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LEAST-COST MILK ASSEMBLY AND MANUFACTURING PLANT LOCATIONS FOR THE NORTHEASTERN DAIRY INDUSTRY

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There is some concern that geographic patterns of dairy cooperative membership, and customary relationships among milk assemblers and processors, may inhibit milk marketing efficiency in the Northeast. Raw milk assembly patterns and hard product manufacturing plant locations are here developed which minimize total regional costs of these functions. Solutions are highly sensitive to season, day-of-the-week, and capacity assumptions. Evidence strongly suggests that regional coordination of milk assembly and manufacturing would result in cost savings and in some re-alignment of present milk shipment patterns.

INTRODUCTION

Owing to population expansion, and to technological advances in the long distance hauling and bulk handling of milk, the Northeastern dairy marketing industry has developed from a series of localized and autonomous markets to a more interdependent market network. Most milk processed into fluid form is assembled by producer cooperatives and delivered on contract to proprietary processors. Farm production in excess of fluid demand is then manufactured by a cooperative or proprietary firm into one or more dairy products. These products are traditionally divided into such "soft" items as yogurt, cottage cheese, and sour cream, which are most closely associated with fluid milk processing, and the "hard" products cheese, butter, and powder.[1]

Together with the growing interdependence of markets has been a reduction in plant numbers through a process of exit and consolidation [Miller and Miller]. In addition, federal order programs in the Northeast have gradually undergone amalgamation [Metzger and Webster, Tidyar and Hardie]. But there is some question whether this trend toward consolidation or coordination has proceeded far enough. For example many cooperatives operating or delivering to manufacturing plants draw milk from heavily overlapping geographic areas, suggesting substantial cross-hauling.[2]

Considerable empirical evidence from the Northeast and other regions has suggested the magnitude of economies that may be gained from regional coordination of the milk marketing system. Kloth and Blakely (1971) found that a great reduction of fluid processing plant numbers in the Northeast would result in processing economies that exceed the resulting assembly or distribution diseconomies. Tidyar and Hardie (1971) confirmed the saving in total marketing costs associated with consolidation of the Middle Atlantic Federal Order. Boehm and Conner (1976) showed that assembly and hard product manufacturing costs would be minimized in the Southeast if only five plants were engaged in cheese, butter, and powder manufacture.

The present analysis explores the spatial structure of the Northeastern raw milk assembly and hard product manufacturing industry that might result if assembly and manufacturing functions were regionally coordinated. Such coordination assumes that individual producers become indifferent over destination of their milk, and that handlers allocate milk shipments so as to minimize collective marketing costs. For the sake of research feasibility, costs of processing and distributing fresh milk and soft dairy products are ignored, as are the costs of distributing hard dairy products.

CONCEPTUAL APPROACH

The volume of fluid grade milk available for cheese, butter, and powder production varies both on a seasonal and a daily basis. Availability is typically highest in the late spring and early summer months when raw milk production has peaked and fluid demands are decreasing. Availability is lowest in the fall when milk production is lowest and fluid demands are at a peak. In any season, most fluid processing plants shut down or operate at reduced rates on weekends, generating significant surpluses that must be stored or manufactured [Smith, Metzger, and Lasley]. These fluctuations in surplus supplies complicate the task of identifying an optimal organization in the milk manufacturing sector.

Both long and short run approaches to the problem are taken in the present study. In the former approach, least-cost locations and operating volumes of manufacturing plants are identified from among a set of potential locations with specified capacity restrictions. These solutions, which incorporate optimal assembly patterns, correspond to late spring surplus milk availabilities under the assumption that there must be sufficient manufacturing capacity to handle peak surplus milk volumes. In subsequent short run solutions, optimal raw milk movement patterns are identified under fall supply-demand conditions, and under weekend conditions in the late spring. Each short run solution assumes the manufacturing plants "constructed" in a long run solution are in place.

The long run solutions are specified as

$$\text{Minimize: } \sum_{ij}\sum T_{ij}X_{ij} + \sum_{ik}\sum T_{ik}X_{ik} + \sum_{ij}\sum P_jX_{ij}$$

$$\text{subject to: (a) } \sum_{i} X_{ij} \leq M_j, \text{ all } j$$

$$\text{(b) } \sum_{i} X_{ik} = F_k, \text{ all } k$$

$$\text{(c) } \sum_{j} X_{ij} + \sum_{k} X_{ik} = S_i, \text{ all } i$$

$$\text{(d) } P_j = P_j(\sum_{i} X_{ij})$$

where T_{ij} = Cost of raw milk shipment from source i to hard product manufacturing plant j, in dollars per hundredweight,

T_{ik} = Cost of raw milk shipment from source i to fluid and soft product processing center k, in dollars per hundredweight,

X_{ij} = Quantity of raw milk shipped from source i to hard product manufacturing plant j, in hundredweight,

X_{ik} = Quantity of raw milk shipped from source i to fluid and soft product processing center k, in hundredweight,

P_j = Unit total cost of manufacturing raw milk into a hard product (butter, powder, or cheese), in dollars per hundredweight raw milk,

M_j = Capacity of hard product manufacturing plant j, in hundredweight raw milk per month,

F_k = Requirements of fluid and soft product processing center k, in hundredweight raw milk per month, and

S_i = Volume of raw milk produced at each aggregated production center, in hundredweight raw milk per month.

In words, the long run solutions minimize the combined monthly cost of transporting raw milk to manufacturing and fluid-soft product processing centers and the monthly cost of hard product manufacturing, subject to the restrictions that (a) the capacity of any manufacturing plant is not exceeded, (b) fluid requirements at each fluid-soft product processing center are satisfied, (c) all milk produced at each source location is utilized in fluid, or soft or hard product form, and (d) per unit manufacturing costs vary with the volume of milk manufactured. Since total costs are nonlinear in $(\sum_i X_{ij})$, all j, per hundredweight manufacturing costs associated with maximum plant volumes are utilized for an initial solution. These costs are iteratively adjusted to conform to successive optimal plant allocations until convergence is achieved [King and Logan].

Short run problems are specified by removing the fixed cost component from manufacturing cost function (d), constraining the set j to those plants selected in a long run solution, and adjusting parameters F_k and S_i as appropriate. If total variable manufacturing costs are linear in $(\sum_i X_{ij})$, no iteration is required and the problem reduces to a least-cost transportation program.

PARAMETERS OF ANALYSIS

The study area selected includes all eastern seaboard states from Maine through Virginia, plus Vermont, Pennsylvania, and parts of West Virginia and North Carolina. This encompasses markets regulated by the New England, New York-New Jersey, and Middle Atlantic Federal Orders and by a variety of state orders. A nineteen-county area in Western Pennsylvania most closely associated with the Eastern Ohio-Western Pennsylvania Federal Order is not incorporated.

Raw milk sources were identified by county, although in some localities with sparse milk production several counties were aggregated into a single unit. This resulted in selection of 126 milk sources. Aggregated production was assumed to be available at the production density-weighted geographic center of each county or unit; a weighted average mileage, representing local assembly to that center, was added to mileage from the production center to each destination point. Fluid-grade production data for October 1976, representing fall supply conditions, and May 1977, representing spring supply conditions, were obtained from federal and state milk marketing administrators and state departments of agriculture. Total production was estimated to be 18,222,760 cwt in October and 21,323,830 cwt in May.

Government and regulatory agencies identified 410 plants processing fluid and soft products in the study area during this period. Groups of three or more plants in reasonably close proximity were considered a single fluid-soft product processing center, and volume data for October 1976 and May 1977 obtained for each of these sixty centers. Total milk volumes processed were 14,502,060 cwt and 15,013,490 cwt, respectively, in these two months. Most processing points were located in major fluid consumption areas.

The long run programs were designed to select from among 54 potential hard product manufacturing sites. Potential sites were principally located in rural areas of dense milk production, where cheese, butter, and powder production would most likely occur. However several were placed near major metropolitan areas that presently house hard product manufacturing facilities. Initially, each plant was provided capacity to manufacture 250,000 cwt of milk per month in an eight hour per day, seven day per week operation. In total, this represented slightly more than double the capacity required to manufacture the 6,310,340 cwt of fluid grade milk produced in excess of Class I and soft product requirements in May 1977.

Raw milk shipped further than 165 miles from source to processing or manufacturing point was required in this analysis to stop at a reloading or cooling station. Tankers with 5600 gallons capacity and attached pumping equipment were assumed to haul all milk to destinations under 165 miles, including reload stations. Hauls from reload stations to plants were made by 5600 gallon capacity over-the-road tankers with no pumping equipment. A set of 23 potential reload points were specified so that every milk source would be within a 165-mile radius of at least one reload point. In a preliminary optimization program, mileage from milk sources to reload stations, and from reload stations to plants, were used in conjunction with transportation cost functions to calculate least-cost transshipment routes from each source to each plant more than 165 miles distant [Boehm]. The associated per hundredweight hauling costs were then utilized in the main transportation programs.

A transportation cost function, linear in miles, representing farm pickup and short hauls was synthesized from dairy cooperative cost data.[3] A linear cost function for over-the-road hauls was statistically estimated from hauler rates. Relationships expressing total costs of butter-powder and cheese production as linear functions of milk input have been synthesized by Boehm and Conner [p. 17]. The cheese function, highly similar to that for butter and powder, was used in this analysis as adjusted to 1977 dollars.

SOLUTION RESULTS

Four least-cost assembly and manufacturing solutions were developed: (a) a long run base solution corresponding to milk supply and fluid-soft product demand levels of May 1977, and assuming 250,000-cwt monthly plant capacities at one shift per day; (b) a long run augmented solution raising these capacities to 450,000 cwt; (c) a short run solution corresponding to milk supply and fluid-soft product demand levels of October 1976, and assuming the manufacturing plants selected for construction in base solution (a) are in place; and (d) a short run solution corresponding to supply and fluid-soft-product demand levels on a typical weekend day in May 1977, and again assuming the manufacturing plants considered optimal in the base solution are in place. Solutions (a) through (c) have no regard for daily variations in fluid demands but more nearly reflect weekday activity. Solution (d) reflects weekend activity only.

LONG RUN BASE SOLUTION

A remarkable feature of the base solution results, pictured in Figure 1, is the nearly linear milkshed boundary extending from north-central Vermont to the northern tip of Virginia. All of the milk produced east of this boundary serves the Class I and soft product needs of the large population centers extending from Boston to Washington, D.C. Milk produced west of the line is divided between manufacturing use and fluid-soft product consumption in scattered metropolitan areas.

An idea of the aggregated shipment volumes associated with Class I and soft product use in this solution is provided in Table 1. Boston attracts nearly all its fluid milk needs from Maine, New Hampshire, and Vermont. Other southern New England cities draw fluid milk from local areas and from the Hudson River region in eastern New York. New York City-Newark's Class I and soft product needs are principally met by the dense production areas in the lower Hudson, eastern Pennsylvania, and northern New Jersey, although the lower Hudson's share in these shipments is relatively small. The Philadelphia-Wilmington area draws almost all its fluid and soft product needs from southeastern Pennsylvania and the Delmarva Peninsula. Little raw milk is shipped southward from Pennsylvania production areas into Baltimore and Washington, D.C. These markets are supplied solely by sources in Maryland and northern Virginia.

Of the 54 potential hard product manufacturing plant sites, the base solution selected 26 for construction. This was the minimum number required, at 250,000 cwt one-shift capacity per plant, to manufacture the 6,310,340 cwt of fluid grade milk remaining in May 1977 after the model's fluid and soft product demands were met. Sites selected for construction, and associated assembly and manufacturing cost data, are shown in Table 2. Least-cost raw milk movements to manufacturing points involved shorter distances, and hence lower assembly costs, than movements to fluid-soft product centers. A large share of the selected sites were in northern Vermont and central and western New York. None of the potential sites located near major metropolitan areas on the east coast was selected.

LONG RUN AUGMENTED SOLUTION

Imposition of a 250,000 cwt capacity on each potential manufacturing plant in the base solution was to some degree arbitrary, and we may wonder how the optimal solution would alter if larger plants were permitted. The question is especially compelling since the point was never reached in the base solution where, as the number of plants decreased, the rate of increase in assembly costs rose above the rate of decrease in manufacturing costs. How large would plant capacity have to be in order to equate marginal assembly with marginal manufacturing costs, and thus create the prospect of significant underutilization of capacity?

To answer this question, monthly plant capacities were increased to 450,000 cwt and the long run optimization problem re-solved. Sixteen manufacturing plants were selected for construction in the new optimal solution, essentially "thinning out" those plants in the base solution incurring the highest per hundredweight total costs in a particular area (Table 2). For

Table 1. Summary of Least-Cost Raw Milk Shipment Patterns to Fluid-Soft Product Processing Areas, May 1977 Base Solution

Fluid-Soft Product Demand Area	Production Source Area[a]		
	VT, NH ME	MA, CT RI	Hudson Valley (NY)
		hundredweight[b]	
Boston, Concord, Lawrence	1,047,048 (94.5%)	49,870 (4.5%)	12,517 (1.1%)
Other Massachusetts, Connecticut, Rhode Island	92,830 (5%)	958,178 (53%)	751,214 (42%)

	Production Source Area[a]				
	Northeastern PA, Northern NJ	Southeastern PA	Delmarva, Southern NJ	Hudson Valley (NY)	Other MD, Northern VA
				hundredweight[b]	
New York City, Newark	795,508 (31%)	1,249,570 (48.5%)	157,000 (6%)	377,790 (14.5%)	—
Philadelphia, Wilmington	—	681,359 (63%)	399,428 (37%)	—	—
Baltimore, Washington, D.C.	—	—	61,308 (6%)	—	988,307 (94%)

[a] Hudson Valley includes all New York counties bordering New England, plus Warren, Saratoga, Schenectady, Albany, Schoharie, Greene, Ulster, and Orange counties. Southeastern Pennsylvania includes Blair, Huntingdon, Mifflin, Juniata, Perry, Dauphine, Lebanon, Berks, and Lehigh counties and all Pennsylvania counties south of these. Northeastern Pennsylvania includes all other Pennsylvania counties represented as production sources in Figure 1. Northern New Jersey includes Mercer, Monmouth, and Ocean counties and those to the north. The indicated boundaries were designed to most closely conform to areas associated with the three federal milk market orders operating in the Northeast [U.S.D.A., Agricultural Marketing Service].

[b] Percentages sum horizontally to 100%.

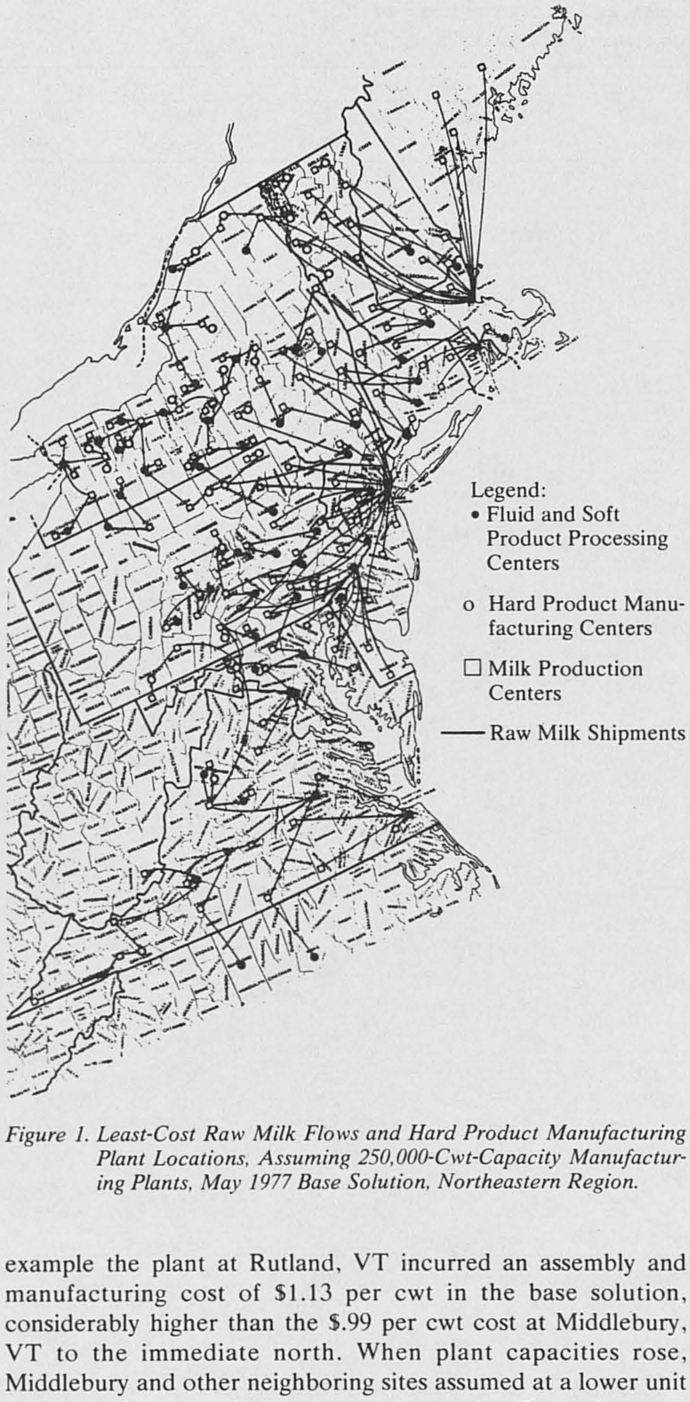

Figure 1. Least-Cost Raw Milk Flows and Hard Product Manufacturing Plant Locations, Assuming 250,000-Cwt-Capacity Manufacturing Plants, May 1977 Base Solution, Northeastern Region.

example the plant at Rutland, VT incurred an assembly and manufacturing cost of $1.13 per cwt in the base solution, considerably higher than the $.99 per cwt cost at Middlebury, VT to the immediate north. When plant capacities rose, Middlebury and other neighboring sites assumed at a lower unit cost the volume that had been manufactured at Rutland.

Five of the sixteen plants constructed in the augmented solution operated at less than capacity in the May flush season. These plants did not capture full size economies and incurred relatively high per hundredweight manufacturing costs. Assembly cost levels varied by location. The Lowville, NY plant handled a small amount of locally produced milk at low assembly costs, a phenomenon typical of peripheral production areas. The plant at Horseheads, NY, on the other hand, was more centrally located but competed with fluid and soft product demands at Elmira: the plant's capacity was filled but at the expense of distant hauls from neighboring counties.

The presence in the augmented solution of more than 450,000 cwt total underutilized capacity indicates that deletion of any plant would increase assembly costs more than it would decrease manufacturing costs. Hence, unlike in the base solution, the augmented solution represents satisfaction of the marginal conditions for optimal processing plant location, and total costs of necessity decline over those in the base solution [Bressler, p. 118]. This does not suggest that the augmented solution represents a global spatial optimum. As long as some plants operate at capacity, total costs might be reduced by further capacity expansion.

SHORT RUN OCTOBER SOLUTION

The quantity of milk produced in excess of fluid and soft product utilization in the Northeast in October 1976 was 3,720,700 cwt, only 59 percent of the May 1977 figure. Higher fluid demands and lower milk production density in the fall meant that milk had to be shipped longer average distances to fluid-soft product demand centers.

However optimal inter-area movement patterns of milk utilized in fluid and soft product forms did not differ appreciably between the May base and October solutions. All eastern seaboard metropolitan areas from Concord, N.H. to New York City-Newark drew relatively greater proportions of their fall fluid milk needs from the Hudson Valley, but shifts were not dramatic. The proportion of milk NYC-Newark drew from southeastern Pennsylvania dropped from 49 percent to 43 percent. Philadelphia-Wilmington pulled a slightly higher proportion of its fluid milk from southeastern Pennsylvania in October than in May. Source breakdowns for Washington, D.C. -Baltimore remained unchanged.

Four of the twenty-six plants constructed in the May base solution shut down operations entirely in October (Table 2). These were plants at Rutland, VT; New Milford, PA; Lewisburg, PA; and Chambersburg, PA. Only four plants continued to operate at capacity: those at St. Albans, VT; Chateaugay, NY; Oneida, NY; and Warsaw, NY. Plants operating at very low volume levels (between 40,000 and 100,000 cwt) included Middlebury, VT; Herkimer, NY; Homer, NY; and Independence, VA. Not surprisingly, the four plants shutting down operations in the fall were each situated along the milkshed boundary separating predominantly fluid-soft product uses from a combination of all uses. They therefore bore the main effect of decreased excess fluid supplies as this boundary shifted westward.

October milk manufacturing operations were associated with higher unit manufacturing costs and lower unit assembly costs than in May. There was a 13.5¢ per cwt increase in manufacturing costs associated with increased idle plant capacity, and a 0.8¢ per cwt decrease in assembly costs resulting from slightly shorter average hauls to manufacturing plants in the fall. On balance, total per hundredweight costs rose from $1.036 to $1.164 between May and October least-cost solutions.

SHORT RUN WEEKEND MAY SOLUTION

Changes in raw milk volumes available to manufacturing plants may be greater on a weekday-weekend basis than on a seasonal basis. Smith, Metzger, and Lasley (p. 21) report 34 percent less milk delivered for Class I purposes to a sample of Northeast fluid processing plants on Sunday, June 15, 1975 than on Thursday, June 19, 1975. Since the proportion of milk utilized for manufacturing purposes in the Northeast is considerably smaller than that utilized in fluid form, this would represent a drastic increase in milk seeking a manufacturing outlet. Estimates of the exact quantities of surplus fluid grade milk available for weekend manufacturing depend upon how much on-farm and processing plant storage is assumed to be used, and whether soft product processing is grouped with fluid or hard product

Table 2. Least-Cost Locations, Volumes, and Operating Costs of Northeastern Hard Dairy Product Manufacturing Plants, 1976 and 1977

	May Base		May Augmented		October		May Weekend	
Location[a]	Volume (cwt)	Costs[b] ($/cwt)	Volume (cwt)	Costs[b] ($/cwt)	Volume (cwt)	Costs[b] ($/cwt)	Volume (cwt)	Costs[b] ($/cwt)
St. Albans, VT	250,000	.250	450,000	.256	250,000	.250	15,089	.260
(Franklin)		.770		.688		.770		.687
Orleans, VT	250,000	.237	450,000	.274	198,000	.230	12,981	.267
(Orleans)		.770		.688		.819		.703
Burlington, VT	250,000	.288	—	—	162,279	.266	5,757	.260
(Chittenden)		.770		—		.872		.855
Middlebury, VT	250,000	.220	450,000	.234	57,684	.220	12,883	.220
(Addison)		.770		.688		1.395		.705
Rutland, VT	250,000	.359	—	—	0	0	16,576	.320
(Rutland)		.770		—		c		.678
Chateaugay, NY	250,000	.282	366,652	.299	250,000	.287	12,528	.301
(Franklin)		.776		.711		.770		.709
Canton, NY	250,000	.231	248,420	.220	183,780	.220	9,797	.220
(St. Lawrence)		.770		.772		.838		.743
Lowville, NY	250,000	.220	130,933	.220	201,699	.220	11,643	.220
(Lewis)		.770		.941		.815		.717
Oneida, NY	250,000	.260	450,000	.281	250,000	.260	15,543	.257
(Oneida)		.770		.688		.770		.683
Herkimer, NY	250,000	.241	—	—	57,476	.220	16,667	.262
(Herkimer)		.770		—		1.398		.678
Norwich, NY	250,000	.220	450,000	.251	155,911	.220	12,324	.241
(Chenango)		.770		.688		.883		.710
Homer, NY	250,000	.222	—	—	81,661	.220	5,811	.220
(Cortland)		.770		—		1.156		.852
Horseheads, NY	250,000	.294	450,000	.327	156,261	.320	13,241	.305
(Chemung)		.770		.688		.883		.701
Auburn, NY	250,000	.240	450,000	.263	240,830	.240	12,872	.246
(Cayuga)		.770		.688		.777		.704
Geneseo, NY	250,000	.248	—	—	130,061	.220	9,536	.250
(Livingston)		.770		—		.943		.750
Warsaw, NY	250,000	.220	450,000	.228	250,000	.220	16,667	.235
(Wyoming)		.770		.688		.770		.676
Batavia, NY	250,000	.241	—	—	109,221	.240	7,177	.240
(Genesee)		.770		—		1.012		.800
New Milford, PA	250,000	.249	—	—	0	0	12,826	.272
(Susquehanna)		.770		—		c		.705
Troy, PA	250,000	.260	450,000	.265	214,292	.260	16,667	.266
(Bradford)		.770		.688		.801		.678
Lewisburg, PA	250,000	.304	—	—	0	0	12,689	.294
(Union)		.770		—		c		.707
Chambersburg, PA	250,000	.220	450,000	.229	0	0	16,667	.239
(Franklin)		.770		.688		c		.677
Belleville, PA	250,000	.322	450,000	.316	140,052	.302	16,667	.318
(Mifflin)		.770		.688		.917		.677
Somerset, PA	250,000	.324	262,552	.324	225,210	.324	8,752	.324
(Somerset)		.770		.762		.791		.761
Hagerstown, MD	250,000	.257	—	—	170,310	.220	16,667	.290
(Washington)		.770		—		.858		.667
Harrisonburg, VA	250,000	.254	350,864	.305	190,351	.250	15,421	.312
(Rockingham)		.770		.717		.829		.684
Independence, VA	59,417	.400	—	—	44,710	.389	6,973	.441
(Grayson)		1.350		—		1.630		.807
ALL PLANTS[d]	6,309,417	.260	6,309,421	.269	3,719,788	.253	330,454	.278
		.776		.701		.911		.706

[a] Counties of location are listed in parentheses.

[b] For each plant site the top number listed is per hundredweight assembly cost and the bottom number listed is per hundredweight manufacturing cost.

[c] Fixed manufacturing costs are incurred but average fixed manufacturing costs are undefined.

[d] Total volumes manufactured depart slightly from amounts available for manufacturing due to program procedure to avoid nonconvergent cycling.

processing. We have here modelled a situation in which 24 percent less milk is received for processing in fluid or soft product form on weekend days than on average days (weekends and weekdays included).[4] Given a May average daily demand (30-day basis) of 500,450 cwt for fluid and soft product uses, this would increase the amount of surplus fluid grade milk by 120,108 cwt per day, or 57 percent over those on average days. Manufacturing plants constructed in the base solution could handle 250,000 cwt of milk per month using one eight-hour shift per day. This 8333 cwt daily capacity could be doubled, by adding an extra shift, to handle weekend surplus.

In the weekend solution results, perimeters of milk production areas supplying fluid and soft product needs contracted dramatically, and those serving hard product manufacturing needs expanded. Maine production, having little alternative outlet, continued to serve Boston fluid-soft product requirements, but much less Vermont milk moved to Boston. The New York-Newark area ceased drawing fluid supplies from southcentral and northcentral Pennsylvania or southern New Jersey. But the Lancaster-Berks-Lebanon County area of Pennsylvania continued to serve New York-Newark, as did counties in northern New Jersey and the lower Hudson Valley. Also having little alternative, Delmarva milk continued to move into Philadelphia, but production in York and Cumberland counties, PA, was diverted from Philadelphia to more local demand points. Washington, D.C. dropped milk from northern Virginia and picked up additional weekend supplies from northern and eastern shore Maryland.

Some manufacturing plants in this solution, shown in Table 2, assumed more of the augmented weekend supplies than did others. Plants at Burlington, VT, Homer and Batavia, NY, Somerset, PA, and Independence, VA actually handled less milk on weekend days than on average days. Owing to the greater average distance milk must travel to manufacturing plants on weekends, per hundredweight raw milk assembly costs increased slightly over those estimated in the base solution. However unit manufacturing costs declined as a result of greater daily volumes and hence reduced per unit fixed costs. On balance, total unit costs dropped from $1.036 in the base solution to $.984 in the weekend solution. This saving was more marked for plants picking up relatively high weekend volumes.

SUMMARY AND CONCLUSIONS

Solution results were reported here which minimize the combined cost of assembling all Northeastern raw milk and manufacturing the surplus quantities into butter, powder, and cheese. Optimal programs differed by season, day of the week, and plant capacity assumptions. In general, cheese, butter, and powder manufacturing was optimally concentrated in northern Vermont, central and western New York, and to a lesser extent central Pennsylvania. In the May base solution, a distinct milkshed boundary from northern Vermont to the northern tip of Virginia divided milk moving eastward into urban fluid and soft product uses from that utilized in the west for all purposes. This boundary shifted slightly westward in the October solution, but adjustments in assembly patterns were greater on an average day-weekend day basis than on a seasonal basis.

Unfortunately there are no published data depicting actual raw milk movement patterns from source to destination areas in the Northeast. Hence complete and accurate comparisons of actual movements with those in the present model are not possible. Data are published which show amounts of milk production in each county associated with each federal order; these data are in some instances comparable to the present study's solution results. For example, the base solution calls for most milk produced in New York's eastern tier of counties to satisfy Class I and soft product processing requirements in southern New England, and USDA data also show that a high proportion of milk in these counties is associated with the New England Federal Order. Similarly, the base solution meets most of New York City's and Newark's fluid and soft product needs from production areas in northeastern Pennsylvania, northern New Jersey, and Lancaster county in southeastern Pennsylvania, areas in heavy association with the New York-New Jersey Federal Order.

There is reason to believe that New York City and Newark draw relatively more milk from southeastern New York, that Washington, D.C. and Baltimore draw more milk from southern and southeastern Pennsylvania, and that Boston receives more milk from the Washington-Rensselaer area in New York State, than is indicated in this study's least-cost solutions.[5] These discrepancies may be due to historical relationships between urban fluid processors and country milk handlers that are no longer efficient in a regional least-cost sense.

The results also suggest that significant economies would accompany Northeastern regional coordination of the milk assembly and manufacturing functions. Given current sizes of most manufacturing plants in the Northeast, reductions in plant numbers, and increases in capacities of those remaining, would likely result in greater processing economies than assembly diseconomies. Whether firm coordination is in fact a desirable goal depends upon society's relative valuation of the associated cost savings and the problems that may result from concentration of decision making power.

FOOTNOTES

Steven T. Buccola is Assistant Professor of Agricultural Economics and M. C. Conner is Emeritus Professor of Agricultural Economics, Virginia Polytechnic Institute and State University, Blacksburg. This paper summarizes results of the research project "Study of the Milk Assembly System in the Northeast," financed by a grant from the Office of the Deputy Administrator for Cooperatives (Economics, Statistics, and Cooperatives Service), U.S. Department of Agriculture. Special appreciation is owed to George Tucker of ESCS, who cooperated closely with the authors during the study period.

[1] In federal order markets adopting three utilization classes, soft products as defined here are generally included in Class II and hard products in Class III. Because Northeastern federal order markets do not recognize a Class III, the terms "soft" and "hard" product are retained in the following discussion.

[2] Private communication, Office of the Deputy Administrator for Cooperatives (Economics, Statistics and Cooperatives Service), USDA.

[3] The estimate assumed once-every-other day farm pickup. Strang and Eiler have compared pickup costs by frequency of pickup. Johnson and Brinegar have also analyzed milk hauling charges in producer cooperatives.

[4] Smith, Metzger, and Lasley's figures separate soft product from fluid use, whereas ours do not. No special accuracy is claimed for the 24% figure used here. It is, however, sufficiently realistic to indicate some of the magnitude of weekend day-average day differences.

[5] Observations are based on discussions with federal milk order representatives.

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