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By

Stuart McLean, Alan S. Kezis, James Fitzpatrick, and Homer B. Metzger*

INTRODUCTION

In recent years, the Maine Milk Commission has come under increased
attack as a result of its pricing policies. The Maine Milk Commission
Law states (4):

> "Minimum wholesale prices paid to dealers shall be established to
> reflect the lowest prices at which milk purchased from Maine
> producers can be received, processed, packaged, and distributed
> within the State of Maine at a just and reasonable return."

The Commission, thus, sets minimum prices for fluid milk products, both
wholesale and retail, in accordance with this legislative mandate.
There is, evidently, considerable concern that this price setting power
has the effect of subsidizing inefficiency, rather than protecting the
interests of both consumers and producers. In order to fulfill its man-
date to set prices at the lowest levels consistent with a "just and rea-
sonable return," the Commission devoted a substantial amount of money to
research in an attempt to investigate and establish what that lowest cost
is. It is the aim of this paper. however. to go beyond the limits of a
study of present cost and, instead to look toward achievable least cost.
A model was developed which included the cost of assembly, processing, and
wholesale distribution of Class I milk within the State of Maine.
Solution of the model with parameter values appropriate to current costs
associated with these three aspects of the milk market yielded an achiev-
able least cost allocation for performing the assembly, processing, and
distribution of milk, adequate to meet demand, throughout the State. It
is hoped that the model will prove a powerful planning and diagnostic
tool. In order to increase the power of the model, it was also run with
cost parameters adjusted to reflect different levels of rising energy costs.
Finally, the model was solved, not only with differing levels of energy
costs, but with maximum processing capacities adjusted, not to reflect the
current market structure, but a market structure with the potential

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for each plant to be as large as those serving the major metropolitan markets. Through this manipulation of both energy cost and plant capacity parameters, it was felt that the planning and diagnostic potential of the model is significantly improved.

METHODOLOGY

To determine the least cost solution for assembly, processing and distribution for Class I milk in Maine, the following transshipment model was used:

Objective Function:

$$\text{Min } Z \quad \sum_{i=1}^{16} \sum_{j=1}^{19} a_{ij} X_{ij} + \sum_{j=1}^{19} b_j Q_j + \sum_{j=1}^{19} \sum_{k=1}^{16} a_{jk} X_{jk} \tag{1}$$

Constraints:

$$\sum_{j=1}^{19} X_{ij} \leq S_i \; ; \qquad\qquad i = 1 \dots 16 \tag{2}$$

$$\sum_{i=1}^{16} X_{ij} \quad \sum_{k=1}^{16} X_{jk} \quad 0 \; ; \qquad j \quad 1 \dots 19 \tag{3}$$

$$\sum_{k=1}^{16} X_{jk} \quad Q_j \; ; \qquad\qquad j = 1 \dots 19 \tag{4}$$

$$Q_j \leq B_j \; ; \qquad\qquad j = 1 \dots 19 \tag{5}$$

$$\sum_{j=1}^{19} X_{jk} \geq Y_k \; ; \qquad\qquad k = 1 \dots 16 \tag{6}$$

Variables:

S = supply available   i   supply area
Y   quantity demanded   j – plant
X = quantity shipped   k = demand area
Q = quantity processed   a   transportation cost per unit
B = processing capacity   b = processing cost per unit

The objective function (1) is a total cost function for assembly, processing, and distribution of Class I milk, which is minimized given the constraint set. The assembly portion of the objective function

$$\sum_{i=1}^{16} \sum_{j=1}^{19} a_{ij} X_{ij}$$

states that the cost of assembly is the summation of the per unit transportation cost for raw milk (a_{ij}) times the volume shipped from each supply area to each plant (X_{ij}). The processing segment

$$\sum_{j=1}^{19} b_j Q_j$$

states that the total processing cost is the summation of per unit processing cost at each plant (b_j) times the quantity processed at that plant (Q_j). The distribution cost segment of the objective function

$$\sum_{j=1}^{19} \sum_{k=1}^{16} a_{jk} X_{jk}$$

states that the distribution cost is the summation of the per unit transportation cost for processed and packaged Class I milk (a_{jk}) times the quantity shipped from each plant to each demand area (X_{jk}).

The constraint set insures that the cost minimization is calculated so that certain limitations and requirements of the marketplace are fulfilled. The first set of constraints, equation (2), insures that the total amount shipped from each supply area $(\Sigma\ X_{ij})$, is less than or equal to the maximum supply available in each area (S_i).

The second set of constraints, equation (3), requires that the summation of the quantity shipped from each supply area to each plant $\left(\sum\limits_{i=1}^{16} X_{ij}\right)$ is equal to the summation of the quantity shipped from each plant to all demand areas $\left(\sum\limits_{j=1}^{19} X_{jk}\right)$. The third block of constraints, equation (4), requires that the summation of the quantity of milk shipped from each supply area to each plant $\left(\sum\limits_{k=1}^{16} X_{jk}\right)$ is equal to the quantity processed at the appropriate plant (Q_j). Thus, the second and third constraints assure that all milk shipped from supply areas to processing plants is processed, and shipped to demand areas. Milk which is not shipped to processing plants for processing as Class I milk is not considered by the model

The fourth block of constraints, equation (5), sets the condition that the summation of milk processed and shipped from all plants to each demand area $\left(\sum\limits_{j=1}^{19} X_{jk}\right)$ is greater than or equal to demand in the appropriate demand areas (Y_k). In summary, the constraint set requires that 1) demand be satisfied in each demand area, 2) processing capacities at each plant not be exceeded, 3) supply capabilities of each supply area not be exceeded, and 4) milk which is sent to plants is processed and shipped to demand areas.

DATA AND ASSUMPTIONS

Supply and Demand Areas

Each of Maine's 16 counties was chosen as a supply and demand area. In each area, one town was chosen as a supply and demand center   This choice was based upon population size, location, and proximity to major highways and roads. It was assumed that the supply and demand centers would be representative of all deliveries to and shipments from demand and supply areas. The 16 counties, representing supply and demand areas, and the 16 towns chosen as the supply and demand centers, are listed in Table 1.

TABLE 1.   Maine Counties and Their Supply and Demand Centers

County	Supply and Demand Center
Androscoggin	Lewiston
Aroostook	Presque Isle
Cumberland	Portland
Franklin	Farmington
Hancock	Ellsworth
Kennebec	Augusta
Knox	Rockland
Lincoln	Damariscotta
Oxford	Rumford
Penobscot	Bangor
Piscataquis	Dover Foxcroft
Sagadahoc	Bath
Somerset	Skowhegan
Waldo	Belfast
Washington	Machias
York	Biddeford

Supply of Raw Milk

Aggregated data on milk production for the State of Maine were found in "Milk Production, Disposition, and Income, 1976-1978," (8). The figures for the entire State are as follows:

1. 58,000 head, dairy cattle
2. 11,000 pounds per year. average production per cow
3. 638,000,000 pounds total annual production

In order to break the aggregated supply figures down to a per county basis so that supply could be allocated among supply areas, a breakdown based upon the 1974 United States Census was computed. The 1974 United States Census indicated a dairy cattle population of 61,793 head. Thus, the 1978 figures represented 93.86 percent of the 1974 population. The 1974 per county dairy cow census figures were, thus, indexed via multiplication by a factor of .9386 to reflect a reasonable 1978 per county dairy cow population. Estimated 1978 per county dairy population was then multiplied by 11,000 pounds to arrive at a per county supply figure. The results of the computation are shown in Table 2.

TABLE 2. 1978 Estimated Raw Milk Production by County

County	Number of Cattle	Milk Production (Cwt.)
Androscoggin	5,695	626,450
Aroostook	3,414	375,540
Cumberland	3,147	346,170
Franklin	2,396	263,560
Hancock	156	17,160
Kennebec	9,048	995,280
Knox	851	93,610
Lincoln	952	104,720
Oxford	3,239	356,290
Penobscot	8,266	909,260
Piscataquis	2,080	228,800
Sagadahoc	982	108,020
Somerset	8,189	900,790
Waldo	4,739	521,290
Washington	458	50,380
York	4,386	482,460
Total	57,998	6,379,780

Transportation Costs Among Supply, Processing, and Demand Centers

The mileage estimation key on the official "Maine State Highway Map" (5) was used to estimate the road distance between all plants and all supply and demand centers. These figures were then doubled to represent round trip distances.

In order to arrive at an appropriate cost factor, it was necessary to compute a per hundredweight per mile shipping cost for both bulk, raw milk, and packaged fluid milk products. Hahn (3) calculates the cost of assembling raw milk in 6,000 gallon bulk tanks. The results of this aspect of his study are summarized below:

Total Annual Fixed Cost	$9,656
Total Variable Cost Per Mile	.6866
Total Annual Miles	40,000
Net Gallons Per Load	6,000

With these figures, a per hundredweight, per mile cost was calculated as follows:

1. 6,000 gallons X 8.6 lbs./gal. = 51,600 lbs.
   51,600 ÷ 100 lbs./cwt. = 516 cwt.

2. $9,656 ÷ 40,000 miles = .2414 fixed cost/mile

3. .2414 fixed cost/mile +
   .6866 variable cost/mile = .928 total cost per mile

4. .928 total cost/mile ÷ 516
   cwt./load = $.0018/cwt./mile

The $.0018 per hundredweight per mile was then indexed by a factor of 1.15 to reflect cost increases between 1979 and 1980, as indicated by the 1980 consumer price index. Thus, a per hundredweight, per mile cost of $.0021 was used.

It was assumed that packaged milk is shipped to demand centers by tractor trailer. The cost of delivery of milk to wholesale and retail customers within the demand areas, from the demand center, was assumed to be similar for all areas, and thus was not considered in the model.

The per hundredweight per mile cost of transporting packaged milk was calculated from previous work done by Metzger (6). His findings are summarized below:

Fixed cost per day	$61.00
Variable cost per mile	0.68
Average daily load (cases)	949
Average miles per day	166

To find the per hundredweight per mile cost, the steps indicated below
were followed:

1. 949 cases X 4 gal./case   3,796 gal.
2. 3,796 gal. X 8.6 lb./gal. ÷
   100 lbs.   326.5 cwt.
3. $61/day ÷ 166 miles/day $.37 fixed cost/mile
4. .37 fixed cost/mile + .68
   variable cost/mile $1.02 total cost/mile
5. $1.02 total cost/mile ÷
   326.5 cwt. $.003/mile/cwt.

More recent, unpublished work by Metzger indicates that since the
data for the 1978 study were gathered, costs for transporting processed,
packaged milk by tractor trailer have risen 42 percent, so that the cost
per mile per hundredweight of packaged milk products was estimated to be
$.00426.

PROCESSING PLANTS, PLANT CAPACITIES, AND
PROCESSING COSTS

Processing Plants

Although there are about 30 processors of fluid milk in the State
of Maine, few firms process the majority of the milk. The four largest
dairies in the State control 50 percent of the market; the ten largest
firms process 80 percent of the total; and the top 20 account for 96
percent of all milk marketed in the State. Thus, in the interest of
simplicity, and with little sacrifice of realism, the 20 largest dairies
were considered significant to this research. During the course of the
research, one of the 20 largest dairies ceased operations, so that the
solutions presented in this paper are the result of an analysis of 19
processing locations. Table 3 lists the 19 processing plants,
identified by location, and their estimated annual processing capacity
in hundredweight, assuming both 10 and 16 hour work days.

TABLE 3.   The Nineteen Largest Milk Processing Plants in the State of
Maine, and Their Estimated Capacities, Assuming Both 10 and
16 Hour Working Days

Plant	Estimated Capacity 10-Hour Day (Cwt./Yr.)	Estimated Capacity 16-Hour Day (Cwt./Yr.)
Auburn	122,165.94	195,465.50
Lewiston	217,590.13	348,144.21
Houlton	183,179.51	293,087.22
Presque Isle	156,363.78	250,182.05
Portland I	851,122.72	1,361,796.35
Portland II	512,752.75	820,404.40
Yarmouth	221,389.89	354,223.82
Ellsworth	201,793.63	322,869.81
Augusta	196,640.75	314,625.20
Benton	167,978.14	268,765.02
Winslow	328,739.13	525,982.61
Bangor	693,038.30	1,108,861.28
Brewer	310,146.62	496,234.59
Hermon	139,085.62	222,536.99
Skowhegan	199,953.50	319,925.60
Machias	168,049.79	268,879.66
Biddeford	161,238.94	257,982.30
Limington	486,560.68	783,297.09
Sanford	169,196.94	270,715.10

Plant Capacities

The estimation of annual capacities for the 19 plants was based
upon previous work by Taylor (10) and current unpublished engineering
data gathered by Metzger   Taylor discovered that 28 percent of the
potential running time of filling machines in Maine milk plants was
devoted to maintenance and cleanup activities. The remaining 72 percent
of the working day was available filling time, though not all potential
filling time was utilized in many cases. It was therefore assumed, for
the purposes of this investigation, that at full capacity utilization
levels, filling machines ran for 7.2 hours of each 10 hour day, or 11.5
hours of each 16 hour day. It was also assumed that plants operated
five days per week, or 260 days per year

The unpublished survey data gathered by Metzger include a mean
filling rate for each filling machine in all plants, expressed in quarts
per minute. Thus, the filling rate in quarts per minute was multiplied
by the number of minutes in a year (of 260 days either 16 or 10 hours
long) yielding the filling capacities for each of the 19 plants, which

are expressed in Table 3 in hundredweight. Central to this calculation of maximum annual capacity for the 19 plants is the assumption that filling machinery is, in all 19 instances, the limiting factor Other aspects of processing and handling may limit capacity of many of the plants, but in the absence of other information, the assumption that filling apparatus limits capacity must suffice.

In an effort to investigate further the potential for centralization of processing in the State, the model was also run with capacities of the 19 plants opened up to reflect capacities of processing plants in the largest metropolitan markets. Based upon unpublished research conducted by R.D. Aplin (1), it was assumed that the capacity of all 19 processing plants could be increased to 1,062,127 hundredweight per year, the capacity of the largest milk processing plant serving the New York City metropolitan area.

Processing Costs

The calculation of per unit processing costs for fluid Class I milk was based upon research by Blair Smith (1979). The results of Smith's findings are summarized below.

Plant Capacity	Cost Per Cwt.
0.0 107.5 cwt./day	$4.23 per cwt.
107.5 215.0 cwt./day	$3.67 per cwt.
215.0 and greater cwt./day	$3.07 per cwt.

Given that daily production of 215 hundredweight per day capacity is equivalent to 55,900 hundredweight per year, all 19 plants included in the study were assumed to operate at the lowest cost figure. In order to determine how processing costs have increased since Smith gathered his data in 1978, Metzger's 1979 cost of processing study was consulted. Based upon that investigation, Smith's 1978 (9) data were indexed by a factor of 1.16 percent to arrive at a processing cost of $3.56 per hundredweight.

Demand for Processed Milk

In order to solve the computer model, it was necessary to estimate demand for processed fluid milk products in each county. Population figures for each county were drawn from the 1974 U.S. Bureau of the

Census Report. Fluid milk products consumption was assumed to be 360 pounds per year per capita. Thus, total demand for each county was estimated by multiplying the population of the county by 360. The results of this calculation are shown in Table 4.

TABLE 4. 1979 Estimated Class I Demand by County

County	Population	Milk Demand (Cwt.)
Androscoggin	94,094	338,738.400
Aroostook	96,044	345,758.400
Cumberland	202,183	727,858.840
Franklin	24,729	89,024.440
Hancock	39,145	140,922.000
Kennebec	100,745	362,682.000
Knox	31,925	114,930.000
Lincoln	23,197	83,509.200
Oxford	45,076	162,273.600
Penobscot	133,671	481,215.600
Piscataquis	16,688	60,076.800
Sagadahoc	26,234	94,442.400
Somerset	43,519	156,668.400
Waldo	26,187	94,273.200
Washington	32,854	118,274.400
York	121,662	437,983.200
Total	1,057,953	3,808,630.880

Excess Supply of Raw Milk

The State of Maine is a net exporter of milk. Milk production which exceeds the needs of the fluid milk processing plants to meet the demand for Class I milk is either shipped to a cheese factory located in Newport, Maine or shipped out of the State. Farmers receive a substantially lower price for milk defined as Class II rather than Class I, so that it was assumed, for the purposes of this analysis, that farmers would maximize their Class I shipments with little regard for the returns received from Class II shipments. Thus, the costs and benefits accruing to and from Class II shipments were not included in the model.

LEAST COST SOLUTION OF THE TRANSSHIPMENT MODEL:
1980 ENERGY COSTS

The data concerning supply of raw fluid milk, processing, and transportation costs, and demand for processed fluid milk were organized in a matrix according to the transshipment model framework as previously discussed. The resulting matrix of parameters was solved using the IBM LPS/360 computer package. Three different matrices representing three assumptions concerning plant capacity were run with 1980 cost parameters. The results of those three computer runs are presented in Tables 5, 6, and 7, and Tables 1 through 6 in the Appendix.

In Table 5, capacity estimates are based upon the assumption of a 10 hour working day and 260 working days per year. At this lowest of the three plant capacity estimates, only one plant, Hermon, is closed. However. four more plants are assigned output at less than half of their estimated annual capacities. All plants assigned outputs of less than half of capacity are located in regions with a high concentration of plant capacity.

TABLE 5.   Estimated Capacity and Assigned Optimal Output of the 19 Largest Milk Processing Plants in the State of Maine, Capacity Estimates Assuming 10 Hour Days

Plant	Assumed Capacity Cwt./Year	Allocated Output Cwt./Year	Percent
Auburn	122,165.94	122,165.94	100
Lewiston	217,590.30	217,590.30	100
Houlton	183,179.59	183,179.59	100
Presque Isle	156,363.78	156,363.78	100
Portland I	851,122.72	263,479.92	31
Portland II	512,752.75	512,752.75	100
Yarmouth	221,389.89	46,068.53	21
Ellsworth	201,793.63	140,922.00	70
Augusta	196,640.70	196,640.70	100
Benton	167,978.14	167,978.14	100
Winslow	328,739.17	328,739.17	100
Bangor	693,038.30	693,038.30	100
Brewer	310,146.62	23,500.65	8
Hermon	139,085.63	0.00	0
Skowhegan	199,953.50	199,953.50	100
Machias	168,049.79	118,274.40	70
Biddeford	161,238.94	161,238.94	100
Limington	486,560.68	107,547.21	22
Sanford	169,196.94	169,196.94	100

Solution of the model with the assumption that plants are operated 16 hours per day as opposed to 10 hours per day increases plant capacity throughout the State by 60 percent. As shown in Table 6, four plants are assigned no output, and ten plants are operating at less than half of estimated capacity under this assumption.

TABLE 6. Estimated Capacity and Assigned Optimal Output of the 19 Largest Milk Processing Plants in the State of Maine, Capacity Estimates Assuming 16 Hour Days

Plant	Assumed Capacity Cwt./Year	Allocated Output Cwt./Year	Percent
Auburn	195,465.50	195,465.50	100
Lewiston	348,144.21	348,144.21	100
Houlton	293,087.22	293,087.22	100
Presque Isle	250,182.05	52,671.18	21
Portland I	1,361,796.35	73,908.52	5
Portland II	820,404.40	653,950.28	80
Yarmouth	354,223.82	0.00	0
Ellsworth	322,869.81	140,922.00	44
Augusta	314,625.20	314,625.20	100
Benton	268,765.02	0.00	0
Winslow	525,982.61	298,430.69	57
Bangor	1,108,861.21	481,215.60	43
Brewer	469,234.59	154,350.00	33
Hermon	222,536.99	0.00	0
Skowhegan	319,925.60	245,692.80	77
Machias	268,879.66	118,274.40	44
Biddeford	257,982.30	167,268.10	65
Limington	783,297.09	0.00	0
Sanford	270,715.10	270,715.10	100

In Table 7, the results of running the model with capacities of all 19 plants set at 1,062,128 hundredweight per year are given. This is a significant increase in capacity for all plants over the estimated 10 hour per day capacities, and for all but two plants at the capacities estimated at 16 hours per day. At this capacity level, 8 plants are assigned no output. Only two out of the 19 plants are assigned an output greater than half of assumed capacity.

In tables 1 through 6 in the Appendix, the patterns of shipment of fluid milk from supply to processing, and processing to demand, are shown for all three assumed capacity levels. In all three instances plants draw milk adequate to fill demand from supply areas that are closest to them. Similarly, demand is satisfied by the output of plants

TABLE 7.   Assigned Optimal Output of the 19 Largest
           Milk Processing Plants in the State of Maine,
           Plant Capacity Set at 1,062,128 Hundredweight
           Per Year for All Plants

Plant	Allocated Output Cwt./Year	Percent
Auburn	0.0	0
Lewiston	595,454.4	56
Houlton	0.0	0
Presque Isle	345,758.4	33
Portland I	0.0	0
Portland II	727,858.8	69
Yarmouth	0.0	0
Ellsworth	140,922.0	13
Augusta	198,439.2	19
Benton	0.0	0
Winslow	362,682.0	34
Bangor	481,215.6	45
Brewer	154,350.0	15
Hermon	0.0	0
Skowhegan	245,692.8	23
Machias	118,274.4	11
Biddeford	0.0	0
Limington	.0.0	0
Sanford	437,983.2	41

closest to demand centers. It is of interest to note that, in each
solution, the output of some supply areas is totally relegated to either
Class II milk or out of state shipments.

      PARAMETRIC ANALYSIS: THE EFFECT OF RISING ENERGY
             COSTS ON THE LEAST COST SOLUTION
      That the cost of energy in the United States has risen dramatically
since 1973 is a fact of which all of us are painfully aware. The
continuation of the trend seems to be accepted as an inevitability.
There can be little doubt that, as energy costs continue to rise, there
will be resultant structural changes manifested throughout American
industry. It would be of interest, then, to examine how this trend
toward ever rising energy costs is likely to effect change in the
pattern of milk shipments and processing in the State of Maine. It is
important, as well, to demonstrate that a tool exists that can both
simulate how the industry is likely to evolve, should market forces be
allowed to function with some degree of freedom, and provide analysts

with a reasonably accurate least cost processing solution.

METHODOLOGY, DATA AND ASSUMPTIONS OF THE PARAMETRIC ANALYSIS

For the purposes of the parametric analysis, only the impact of escalating energy costs was examined. Thus, quantities supplied and demanded, location of supply and demand centers, location of processing plants, non-energy costs associated with milk shipment and processing, and capacities of processing plants, were allowed to remain the same as in the 1980 value solutions.

Research undertaken by Metzger and Anderson (7) to provide the Maine Milk Commission with an analysis of the cost of shipping and processing milk within the State of Maine provided the basic data for the parametric analysis. Examination of unpublished data made available by Metzger and Anderson indicates that the cost of energy accounts for eight percent of the cost of processing milk, 19 percent of the cost of shipping raw milk from farm to processing, and 10 percent of the cost of shipping packaged, processed milk from plants to demand areas.

For the purpose of this analysis, the authors investigated three scenarios concerning energy costs: that they were 50, 100, and 150 percent higher than 1980 levels. Thus, the model was run with raw milk shipping and processing, and packaged milk shipping costs parameters altered to reflect each of the three levels of energy cost escalation, at all three estimated plant capacity levels -- a total of nine separate solutions.

RESULTS OF THE PARAMETRIC ANALYSIS

Results of the parametric analysis are shown in Tables 8, 9, and 10, and 7 through 12 in the Appendix. The first three tables show the percent of estimated capacity allocated to each of the 19 plants, at all three levels of energy cost escalation, and at all three levels of estimated processing capacity. At each capacity level there is significant movement in allocation between plants. However. plants which are relatively closest to a particular demand area tend to fill the demand in that area regardless of the rising energy costs. Only where there are multiple plants concentrated in an area are there significant changes manifested, and there seems to be little pattern

TABLE 8.   Parametric Results: Estimated Capacity with Ten Hour Days
and Percentage of Capacity Allocated to Each Plant at 1980
Costs, and with Energy Costs Increased by 50, 100, and 150
Percent

Plant	Estimated Capacity Cwt./Year	Allocated Percentage of Capacity			
		1980	+50%	+100%	+150%
Auburn	122,165.94	100	100	100	100
Lewiston	217,590.30	100	100	100	100
Houlton	183,179.51	100	100	100	100
Presque Isle	156,363.78	100	100	100	100
Portland I	851,122.72	31	10	97	97
Portland II	512,755.75	100	100	0	0
Yarmouth	221,389.89	21	100	0	0
Ellsworth	201,793.63	70	70	70	70
Augusta	196,640.75	100	100	100	100
Benton	167,478.14	100	100	100	100
Winslow	328,739.17	100	100	100	100
Bangor	693,038.30	100	44	83	73
Brewer	310,146.62	8	100	0	24
Hermon	139,085.63	0	72	100	100
Skowhegan	199,953.50	100	100	100	100
Machias	168,049.79	70	70	70	70
Biddeford	161,238.94	100	100	100	100
Limington	486,560.68	22	57	57	57
Sanford	169,196.94	100	0	0	0

TABLE 9. Parametric Results: Estimated Capacity with 16 Hour Days and
Percentage of Capacity Allocated to Each Plant at 1980 Costs,
and with Energy Costs Increased by 50, 100, and 150 Percent

Plant	Estimated Capacity Cwt./Year	Allocated Percentage of Capacity			
		1980	+50%	+100%	+150%
Auburn	195,465.50	100	100	100	100
Lewiston	348,144.21	100	100	100	100
Houlton	293,087.22	100	100	100	100
Presque Isle	250,182.05	21	21	21	21
Portland I	1,361,796.35	5	0	27	0
Portland II	820,404.40	80	89	0	89
Yarmouth	354,223.82	0	0	100	0
Ellsworth	322,869.81	44	44	44	44
Augusta	314,625.20	100	100	73	100
Benton	268,765.02	0	100	100	100
Winslow	525,982.61	57	6	22	6
Bangor	1,108,861.28	43	0	37	43
Brewer	469,234.59	33	88	0	0
Hermon	222,536.99	0	100	100	69
Skowhegan	319,925.60	77	77	77	77
Machias	268,879.66	44	44	44	44
Biddeford	257,982.30	65	0	100	65
Limington	783,297.09	0	21	0	0
Sanford	270,715.10	100	100	66	100

TABLE 10. Parametric Results: Capacity Set at 1,062,128 Hundredweight
Per Year. and Percentages of Capacity Allocated to Each
Plant at 1980 Costs, and with Energy Costs Increased by 50,
100, and 150 Percent

Plant	Allocated Percentage of Capacity			
	1980	+50%	+100%	+150%
Auburn	0	0	0	0
Lewiston	56	56	56	56
Houlton	0	0	0	0
Presque Isle	33	33	33	33
Portland I	0	32	0	69
Portland II	69	33	69	0
Yarmouth	0	4	0	0
Ellsworth	13	13	13	13
Augusta	19	19	0	19
Benton	0	34	53	0
Winslow	34	0	0	34
Bangor	45	60	0	60
Brewer	15	0	0	0
Hermon	0	0	60	0
Skowhegan	23	23	23	23
Machias	11	11	11	11
Biddeford	0	41	0	41
Limington	0	0	41	0
Sanford	41	0	0	0

to the changes. Thus, in Table 10, Presque Isle, Machias, and Ellsworth
continue to process at constant percentages of capacity, while Biddeford,
Limington, and Sanford seem to take turns processing enough milk to
supply one demand area (York). Examination of the tables in the
Appendix which show the specific patterns of shipment from supply to
processing (Appendix Tables 7-9) and processing to demand (Appendix
Tables 10-12) confirms this observation.

The number of plants which are removed from the solution increases
as estimated processing capacity increases at all three levels of
parametric analysis. The minimum number of plants chosen to process

milk, nine, occurs with open plant capacities (1,062,128 cwt./yr.) at 1980 + 100 percent energy costs. Eighteen plants, the maximum number, were chosen at capacity levels estimated for 10-hour days at both 1980 energy cost levels and 1980 + 50 percent energy cost levels.

CONCLUSIONS

The transshipment model is easily adapted to an examination of patterns of milk shipment and processing in Maine. However, the results of this paper, and any transshipment model, are limited by the accuracy of the data and the validity of the assumptions underlying the data. The model performed well given the available data and necessary assumptions.

The primary limitation on the data in this analysis concerns the estimation of the annual processing capacity of the 19 plants under consideration. The authors satisfied themselves that no hard data exist concerning the actual processing capacities of the plants, and financial constraints prevented an actual engineering examination of all 19 plants. Thus, capacities were estimated based upon Metzger's data concerning the filling rate of the machines utilized by each of the plants. This estimate contains an implicit assumption that, in each of the 19 situations, the filling machinery was the limiting factor in production. There can be no doubt that other factors, such as cold storage capacity, might limit production. It is the opinion of the authors, however, that lacking better data, the capacity estimates arrived at are adequate for this analysis. The 1,062,128 hundredweight per year capacity assumed for all plants in some of the runs removes this objection, as well.

Inherent in the standard linear programming model is the assumption of a linear objective function. More specifically, this transshipment model assumes constant per unit processing cost associated with low levels of capacity utilization. Consequently, there are numerous examples of plants in the optimal solutions at very low levels of capacity utilization which might not otherwise have been the case. Obviously, the power of the model as an analytical tool can be much improved through the incorporation of a curvilinear cost structure in the objective function, especially in the processing parameters.

Given the limitations mentioned above, the base model functioned well. The minimized total cost of assembly, processing, and distribution, as shown in Table 11, fell as capacity estimates were increased, demonstrating that there are costs associated with the decentralized nature of the industry. The savings associated with a change in estimated

TABLE 11. Least Cost Solutions of the Transshipment Model of Maine Milk Processing and Distribution Under Varying Assumptions Concerning Plant Capacities and Energy Costs

Assumption Capacity	Energy Cost	Cost, Dollars Per Year
122,166 851,123 Cwt./Yr.		
10 Hr./Day	1980	$13,882,422.21
10 Hr./Day	+50%	14,448,324.70
10 Hr./Day	+100%	15,018,283.19
10 Hr./Day	+150%	15,584,390.79
195,466 1,361,796 Cwt./Yr		
16 Hr./Day	1980	13,822,908.23
16 Hr./Day	+50%	14,384,191.10
16 Hr./Day	+100%	14,949,235.15
16 Hr./Day	+150%	15,510,601.56
1,062,128 Cwt./Yr	1980	13,821,196.50
1,062,128 Cwt./Yr.	+50%	14,382,366.90
1,062,128 Cwt./Yr.	+100%	14,947,246.74
1,062,128 Cwt./Yr	+150%	15,508,543.86

plant capacity from operating 10 hours per day to an open capacity assumed to be 1,062,128 cwt./yr. at 1980 energy costs is $61,225.71 annually. The savings with a similar change in capacity estimates at 1980 +150% energy costs is $75,846.93. The gradual attrition of firms in the industry is strong evidence that the market forces indicated by the results of this study are strongly influencing the evolution of the industry now, and it would be a fair assumption that the forces at work will continue in the future.

APPENDIX

TABLE 1. Shipments of Raw Milk from Counties (Supply Areas) to Plants, with 10 Hour Day Capacity Limits

Supply County and Receiving Plant	Quantity		Percent	
	Shipped	Received	Shipped	Received
Androscoggin	508,107.13		100.0	
Auburn		122,165.94		24.0
Lewiston		217,590.30		42.8
Portland II		166,649.19		32.8
Yarmouth		1,701.73		0.3
Aroostook	339,543.29		100.0	
Houlton		183,179.51		53.9
Presque Isle		156,363.78		46.1
Cumberland	346,103.56		100.0	
Portland II		346,103.56		100.0
Franklin	263,479.92		100.0	
Portland I		263,479.92		100.0
Hancock	17,169.90		100.0	
Ellsworth		17,169.90		100.0
Kennebec	693,358.02		100.0	
Augusta		196,640.75		28.4
Benton		167,978.14		24.2
Winslow		328.739.13		47.4
Knox (Not shipped to plants)	0.00		0.0	
Lincoln (Not shipped to plants)	0.00		0.0	
Oxford (Not shipped to plants)	0.00		0.0	
Penobscot	908,185.45		100.0	
Ellsworth		123,752.10		13.6
Bangor		693,038.30		76.3
Brewer		23,500.65		2.6
Machias		67,894.40		7.5
Piscataquis (Not shipped to plants)	0.00		0.0	

APPENDIX

TABLE 1. (Continued)

Supply County and Receiving Plant	Quantity		Percent	
	Shipped	Received	Shipped	Received
Sagadahoc (Not shipped to plants)	0.00		0.0	
Somerset Skowhegan	199,953.50	199,953.50	100.0	100.0
Waldo (Not shipped to plants)	0.00		0.0	
Washington Machias	50,380.00	50,380.00	100.0	100.0
York Yarmouth Biddeford Limington Sanford	482,350.00	44,366.80 161,238.94 107,547.32 169,196.94	100.0	9.2 33.4 22.3 35.1

APPENDIX

TABLE 2. Shipments of Raw Milk from Counties (Supply Areas) to Plants, with 16 Hour Day Capacity Limits

Supply County and Receiving Plant	Quantity		Percent	
	Shipped	Received	Shipped	Received
Androscoggin	617,518.23		100.0	
Auburn		195,465.50		31.7
Lewiston		348,144.21		56.4
Portland I		73,908.52		12.0
Aroostook	345,758.40		100.0	
Houlton		293,087.22		84.8
Presque Isle		52,671.18		15.2
Cumberland	346,103.56		100.0	
Portland II		346,103.56		100.0
Franklin	263,479.92		100.0	
Portland II		263,479.29		100.0
Hancock	17,169.90		100.0	
Ellsworth		17,169.90		100.0
Kennebec	612,965.89		100.0	
Augusta		314,625.20		51.3
Winslow		298,340.69		48.7
Knox (Not shipped to plants)	0.00		0.0	
Lincoln (Not shipped to plants)	0.00		0.0	
Oxford (Not shipped to plants)	0.00		0.0	
Penobscot	827,212.10		100.0	
Ellsworth		123,752.10		15.0
Bangor		481,215.60		58.2
Brewer		154,350.00		18.7
Machias		67,894.40		8.2
Piscataquis (Not shipped to plants)	0.00		0.0	

APPENDIX

TABLE 2. (Continued)

Supply County and	Quantity		Percent	
Receiving Plant	Shipped	Received	Shipped	Received
Sagadahoc (Not shipped to plants)	0.00		0.0	
Somerset Skowhegan	245,692.80	245,692.80	100.0	100.0
Waldo (Not shipped to plants)	0.00		0.0	
Washington Machias	50,380.00	50,380.00	100.0	100.0
York Portland II Biddeford Sanford	482,350.00	44,366.80 167,268.10 270,715.10	100.0	9.2 34.7 56.1

APPENDIX

TABLE 3. Shipments of Raw Milk from Counties (Supply Areas) to Plants, with Capacities Set at 1,062,128 Hundredweight Per Year

Supply County and Receiving Plant	Quantity		Percent	
	Shipped	Received	Shipped	Received
Androscoggin	626,233.00		100.0	
Lewiston		595,454.40		95.1
Portland II		30,778.68		4.9
Aroostook	345,758.40		100.0	
Presque Isle		345,758.40		100.0
Cumberland	346,103.56		100.0	
Portland II		346,103.56		100.0
Franklin	263,479.92		100.0	
Portland II		263,479.92		100.0
Hancock	17,169.90		100.0	
Ellsworth		17,169.90		100.0
Kennebec	561,121.20		100.0	
Augusta		198,439.20		35.4
Winslow		362,682.00		64.6
Knox (Not shipped to plants)	0.00		0.0	
Lincoln (Not shipped to plants)	0.00		0.0	
Oxford (Not shipped to plants)	0.00		0.0	
Penobscot	827,212.10		100.0	
Ellsworth		123,752.10		15.0
Bangor		481.215.60		58.2
Brewer		154,350.00		18.7
Machias		67,894.40		8.2
Piscataquis (Not shipped to plants)	0.00		0.0	

APPENDIX

TABLE 3. (Continued)

Supply County and Receiving Plant	Quantity		Percent	
	Shipped	Received	Shipped	Received
Sagadahoc	43,129.84		100.0	
Portland II		43,129.84		100.0
Somerset	245,692.80		100.0	
Skowhegan		245,692.80		100.0
Waldo (Not shipped to plants)	0.00		0.0	
Washington	50,380.00		100.0	
Machias		50,380.00		100.0
York	482,350.00		100.0	
Portland II		44,366.80		9.2
Sanford		437,983.20		90.8

APPENDIX

TABLE 4. Shipments of Processed Milk from Plants to Counties (Demand
Areas); 10 Hour Day Capacity Limits

Plant and	Quantity		Percent	
Receiving County	Shipped	Received	Shipped	Received
Auburn	122,165.94		100.0	
Androscoggin		122,165.94		100.0
Lewiston	217,590.24		100.0	
Androscoggin		216,572.40		99.5
Oxford		1,017.84		0.5
Houlton	183,179.51		100.0	
Aroostook		183,179.51		100.0
Presque Isle	156,363.78		100.0	
Aroostook		156,363.78		100.0
Portland I	263,479.92		100.0	
Cumberland		263,479.92		100.0
Portland II	512,752.75		100.0	
Cumberland		464,378.88		90.6
Sagadahoc		48,373.87		9.4
Yarmouth	46,068.53		100.0	
Sagadahoc		46,068.53		100.0
Ellsworth	140,922.00		100.0	
Hancock		140,922.00		100.0
Augusta	197,100.75			
Kennebec		35,844.99		18.2
Oxford		161,255.76		81.8
Benton	167,968.14		100.0	
Kennebec		167,968.14		100.0
Winslow	288,567.37		100.0	
Franklin		45,739.30		15.9
Kennebec		159,318.87		55.2
Lincoln		83,509.20		28.9
Bangor	692,988.30		100.0	
Aroostook		6,215.11		0.9
Knox		74,758.24		10.8
Penobscot		481,215.60		69.4
Piscataquis		60,076.80		8.7
Waldo		70,722.55		10.2

APPENDIX

TABLE 4. (Continued)

Plant and Receiving County	Quantity		Percent	
	Shipped	Received	Shipped	Received
Brewer	23,500.65		100.0	
Waldo		23,500.65		100.0
Hermon (No shipments Plant not in solution)	0.00		0.0	
Skowhegan	199,953.50		100.0	
Franklin		43,285.10		21.7
Somerset		156,668.40		78.4
Machias	118,274.40		100.0	
Washington		118,274.40		100.0
Biddeford	161,238.94		100.0	
York		161,238.94		100.0
Limington	107,547.32		100.0	
York		107,547.32		100.0
Sanford	169,196.94		100.0	
York		169,196.94		100.0

APPENDIX

TABLE 5. Shipments of Processed Milk from Plants to Counties (Demand
Centers); 16 Hour Day Capacity Limits

Plant and	Quantity		Percent	
Receiving County	Shipped	Received	Shipped	Received
Auburn	195,465.50		100.0	
Androscoggin		33,191.90		17.0
Oxford		162,273.60		83.0
Lewiston	348,144.21		100.0	
Androscoggin		305,546.50		87.8
Sagadahoc		42,597.71		12.2
Houlton	293,087.22		100.0	
Aroostook		293,087.22		100.0
Presque Isle	52,671.18		100.0	
Aroostook		52,671.18		100.0
Portland I	73,908.52		100.0	
Cumberland		73,908.52		100.0
Portland II	653,950.28		100.0	
Cumberland		653,950.28		100.0
Yarmouth (No shipments Plant not in solution)	0.00		0.0	
Ellsworth	140,922.00		100.0	
Hancock		140,922.00		100.0
Augusta	319,625.20		100.0	
Kennebec		267,780.51		83.8
Sagadahoc		51,844.69		16.2
Benton (No shipments Plant not in solution)	0.00		0.0	
Winslow	298,340.69		100.0	
Kennebec		99,901.49		33.5
Knox		114,930.00		38.5
Lincoln		83,509.20		28.0
Bangor	481,215.60		100.0	
Penobscot		481,215.60		100.0

APPENDIX

TABLE 5. (Continued)

Plant and	Quantity		Percent	
Receiving County	Shipped	Received	Shipped	Received
Brewer	154,350.00		100.0	
Piscataquis		60,076.80		38.9
Waldo		94,273.20		61.1
Hermon	0.00		0.0	
(No shipments				
Plant not in solution)				
Skowhegan	245,692.80		100.0	
Franklin		89,024.40		36.2
Somerset		156,668.40		63.8
Machias	118,274.40		100.0	
Washington		118,274.4		100.0
Biddeford	167,268.10		100.0	
York		167,268.10		100.0
Limington	0.00		0.0	
(No shipments -				
Plant not in solution)				
Sanford	270,715.10		100.0	
York		270,715.10		100.0

APPENDIX

TABLE 6.   Shipments of Processed Milk from Plants to Counties (Demand Areas); with Capacities Set at 1,062,128 Hundredweight Per Year

Plant and Receiving County	Quantity Shipped	Quantity Received	Percent Shipped	Percent Received
Auburn (No shipments)	0.00		0.0	
Lewiston	595,454.40		100.0	
Androscoggin		338,738.40		56.9
Oxford		162,273.60		27.3
Sagadahoc		94,442.40		15.9
Houlton (No shipments)	0.00		0.0	
Presque Isle	345,758.40		100.0	
Aroostook		345,758.40		100.0
Portland I (No shipments)	0.00		0.0	
Portland II	727,858.80		100.0	
Cumberland		727,858.80		100.0
Yarmouth (No shipments)	0.00		0.0	
Ellsworth	140,922.00		100.0	
Hancock		140,922.00		100.0
Augusta	198,439.20		100.0	
Knox		114,930.00		57.9
Lincoln		83,509.20		42.1
Benton (No shipments)	0.00		0.0	
Winslow	362,682.00		100.0	
Kennebec		362,682.00		100.0
Bangor	481,215.60		100.0	
Penobscot		481,215.60		100.0
Brewer	154,350.00		100.0	
Piscataquis		60,076.80		38.9
Waldo		94,273.20		61.1

APPENDIX

TABLE 6.   (Continued)

Plant and Receiving County	Quantity Shipped	Quantity Received	Percent Shipped	Percent Received
Hermon (No shipments)	0.00		0.0	
Skowhegan	245,692.80		100.0	
Franklin		89,024.40		36.2
Somerset		156,668.40		63.8
Machias	118,274.40		100.0	
Washington		118,274.40		100.0
Biddeford (No shipments)	0.00		0.0	
Limington (No shipments)	0.00		0.0	
Sanford	437,983.20		100.0	
York		437,983.20		100.0

TABLE 7. Parametric Results: Shipments from Counties (Supply Areas) to Plants; 10 Hour Per Day Plant
Capacity, and Energy Costs Assumed Rising by 50, 100, and 150 Percent

Supply County and Receiving Plant	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Androscoggin	508,107.16		508,107.16		507,224.45	
Auburn		122,165.94		122,165.94		122,165.94
Lewiston		217,590.30		217,590.30		217,590.30
Portland I		43,791.76		168,350.92		167,468.21
Portland II		124,559.16		0.00		0.00
Aroostook	339,543.29		339,543.29		339,543.29	
Houlton		183,179.51		183,179.51		183,179.51
Presque Isle		156,363.78		156,363.78		156,363.78
Cumberland	346,103.56		346,103.56		346,103.56	
Portland II		346,103.56		0.00		0.00
Portland I		0.00		346,103.56		303,105.46
Franklin	263,479.92		263,479.92		263,479.92	
Portland I		263,479.92		263,479.92		263,479.92
Hancock	17,169.90		17,169.90		17,169.90	
Ellsworth		17,169.90		17,169.90		17,169.90
Kennebec	693,358.02		693,358.02		613,358.02	
Augusta		196,640.75		196,640.75		196,640.75
Benton		167,978.14		167,978.14		167,978.14
Winslow		328,739.13		328,739.13		328,739.13
Knox	0.00		0.00		0.00	

TABLE 7. (Continued)

Supply County and Receiving Plant	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Lincoln	0.00		0.00		0.00	
Oxford	0.00		0.00		0.00	
Penobscot	908,185.45		908,185.45		909,068.16	
Ellsworth		123,752.10		123,752.10		123,752.10
Bangor		305,904.02		577,453.33		502,695.09
Brewer		310,146.62				75,640.95
Hermon		100,448.31		139,085.62		139,085.62
Machias		67,894.40		67,894.40		67,894.40
Piscataquis	0.00		0.00		0.00	
Sagadahoc	0.00		0.00		0.00	
Somerset	199,953.50		199,953.50		199,953.50	
Skowhegan		199,953.50		199,953.50		199,953.50
Waldo	0.00		0.00		0.00	
Washington	50,380.00		50,380.00		50,380.00	
Machias		50,380.00		50,380.00		50,380.00
York	482,350.00		482,350.00		482,350.00	
Portland		44,366.80		44,366.80		44,366.80
Biddeford		161,238.94		161,238.94		161,238.94
Limington		276,744.26		276,744.26		276,744.26

The header row above each pair of Shipped/Received columns is under "Quantity".

TABLE 8. Parametric Results: Shipments from Counties (Supply Areas) to Plants; 16 Hour Per Day Plant
Capacities, and Energy Costs Assumed Rising by 50, 100, and 150 Percent

Supply County and Receiving Plant	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Androscoggin	617,518.23		617,518.23		617,518.23	
Auburn		195,465.50		195,465.50		195,465.50
Lewiston		348,144.21		348,144.21		348,144.21
Portland II		73,908.52		65,788.26		73,908.52
Portland I		0.00		0.00		0.00
Yarmouth		0.00		8,120.26		0.00
Aroostook	345,758.40		345,758.40		345,758.40	
Houlton		293,087.22		293,087.22		293,087.22
Presque Isle		52,671.18		52,671.18		52,671.18
Cumberland	346,103.56		346,103.56		346,103.56	
Portland II		346,103.56		0.00		346,103.56
Yarmouth		0.00		346,103.56		0.00
Franklin	263,479.92		263,479.92		263,479.92	
Portland II		0.00		0.00		263,479.92
Portland I		263,479.92		263,479.92		0.00
Hancock	17,169.90		17,169.90		17,169.90	
Ellsworth		17,169.90		17,169.90		17,169.90
Kennebec	612,965.89		612,965.89		612,965.89	
Augusta		314,625.20		229,270.87		314,625.20
Benton		268,765.02		268,765.02		268,765.02
Winslow		29,575.67		114,930.00		29,575.67
Knox	0.00		0.00		0.00	

TABLE 8. (Continued)

Supply County and Receiving Plant	Quantity (+50%) Shipped	Received	(+100%) Shipped	Received	(+150%) Shipped	Received
Lincoln	0.00		0.00		0.00	
Oxford	0.00		0.00		0.00	
Penobscot	827,212.10		827,212.10		827,212.10	
Augusta		123,752.10		0.00		0.00
Brewer		413,028.61		0.00		0.00
Hermon		222,536.99		222,536.99		154,350.00
Machias		67,894.40		67,894.40		67,894.40
Ellsworth		0.00		123,752.10		123,752.10
Bangor		0.00		413,028.61		481,215.60
Piscataquis	0.00		0.00		0.00	
Sagadahoc	0.00		0.00		0.00	
Somerset	245,692.80		245,692.80		245,692.80	
Skowhegan		245,692.80		245,692.80		245,692.80
Waldo	0.00		0.00		0.00	
Washington	50,380.00		50,380.00		50,380.00	
Machias		50,380.00		50,380.00		50,380.00
York	482,350.00		482,350.00		482,350.00	
Portland II		44,366.80		0.00		44,366.80
Limington		167,268.10		0.00		0.00
Sanford		270,715.10		180,000.90		270,715.10

APPENDIX

TABLE 8. (Continued)

Supply County and Receiving Plant	Quantity (+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
York (Continued)						
Portland I		0.00		44,366.80		0.00
Biddeford		0.00		257,982.30		167,268.10

TABLE 9. Parametric Results: Shipments from Counties (Supply Areas) to Plants with Capacities Set at 1,062,128 Hundredweight Per Year, and Energy Costs Rising by 50, 100, and 150 Percent

Supply County and Receiving Plant	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Androscoggin	626,233.08		626,233.08		626,233.08	
Lewiston		595,454.40		595,454.40		595,454.40
Portland I		30,778.68		0.00		30,778.68
Portland II		0.00		30,778.68		0.00
Aroostook	345,758.40		345,758.40		345,758.40	
Presque Isle		345,758.40		345,758.40		345,758.40
Cumberland	346,103.56		346,103.56		346,103.56	
Portland II	'	346,103.56		346,103.56		0.00
Portland I		0.00		0.00		346,103.56
Franklin	263,479.92		263,479.92		263,479.92	
Portland I		263,479.92		0.00		263,479.92
Portland II		0.00		263,479.92		0.00
Hancock	17,169.90		17,169.90		17,169.90	
Ellsworth		17,169.90		17,169.90		17,169.90
Kennebec	561,121.20		561,121.20		561,121.20	
Augusta		198,439.20		0.00		198,439.20
Winslow		362,682.00		0.00		362,682.00
Benton		0.00		561,121.20		0.00
Knox	0.00		0.00		0.00	

APPENDIX

TABLE 9. (Continued)

Supply County and Receiving Plant	Quantity					
	(+50%)		(+100%)		(150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Oxford	0.00		0.00		0.00	
Penobscot	827,212.10		827,212.10		827,212.10	
Ellsworth		123,752.10		123,752.10		123,752.10
Bangor		635,565.60		0.00		635,565.60
Machias		67,894.40		67,894.40		67,894.40
Hermon		0.00		635,565.60		0.00
Piscataquis	0.00		0.00		0.00	
Sagadahoc	43,129.80		43,129.80		43,129.80	
Yarmouth		43,129.80		0.00		0.00
Portland II		0.00		43,129.80		0.00
Portland I		0.00		0.00		43,129.80
Somerset	245,692.80		245,692.80		245,692.80	
Skowhegan		245,692.80		245,692.80		245,692.80
Waldo	0.00		0.00		0.00	
Washington	50,380.00		50,380.00		50,380.00	
Machias		50,380.00		50,380.00		50,380.00
York	482,350.00		482,350.00		482,350.00	
Portland I		44,366.80		0.00		44,366.80
Biddeford		437,983.20		0.00		437,983.20
Portland II		0.00		44,366.80		0.00

APPENDIX

TABLE 9. (Continued)

| Supply County and | Quantity | | | | | |
| Receiving Plant | (+50%) | | (+100%) | | (+150%) | |
	Shipped	Received	Shipped	Received	Shipped	Received
York (Continued)						
Limington		0.00		437,983.20		0.00

APPENDIX

TABLE 10. Parametric Results: Shipments of Processed Milk from Plants to Counties (Demand Areas) with 10 Hour Day Capacity Limits, and Energy Prices Rising by 50, 100, and 150 Percent

Plant and Receiving County	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Auburn	122,165.90		122,165.90		122,165.90	
Androscoggin		121,148.10		121,148.10		121,148.10
Oxford		1,017.84		1,017.84		1,017.84
Lewiston	217,590.30		217,590.30		217,590.30	
Androscoggin		217,590.30		217,590.30		217,590.30
Houlton	183,179.51		183,179.51		183,179.51	
Aroostook		183,179.51		183,179.51		183,179.51
Presque Isle	156,363.78		156,363.78		156,363.78	
Aroostook		156,363.78		156,363.78		156,363.78
Portland I	88,158.56		822,301.20		821,418.40	
Sagadahoc		88,158.56		94,442.40		93,559.69
Cumberland		0.00		727,858.80		727,858.80
Portland II	512,752.75		0.00		0.00	
Cumberland		506,468.91		0.00		0.00
Sagadagoc		6,283.84		0.00		0.00
Yarmouth	221,389.89		0.00		0.00	
Cumberland		221,389.89		0.00		0.00
Ellsworth	140,922.00		140,922.00		140,922.00	
Hancock		140,922.00		140,922.00		140,922.00

TABLE 10. (Continued)

Plant and Receiving County	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Augusta	196,640.75		196,640.75		195,758.04	
Franklin		45,739.30		0.00		0.00
Lincoln		83,509.20		0.00		83,509.20
Oxford		67,392.25		0.00		27,220.49
Kennebec		0.00		194,703.86		0.00
Knox		0.00		1,936.89		39,289.05
Cumberland		0.00		0.00		45,739.30
Benton	167,978.14		167,978.14		167,978.14	
Kennebec		127,806.38		167,978.14		167,978.14
Knox		40,171.76		0.00		0.00
Winslow	328,739.13		328,739.13		328,739.13	
Kennebec		234,875.62		0.00		194,703.86
Oxford		93,863.51		161,255.76		134,035.27
Franklin		0.00		45,739.30		0.00
Knox		0.00		38,234.87		0.00
Lincoln		0.00		83,509.20		0.00
Bangor	305,904.20		577,453.33		502,695.01	
Penobscot		305,904.02		481,215.60		481,215.60
Knox		0.00		74,758.24		0.00
Piscataquis		0.00		21,479.49		0.00
Waldo		0.00		0.00		21,479.49
Brewer	310,146.62		0.00		75,640.95	
Knox		74,758.24		0.00		75,640.95

TABLE 10. (Continued)

Plant and Receiving County	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Brewer (Continued)						
Penobscot		175,311.58		0.00		0.00
Piscataquis		60,076.80		0.00		0.00
Hermon	100,488.31		139,085.51		139,085.62	
Aroostook		6,215.11		6,215.11		6,215.11
Waldo		94,273.20		94,273.20		72,793.71
Piscataquis		0.00		38,597.31		60,076.80
Skowhegan	199,953.50		199,953.50		199,953.50	
Franklin		43,285.10		43,285.10		43,285.10
Somerset		156,668.40		156,668.40		156,668.40
Machias	118,274.40		118,274.40		118,274.40	
Wasnington		118,274.40		118,274.40		118,274.40
Biddeford	161,238.94		161,238.94		161,238.94	
York		161,238.94		161,238.94		161,238.94
Limington	276,744.26		276,744.26		276,744.26	
York		276,744.26		276,744.26		276,744.26
Sanford	0.00		0.00		0.00	
York		0.00		0.00		0.00

TABLE 11. Parametric Results: Shipments of Processed Milk from Plants to Counties (Demand Areas) with 16 Hour Day Capacity Limits, and Energy Costs Rising by 50, 100, and 150 Percent

Plant and Receiving County	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Auburn	195,465.50		195,465.50		195.465.50	
Oxford		162,273.60		0.00		152,867.79
Sagadahoc		33,191.90		0.00		42,597.71
Androscoggin		0.00		195,465.50		0.00
Lewiston	348,224.20		348,604.20		348,144.20	
Androscoggin		338,738.40		143,272.90		338,738.40
Sagadahoc		9,485.81		42,597.71		0.00
Oxford		0.00		162,733.60		7,405.81
Houlton	293,087.22		293,087.22		293,087.22	
Aroostook		293,087.22		293,087.22		293,087.22
Presque Isle	52,671.18		52,671.18		52,671.18	
Aroostook		52,671.18		52,671.18		52,671.18
Portland I	0.00		373,634.98		0.00	
Cumberland		0.00		373,634.98		0.00
Portland II	757,828.80		0.00		727,828.80	
Cumberland		727,858.80		0.00		727,828.80
Yarmouth	0.00		354,223.82		0.00	
Cumberland		0.00		354,223.82		0.00
Ellsworth	140,922.00		140,922.00		140,922.00	
Hancock		140,922.00		140,922.00		140,922.00

TABLE 11.   (Continued)

Plant and Receiving County	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Augusta	314,625.20		229,270.87		314,625.20	
Kennebec		314,625.20		93,916.98		314,625.20
Lincoln		0.00		83,509.20		0.00
Sagadahoc		0.00		51,844.69		0.00
Benton	268,765.02		268,765.02		268,765.02	
Kennebec		18,481.13		268,765.02		18,481.13
Knox		114,930.00		0.00		114,930.00
Lincoln		83,509.20		0.00		83,509.20
Sagadahoc		51,844.69		0.00		51,844.69
Winslow	29,575.67		114,930.00		29,575.67	
Kennebec		29,575.67		0.00		29,575.67
Knox		0.00		114,930.00		0.00
Bangor	0.00		420,028.61		481,215.60	
Penobscot		0.00		359,951.81		481,215.60
Piscataquis		0.00		60,076.80		0.00
Brewer	413,028.61		0.00		0.00	
Penobscot		413,028.61		0.00		0.00
Hermon	222,536.99		222,536.99		154,350.00	
Penobscot		68,186.99		128,263.79		0.00
Piscataquis		60,076.80		0.00		60,076.80
Waldo		94,273.20		94,273.20		94,273.20

APPENDIX

TABLE 11.   (Continued)

| Plant and Receiving County | Quantity | | | | | |
| | (+50%) | | (+100%) | | (+150%) | |
	Shipped	Received	Shipped	Received	Shipped	Received
Skowhegan	245,692.80		245,692.80		245,692.80	
Franklin		89,024.40		89,024.40		89,024.40
Somerset		156,668.40		156,668.40		156,668.40
Machias	118,274.40		118,274.40		118,274.40	
Washington		118,274.40		118,274.40		118,274.40
Biddeford	0.00		257,982.30		167,268.10	
York		0.00		257,982.30		167,268.10
Limington	167,268.10		0.00		0.00	
York		167,268.10		0.00		0.00
Sanford	270,715.10		180,000.90		270,715.10	
York		270,715.10		180,000.90		270,715.10

APPENDIX

TABLE 12. Parametric Results: Shipments of Processed Milk from Plants to Counties (Demand Areas) with
Plant Capacities Set at 1,062,128 Hundredweight Per Year, and Energy Costs Rising by 50, 100
and 150 Percent

Plant and Receiving County	(+50%) Shipped	(+50%) Received	(+100%) Shipped	(+100%) Received	(+150%) Shipped	(+150%) Received
Auburn	0.00		0.00		0.00	
Lewiston	595,454.40		595,454.40		595,454.40	
Androscoggin		338,738.40		338,738.40		338,738.40
Oxford		162,273.60		162,273.60		162,273.60
Sagadahoc		94,442.40		94,442.40		94,442.40
Houlton	0.00		0.00		0.00	
Presque Isle	345,758.40		345,758.40		345,758.40	
Aroostook		345,758.40		345,758.40		345,758.40
Portland I	338,625.40		0.00		727,858.80	
Cumberland		338,625.40		0.00		727,858.80
Portland II	346,103.56		757,828.80		0.00	
Cumberland		346,103.56		727,858.80		0.00
Yarmouth	43,129.84		0.00		0.00	
Cumberland		43,129.84		0.00		0.00
Ellsworth	140,922.00		140,922.00		140,922.00	
Hancock		140,922.00		140,922.00		140,922.00
Augusta	198,439.00		0.00		198,439.00	
Knox		114,930.00		0.00		114,930.00
Lincoln		83,509.00		0.00		83,509.00

TABLE 12. (Continued)

Plant and Receiving County	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Benton	362,682.00		561,121.20		0.00	
Kennebec		362,682.00		362,682.00		0.00
Knox		0.00		114,930.00		0.00
Lincoln		0.00		83,509.20		0.00
Winslow	0.00		0.00		362,682.00	
Kennebec		0.00		0.00		362,682.00
Bangor	636,565.60		0.00		635,565.60	
Penobscot		481,215.60		0.00		481,215.60
Piscataquis		60,076.80		0.00		60,076.80
Waldo		94,273.20		0.00		94,273.20
Brewer	0.00		0.00		0.00	
Hermon	0.00		635,565.60		0.00	
Penobscot		0.00		481,215.60		0.00
Piscataquis		0.00		60,076.80		0.00
Waldo		0.00		94,273.20		0.00
Skowhegan	245,692.80		245,692.80		245,692.80	
Franklin		89,024.40		89,024.40		89,024.40
Somerset		156,668.40		156,668.40		156,668.40
Machias	118,274.40		118,274.40		118,274.40	
Washington		118,274.40		118,274.40		118,274.40

APPENDIX

TABLE 12.   (Continued)

Plant and Receiving County	Quantity					
	(+50%)		(+100%)		(+150%)	
	Shipped	Received	Shipped	Received	Shipped	Received
Biddeford	437,983.20		0.00		437,983.20	
York		437,983.20		0.00		437,983.20
Limington	0.00		437,983.20		0.00	
York		0.00		437,983.20		0.00
Sanford	.0.00		0.00		0.00	

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