FOREWORD

This report is being published as part of the North Central Regional Project NCM-39, "Cost Reducing Structural Adjustments in Turkey Marketing." This is a cooperative study involving Agricultural Experiment Stations in the North Central Region and agencies of the U.S. Department of Agriculture.

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SUMMARY

This study dealt with finding a minimum-cost marketing system for assembling and processing turkeys grown in Minnesota, Iowa, and Wisconsin (called "Miniowisc" in this report). Each county in Miniowisc in which 50,000 or more turkeys were grown in 1964 was considered as a source of supply. There were 116 such counties, and they grew 94 percent of the turkeys grown in Miniowisc in 1964. A number of towns were selected as possible locations for turkey processing plants. Costs of processing turkeys in plants of various sizes were obtained, and costs of hauling turkeys from each source of supply to each possible plant location also were computed.

Various combinations of different numbers of processing plants and different locations of plants were considered. From these, we found the number, location, and size of turkey-processing plants that would process turkeys grown in Miniowisc at the lowest possible total assembling and processing cost. Results obtained for 94 percent of the turkeys were extended to include all turkeys grown in Miniowisc in 1964. Effects of variations in truck operating costs and of variations in processing costs were studied.

The results show that total costs of assembling and processing all turkeys grown in Miniowisc could be reduced from $21.2 million or more to $18.3 million by reducing the number of processing plants to six (there are now 33) and by properly locating these plants. This $2.9 million saving amounts to a saving of 0.7 cent per pound ready-to-cook weight or 0.56 cent per pound liveweight for all turkeys grown in Miniowisc. Half of this saving could be achieved by reducing the number of processing plants to 24, and 84 percent of this saving could be achieved by reducing the number to 13 properly located plants. Realistic variations in truck operating costs and in processing costs had little effect on the results.

The substantial savings realizable from reorganization of the turkey-processing industry arise mainly from the existence of economies of large-scale operation in processing plants. The results of this study indicate that each firm in the turkey-processing industry will continue to face strong competitive pressures as other firms try to expand their operations to take advantage of these economies of large-scale operations. The results can provide guidance to individual firm managers in helping them to adjust their operations and to industry leaders in helping them to determine likely or desirable changes.

Least-cost Number, Size, and Location of Turkey-processing Plants in Minnesota, Iowa, and Wisconsin[1]

by George W. Ladd and M. Patrick Halvorson

In the last few years, various reports have dealt with costs of operation of turkey-processing plants. Through these reports and through their own experiences, processing plant managers are well aware of the existence of economies of large-scale operation and the reduction in costs possible from operating at or near capacity. Although the significance of economies of large-scale operation for the individual plant manager is well understood, the significance of these economies for an entire marketing system or for an entire turkey-production region has not been systematically investigated.

In an earlier study of the turkey growing and processing industry in Iowa, Petersen (2) found: (a) Location of turkey-processing facilities at favorable locations could reduce average processing costs per pound. (b) A more nearly optimum procurement pattern would reduce aggregate procurement costs. (c) Half of the existing Iowa turkey-processing plants had the potential capacity (with minor changes in sharp-freezing facilities) to process all turkeys grown in Iowa. (d) Storage, water, sewage, and labor facilities were not limiting factors in Iowa turkey-processing plants. (e) A more nearly optimum procurement pattern would reduce farm-to-plant shrink of turkeys. (f) Procurement costs appear to rise with an increase in procurement area and a decrease in production density. (g) Slaughter and pick-up schedules could be more closely meshed with shorter procurement distances, thus reducing waiting time at the plant.

His study showed that savings were possible, but did not provide detailed guidance on how to achieve the greatest savings in procurement and processing costs. His study did show that adequate guidance would not be provided by an analysis limited to Iowa since about 30 percent of the turkeys grown in Iowa were processed elsewhere and about 20 percent of the turkeys processed in Iowa were grown elsewhere. Farm-production data indicate that a study of Minnesota, Iowa, and Wisconsin will provide useful results.

Table 1 shows 1964 turkey production in each state in the North Central Region in 1964, the most recent year for which census data on turkey production by county were available when this study was done.

The three-state area of Iowa, Minnesota, and Wisconsin is an area of concentrated turkey production. In 1964, these three states produced 56 percent of all turkeys produced in the North Central Region and 28 percent of all turkeys produced in the nation. This three-state area is referred to as Miniowisc in this report. All states bordering Miniowisc except Missouri have relatively light production.

The bulk of Missouri's production takes place in the southern half of the state, and this area is part of another area of concentrated turkey production including southwestern Missouri and northwestern Arkansas. There is a band of light production in northern Missouri and southern Iowa separating Miniowisc from the concentrated area of production just to the south. Miniowisc is bordered on the west by states of light turkey production and bordered on the east by a state of light turkey production and by Lake Michigan. Whereas Iowa's turkey industry is not isolated from the turkey industry of surrounding states, the turkey industry of Miniowisc is relatively isolated.

Table 1. Turkey production in the north central states in 1964.

State	Number
Minnesota	14,549,197
Iowa	8,297,234
Wisconsin	5,728,918
Subtotal	28,575,349
Missouri	6,856,028
Indiana	4,821,459
Ohio	3,865,684
Michigan	1,383,523
Illinois	1,347,630
Nebraska	1,172,811
North Dakota	1,102,768
South Dakota	934,015
Kansas	805,687
Total	50,864,954

Source: U.S. Department of Commerce. Bureau of the Census, 1964 Census of Agriculture. U.S. Gov. Print. Off. Washington, D.C. 1966.

[1] The authors are grateful to Clark Burbee, Lee Schrader, George Rogers, and William Gallimore for their helpful comments on an earlier draft of this report.

OBJECTIVE

The research covered in this report dealt with turkey assembling and processing in Miniowisc. Our objective was to determine a least-cost system of assembling and processing all turkeys grown in Miniowisc. We attained this objective by determining the number, locations, and sizes of processing plants that would assemble and process turkeys for a lower cost than any alternative arrangment of number, location, and size.

RESEARCH METHOD

The method used in this study was developed by Stollsteimer (6,7). It is a long-run or planning procedure that permits the determination of the number, size, and location of processing plants that will minimize the total cost of assembling and processing the total quantity of raw material produced at scattered points. Since technical discussions of the Stollsteimer model and procedure are available in several places (1,5,6,7,13), we will use only an example to illustrate the procedure.

As a first step, various possible sources of supply are identified, and the amount of raw material available from each source is determined. For example, suppose we have three possible sources—Source 1, Source 2, and Source 3—and suppose that the amounts of raw material available from them are Amount 1, Amount 2, and Amount 3, respectively. Next, possible plant sites are selected. In the example, we will consider three plants sites: Site A, Site B, Site C. The total cost of hauling raw material from each source to each plant site is computed. Costs of processing various volumes are determined for each plant site.

Several assumptions are made to make the problem manageable.(a) The quantity available from each source is a constant amount. (b) The same processing technology is used in every plant. (c) The long-run cost function for building and operating a plant can be written:

[1] Total annual processing cost per plant = (Minimum average annual long-run cost of establishing and maintaining a plant) + [(added cost per unit of output) x (quantity of output)]

That is, total annual processing cost is a linear function of output. (d) Minimum average annual long-run cost and added cost per unit of output in equation 1 are the same at each possible plant site. That is, cost of plant construction and operation does not vary among plant sites.

The first step in solving the problem is to determine where a plant should be built if only one is to be built. For the problem involving three sources and three plant sites, this is handled in four stages. (a) Determine costs of processing and assembly if a plant is built at Site A and all sources send their raw material to Site A. (b) Determine costs of processing and assembly if a plant is built at Site B and all raw material is sent there for processing. (c) Determine costs of processing and assembly if a plant is built at Site C and all raw material is sent there for processing. (d) Compare costs from steps a, b, and c to determine which site provides lowest costs if only one plant is to be operated.

The next step is to determine which possible locations for two plants provides lowest costs. This requires consideration of 18 possibilities, six of which are shown in table 2. There are six more possibilities if plants are located at sites A and C, and six more if plants are located at sites B and C. Processing and assembly costs must be computed for each of these 18 situations. For example, to evaluate situation 1 in table 2, it is necessary to compute costs of building plants at sites A and B, costs of hauling from Source 1 to Site A, costs of hauling from sources 2 and 3 to Site B and costs of processing the resulting volumes in these two plants. Costs are also computed for each of the other five situations in table 2 and for the 12 comparable possibilities that exist if plants are located at sites A and C and at sites B and C. Whichever one of the 18 situations provides the lowest total hauling and processing costs is the best two-plant possibility.

Table 2. Possible situations if plants are located at sites A and B.

Situation	Sources of supply for plant at Site A	Sources of supply for plant at Site B
1	Source 1	Sources 2 and 3
2	Source 2	Sources 1 and 3
3	Source 3	Sources 1 and 2
4	Sources 1 and 2	Source 3
5	Sources 1 and 3	Source 2
6	Sources 2 and 3	Source 1

The next step is to determine costs if three plants are built. This requires consideration of the six possibilities listed in table 3. Costs are computed for each situation. For example, for situation 1, we compute the costs of building at sites A, B, and C, the costs of hauling from Source 1 to Site A, from Source 2 to Site B, and from Source 3 to Site C and costs of processing the resulting volumes in these three plants. Comparison of costs for these six situations shows which one provides minimum hauling and processing costs.

The final step involves comparison of the lowest-cost one-plant situation with the lowest-cost two-plant situation and the lowest-cost three-plant situation. Whichever one of these three situations provides the lowest total of hauling and processing cost is the minimum cost solution. It shows how many plants should be built, where they should be located, and where each should obtain its raw

Table 3. Possible situations if plants are located at sites A, B, and C.

Situation	Sources of supply for plant at Site A	Sources of supply for plant at Site B	Sources of supply for plant at Site C
1	Source 1	Source 2	Source 3
2	Source 2	Source 3	Source 1
3	Source 3	Source 1	Source 2
4	Source 1	Source 3	Source 2
5	Source 2	Source 1	Source 3
6	Source 3	Source 2	Source 1

material to minimize total costs of assembling and processing all raw material available from the three sources.

The Stollsteimer method provides a systematic procedure for computing costs for every possible combination of plant locations and sources of supply for each plant.

DATA

Sources of Supply

The 1964 Census of Agriculture (12) was used to determine 1964 turkey production in each of the 257 counties in Miniowisc. If each county had been treated as a source of supply, solution costs would have been prohibitive. Each county reporting production of 50,000 or more turkeys in 1964 was selected as a source of supply. There were 116 such counties. These 116 sources of supply are shown on the map in fig. 1. These counties produced 94 percent of the 28.6 million turkeys grown in Miniowisc in 1964. The number of turkeys available from each county was taken to be the number produced in each county as reported in the 1964 Census of Agriculture.

Plant Sites [2]

Selection of possible plant sites was done in three steps. First, all cities in Miniowisc with populations greater than 5,000 were selected unless they happened to lie beyond the periphery of the sources of supply. For example, Milwaukee, Wisc., lies outside the area of the supply sources and was excluded. Some cities of greater than 5,000 population were excluded because the cities are part of a complex of large cities, such as the Minneapolis-St. Paul metropolitan area, and because no processing plants are presently in the city and are not likely to locate there because of zoning laws, difficuty of access, etc. Smaller towns surrounding

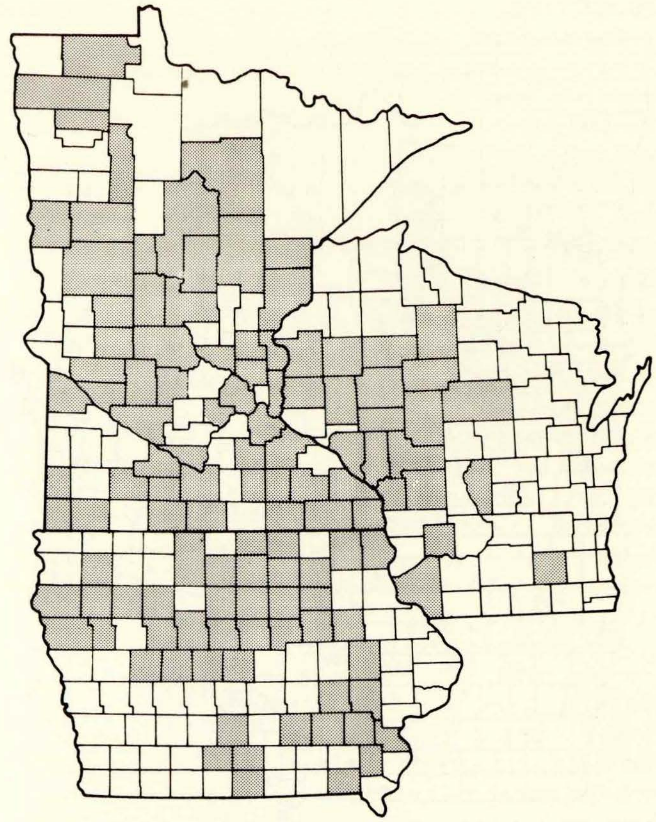

Figure 1. The 116 supply sources in Miniowisc are shown as shaded areas.

these metropolitan areas were included to approximate the actual locations that firms might choose if they decided to locate in these areas. Many sites on the peripheries of cities with greater than 50,000 population were included to provide freedom of location in and around these cities.

The next step in the selection of potential plant sites involved trying to make the distribution of plant sites uniform over the area of the supply sources.

Third, all population centers with an existing processing plant were included. Thirty-three existing processing plants were found in Miniowisc. The set of 184 sites finally selected contains the set of 33 existing sites (plants) in the industry. The set of 184 sites is shown in fig. 2, in which the locations of the 33 existing plants are shown by numbers; the identification of the numbered towns is given in table 4.

Assembly Costs

The Rand McNally Standard Highway Mileage Guide (3) was used to determine the highway distance between each of the 184 plant sites and the centers of each of the 116 counties. This highway distance was doubled to account for roundtrip distance. To determine the total cost of each round trip, the roundtrip distance in miles was multiplied

[2] A "plant site" is a point at which a plant may be located. The analysis determines whether a plant will be located there. A "plant location" is a plant site where a plant should be located according to the results of the analysis.

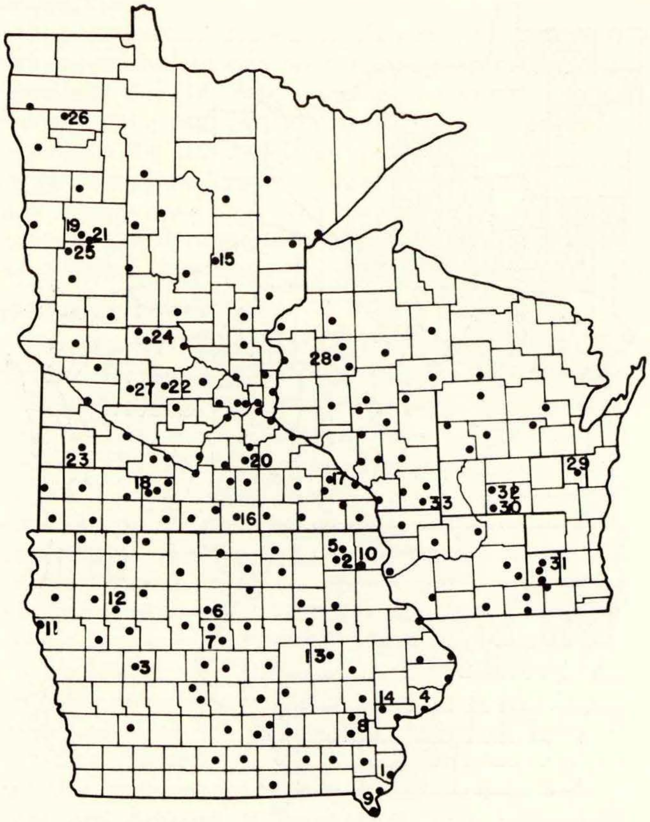

Figure 2. 184 plant sites, with locations of existing plants numbered according to table 4.

by average hauling cost per mile, which is the average total cost per mile of truck operation, including cost of a driver. Petersen (2, p. 24) had data on assembly costs for two situations. Average costs of assembly in the respective situations were 35.41 and 46.45 cents per mile. The average of these two figures, 40.9 cents per mile, was taken

Table 4. The 33 existing plant sites, 1967.

1. Burlington	18. Butterfield
2. Calmar	19. Detroit Lakes
3. Carroll	20. Faribault
4. Davenport	21. Frazee
5. Decorah	22. Litchfield
6. Eagle Grove	23. Marshall
7. Ellsworth	24. Melrose
8. Kalona	25. Pelican Rapids
9. Keokuk	26. Thief River Falls
10. Postville	27. Willmar
11. Sioux City	28. Barron
12. Storm Lake	29. Chilton
13. Vinton	30. Endeavor
14. West Liberty	31. Johnson Creek
15. Aitkin	32. Westfield
16. Albert Lea	33. Wilton
17. Altura	

as the per-mile cost of truck operation for this study. Data on truck operating costs were obtained from two turkey-processing plants in 1967. Average cost per mile for these two plants was close to 40.9 cents. The truck is assumed to haul a 30,000-pound payload on a tandem trailer.

Table 5 presents the average liveweight for each market class of turkeys. The average liveweight of a turkey was estimated from the average liveweights of each of the four market classes—toms, hens, breeders, and fryer-roasters—to be 18.04 pounds. The number of turkeys produced in each county was multiplied by 18.04 to obtain the total liveweight of all turkeys produced in the county. The total liveweight was then divided by 30,000 pounds—the amount hauled by truck on each trip—to determine the number of trips required to assemble the turkeys from that county. A fractional truck load was taken as a full load for computing purposes. To obtain the total cost of hauling turkeys from each county to each plant site, the number of trips required to haul the county's turkeys was multiplied by the cost of one roundtrip to each plant site.

Table 5. Average liveweight by market classes.

Class	Liveweight
Heavy young hens	14.9[a]
Heavy young toms	25.4[a]
Breeders	18.1[b]
Fryer-roasters	8.7[a]

[a] U.S. Department of Agriculture. Agricultural Statistics, 1966. U.S. Dept. Agr. Washington, D.C. 1966.

[b] The average liveweight for all turkeys was used to approximate the weight of breeders.

Cost of loading turkeys onto trucks at the farm were excluded from our assembly-cost figures. These costs are constant for each county, determined only by number of turkeys to be loaded; these costs do not affect, and are not affected by, plant location or plant size.

Processing Costs

Rogers and Rinear (4) synthesized 10 model turkey-processing plants by the economic-engineering approach. The plants ranged in size from 3 to 65 million pounds processed per year. The number of birds in each market class that the plants are capable of processing each hour is given in table 6. The data presented in their study are calculated on the basis of ready-to-cook weight of the turkeys for all market classes.

The assembly-cost functions are calculated on the liveweight basis, which is the weight of the turkeys at the supply sources. The turkeys are assumed not to lose weight in transit; that is, the

Table 6. Capacity of each plant size in number of birds per hour by market classes.[a]

Market classes	Plant sizes[b] 1	2	3	4	5	6	7	8	9	10
Heavy young hens	150	300	450	600	750	900	1,125	1,500	2,250	3,000
Heavy young toms	200	400	600	800	1,000	1,200	1,500	2,000	3,000	4,000
Breeders	120	240	360	480	600	720	900	1,200	1,800	2,400
Fryer-roasters	250	500	750	1,000	1,250	1,500	1,875	2,500	3,750	5,000

[a] George B. Rogers and Earl H. Rinear. Costs and economies of scale in turkey processing plants. U.S. Dept. Agr. Market. Res. Rpt. 627. p. 26. 1963.

[b] The plants ranged in size from 3 to 65 million pounds processed per year.

Table 7. Total pounds processed per year for each plant size by market class.

Market classes	Plant sizes[a] 1	2	3	4	5
Heavy young hens	2,246,400	4,492,800	6,739,200	8,985,600	11,232,000
Heavy young toms	5,068,800	10,137,600	15,206,400	20,275,200	25,344,000
Breeders	2,211,840	4,423,680	6,635,520	8,847,360	11,059,200
Fryer-roasters	2,016,000	4,032,000	6,048,000	8,064,000	10,080,000

Table 7. (Cont'd).

Market classes	Plant sizes[a] 6	7	8	9	10
Heavy young hens	13,478,400	16,848,000	22,464,000	33,696,000	44,928,000
Heavy young toms	30,412,800	38,016,000	50,686,000	76,032,000	101,376,000
Breeders	13,271,040	16,588,800	22,118,400	33,177,600	44,236,800
Fryer-roasters	12,096,000	15,120,000	15,160,000	30,240,000	40,320,000

[a] The plants ranged in size from 3 to 65 million pounds processed per year.

shrink factor is zero. The processing-cost functions are calculated on the ready-to-cook weight basis. Therefore, the liveweight was converted to ready-to-cook weight before calculating the processing cost function. The conversion factor is assumed 0.80, the figure used by the U.S. Department of Agriculture (10).

The capacity of each plant in pounds per hour by market class was determined by multiplying the rows of table 6 by the respective average ready-to-cook weight of each market class as given by Rogers and Rinear (4). The total pounds per year can be derived by multiplying hourly capacity by the number of hours operated in a year. Rogers and Rinear (4) assumed the plants to operate 144 days per year at 100 percent of capacity; 144 operating days per year is equivalent to about 7 months of operation.[3] Assuming typical 8-hour days, the total number of hours per year would be 1,152. This was the figure used to find the total pounds processed per year given in table 7.

The average costs per pound of processing were updated from the 1962 price levels used in Rogers and Rinear to the first half of 1967 price levels. The average processing costs per pound were presented by Rogers and Rinear (4) for each of four market classes: heavy young hens, heavy young toms, breeders, and fryer-roasters. They had the factors that made up the average processing costs

[3] In his survey of six Iowa plants, which processed more than half of all turkeys grown in Iowa, Petersen (2, p. 35) found that 94 percent of their annual slaughter occurred during the 7-month period, June through December.

broken into five categories: plant wages, supplies and materials, management, utilities and miscellaneous, and capital ownership and use.

The plant wages and management categories were added together since management was a small percentage of average costs in all instances. An index of factor prices for all agricultural marketing firms (11) was used to update the average processing costs in all categories except plant wages and management.

The index figure used to update the plant-wages-and-management category was derived from average hourly earnings for workers in poultry dressing and packing(8). The average increase in wages between 1962 and mid-1967 was 15 percent. Therefore, an index figure of 1.15 was used for the plant-wages-and-management category. The indexes for the four categories of inputs are presented in table 8.

Rogers and Rinear's cost for each category of input was multiplied by the corresponding index in table 8. The results for each class of turkey were added to obtain updated average processing costs, as presented in table 9.

Each cost in table 9 represents average processing cost per pound for a plant that processes only one class of turkeys. We needed total yearly cost for a plant processing several classes of turkeys. Multiplying the elements of table 7 (total pounds processed per year) and the corresponding elements of table 9 (the updated average processing costs) gives the total costs per year of processing each class in each plant size. Total costs for each plant size are found by taking a weighted average of the costs by market classes. The weights are the percentages of each class slaughtered under federal inspection in 1960 as taken from Rogers and Rinear (4, p. 34). The same weights are used for the yearly capacities in table 7 to obtain the yearly capacity of each plant size processing all four classes. We now have the yearly capacity of each size of plant and the corresponding total yearly cost of each plant size (table 10). Data in table 10 were used to determine the effect of plant size on total costs; i.e., to determine equation 1.

[2] Total annual processing cost per plant = $133,040 + $0.04 V (in pounds ready-to-cook weight), where V is the volume of turkey processed in the plant, $133,040 is the minimum average annual long-run cost of establishing and maintaining a plant, and 4 cents is the added cost for each additional pound of turkey processed.

Table 8. Indexes of factor prices for January to June 1967 for agricultural marketing firms, 1962 = 100.

Factors	Index
Supplies and materials	1.05[a]
Utilities and miscellaneous	1.02[a]
Capital ownership and use	1.08[a]
Plant wages and management	1.15[b]

[a] Data from U.S. Department of Agriculture, Economic Research Service. Marketing and Transportation Situation MTS-167. November 1967.

[b] Data from U.S. Bureau of Labor Statistics. Employment and earning statistics for the United States, 1909-1966. U.S. Bur. Labor Stat. Washington, D.C. 1966.

Table 10. Total pounds processed yearly and total yearly costs for 10 sizes of processing plants, each operating at capacity.

Plant size	Pounds/year	Total costs/year ($)
1	3,249,677	223,384.32
2	6,499,354	395,182.08
3	9,749,030	554,584.32
4	12,998,707	708,791.04
5	16,248,384	854,853.12
6	19,497,946	1,006,295.04
7	24,372,518	1,237,766.40
8	32,496,653	1,589,587.20
9	48,745,037	2,248,439.04
10	64,993,306	2,940,791.04

Table 9. Average costs in cents per pound of processing turkeys in 1967 for plant sizes by market classes.

	Plant sizes[a]									
Market classes	1	2	3	4	5	6	7	8	9	10
Heavy young hens	7.421	6.553	6.131	5.868	5.659	5.549	5.465	5.260	4.947	4.855
Heavy young toms	6.177	5.491	5.147	4.942	4.770	4.680	4.600	4.435	4.189	4.116
Breeders	8.451	7.347	6.830	6.516	6 286	6.172	6.081	5.842	5.515	5.362
Fryer-roasters	9.346	8.140	7.549	7.224	6.969	6.839	6.744	6.486	6.123	5.952

[a] The plants ranged in size from 3 to 65 million pounds processed per year.

RESULTS

116 Supply Sources, 94 Percent of Turkeys

Initial Costs

The Stollsteimer model was applied to two different problems. In one problem, 184 possible plant sites shown in fig. 2 were included. In the other problem, only the 33 sites listed in table 4 were included. Both problems used the same cost data and used the same 116 sources of supply. To find solutions, the Warrack "iterative" method of solution (13), a variation of the Stollsteimer method, was used. This substitution was necessary because Warrack's method can be used to solve problems with large numbers of supply sources and plant sites, whereas the Stollsteimer method proper frequently cannot be used in such instances.

Results of the analysis with 184 possible plant sites were so similar to the results of the analysis with 33 plant sites that it is not worthwhile to present both sets of results. Only results for the 33-plant-site problem will be presented here.[4] Results are summarized in tables 11 and 12 and in fig. 3. Table 11 must be read consecutively. If one plant, located at Faribault, handles all the turkeys from the 116 sources of supply, the costs will be as shown in the first row of table 11. If there are two plants—one at Faribault and one at Melrose—the costs for the two plants *in total* will be those shown in the second line. If there are three plants—one each at Faribault, Melrose, and Ellsworth—the costs for the three plants in total will be those shown in the third line. Each time a plant is added, total processing costs rise by $133,040 (the minimum average annual long-run cost of establishing and maintaining a plant), and total assembly costs fall. Each time another plant is added—until there are six plants—total costs fall. Adding more plants—a seventh or eighth or ninth plant—increases total costs. The lowest total cost occurs with six plants.

[4] Results for the 184-plant-site problem and the 33-plant-site problem are presented in Halvorson (1).

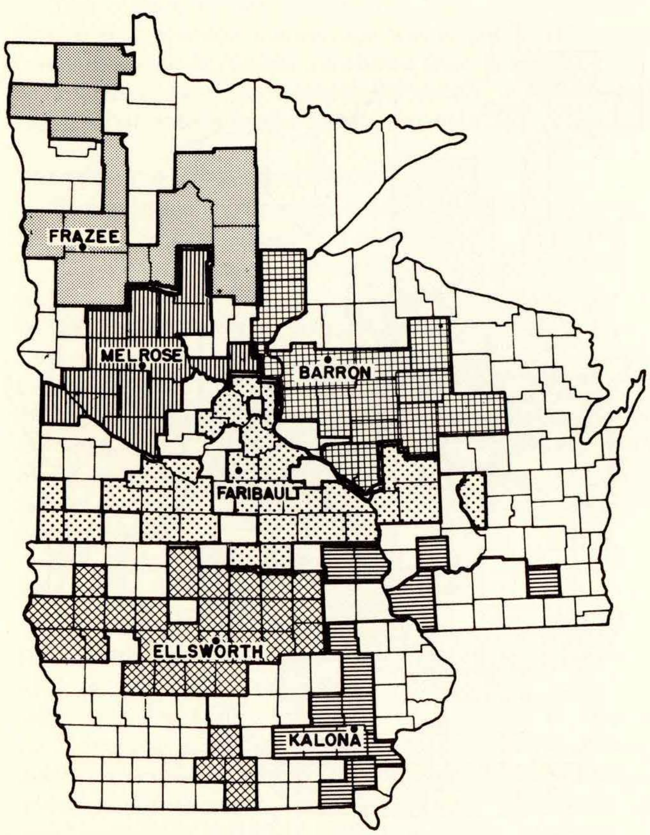

Figure 3. Locations of six plants in the least-cost solution and supply areas serving each plant.

Table 11. Total annual assembly costs, total annual processing costs, and total annual costs for the solution of the 33 existing plant site problem.

Plant	Total assembly costs	Total processing costs	Total costs
Faribault	$2,402,594	$15,631,484	$18,034,078
Melrose	1,788,855	15,764,524	17,553,379
Ellsworth	1,390,028	15,897,564	17,287,592
Barron	1,182,139	16,030,604	17,212,743
Kalona	1,041,252	16,163,644	17,204,897
Frazee	902,801	16,296,684	17,199,486
Wilton	813,509	16,429,724	17,243,234
Willmar	734,494	16,562,764	17,297,259
Storm Lake	672,327	16,695,804	17,368,132
Aitkin	625,570	16,828,844	17,454,415
Thief River Falls	584,997	16,961,884	17,546,882
Decorah	550,543	17,094,924	17,645,467
Butterfield	520,111	17,227,964	17,748,075
Altura	503,889	17,361,004	17,864,893
Westfield	489,553	17,494,044	17,983,597
Sioux City	479,119	17,627,084	18,106,203
Albert Lea	470,362	17,760,124	18,230,487
Jackson Creek	463,837	17,893,164	18,357,002
Litchfield	457,909	18,026,204	18,484,113
Vinton	452,624	18,159,244	18,611,869
Eagle Grove	447,911	18,292,284	18,740,196
Carroll	444,208	18,425,324	18,869,532
Burlington	441,381	18,558,364	18,999,745
Marshall	439,250	18,691,404	19,130,654
Calmar	437,458	18,824,444	19,261,902
Postville	436,862	18,957,484	19,394,347
West Liberty	436,444	19,090,524	19,526,968
Detroit Lakes	436,089	19,223,564	19,659,654
Keokuk	435,900	19,356,604	19,792,505
Davenport	435,900	19,489,644	19,925,545
Pelican Rapids	435,900	19,622,684	20,058,585
Chilton	435,900	19,755,724	20,191,625
Endeavor	435,900	19,888,764	20,324,665

Table 12. Annual costs and total pounds processed[a] per year for each of the six plants in the least-cost solution in table 11.

Plant location	Plant's assembly cost	Plant's processing cost	Thousands of pounds processed	Assembly cost per pound	Processing cost per pound	Assembling and processing cost per pound
	($)	($)		(¢)	(¢)	(¢)
Faribault	182,129	2,603,782	61,769	0.29	4.22	4.51
Melrose	155,309	3,781,711	91,217	0.17	4.15	4.32
Ellsworth	185,048	3,058,904	73,147	0.25	4.18	4.43
Barron	149,870	2,793,176	66,503	0.23	4.20	4.43
Kalona	96,989	1,737,352	40,108	0.24	4.33	4.57
Frazee	133,455	2,321,756	54,718	0.24	4.24	4.48
Totals	902,800	16,296,681	387,461			

[a] Ready-to-cook weight.

Table 11 presents aggregate data for all plants; table 12 presents data for each plant in the least-cost solution. Figure 3 shows plant locations and supply areas providing turkeys to each of these six plants.

Total costs (last column of table 11) are not sensitive to variations in numbers of plants so long as the number of plants in the solution is relatively small. Total costs with six plants are $17,199,486. Total costs are within 3.2 percent of this figure for any number of plants up to and including 13 plants. The locations of the 13 plants in the 13-plant solution and the supply areas providing turkeys to each of these plants are shown in fig. 4.[5]

Shrink and Variation in Hauling Costs

Computation of hauling and processing costs made no provision for shrinkage of turkeys during hauling. There are two reasons for this: (a) There is little available data on shrinkage, especially for relatively short trips such as most of the trips called for by the solutions. (b) Even the longest trips in the least-cost solutions are relatively short. The longest trips generally are between 170 and 190 miles one way. Some tentative calculations made with available shrinkage data indicate that the shrinkage on these longer trips is not sufficiently greater than the shrinkage on shorter trips to offset the costs of constructing additional plants. These calculations indicate that adjusting hauling costs for shrinkage would not have changed the number and location of plants in the least-cost solutions. This conclusion is supported by some additional indirect evidence.

Results in preceding tables and in tables 14 and 15 (to be presented later) were obtained by using the costs:

truck cost per mile = 40.9 cents

[2] Total annual processing cost per plant = $133,040 + $0.040V.

With these costs, the number of plants in the least-cost solution is six. If plant costs remain as described by equation 2 but truck cost per mile changes, the minimum-cost number of plants changes

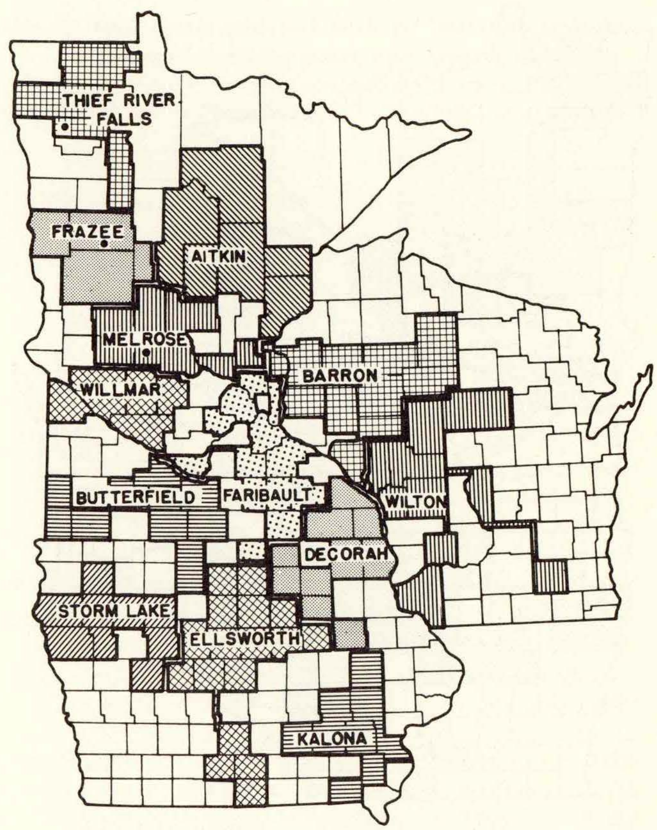

Figure 4. Locations of 13 plants and supply areas serving each.

[5] Cost and volume data for each of these 13 plants will be presented later.

Table 13. Relation of number of plants that minimize total cost to cost per mile of truck operation, 33 plant sites.

Cost of truck operation per mile (cents)	Number of plants in minimum cost solution
Less than or equal to 8.9	1
Between 8.9 and 13.6	2
Between 13.6 and 26.2	3
Between 26.2 and 38.6	4
Between 38.6 and 39.3	5
Between 39.3 and 60.9	6
Between 60.9 and 68.9	7
Between 68.9 and 87.5	8
Between 87.5 and 116.4	9

as shown in table 13. This table shows the least-cost number of plants for different costs of truck operation. It shows that any cost per mile between 39.3 cents and 60.9 cents would have provided six plants in the minimum-cost solution. Cost per mile of truck operation between 60.9 cents and 68.9 cents would have provided seven plants in the minimum-cost solution.

The effect of adjusting the 40.9-cents-per-mile figure to allow for shrinkage would generally have been to raise it. Table 13 shows that it would have to be increased to nearly 61 cents to affect the number of plants in the least-cost solution.

Variations in Processing Costs

The preceding results were obtained by using the cost relation presented earlier:

[2] Total annual processing cost per plant= $133,040 + $0.04V, where V is the volume of turkey processed in pounds ready-to-cook weight. The manner of deriving this relation—using data from Rogers and Rinear (4)—has already been discussed. Rogers and Rinear also present some data (4, p. 7) that indicate that, for plants with a capacity of less than about 28 million pounds ready-to-cook weight, the cost relation may be written.

[3] Total annual processing cost per plant = $25,118 + 0.055V.

We ran one analysis of the 184-plant-site problem using 40.9 cents truck operating cost per mile and using both equations 2 and 3. Equation 3 was used for a plant processing 28 million pounds or less, and equation 2 was used for plants processing more than 28 million pounds. The least-cost solution for this problem was exactly the same as the least-cost solution obtained using equation 2. This happens because each plant in the original solution processed more than 28 million pounds. If more plants are added, the solution differs somewhat from the original solution, but the difference is not great, and total costs with 15 plants are less than 5 percent greater than the total cost with 6 plants. These results indicate that the least-cost solutions are not sensitive to variations in processing-cost equations consistent with the available information on turkey-processing costs.

All Turkeys

To make the problem manageable, only those 116 counties producing 50,000 or more turkeys each were included in the Stollsteimer-model analysis. This covered 94 percent of the turkeys produced. Previous results refer to these 116 counties and 94 percent of the turkeys. Two different adjustments were made to table 12 to account for the remaining 6 percent of the turkeys. In one, we assumed that each plant would take an equal amount of the 6 percent. In the other adjustment, we assumed that each plant's share of all turkeys would be the same as its share of the 94 percent of the turkeys as shown in table 12. Both revisions gave nearly the same results. Results of the second revision are presented in table 14. Results of applying this same revision to the first 13 plants in table 11 are summarized in table 15.

Each county not assigned to a plant in the maps in figs. 3 and 4 can be assigned to the nearest plant without affecting cost or volume figures substantially. Some perspective on the relative importance of each excluded county is provided by this comparison: 50,000 birds have a total liveweight of about 900,000 pounds. Each truckload carried 30,000 pounds liveweight. The largest excluded counties produce no more than 30 truckloads of turkeys a year. The smallest plant in table 12 processes 1,333 truckloads of turkeys each year.

If we revise the results for all 33 plants in table 11 to include all turkeys grown in Miniowisc, we obtain: Total assembly costs = $471,775. Total processing costs = $20,758,026. Total assembly and processing costs = $21,229,801. We can use this figure of $21,229,801 as an estimate of the cost of assembling and processing turkeys in Miniowisc with the existing 33 plants. Table 14 shows that these turkeys could be assembled and processed for $2.9 million less, for $18,325,408. This represents a saving of 13.7 percent in costs of assembling and processing, which amounts to 0.7 cent per pound of ready-to-cook weight, or 0.56 cent per pound liveweight for all turkeys grown in Miniowisc.

This $2.9 million saving understates the actual savings that could be realized by reducing the number of plants and reorganizing patterns of procurement. The $21.2 million estimate of costs with the present system of 33 plants is an underestimate since it is based on these assumptions: (a) All

Table 14. Annual costs and total pounds processed[a] per year in each of the six plants in the minimum cost solution in table 12; results of revising table 12 to cover all turkeys raised in Miniowisc.

Plant location	Total assembly cost	Total processing cost	Thousands of pounds processed	Assembly cost per pound	Processing cost per pound
	($)	($)		(¢)	(¢)
Faribault	209,735	2,761,470	65,711	0.32	4.20
Melrose	178,863	4,014,583	97,039	0.18	4.14
Ellsworth	213,071	3,245,578	77,813	0.27	4.17
Barron	172,592	2,962,933	70,747	0.24	4.19
Kalona	111,664	1,839,741	42,668	0.26	4.31
Frazee	153,663	2,461,440	58,210	0.26	4.23
Totals[b]	1,039,587	17,285,745	412,188		

[a] Ready-to-cook weight.

[b] Total assembly cost + total processing cost = $18,325,408.

of each county's turkeys are delivered to the nearest processing plant. (b) Each processing plant is a new and efficient plant.

To achieve this saving of $2.9 million would require drastic reorganization of the Miniowisc turkey-processing industry: reducing the number of processing plants to six. Table 15 shows, however, that most of this saving, $2.4 million, could be achieved by a less drastic reorganization—reducing the number of plants to 13. Half of the $2.9 million savings could be achieved by reducing the number of plants to 24, the first 24 plants listed in table 11.

Changing Numbers of Turkeys

The number of turkeys grown can vary without changing the number of plants in the least-cost solution. The analysis of 116 supply areas covered 26,861,000 turkeys. If production in each of these counties were to vary by the same proportion, the least-cost six-plant solution presented earlier would still be the least-cost solution for any number of turkeys between 25,813,000 and 40,023,000.

Between 1964 and 1967, turkey production in Minnesota rose by 22 percent, while turkey production in Iowa and Wisconsin fell by 9 and 12 percent, respectively. Rerunning the analyses for 1967 might indicate a somewhat different pattern of plant location necessary to minimize costs and might indicate a least-cost solution of 7, rather than 6, plants. It would, however, still show a least-cost solution of substantially fewer than 33 plants.

Effect of Economies of Scale

The results summarized in tables 11 to 15 and in figs. 1 to 4 reflect the existence of economies of large-scale operation in turkey processing.

Tables 12 and 14 show that plants with larger volumes have lower processing costs per pound. If there were no economies of large-scale operation, processing cost per pound would be the same for every plant size. If processing cost per pound were the same for every plant size, total cost of processing all turkeys would not be affected by changes in the number of plants. Then every figure in the total-processing-costs column of table 11 would be

Table 15. Annual costs and total pounds processed[a] per year in each of the first 13 plants in table 11; results of revising table 11 to cover all turkeys raised in Miniowisc.

Plant location	Total processing cost	Thousands of pounds processed
	($)	
Faribault	1,237,487	27,612
Melrose	1,556,041	35,575
Ellsworth	2,049,361	47,908
Barron	1,979,331	46,157
Kalona	1,369,041	30,900
Frazee	1,375,575	31,063
Wilton	1,590,980	36,449
Willmar	2,382,617	56,239
Storm Lake	1,026,508	22,337
Aitkin	903,785	19,268
Thief River Falls	722,503	14,737
Decorah	1,113,209	24,504
Butterfield	910,780	19,443
Totals[b]	18,217,218	412,192

[a] Ready-to-cook weight.

[b] Total assembly cost = $562,937. Total assembly cost + total processing cost = $18,780,155.

the same. For example, if a plant's processing costs were 4 cents per pound regardless of plant size, every figure in the total processing cost column in table 11 would be $15,498,444. In this instance, total assembly and processing costs would be minimized by having between 29 and 33 plants.

If there were no economies of large-scale operation in turkey-processing plants, the least-cost number of plants would be 29 or more. Since there are economies of large-scale operation, however, the least-cost number of plants is 6.

CONCLUSIONS

Total costs of assembling and processing all turkeys grown in Miniowisc would be lower if assembling and processing were done by a few large plants than if done by many small plants. Total costs would be minimized with 6 properly located plants. The total costs for assembling and processing turkeys with 6 plants would amount to $18.3 million, at least $2.9 million less than the cost with the 1967 system of 33 plants. Of this $2.9 million potential saving from reducing the number of plants to 6, some $2.4 million could be achieved by reducing the number of plants to 13, and half could be achieved by reducing the number of plants to 24.

The results show that some variation can occur in the locations of the 6 plants without affecting cost substantially. For example, the cost with 6 plants (located at Faribault, Melrose, Ellsworth, Barron, Kalona, and Frazee) in table 11 is $17,199,486. The cost for six plants (located at Mound, Iowa Falls, Frazee, Chippewa Falls, Willmar, and Washington) in the problem with 184 plant sites is within 0.3 percent of this: $17,158,169.

The results of the study are not sensitive to reasonable variations in processing-cost equations and truck operating costs.

The findings of this study can be interpreted as explanation, as prediction, or as prescription:

(a) As explanation, they show why turkey-processing plants are becoming generally fewer and larger. Because of economies of large-scale operation, a plant's processing cost per pound declines as the volume processed increases. Also, the total cost of assembling and processing all turkeys grown in Miniowisc is reduced as the number of plants declines and as their average size increases, until the number of plants is reduced to 6.

(b) As prediction, the results show that the trend to fewer and larger plants probably will continue since many existing plants are too small to take full advantage of economies of large-scale operation. Thus, total costs of assembling and processing all turkeys grown in Miniowisc can still be reduced substantially from present levels. Plants too small to take advantage of economies of large-scale operation likely will be squeezed out by plants that are large enough to enjoy these advantages.

(c) As prescription, the results of this study can provide some guidance to the future development of the Miniowisc turkey-processing industry. To the industry as a whole, the results indicate how the industry can be reorganized to reduce costs. To the individual firm manager, the results indicate how he needs to adjust if he is to remain competitive and provide useful information for firms considering construction of new facilities.

The results do *not* show which existing plants have competitive advantages over other existing plants. For example, it is not valid to interpret tables 12 or 14 as showing that the plants at Faribault, Melrose, Ellsworth, Barron, Kalona, and Frazee have a competitive advantage over the other 27 existing plants. Whether any existing plant has a competitive advantage over another existing plant depends upon, among other things, the effectiveness and efficiency of the managers and other employees, the age and design of the plant, the size of the building and equipment, and the markets to which a plant sells its processed turkeys. For purposes of this study, markets for processed turkeys were ignored; all managers and other employees were assumed "typical" (i.e., of equal effectiveness), and age and design of buildings and equipment were assumed to be the same for every plant.

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