bushel mile plus a fixed charge of 2.5 cents.

REFERENCES

1. Araji, Ahmed A., "Optimum Size and Location of Grain Elevators in Nebraska," Unpublished M.Sc. Thesis, University of Nebraska, Lincoln, Nebraska, June 1964.

2. Heifner, Richard G., "The Function and Structure of Country Elevators in the United States," in *Marketing Grain,* Proceedings of the NCM-30 Grain Marketing Symposium, North Central Regional Research Publication No. 176, Purdue University, 1968.

3. Olsen, Fred L., "Location Theory as Applied to Milk Processing Plants," *Journal of Farm Economics.* December 1959.

4. Ranson, D. E. and H. J. Zimmerman, "Farm Custom Rates Paid in Nebraska," Extension Service, University of Nebraska, College of Agriculture and U. S. Department of Agriuclture Cooperating, 1962.

5. Sorenson, V. L., and C. D. Keyes, "Cost Relations in Grain Plants," Technical Bulletin No. 292, Agricultural Experiment Station, Michigan State University, East Lansing, 1962.

6. Yager, Francis P., "Country Elevator Cost Volume Relations in the Spring Wheat Belt," Farmer Cooperative Service Report Number 63, U. S. Department of Agriculture, Washington, D. C., September 1963.

FOOTNOTE

*We are indebted to Professor W. E. Folz and the Department of Agricultural Economics at the University of Idaho for computer time.