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Impact of Transportation, Processing, and Energy Costs on Optimum Number, Size, and Location of Dairy Plants in the Intermountain West

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By

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Rondo A. Christensen*

INTRODUCTION

At one time most milk markets were local in nature. The assembly, processing, and distribution of milk, and the balancing of supplies with demand, all took place in relatively small geographic areas. Subsequent advances in technology, economies of size, and competitive forces have led to fewer but larger more centrally located processing plants, and to the balancing of milk supplies with demand on a wider scale. As a result, most milk markets are now statewide, if not regional in structure.

Many fluid and manufacturing milk plants in the intermountain area are getting old and will need to be replaced during the next decade. Considerable care needs to be exercised in locating them to maximize the potential of their remaining efficient throughout their lifetime.

OBJECTIVES

This study was made to determine whether under current costs the Grade A dairy industry in the intermountain area should continue to centralize the location of its milk processing and manufacturing facilities to take advantage of plant economies of size, or begin to decentralize them to minimize assembly and distribution transportation costs. A second objective was to determine how potential increases in energy costs during the next decade might impact on the economic incentive to centralize versus

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decentralize dairy plants, given existing plant economies of size, transportation costs, and dispersion of supply and demand in the area.

PROCEDURE

The dairy industry in the intermountain area was conceptualized as a set of raw product or production centers, a set of processing and manufacturing plants at various locations, and a set of finished product or consumption centers.

The study area included the five federal milk marketing areas of Black Hills, Eastern Colorado, Great Basin, Lake Mead, and Southwest Idaho-Eastern Oregon. At the time of the study, a Utah based regional dairy cooperative, together with its six member cooperatives, supplied and marketed a majority of the milk used by pool plants in the area, and operated many of the pool plants. Counties were used as production and consumption centers. All counties were included from which producer milk was received by one or more pool plants in the five federal orders, or in which finished products were distributed by pool plants.

The study included all of the fluid milk and cream, ice cream, and cottage cheese plants operating in the area and using Grade A milk pooled in one of the five federal orders in December 1983. To facilitate the analyses and to include the role they play in helping to "balance" Grade A milk supplies, manufacturing plants that used milk pooled in one or more of the five federal orders or purchased milk from one of the six producer cooperatives were also included in the study, together with their Grade B milk supplies.

The following constraints were used in the analyses. All producer milk had to be used and all demand for dairy products had to be met. The Grade B milk was restricted to use by the manufacturing plants normally receiving it. The Grade A milk pooled in the five federal orders was available to all processing and manufacturing plants. A constraint was included in the model to limit the movement of producer milk, excess fat, and finished dairy products to a maximum of 1,000 miles. This served to limit the size of the model but had no effect on the results of the study.

First priority for use of Grade A milk went to meeting consumption requirements for fluid milk and cream, then cottage cheese, and then ice cream. Producer milk remaining after meeting these needs was available for manufacturing cheese. Excess fat in milk used by fluid milk and cottage cheese plants was allowed to be transferred to ice cream and manufacturing plants. A two percent shrink was included in moving producer milk from supply areas to plants. All distances used in the analyses were first calculated in terms of air miles, one way, using longitude and latitude coordinates, then increased to compensate for physical barriers and the fact that most roads follow a grid pattern rather than run direct from one point to another. East-west movement was increased 20 percent, and north-south movement was increased 10 percent.

Linear programming transshipment and plant location models, based on current and alternative plant structures and cost functions, were run iteratively using the MINOS algorithm to perform the analyses. MINOS is a computer program designed to minimize a linear or nonlinear function subject to linear constraints (see Murtagh and Saunders). Minimizing the total cost of assembly, processing and distribution of milk pooled in the five-federal-order market was the objective of the analyses. No effort was made to maximize the profit of individual milk handlers or processors.

To estimate current assembly, processing, and distribution costs to use as a basis for comparison, the model was first run with minimum and maximum volume constraints for each product set to each plant's current (1983) operating volume. The result indicated what total costs would have been had all plants operated at their 1983 volume, assembled milk from the closest available supply area, and distributed finished products in the nearest available consumption center. This obviously understated current costs to some extent, since there was some overlapping among plant supply and distribution routes.

After resetting the maximum volume constraints for each plant to the maximum sizes used in the study, the model was run repeatedly until the least-cost number, size, and location of plants was determined, using current (1985) as well as increased energy costs. If size of plant changed as the model allocated more or less volume to a plant, costs were adjusted to their proper level and the model was run again. Alternative locations were tried for some plants to determine which locations resulted in the least total cost. In making these analyses the maximum monthly volume constraints used were as follows: fluid milk and cream, 20.0 million pounds; cottage cheese, 1.35 million pounds; ice cream, 4.0 million pounds; and cheese, 5.5 million pounds. In these analyses, the only minimum volume constraint was that the manufacturing plants that received Grade B milk had to continue to use it.

SUPPLY AND DEMAND FOR MILK AND MILK PRODUCTS

Milk Supply and Production Areas

The total supply of producer milk included in the study was 331.63 million pounds. The total included 227.17 million pounds of Grade A milk received by pool plants in the five federal orders included in the study,

Table 1. Total Supply of Producer Milk Included in the Study, Five-Federal-Order Intermountain Study Area, by State, December 1983.

	Grade A milk pooled in five intermountain federal orders			Grade B milk used by manufacturing plants		
State	Milk, million pounds	Avg BF test*	Avg SNF test#	Milk, million pounds	Avg BF test*	Avg SNF test#
Colorado	75.10	3.73	8.65	---	---	---
Idaho	68.33	3.80	8.68	45.69	3.82	8.37
Kansas	4.45	3.73	8.65	---	---	---
Nebraska	2.99	3.73	8.65	18.50	3.70	8.60
Nevada	7.35	3.67	8.63	---	---	---
Oregon	2.16	3.83	8.69	---	---	---
So. Dakota	5.48	3.78	8.67	4.35	3.71	8.58
Utah	59.62	3.69	8.64	31.32	3.69	8.37
Wyoming	1.69	3.72	8.65	4.60	3.75	8.66
Total	227.17	3.74	8.66	104.46	3.75	8.43

*Butterfat tests were not available by county. For this reason milk received by pool plants in each of the five federal orders was assigned the market average butterfat test, order by order. Butterfat tests of Grade B milk was based on estimates by industry personnel.

#Solids-not-fat in milk were estimated using the following formula:
SNF per hundredweight of milk = 7.3325 + 0.3541(BF).

and 104.46 million pounds of Grade B and other source Grade A milk used by the associated manufacturing dairy plants (Table 1).

The supply area included 120 counties, and covered all or parts of nine states including Colorado, Idaho, Kansas, Nebraska, Nevada, Oregon, South Dakota, Utah, and Wyoming.

Milk Demand and Consumption Areas

Consumption of fluid milk and cream during the month of the study amounted to 134.02 million pounds (Table 2). The average butterfat test

Table 2. Total Consumption of Fluid Milk and Cream, Cottage Cheese and Ice Cream Included in the Study, Five-Federal-Order Intermountain Study Area, by State, December 1983.

	Fluid milk & cream			Cottage cheese			Ice cream		
State	Mil lbs	Avg BF	Avg SNF	Mil lbs	Avg BF	Avg SNF	Mil lbs	Avg BF	Avg SNF
Arizona	1.35	3.35	8.50	0.02	0.80	20.29	0.07	8.73	11.21
Colorado	60.82	3.43	8.51	1.12	0.80	20.29	3.08	8.73	11.21
Idaho	14.71	3.18	8.46	0.33	0.80	20.29	0.90	8.73	11.21
Kansas	0.44	3.41	8.50	0.01	0.80	20.29	0.02	8.73	11.21
Nebraska	0.43	3.41	8.50	0.01	0.80	20.29	0.02	8.73	11.21
Nevada	11.93	3.33	8.49	0.22	0.80	20.29	0.59	8.73	11.21
Oregon	1.54	3.37	8.50	0.04	0.80	20.29	0.11	8.73	11.21
So. Dakota	2.92	2.93	8.40	0.09	0.80	20.29	0.21	8.73	11.21
Utah	36.24	2.94	8.40	0.64	0.80	20.29	1.76	8.73	11.21
Wyoming	3.65	3.16	8.45	0.07	0.80	20.29	0.19	8.73	11.21
Total	134.02	3.24	8.47	2.55	0.80	20.29	6.95	8.73	11.21

was 3.24 percent, and the associated solids-not-fat test was estimated to be 8.47 percent.

Cottage cheese consumption totaled 2.55 million pounds. Cottage cheese was estimated to include 0.80 percent fat and 20.29 percent solids-not-fat. Ice cream consumption was 6.95 million pounds. The average content of ice cream was estimated to include 8.73 percent fat and 11.21 percent solids-not-fat. The total volume of each product was based on the amount of producer milk used in each individual product during December 1983 as reported by administrators of the five federal orders, converted to pounds of final product using USDA conversion factors and weights and measures (see U.S. Department of Agriculture 1979).

The consumption area of the study included 157 counties, and covered all or parts of ten states, including Arizona, Colorado, Idaho, Kansas, Nebraska, Nevada, Oregon, South Dakota, Utah, and Wyoming.

Number and Location of Milk Plants

The initial selection of processing and manufacturing plant sites was based on the actual location of plants in the study area. All pool plants in the five-federal-order area were included, plus all manufacturing plants that used some Grade A milk pooled in the five federal orders, or milk from one or more of the six major dairy cooperatives supplying milk to pool plants in the study area. Not included in the study were a few manufacturing plants, primarily in Idaho, that neither used excess Grade A milk pooled in the five federal orders, nor purchased milk from the major cooperatives supplying pool plants. These plants relied entirely on their own independent supplies of milk.

Included in the study were 36 plants that processed fluid milk and cream products, 9 that made cottage cheese, 17 that made ice cream, and 17 that manufactured dairy products, primarily cheese (Table 3). While they were scattered throughout much of the study area, about half of the fluid milk and cream plants were in Colorado, and most of the manufacturing plants were in Utah and Idaho.

Table 3. Number and Location of Dairy Plants Included in the Study, by State and Type of Plant, December 1983.

State	Fluid milk and cream	Cottage cheese	Ice cream	Manufacturing
Colorado	17	4	6	1
Idaho	7	2	5	7
Nebraska	-	-	-	1
Nevada	2	1	1	-
South Dakota	1	1	1	2
Utah	9	1	4	5
Wyoming	-	-	-	1
Total	36	9	17	17

COST FUNCTIONS

Processing

Costs for fluid milk processing were based on analyses of fluid milk processing costs by the University of Minnesota (see Fischer 1979). Cottage cheese and ice cream processing costs were based on analyses of cost data received directly from cheese and ice cream plants. Cheese manufacturing costs were based on a study of cheese plants conducted by the Agricultural Cooperative Service of the U.S. Department of Agriculture (see Ling). The plants varied in size and operated in different parts of the country. It is assumed that the cost functions developed from these data represent plant costs, processing technology, and economies of size that either exist, or are available to milk plants in the five-federal-order intermountain study area.

Plant costs included total fixed costs per month and variable costs per hundredweight of product produced during the month, by plant size, with plant size expressed in terms of millions of pounds of product produced. An examination of cost data for each plant group demonstrated that costs were nonlinear. For this reason power curves based on regression analyses, where $Y = ax^b$, were used to quantify the economies of size that existed in the data. Where necessary, costs were adjusted to 1985 cost levels using selected Bureau of Labor Statistics price indexes (see U.S. Department of Labor).

The cost functions thus derived were used to predict fixed and variable costs at the midpoint of several plant volume ranges for each type of plant. These costs are shown in Tables 4 - 7. Alternative variable costs were calculated to simulate a 100 percent increase in energy costs.

Table 4. Estimated Fluid Milk and Cream Processing Costs, by Plant Volume and Level of Energy Costs.

Plant size: Size group	Plant size: Range, million pounds per month	Plant size: Mid point of range, million pounds	Total fixed costs	Variable costs per cwt. with energy costs: At 1985 levels	Variable costs per cwt. with energy costs: Increased 100 percent*
Small	5.0 or less	2.5	$26,840	$3.95	$4.29
Medium	5.1 - 10.0	7.5	50,566	3.68	4.00
Large	10.1 - 15.0	12.5	67,884	3.56	3.87
XLarge	15.1 - 20.0	17.5	82,417	3.48	3.78

*Based on energy costs in 1985 equal to 8.6 percent of total variable costs. Variable costs for small plants with energy costs increased 100 percent, for example, were $3.95 times 1.086, or $4.29 per hundredweight.

Table 5. Estimated Cottage Cheese Processing Costs, by Plant Volume and Level of Energy Costs.

Plant size: Size group	Plant size: Range, million pounds per month	Plant size: Mid point of range, million pounds	Total fixed costs	Variable costs per cwt. with energy costs: At 1985 levels	Variable costs per cwt. with energy costs: Increased 100 percent*
Small	0.16 - 0.45	0.3	$15,701	$26.53	$28.39
Medium	0.46 - 0.75	0.6	26,910	21.18	22.66
Large	0.76 - 1.05	0.9	36,881	18.57	19.87
XLarge	1.06 - 1.35	1.2	46,123	16.91	18.09

*Based on energy costs in 1985 equal to 7.0 percent of total variable costs.

Table 6. Estimated Ice Cream Processing Costs, by Plant Volume and Level of Energy Costs.

Plant size				Variable costs per cwt. with energy costs:	
Size group	Range, million pounds per month	Mid point of range, million pounds	Total fixed costs	At 1985 levels	Increased 100 percent*
Small	1.0 or less	0.5	$39,942	$23.96	$25.56
Medium	1.1 - 2.0	1.5	51,658	17.50	18.67
Large	2.1 - 3.0	2.5	58,222	15.13	16.14
XLarge	3.1 - 4.0	3.5	62,994	13.74	14.66

*Based on energy costs in 1985 equal to 6.7 percent of variable costs.

Table 7. Estimated Cheese Manufacturing Costs, by Plant Volume and Level of Energy Costs, 1985.

Plant size				Variable costs per cwt. with energy costs:	
Size group	Range, million pounds per month	Mid point of range, million pounds	Total fixed costs	At 1985 levels	Increased 100 percent*
XSmall	1.5 or less	1.0	$28,930	$13.36	$15.15
Small	1.6 - 2.5	2.0	43,060	9.94	11.27
Medium	2.6 - 3.5	3.0	54,600	8.46	9.59
Large	3.6 - 4.5	4.0	65,960	7.62	8.64
XLarge	4.6 - 5.5	5.0	80,200	7.40	8.39

*Based on energy costs in 1985 equal to 13.4 percent of total variable costs.

Assembly and Distribution

Separate cost schedules were used in calculating the cost of hauling bulk milk and cream and distributing finished dairy products. They are shown in Table 8. These costs were based on cost analyses for 1985 by milk handlers with extensive trucking operations in the study area. The alternative cost schedules in Table 8 include costs at their 1985 levels, and with energy costs increased 100 percent.

Table 8. Truck Operating Costs per Loaded Mile Traveled, by Type of Haul, 1985.

	Average cost per mile per cwt.	
Type of haul	With 1985 costs	With energy costs increased 100 percent
Bulk milk from supply areas to plants, and cream from plant to plant*	$.00355	$.00433
Finished dairy products from plants to consumption centers#	.00515	.00640

*Based on a fleet average cost of $1.72 per loaded mile for over-the road bulk milk trucks by a large milk handler operating in the intermountain area. Costs included a driver and a truck. A typical truck configuration included a tractor plus a trailer with a 50,000 pound capacity and a payload averaging between 48,000 and 49,000 pounds. Fuel in 1985 was priced at $1.00 per gallon. Fuel consumption was based on 5.3 miles per gallon. Energy costs in 1985 amounted to 22.1 percent of total variable costs. To these costs were added 2.5 cent per hundredweight for unloading bulk milk trucks and 5.0 cents per hundredweight for loading and unloading trucks hauling cream.

#Based on a fleet average cost of $2.06 per loaded mile for over-the-road wholesale delivery trucks by a large milk handler operating in the intermountain area. Costs included a driver and a truck. A typical truck configuration included a tractor plus a 40 foot reefer with a 40,000 pound average payload. Fuel in 1985 was priced at $1.00 per gallon. Fuel consumption was based on 4 miles per gallon. Energy costs in 1985 amounted to 24.3 percent of total variable costs. To these costs were added 10.0 cents per hundredweight for loading and unloading.

ANALYSIS OF DATA

The cost functions described above were used in three different models to estimate the cost of assembling, processing, and distributing milk and dairy products in the study area. The models were based on the following market and cost structures: (1) the current number, size, and location of plants and current costs, (2) the optimum number, size, and location of plants with current costs, and (3) the optimum number, size, and location of plants with energy costs increased 100 percent. In all three scenarios, the supply of producer milk and its source were held constant, as was the demand for fluid milk and cream, cottage cheese, and ice cream.

The optimum solutions were solutions to respective sets of processing and transportation cost functions, given the product availability and demand, that minimized total assembly, processing and distribution costs. The likelihood of arriving at other optimal solutions significantly different than those shown below is small. Over 100 different combinations of plant numbers, sizes, and locations were tested in arriving at the optimum solutions presented.

Optimum Number, Size, and Location of Plants

Fluid Milk

There were 36 fluid milk processing plants operating in the study area in December 1983, or what is referred to as the current period (Table 9). The plants were widely dispersed in such locations as Rapid City, South Dakota; Denver, Colorado; Boise, Idaho; Salt Lake City, Utah; and Las Vegas, Nevada. Most plants were small when classified according to the plant size groups used in the study.

Table 9. Number, Size, and Location of Fluid Milk Under Current and Optimum Marketing Structures, 36 Plants, Five-Federal-Order Study Area.

Plant	Plant location: State	Plant location: City	Current plant size*	Optimum plant size with: Current costs	Optimum plant size with: Energy costs increased 100 percent
				Million pounds per month	
1	SD	Rapid City	Small	3.02	3.02
2	CO	Ft. Collins	Small	-----	--- -
3	CO	Greeley	Small	20.00#	20.00#
4	CO	Boulder	Small	-----	-----
5	CO	Longmont	Small	-----	-----
6	CO	Denver	Medium	-----	-----
7	CO	Denver	Small	-----	-----
8	CO	Denver	Small	-----	-----
9	CO	Denver	Large	20.00#	20.00#
10	CO	Denver	Small	-----	-----
11	CO	Denver	Medium	-----	-----
12	CO	Colo. Springs	Small	-----	-----
13	CO	Colo. Springs	Medium	19.36	19.46
14	CO	Pueblo	Small	-----	-----
15	CO	Delta (CO)	Medium	6.91	6.91
16	CO	Grand Junction	Small	-----	-----
17	CO	Grand Junction	Small	-----	-----
18	CO	Montrose	Small	-----	-----
19	UT	Ogden	Medium	14.83	14.73
20	UT	Salt Lake City	Large	20.00#	20.00#
21	UT	Salt Lake City	Medium	-----	-----
22	UT	Salt Lake City	Small	-----	-----
23	UT	Salt Lake	Small	-----	-----
24	UT	Murray	Small	-----	-----
25	UT	Murray	Medium	-----	-----
26	UT	Draper	Small	-----	-----
27	UT	Cedar City	Small	-----	-----
28	NV	Logandale	Small	-----	-----
29	NV	Las Vegas	Medium	13.28	13.28
30	ID	Idaho Falls	Small	-----	-----
31	ID	Idaho Falls	Small	-----	-----
32	ID	Pocatello	Small	6.94	6.94
33	ID	Buhl	Small	-----	-----
34	ID	Twin Falls	Small	-----	-----
35	ID	Boise	Small	9.69	9.69
36	ID	Boise	Small	-----	-----

*Based on December 1983. Plant volume is not listed for reasons of confidentiality. Refer to Table 4 for plant volume ranges by size group.
#Maximum plant capacity permitted in the model.

Under the optimal solution with current costs, there would be fewer but larger fluid milk plants. The total number would decrease from 36 to 10 (Figures 1 and 2). Remaining plants would be located primarily in the middle of the larger consumption centers. Wherever consumption centers were large enough to justify them, plants would be as large as the model would permit. For example in the Greeley-Denver-Colorado Springs area, there would be one extra-large plant in each city, with two operating at maximum capacity. In the Ogden-Salt Lake City area there would be two plants: one extra-large plant operating at maximum capacity, and one large plant.

Other smaller consumption centers would be served by one plant each. For example, Las Vegas would require one large plant; Delta, Colorado; Pocatello, Idaho; and Boise, Idaho would each require one medium-size plant; and Rapid City, South Dakota would need a small plant.

Under optimal conditions where total industry costs are minimized, there would be little, if any, overlapping of distribution areas. Each plant would handle the adjacent market. Optimal marketing areas for each fluid milk plant are illustrated by the circles in Figure 2.

Increasing energy costs 100 percent for both transportation and plant operations had no impact on the optimum number, size, and location of plants. It appears from these analyses that the impact of increased energy costs in plant operations was offset by the increased energy costs in transportation. Increasing energy costs would increase total marketing costs, but total costs would still be minimized by continued centralization of plants and taking further advantage of economies of plant size, especially in the larger consumption centers.

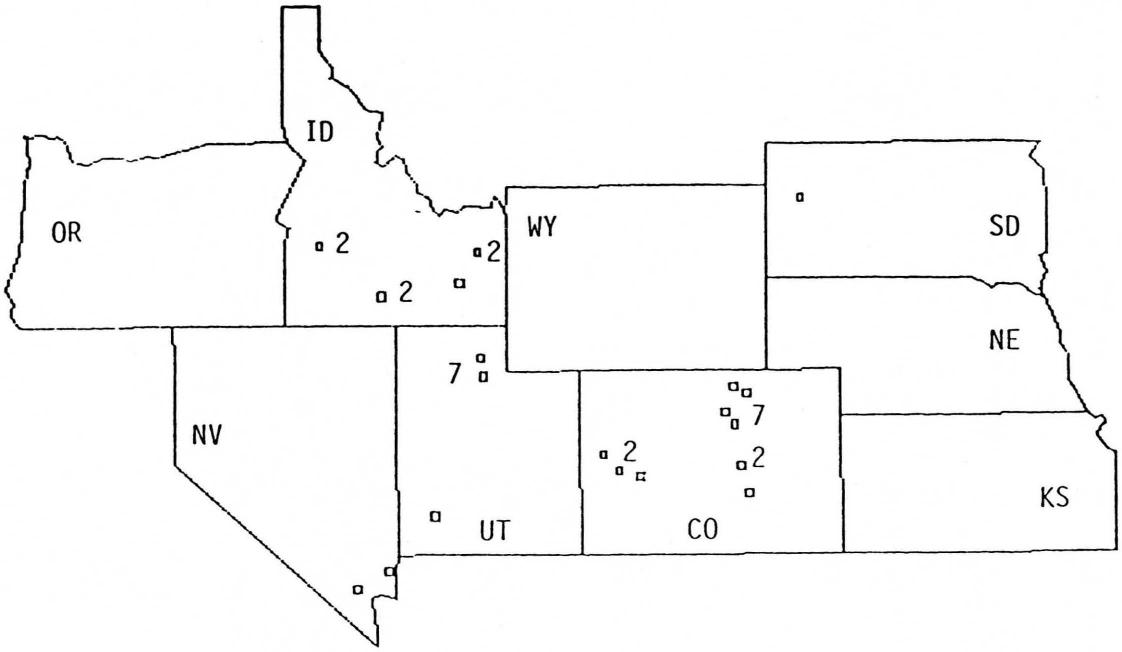

Figure 1. Fluid Milk Plants: Number and Location, 36 Plants, Five-Federal-Order Intermountain Study Area, 1983.

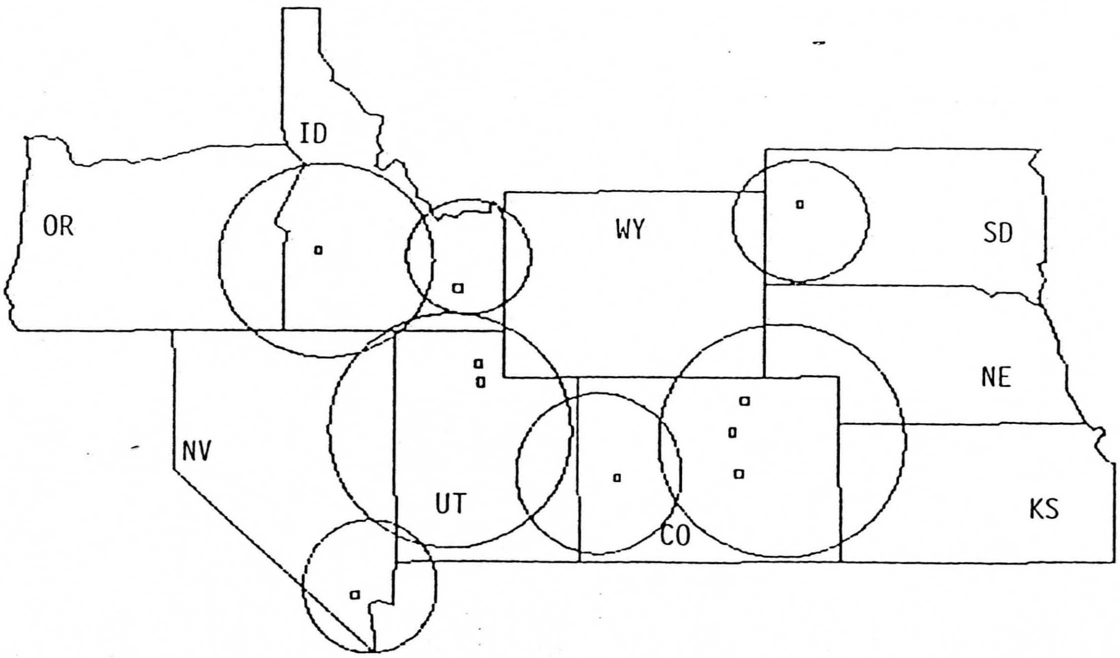

Figure 2. Fluid Milk Plants: Optimum Number, Location, and Marketing Area, 10 Plants, Five-Federal-Order Intermountain Study Area.

These results demonstrate that in fluid milk processing, the dairy industry in the study area has not yet achieved maximum economies of size, and that competitive forces can be expected to continue to drive the industry further toward centralization of plant facilities, even in the face of increasing energy costs.

Under optimal solutions, smaller regional population centers such as Ft. Collins, Boulder, Longmont, Pueblo, Grand Junction, Murray, Draper, Cedar City, Logandale, Idaho Falls, Buhl, and Twin Falls would not have a fluid milk processing plant. This shows that under currently available plant technologies, in many areas where distances are not too great, economies of plant size are sufficient to more than offset increased assembly and distribution costs as market areas increase in size. Distance can become a barrier, however, as was the case with Boise and Pocatello, Idaho. Total assembly, processing, and distribution costs are minimized when each population center is served separately by a medium-sized plant, rather than when both population centers are served by one large plant.

Cottage Cheese Plants

There were 9 cottage cheese plants operating in the study area in December 1983 - 6 small, 2 medium and 1 large (Table 10). The optimal solution with current energy costs would include 2 extra-large plants, one in Greeley, Colorado and one in Ogden, Utah near the larger population centers, with both plants operating near capacity (Figures 3 and 4).

Like fluid milk plants, increasing energy costs 100 percent had no impact on the optimum number, size, and location of cottage cheese plants. While doing so would increase total marketing costs, the impact of increased plant costs on the optimum number, size, and location of plants would be offset by increased transportation costs.

Table 10. Number, Size, and Location of Cottage Cheese Plants Under Current and Optimum Marketing Structures, 9 Plants, Five-Federal-Order Intermountain Study Area.

	Plant location			Optimum plant size with:	
Plant	State	City	Current plant size*	Current costs	Energy costs increased 100 percent
				Million pounds per month	
1	SD	Rapid City	Small	----	----
2	CO	Greeley	Large	1.30	1.30
3	CO	Boulder	Small	----	----
4	CO	Denver	Small	----	----
5	CO	Denver	Medium	----	----
6	UT	Ogden	Medium	1.25	1.25
7	NV	Las Vegas	Small	----	----
8	ID	Twin Falls	Small	----	----
9	ID	Boise	Small	----	----

*Based on December 1983. Plant volume is not listed for reasons of confidentiality. Refer to Table 5 for plant volume ranges by size group.

These results demonstrate that in cottage cheese processing, the dairy industry in the study area has not yet achieved maximum economies of size, and that competitive forces can be expected to continue to push toward larger, more efficient, cottage cheese processing plants.

There would be fewer cottage cheese plants than fluid milk plants under optimum solutions. Not only is the demand for cottage cheese much less, but achieving maximum economies of plant size offsets a greater number of miles in making and distributing cottage cheese than fluid milk because cottage cheese is less bulky, making it less expensive to transport in relation to the amount of raw milk required to produce it.

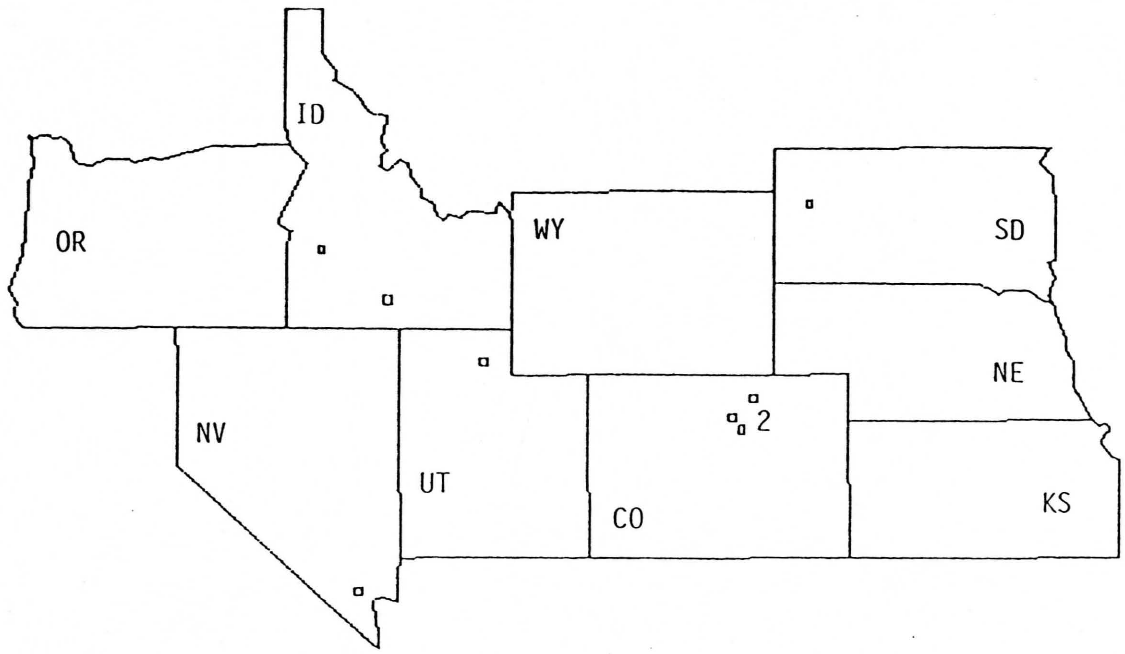

Figure 3. Cottage Cheese Plants: Number and Location, 9 Plants, Intermountain Area, 1983.

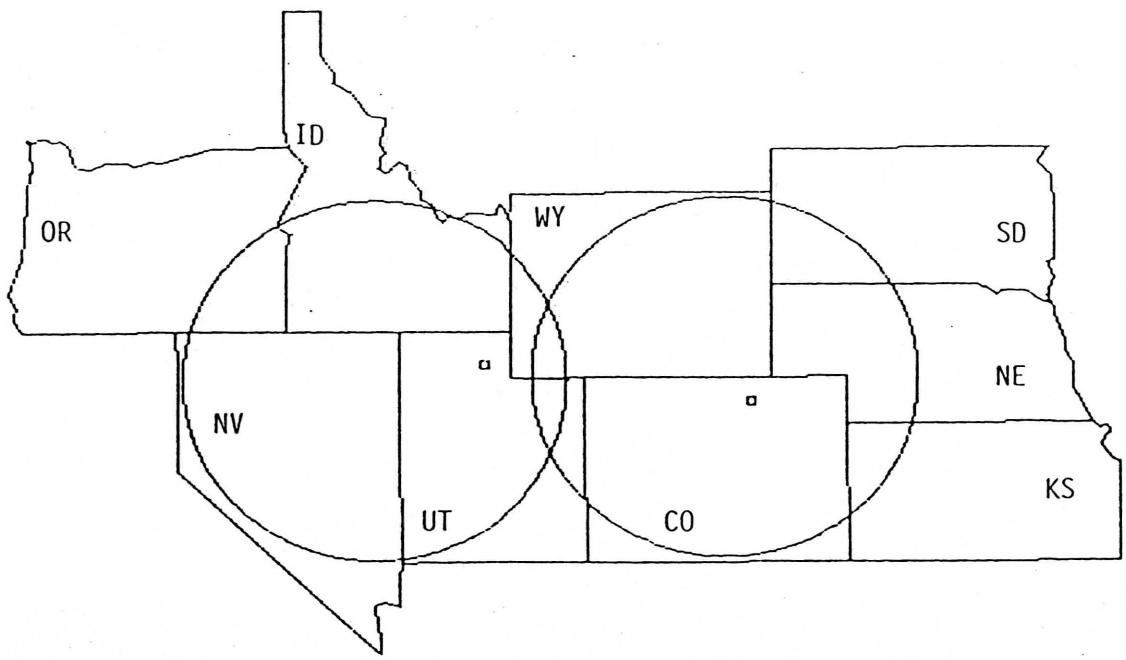

Figure 4. Cottage Cheese Plants: Optimum Number, Location, and Marketing Area, 2 Plants, Five-Federal-Order Intermountain Study Area.

Ice Cream Plants

Ice cream plants followed the same pattern as cottage cheese plants. Operating in December 1983 were 14 plants (Table 11). Of these, 11 were small plants and 3 were medium-sized plants. Under optimum solutions, there would only be 2, both situated near the larger population centers, including one extra-large plant operating at maximum capacity in Greeley, Colorado, and one large plant located in Salt Lake City (Figures 5 and 6).

Table 11. Number, Size, and Location of Ice Cream Plants Under Current and Optimum Marketing Structures, 15 Plants, Five-Federal-Order Intermountain Study Area.

	Plant location			Optimum plant size with:	
Plant	State	City	Current plant size*	Current costs	Energy costs increased 100 percent
				Million pounds per month	
1	SD	Rapid City	Small	----	----
2	CO	Greeley	-----	4.00#	3.45
3	CO	Denver	Small	----	----
4	CO	Denver	Small	----	----
5	CO	Denver	Medium	----	----
6	CO	Colo. Springs	Medium	----	----
7	UT	Ogden	Medium	----	----
8	UT	Salt Lake City	Small	2.95	3.50
9	UT	Salt Lake City	Small	----	----
10	UT	Murray	Small	----	----
11	NV	Las Vegas	Small	----	----
12	ID	Pocatello	Small	----	----
13	ID	Buhl	Small	----	----
14	ID	Twin Falls	Small	----	----
15	ID	Boise	Small	----	----

*Based on December 1983. Plant volume is not listed for reasons of confidentiality. Refer to Table 6 for plant volume ranges by size group.

#Maximum plant capacity permitted in the model.

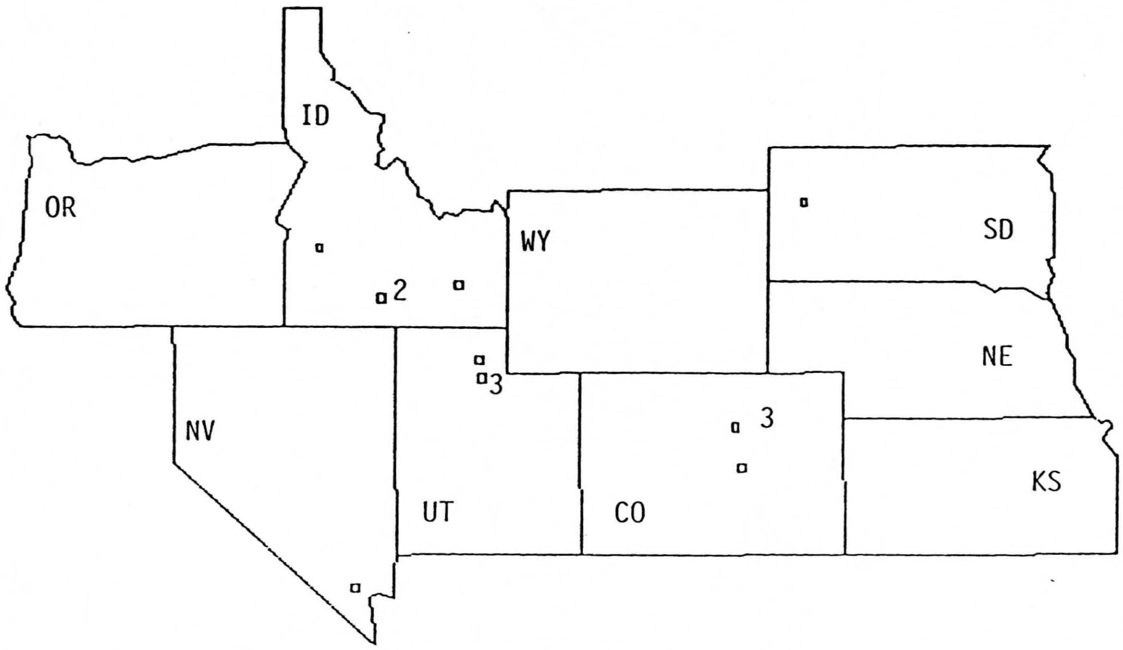

Figure 5. Ice Cream Plants: Number and Location, 14 Plants, Five-Federal-Order Intermountain Study Area, 1983.

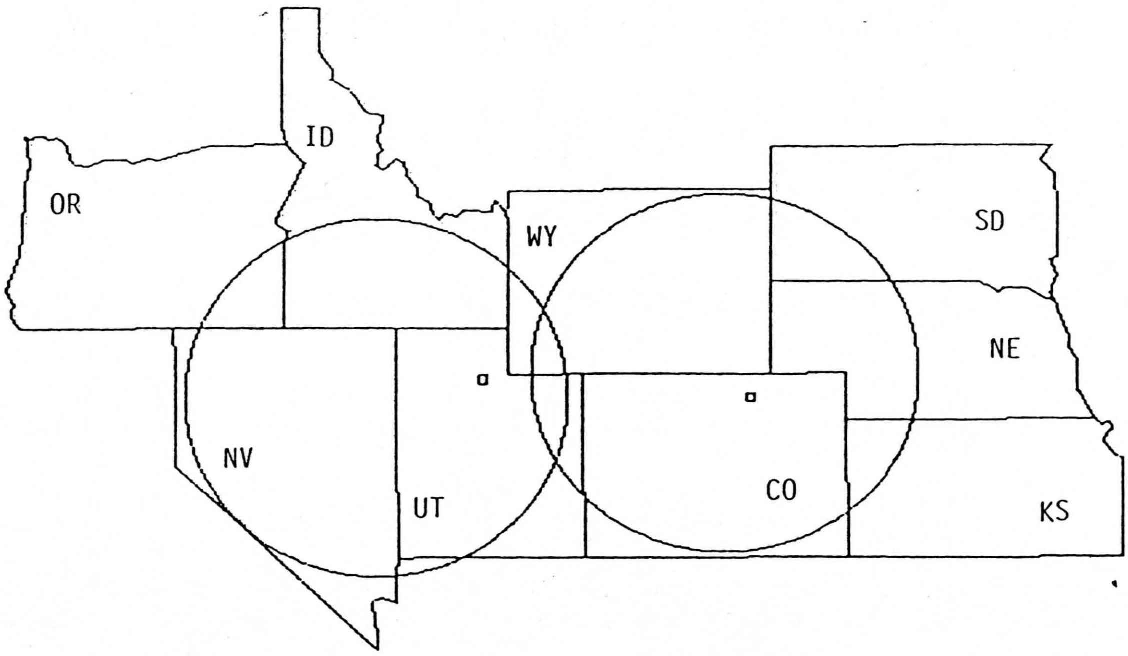

Figure 6. Ice Cream Plants: Optimum Number, Location, and Marketing Area, 2 Plants, Five-Federal-Order Intermountain Study Area.

With increased energy costs, some of the volume handled by the Greeley plant would be more efficiently handled by the Salt Lake City plant. None of the currently existing plants included in the study processed ice cream in Greeley, Colorado. But total assembly, manufacturing and distribution costs would be less if an ice cream plant were located there, for example, rather than in Denver.

Under the optimum number, size, and location of plants in the inter mountain area, there would be little if any overlapping of milk supply assembly routes. Each plant would tend to receive milk from nearby producers. Optimal supply areas for combined fluid milk, cottage cheese, and ice cream plants are shown in Figure 7.

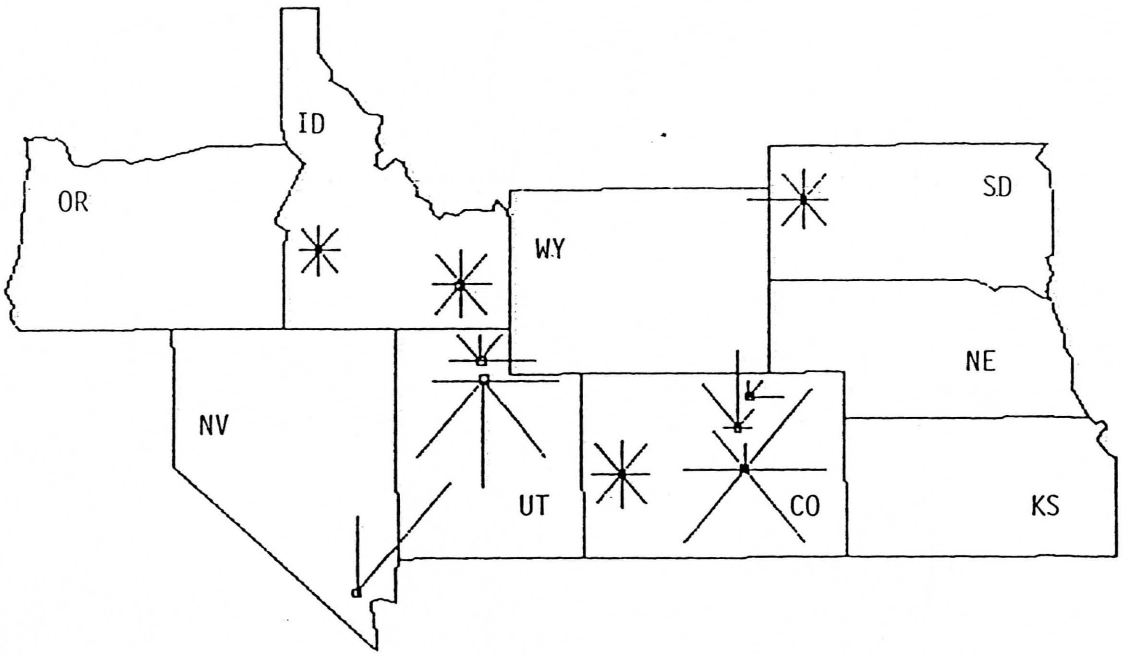

Figure 7. Optimal Milk Supply Areas, 10 Fluid Milk, Cottage Cheese, and Ice Cream Plant Locations, Five-Federal-Order Intermountain Study Area.

Manufacturing Plants

During December 1983 there were 17 manufacturing plants operating in the study area using some excess Grade A milk from plants in the five federal order pools, or buying milk from the six major dairy cooperatives supplying milk to pool plants (Table 12). Most of the plants were located in Utah and Idaho in the western portion of the supply area. There were also, however, a few manufacturing plants on the east side of the supply area (Figure 8).

All manufacturing plants were small, based on the size groups used in the study, except for two extra-large plants and one medium-size plant operating in Northern Utah, one extra-large plant in Western Idaho, and one large plant in Nebraska.

With optimal movement and manufacture of excess supplies of Grade A milk in the study area, both with current and increased energy costs, there would be four primary manufacturing balance plants, all operating at capacity (see Table 12 and Figure 9). Three would be located on the western side of the supply area - one in northern Utah, one in south central Idaho, and one in southwestern Idaho. The fourth would be on the east side of the supply area in Nebraska. No attempt was made to determine a more optimum location for the plant in Nebraska since its primary function was to serve as a balance plant for pool plants in federal orders to the east of the intermountain area.

In addition, 6 of the 17 manufacturing plants would possibly continue operating, using mainly their own Grade B milk during the short-supply milk season, and in addition, some of the excess Grade A milk supplies from the five-federal-order milk supply during months of high production.

Table 12. Number, Size, and Location of Manufacturing Plants Under Current and Optimum Marketing Structures, 17 Plants, Five-Federal-Order Intermountain Study Area.

	Plant location			Optimum plant size with:	
Plant	State	City	Current plant size*	Current costs	Energy costs increased 100 percent
				Million pounds per month	
1	NB	Superior	Large	5.50#	5.50#
2	SD	Sturgess	Small	0.40+	0.40+
3	SD	Rapid City	Small	0.28@	0.28@
4	CO	Denver	Small		
5	WY	Thane	Small	0.46+	0.46+
6	UT	Richmond	XLarge	----	----
7	UT	Amalga	XLarge	5.50#	5.50#
8	UT	Ogden	Medium	----	----
9	UT	Delta	Small	----	----
10	UT	Beaver	Small	0.35+	0.35+
11	ID	Idaho Falls	Small	0.41@	0.41@
12	ID	Buhl	Small	----	----
13	ID	Twin Falls	Small	5.50#	5.50#
14	ID	Twin Falls	Small	----	----
15	ID	Richfield	Small	0.90@	0.90@
16	ID	Caldwell	XLarge	5.50#	5.50#
17	ID	Nampa	Small	----	----

*Based on December 1983. Plant volume is not listed for reasons of confidentiality. Refer to Table 7 for plant volume ranges by size group.

#Maximum plant capacity permitted in the model.

+Lower limit permitted in the model (equal to receipts of Grade B milk).

@Plant retained in the model because it had it's own supply of Grade B milk. Plant volume listed includes some nearby excess Grade A milk pooled in the five federal orders.

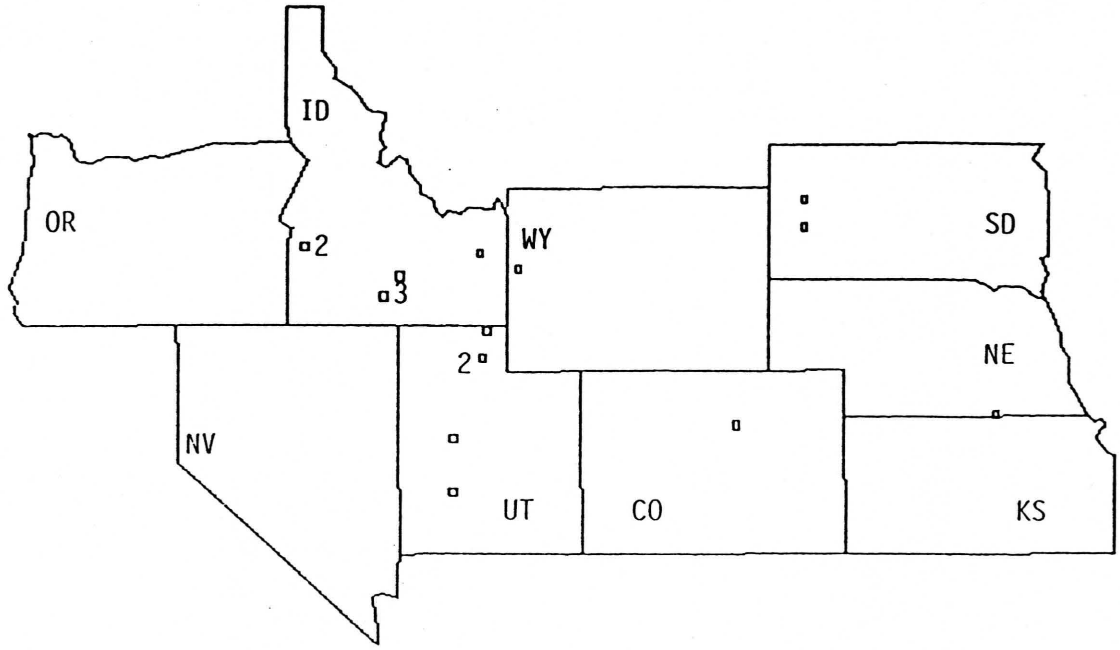

Figure 8. Location of 17 Manufacturing Plants That Bought Milk From Pool Plants, Five-Federal-Order Intermountain Study Area, December 1983.

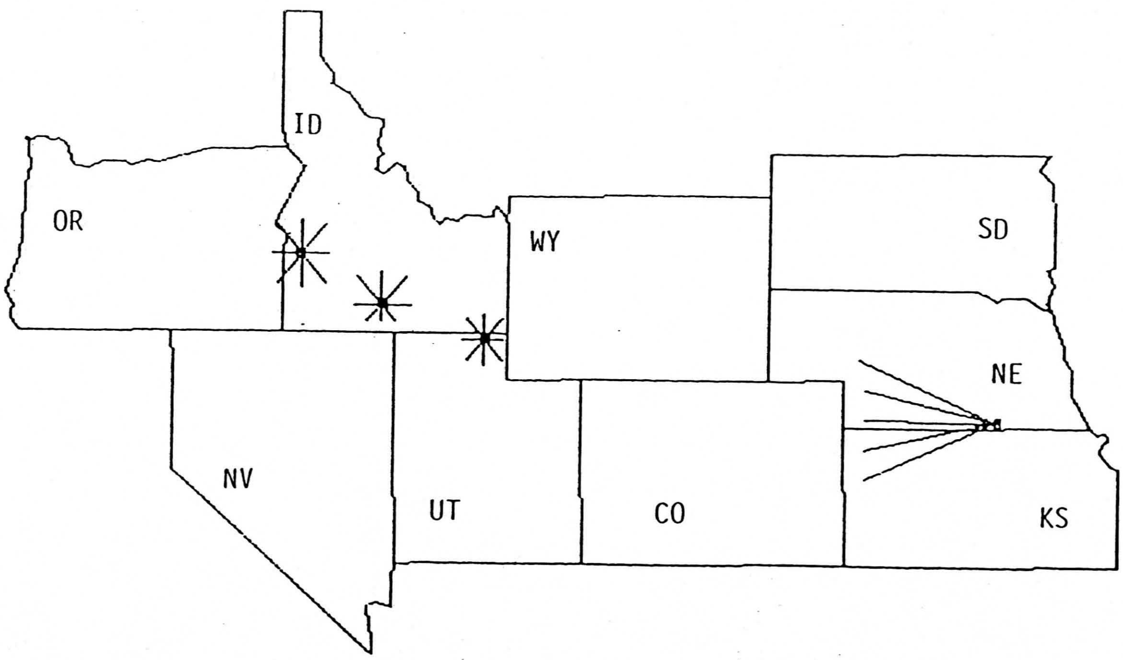

Figure 9. Manufacturing Balance Plants: Optimum Location and Milk Supply Areas for 4 Primary Plants, Five-Federal-Order Intermountain Study Area.

Figure 9 shows the supply areas from which excess supplies of Grade A milk would be diverted to the four primary manufacturing "balance" plants under optimal conditions and with market-wide coordination of milk supplies and movement of milk.

These analyses show that there are still considerable economies of size to be captured in the manufacturing of excess Grade A milk in the study area, and that fewer but larger manufacturing plants would reduce overall costs in the industry as a whole. In handling excess supplies of Grade A milk, the optimal solutions show that total assembly and manufacturing costs would be reduced if a greater proportion of the Grade A milk produced in South-Central Idaho remained in the area to be manufactured there, than currently is being done.

Total Assembly, Processing, and Distribution Costs

Total assembly, processing, and distribution costs amounted to $13,229,000 using the "current" model (Table 13). This included $482,000 in assembly costs; $9,022,000 to process fluid milk and cream, cottage cheese, and ice cream; $3,166,000 to manufacture cheese; and $559,000 to distribute fluid milk and cream, cottage cheese, and ice cream. These costs represent one month's operations.

The "current" model included milk supplies and use of milk as existed in the market in December 1983, with all plants operating at their December 1983 volumes, and plant and transportation costs at their 1985 levels.

The model understates current costs to some degree, because in reality individual plants do not necessarily receive milk from the least-cost source nor distribute finished products to least-cost markets, as though all plants were coordinated and operated by one firm. Instead, there is

Table 13. Total Assembly, Processing, and Distribution Costs for Milk and Milk Products Under Current and Optimum Marketing Structures, Five-Federal-Order Intermountain Study Area.

Cost item	Current costs and number, size and location of plants	Optimum number, size and location of plants with: Current costs	Optimum number, size and location of plants with: Energy costs increased 100 percent
	-------- Thousands of dollars --------		
Assemble producer milk from production centers to processing plants	482	455	544
Process fluid milk and cream, cottage cheese and ice cream	9,022	7,032	7,500
Manufacture excess Grade A, Grade B, and other source milk into cheese	3,166	2,497	2,765
Distribute fluid milk and cream, ice cream and cottage cheese to consumer centers	559	505	584
Total	13,229	10,489	11,393

considerable duplication and overlapping in assembly and distribution routes. Nevertheless, the total assembly, processing, and distribution cost of $13,229,000 for all plants serves as a useful base from which to measure the impact of alternative combinations of number, size, and location of plants.

When number, size and location of plants were optimized to minimize total assembly, processing, and distribution costs, costs decreased from $13,229,000 to $10,489,000, or $2,740,000. The savings would amount to $1.21 per hundredweight of Grade A milk, or about 10 cents per gallon.

Reduction in costs occurred in all cost areas, including assembly, processing, manufacturing, and distribution. The greatest reduction - $1,990,000 - was in processing fluid milk and cream, cottage cheese, and ice cream, as economies of size were achieved by reducing the number of plants, increasing volume per plant, and reducing average cost per unit. The second largest savings - $669,000 - was accomplished in a similar manner by reducing the number of plants manufacturing cheese.

Even with fewer, more widely dispersed plants, there were modest savings in assembling producer milk and in distributing finished products, $27,000 and $54,000, respectively, as a result of plants being located more strategically with regard to sources of milk and consumption centers.

If energy costs increased 100 percent, total costs under an optimal solution would increase from $10,489,000 to $11,393,000, or 8.6 percent. The impact would be varied, however. Assembly costs would increase 19.6 percent; processing fluid milk and cream, cottage cheese, and ice cream 6.7 percent; manufacturing cheese 10.7 percent; and distributing fluid milk and cream, cottage cheese, and ice cream 15.6 percent.

SUMMARY AND CONCLUSIONS

For many years advances in technology, economies of size, and competitive forces have led to fewer but larger more centrally located processing plants, and to balancing Grade A milk supplies with demand over a wider geographic area. Many milk plants in the intermountain area are becoming old, inefficient, and obsolete, and need to be replaced. Careful market analyses and capital planning need to precede the construction of new plants to maximize the potential of their remaining efficient throughout their lifetime.

This study of the Grade A milk market in a five-federal-order area, was made to determine whether under current transportation and plant cost structures, as well as with increased energy costs, it would still be more efficient to operate with fewer but larger more centrally located processing plants, or whether the dairy industry should begin to decentralize its processing facilities. The focus of this study was on the Grade A milk market and Grade A milk plants, but also included the manufacturing plants that used excess Grade A milk supplies in the study area, and by doing so, served as "balance plants" for the Grade A milk market.

Linear programming models based on current and alternative plant structures and cost functions were run, iteratively, using the MINOS algorithm to determine which combination of plants would be the most efficient. The objective of the analyses was to determine the number, size, and location of processing and manufacturing plants that would minimize total assembly, processing, and distribution costs.

Study results show that under current technology, costs, and plant economies of size, combined assembly, processing, manufacturing, and distribution costs could be reduced further in the dairy industry by operating with fewer, but larger, more centrally located processing and manufacturing plants. Even with increased energy costs, the economies that can be achieved by operating with fewer but larger plants more than offset additional assembly and distribution costs.

Fluid milk, cottage cheese, and ice cream plants would optimally be located in or near the major consumption centers, whereas cheese plants would best be located near the major surplus milk supply areas.

Under optimal conditions, the number of fluid milk plants in the study area would decrease from 36 to 10, cottage cheese plants from 9 to 2, and ice cream plants from 14 to 2. The number of manufacturing plants would decrease from 17 to 4 primary balance plants in the short-supply season. More would be required to handle excess Grade A milk supplies during high milk production months.

Total assembly, processing, manufacturing, and distribution costs would decrease from $13.2 million per month operating with the current market structure and costs, to $10.5 million per month operating with the optimum number, size, and location of plants. This would amount to a decrease of about $2.7 million per month, $1.21 per hundredweight of Grade A milk, or $0.10 per gallon of fluid milk.

While the operation of many independently owned and operated milk marketing firms in the study area will inhibit the achievement of all of these economies of size in plant operations, competitive market forces can be expected to continue to push toward fewer but larger plants.

To remain competitive and to achieve the greatest efficiencies possible, firms building new plants should give careful consideration to size and location, and wherever possible through joint ownership or contractual arrangements with other milk marketing firms, take full advantage of potential plant economies of size. In the long run, processors, producers, and consumers can all be expected to share in some of the benefits of the cost savings that would result from doing so.

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