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# Fluid Milk Processing Costs: Current State and Comparisons[1]

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## ABSTRACT

An economic-engineering model is used to derive the theoretically minimum cost of processing and distributing fluid white milk for the state of Maine. This model represents a state-of-the-art milk processing facility and is used to evaluate three questions: 1) the components of total processing costs; 2) whether the cost of milk processing declines with increasing plant size; and 3) the minimum processing volume to financially justify in-plant blow-molding technology. The model indicates that significant savings in per-container processing costs can be achieved by increasing plant size. However, distribution costs, related to the geographical distribution of consumer demand and plant location in the state of Maine do not favor large centralized plants.

In addition, this model is compared with results published in 1993 to evaluate cost trends over a 7-yr period. The model indicates import shifts to more technologically advanced processing equipment and a dramatic increase in labor costs. Overall, processing costs have risen 2.9% annually above the rate of inflation. Dairies that are unable to respond to increased labor costs through capital investment and expansion will likely find it more difficult to remain competitive in the milk processing industry.
(**Key words:** dairy processing, cost, economic-engineering)

**Abbreviation key: MMC** = Maine Milk Commission.

## INTRODUCTION

This study estimates the minimum cost of processing fluid white milk in the State of Maine. Maine is one of the few states in the nation that regulates the production, processing, and retail marketing of white milk. Regulation of fluid milk prices is conducted by the Maine Milk Commission (**MMC**), a regulatory body consisting of four government-appointed citizens plus an appointee of the Maine Commissioner of Agriculture. State legislation requires that the minimum wholesale processing margin on white milk be based upon the lowest achievable cost of production as estimated through a theoretically "most efficient" processor (7 M.R.S.A., section 2954). Based upon the cost of production for this plant, the MMC establishes the minimum allowable wholesale margin for packaged milk products after adjusting for Maine business conditions. In addition to the applied importance of this study, this research provides a unique opportunity to examine production costs in a privately controlled industry.

In order to estimate the minimum cost of processing fluid while milk, the MMC considered four state-of-the art dairy facilities: one processing 335,000 gallons/wk, a second processing 400,000 gallons/wk, the third, a variation of the 400,000-gallon/wk model that included blow-molding bottling technology, and a fourth model with a 600,000-gallon/wk capacity and blow-molding technology. In addition to the cost of processing white milk, the MMC incorporated distribution costs into the processing models to reflect the wholesale delivered cost of milk.

This article describes the methods used in determining the hypothetical least-cost processing facility and the most important expenses affecting processing costs per container. The results of this research find that milk processing costs decrease as plant size increases. However, these cost savings cannot be passed on to consumers due to high distribution costs associated with a single large dairy serving the entire state. Secondly, blow-molding technology is not financially feasible for dairies serving the state due to limited processing volume. In addition, this report summarizes the evolution of dairy processing costs over the past 7 yr in order to identify factors of production increasing in cost at a rate faster than inflation. A more detailed description of this study is contained in the bulletin by Dalton, Criner, and Halloran (2001). Similar earlier work includes Anderson (1986), Jacobs and Criner (1990), Criner and Jacobs (1992), and Criner et al. (1995).

## MATERIALS AND METHODS

Economic-engineering models are physical representations of production or marketing processes where tech-

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nical and price information is combined. These models are usually described using mathematical equations. The engineering information includes the technical and industrial engineering specifics of facility construction, equipment and processing technology plus quantitative information on labor, utilities, supplies, and production capacity. The economic component of the model involves determining costs for all plant inputs by combining the fixed and variable input prices with the technical engineering requirements. Economic-engineering models are particularly useful in allocating costs to different stages of production and then to the various items produced. Allocable costs are attributed directly to containers, in the milk processing example, but nonallocable costs are assigned to containers based upon logical rules. Cost allocations are based primarily upon equipment utilization, volume produced (or handled), or space occupied by inputs used in a particular container process. Since most economic-engineering models convert all costs to annual values, the economic-engineering methodology is similar to what contemporary engineering economic books call "annual equivalent worth analysis" which places all monetary values on an annual basis using amortization and other time-value-of-money techniques (see, for example, Park, 2001 or Collier and Glagola, 1998).

The economic-engineering methodology was initially developed in the 1950s and has been utilized in many cost-estimation studies (Black, 1955; Samment and French, 1953). An early use of the method to estimate food-processing costs was conducted by French, Samment, and Bessler in 1956, when they analyzed efficiency of plant operations in canning California pears. More recently, Fischer, Hammond, and Hardie published a report that used the economic-engineering methodology to estimate milk processing costs for three different-sized dairy plants. This study was adapted to Maine conditions and used by the MMC for several years. While the methods used in the Fischer, Hammond, and Hardie study are similar to those of our analysis, the 1979 plant design is no longer state-of-the-art and the model does not produce and distribute the same variety of products.

Creation of an economic-engineering model involves collection of all inputs used in processing fluid milk, their prices, and a description of the engineering process. Costs are calculated for each phase of production as the raw material is transformed into a processed product. Annual processing costs are collected for the entire plant and then allocated to containers in the final analytical stage. In many cases, variable costs can be allocated directly to a particular container size, for example, with packaging material or labor on a container filler. Fixed costs, in general, are more difficult to allocate. Fixed costs are usually spread over numerous containers and, in addition, the equipment or facility is used for multiple years.

The first step in allocating fixed costs is to calculate an annualized value for capital items such as buildings and equipment. These items are amortized based on their original cost, expected life, salvage value, and an interest rate. Based on prevailing economic conditions at the time of this study, an interest rate of 10%, set at the prime interest rate plus 1%, was used. The life-cycles of particular pieces of equipment were estimated by the dairy engineering firm. Annual maintenance and upkeep charges are added to the annualized cost of durable equipment. To examine the sensitivity of processing costs due to varying interest rates, the cost model was analyzed with several different interest rates.

## Plant Operation Specifications

The model plants are designed to have the capacity to process and package 335,000, 400,000 and 600,000 gallons of white milk weekly. These volumes were specified by the MMC in order to determine the cost effectiveness of increased plant volume. In addition to white milk, the plant also packages by-products: chocolate milk and buttermilk, fruit drinks and orange juice, and creams and nogs. In accordance with current Maine production patterns, by-products increase the plant's output volume by 14.6%. A variety of container sizes and types are packaged in volumes that approximate current Maine dairy operating procedures (see Table 1). Blow-molding bottle production technology was simulated for two of the plant sizes: the 400,000-gallons/wk and 600,000-gallons/wk models. Overall, the combination of volume and blow-molding technology permits comparison of four models in this paper: model 1: 335,000 gallons/wk without blow-molding technology; model 2: 400,000 gallons/wk without blow-molding technology; model 3: 400,000 gallons/wk with blow-molding technology; and model 4: 600,000 gallons/wk with blow-molding technology.

## Plant Construction

An industrial engineering firm specialized in the design of milk processing plants designed the model facilities and estimated construction costs. All model facilities have three buildings: the processing plant, the corporate office, and the truck service. A breakdown of the area allocated to each cost center of the models is presented in Table 2. Average cost per square foot was estimated and adjusted for geographical location using the *Means Building Construction Cost Data 2000* (Mahoney, 2000). Besides actual construction cost, additional construction costs include project support costs, such as design, travel for construction employees, and an on-site trailer for

Table 1. Production capacity per week, white milk and by-products by model in gallons.

| | Model 1 | | | Models 2 & 3 | | | Model 4 | | |
|---|---|---|---|---|---|---|---|---|---|
| Container type | White | By-product | Total | White | By-product | Total | White | By-product | Total |
| Plastic gallon | 211,050 | 25,326 | 236,376 | 208,000 | 20,800 | 228,800 | 312,000 | 31,200 | 343,200 |
| Plastic ½-gallon | 83,750 | 15,075 | 98,825 | 80,000 | 9600 | 89,600 | 120,000 | 14,400 | 134,400 |
| Plastic quart | 10,050 | 1307 | 11,357 | 12,000 | 1560 | 13,560 | 18,000 | 2340 | 20,340 |
| Paper ½-pint | 16,750 | 3852 | 20,602 | 28,000 | 6440 | 34,440 | 42,000 | 9660 | 51,660 |
| Bulk 5 gallon | 6700 | 200 | 6900 | 12,000 | 360 | 12,360 | 18,000 | 540 | 18,540 |
| Plastic pint | 6700 | 2077 | 8777 | 12,000 | 2520 | 14,520 | 18,000 | 3780 | 21,780 |
| Paper ½-gallon | | | | 25,000 | 1125 | 26,125 | 37,500 | 1688 | 39,188 |
| Paper quart | | | | 13,000 | 455 | 13,455 | 19,500 | 682 | 20,182 |
| Paper pint | | | | 10,000 | 1000 | 11,000 | 15,000 | 1500 | 16,500 |
| Total | 335,000 | 47,837 | 382,837 | 400,000 | 43,860 | 443,860 | 600,000 | 65,790 | 665,790 |

project staff during the 18-mo construction period. These charges account for approximately 6% of total construction costs. The costs of equipment piping and installation and other items unique to an area of the facility are explicitly included in the analysis. Table 3 shows the total cost of the facilities, broken down by construction and equipment cost. These costs do not include the cost of land and construction capital.

Eight acres of land would be required to support the facility. It is estimated that approximately 28% of the acreage is allocated to the plant building; 70% is occupied by the truck service building, distribution vehicle parking areas and supporting grounds; and the final 2% is allotted for the corporate office building. Land investment costs are assigned to the three facility structures based on these assigned portions of total acreage.

Construction of the entire facility would be expected to take 18 mo. During this time, costs would be incurred without revenue from sales. The cost of construction capital represents interest paid on money lent for purchase of the land and equipment and the construction of the building. Between $24.5 million (for the smallest plant) and $33.6 million (for the largest) would be required to complete the project. At the suggestion of the dairy engineering firm retained for the analysis, it was assumed that the money would be spent equally over the 18-mo period. Using the assumed interest rate (10%), the cost of construction capital was derived and allocated over the assumed 33-yr life of the facility.

## Facility Equipment

The facility has been equipped to support the production, distribution, and marketing of the packaged products based on the plant volume specifications. Milk processing equipment capacities were based on packaging requirements and on an average daily run-time of 12 hr. Equipment was selected to meet daily and seasonal peak processing volume fluctuations.

Certain pieces of equipment in the production process, such as fillers, product tanks, pasteurizers, and so on, that are linked together or cleaned in place, have the added cost of piping. The engineers arrived at an average piping cost per unit of equipment by examining piping costs, control costs, and dedicated installation for similar projects. The average cost of piping was composed of 49% hardware cost, 30% controllers, and 21% labor for installation. Total equipment costs ranged from $12.5 million for the smallest plant to $16.4 for the largest plant. In-plant bottle molding technology increases equipment costs by approximately $2.5 million.

## Labor

Labor for the facility includes all employees required to operate and maintain the processing plant and also

Table 2. Plant facility areas (square feet).

| General area | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Receive & process | 13,530 | 13,747 | 13,687 | 15,337 |
| Blow molding or bottle room | 6980 | 6980 | 8835 | 9881 |
| Dry storage | 9578 | 9866 | 9866 | 12,542 |
| Case—Store and clean | 7227 | 8103 | 8103 | 11,135 |
| Filling and packing | 6912 | 8256 | 8257 | 9000 |
| Cooler | 25,676 | 27,237 | 27,237 | 33,480 |
| Corporate office | 8500 | 8500 | 8500 | 8500 |
| Truck service | 9300 | 9300 | 9300 | 9300 |
| Miscellaneous and overhead | 17,697 | 17,811 | 17,950 | 21,060 |
| Total | 105,400 | 109,800 | 111,735 | 130,235 |

**Table 3.** Construction and equipment costs by model (2000 $).

| Construction and equipment costs | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Construction costs | $12,013,550 | $12,611,338 | $12,802,535 | $14,358,394 |
| Equipment costs | $12,535,952 | $13,700,068 | $16,165,438 | $18,896,810 |
| Total construction and equipment | $24,549,502 | $26,311,406 | $28,967,973 | $33,255,204 |
| Construction costs per square foot | $113.98 | $114.86 | $114.58 | $110.25 |

includes management, sales, and clerical staff. Plant labor requirements are based on a 5-d, two-shift schedule for the process employees and a 7-d, single-shift schedule, for milk receiving. Employees in the corporate office work a 5-d, single-shift schedule. All employees are assumed to work a regular 40-hr wk. Given these assumptions, it is estimated the smallest facility would employ 85 people, the medium size plants 101.5, and the largest facility 134 (Table 4). No additional employees are required for blow molding in the medium-sized plant, but job responsibilities are reallocated from bottle handling to molding.

Total labor costs include wages, vacation and sick time, taxes, and benefits. Employee benefits include full coverage health insurance for the worker and one dependent. Workers' compensation insurance, FICA tax, and unemployment compensation tax are calculated and applied appropriately. Health insurance costs were estimated from a survey of Maine dairies at $105/wk per worker.

### Utilities

Charges exist for kWh usage, peak kW demand, and reactive demand (based on kVars). To calculate electricity costs, the electrical usage rate structures were obtained from local service providers. Time of day and season also influence this rate. Electrical usage estimates from the dairy engineers provided details of approximate kWh usage for container-specific facility machinery, as well as general plant usage. In particular, this includes the plastic blow molders and the product fillers. Remaining electricity usage is based on facility structure and purpose; for example, distinctions are made between the cooler versus corporate office.

Fuel oil would be used to heat the buildings and to heat water for processing and sanitation. Fuel oil utilization ranges from 2412 gallons/wk to 4335 gallons/wk based upon model size.

In addition to fuel and electricity, the plants consume large quantities of water for product processing and equipment cleansing. It is estimated by the engineers that 323,400 gallons of water would be consumed weekly by the 335,000-gallon plant, 386,400 gallons of water by the 400,000-gallon plant, and 558,200 by the 600,000-gallon plant.

The basic sewer rate would be governed by water consumption. In addition to this rate, a surcharge for pounds of biological oxygen demand would also be assessed ($163/1,000 lbs). To minimize this cost, returns and dated products would not be disposed of in the sewer. Instead, this milk would be dumped into a dedicated tank truck and transported to a swine farmer. Some milk, however, still enters the sewer through product loss (equipment wash, spillage, etc.), and thus a biological oxygen demand charge is levied.

### Supplies

A large portion of supply costs result from the purchase of product packages. Paper container prices vary ac-

**Table 4.** Number of employees allocated to dairy cost centers.

| | Model | | |
|---|---|---|---|
| | 1 | 2 & 3 | 4 |
| Cooler | 17 | 18.5 | 26.5 |
| Cases and returns | 4.5 | 5 | 9 |
| Blow mold and/or bottle handling | 4 | 6 | 12 |
| Milk receiving | 1.5 | 1.5 | 3.5 |
| Laboratory | 3 | 3 | 4 |
| Processing | 3 | 3 | 3 |
| Filling and packing | 9 | 10 | 14.5 |
| Dry storage | 2 | 2 | 3 |
| Maintenance | 6 | 6.5 | 8 |
| Sanitation | 4.5 | 4.5 | 5.5 |
| Corporate office | 31.5 | 31.5 | 31.5 |
| Miscellaneous | 10 | 10 | 13.5 |
| Total | 96 | 101.5 | 134 |

Table 5. Total annual processing costs for the facilities by cost center (2000 $).

| | Model 1 | Model 2 | Model 3 | Model 4 | Average percentage of total cost |
|---|---|---|---|---|---|
| Land and building | $1,741,060 | $1,825,816 | $1,920,522 | $2,217,726 | 12.2 |
| Labor | $4,505,812 | $4,714,420 | $4,714,420 | $5,924,802 | 31.4 |
| Equipment | $2,165,051 | $2,389,392 | $3,101,635 | $3,629,538 | 17.7 |
| Supplies | $4,010,108 | $4,924,142 | $4,135,125 | $6,159,610 | 30.2 |
| Electricity | $471,902 | $539,368 | $824,291 | $1,089,173 | 4.5 |
| Fuel oil | $145,693 | $174,565 | $174,565 | $261,848 | 1.2 |
| Water and sewer | $139,351 | $157,314 | $157,314 | $206,300 | 1.0 |
| Product loss | $142,842 | $177,466 | $177,466 | $266,198 | 1.2 |
| Operating capital | $84,033 | $95,061 | $94,164 | $127,596 | 0.6 |
| Total | $13,405,850 | $14,997,545 | $15,299,502 | $19,882,791 | |

cording to the volume purchased and the number of colors with which they are printed. Effective use of the plant's dry storage area allowed for higher volume purchases and thus, a lower cost per container.

Premolded containers are purchased in tractor-trailer-sized quantities and remain on the trailers until needed. An estimated price for the container includes caps, product labels, and shipping costs. Five-gallon bulk containers ("Bag and Case") are also purchased in the same manner. A 2% damage rate is assigned to each milk container to account for container damage.

The cost effectiveness of in-plant blow molding is an important question regarding least-cost production. In two of the models, the plastic gallon and half-gallon containers are produced with the in-plant blow molding equipment. The variable supply costs for these containers include plastic resin pellets, caps, and product labels.

Milk cases are durable items but are treated as supplies due to their high replacement rate. Based on the average for Maine dairies, 25% are replaced annually. A few remaining supply costs are also accounted for, such as cleaning and maintenance supply costs, and corporate office supply costs for paper, forms, mailings, and so on.

### Taxes and Insurance

The re-occurring costs of property tax and fire and liability insurance are also included. Property tax is based on total property value (the worth of land, buildings, and equipment). A cost for fire and liability insurance was established based on MMC records of three Maine milk plants and adjusted for differential plant size.

## RESULTS

Table 5 presents the annual cost to operate the four plants broken down into cost components. On average, labor and supplies are the largest cost categories and when combined, these two cost categories constitute nearly two-thirds of the cost of milk processing. Labor costs are the largest component of total cost and constitute 31.4% of the annual operating cost of the facilities on average across the models. Supply costs, the second most important category (at 30.2% of total cost, on average), are largely composed of packaging costs (containers, resin, labels, caps), with the remainder accruing to office and cleaning supplies. The third major cost component is facility equipment (at 17.7% of total cost). Land and building charges are the fourth most important cost components of the models. This cost component is primarily composed of the annualized cost of land, buildings and construction charges, plus recurrent costs such as insurance and taxes. Combined, fuel, electricity, water and sewer, product loss, and operating capital are less than 9% of annual expenses.

Several trends in the cost of processing emerge as plant size increases. Labor plus land and building costs, as a percentage of total production cost, declines. On the other hand, equipment, supplies, and electricity costs increase, as a percentage of total production cost, with plant size. A portion of this shift is also due to the inclusion of blow molding. In general, this points to a cost shift toward a system of more mechanically intensive production processes tied to long-term fixed capital, and a reduction away from labor, as size and scope (when blow molding is included) increases. In response to the demand of blow molding, electricity costs increase as a percentage of total cost. The percentage of total cost attributable to the remaining cost centers remains constant across models.

Production costs in Table 6 are allocated to the different products using direct and indirect mechanisms. Direct allocation occurs based upon product run-time. Indirect allocations are related to the number of containers produced, the fluid quantity of production, or the number of cases shipped of a specific container. Combining the total cost with the product volume in Table 1, the per-container costs across the different models is presented

**Table 6.** Comparative processing costs per container across models (2000 $).

| Container type | Model 1 | Model 2 | Model 3 | Model 4 | Cost difference of model 4 over model 3 |
|---|---|---|---|---|---|
| Plastic gallon | $0.518 | $0.465 | $0.465 | $0.402 | −13.5% |
| Plastic ½-gallon | $0.322 | $0.283 | $0.314 | $0.274 | −12.7% |
| Plastic quart | $0.257 | $0.228 | $0.234 | $0.212 | −9.4% |
| Paper ½-pint | $0.079 | $0.062 | $0.061 | $0.055 | −9.8% |
| Bulk 5-gallon | $3.573 | $2.414 | $2.398 | $2.100 | −12.4% |
| Plastic pint | $0.266 | $0.231 | $0.238 | $0.222 | −6.8% |
| Paper ½-gallon | | $0.262 | $0.259 | $0.229 | −11.6% |
| Paper quart | | $0.154 | $0.153 | $0.134 | −12.4% |
| Paper pint | | $0.099 | $0.099 | $0.087 | −12.1% |

in Table 6. The total cost of producing any specific container decreases as plant size increases, indicating more efficient distribution of fixed production costs and a wider distribution of overhead charges. Two important cost comparisons can be made from this analysis.

## Blow-Molding Technology

A comparison between model 2 and model 3 in Table 6 reveals that the blow molding of gallon and half-gallon containers does not reduce production costs but increases the total cost of production by $272,043 annually. For gallon containers, the processing costs are equal under the blow-molding and the no-blow-molding (purchased container) scenarios. However, due to a smaller volume of plastic half-gallon containers, processing costs are higher with blow molding than without. More than 208,000 gallon containers per week must be produced by the firm to cover the increased equipment and electricity costs associated with blow-molding. Under-utilization of blow-molding capacity is the primary source of financial inefficiency. In addition, supply costs decrease with the addition of blow molding, as much of the total cost of purchased bottles is shifted into the labor, equipment, and electricity categories of molded containers.

## Size Economies and Distribution Costs

A second comparison is related to plant size and is evident in the comparison between models 3 and 4 in Table 6. Model 4 represents a 50% increase in processed milk volume over model 3. The cost of a container of processed milk is reduced on average by 11.2% through processing the higher volume of milk (column 6, Table 6). This is an indication of the potential cost savings that could be passed on to consumers.

The margin established by the MMC is only partly composed of the cost of production. The second component of the wholesale margin consists of the cost of distributing milk to retail vendors. This cost component is calculated by modeling characteristic distribution patterns of Maine dairies to metropolitan and nonmetropolitan areas. The demographic geography of Maine indicates that the majority of the population is located in the southern and central areas of the state, with more isolated smaller population centers in the northern and eastern regions of the state. Because the northern core is approximately 250 miles from the model-processing facility, additional distribution costs are required to serve this region.

Approximately one-third of processed white milk is assumed to be distributed to the remote parts of the state. In order to serve these remote areas, a dairy would be required to establish at least one intermediate handling depot into which bulk shipment of processed milk would arrive and out of which smaller loads of mixed products would be distributed to retailers. This depot site requires a limited amount of infrastructure, management, and delivery labor, plus a fleet of retail delivery vehicles. Transportation of the product from the dairy to the depot would dramatically increase delivery costs as well. On the average, the weighted distribution cost for each container of milk increases by over 50% when a single large plant, with lower production cost, distributes milk through this method (Table 7). Overall, increased distribution costs erase any production cost savings resulting from the processing economies of size and, in fact, increase the wholesale cost. Thus, geography and the heterogeneous distribution of Maine's population limit any potential cost savings arising from increased processing volume at any one plant. The net impact of increased distribution costs is calculated in the final column of Table 7.

## Cost Evolution from 1993 to 2000

In comparison with previous studies on milk processing costs (Criner and Jacobs, 1991; Criner et al., 1995), total processing costs have increased at an annual rate of 2.4%/yr above the rate of inflation over the last 7 yr (Table 8). Several cost-center increases merit discussion, including equipment, land and building, labor, fuel oil, and operating capital.

**Table 7.** Comparative distribution costs per container across models (2000 $).

| Container type | Model 1 | Model 2 | Model 3 | Model 4 | Cost difference of model 4 over model 3 |
|---|---|---|---|---|---|
| Plastic gallon | $0.147 | $0.144 | $0.144 | $0.226 | 56.9% |
| Plastic ½-gallon | $0.065 | $0.064 | $0.064 | $0.100 | 56.2% |
| Plastic quart | $0.037 | $0.035 | $0.036 | $0.056 | 55.6% |
| Paper ½-pint | $0.008 | $0.011 | $0.012 | $0.018 | 50.0% |
| Bulk 5-gallon | $0.586 | $0.574 | $0.573 | $0.900 | 57.1% |
| Plastic pint | $0.075 | $0.049 | $0.049 | $0.071 | 45.5% |
| Paper ½-gallon | | $0.064 | $0.064 | $0.100 | 56.2% |
| Paper quart | | $0.036 | $0.036 | $0.057 | 58.3% |
| Paper pint | | $0.021 | $0.020 | $0.033 | 65.0% |

Equipment costs have more than doubled since the 1993 model, reflecting technological innovation in dairy processing and higher interest rates. Technological innovation has taken place in two primary areas. The first area is in improved efficiency in the speed of fillers and container handling. This area of industrial engineering is one that receives continued attention, and improvements are largely confined to the filling room. The second area of innovation has occurred on a plant-wide scale. The current facility is highly automated through a centralized computer monitoring system. This system monitors the entire processing chain, from receipt of milk through processing, cold storage and into the bundling delivery packages. The computerization of the production system not only requires centralized processors, it also requires controllers, cabling, and specialized software.

Moreover, installation of these systems is an additional cost element captured in the land and building component. Land and building charges have increased by 3.8% above the rate of inflation over the 7-yr period, despite the fact that land prices have declined by nearly 33%. These two costs are not analyzed separately, but controlling for the decrease in land prices would only reinforce the impact of increased construction costs required to accommodate the change in processing technology and improvements in refrigeration and storage.

While increases in dairy equipment prices are specific to the dairy industry, other leading changes in cost categories are related to economy-wide price trends. While still a small component of total cost, operating capital has increased largely, reflecting an increase in the short-term lending interest rate. Fuel oil costs have increased by 4.6%/yr reflecting economy-wide trends in energy prices. Labor costs have increased for two reasons. First, health insurance and benefits have driven up total employment costs across all labor categories. This has been the most important source of appreciation in this cost category. Secondly, but to a lesser extent, plants have hired more workers with high levels of technical experience in order to manage and maintain plant automation. In 1993, labor costs were slightly more than 28% of total cost in comparison with 31.2% in the current model.

## CONCLUSIONS

This study reports the findings of an economic-engineering model used to determine the theoretically lowest achievable processing and distribution cost of white milk in the state of Maine. Maine is one of the few states in the nation that regulates wholesale milk pricing. Through this model, insights into least-cost dairy-processing practices are derived for an industry that is otherwise closed to research due to vibrant competition, confidentiality, and protection of processing techniques among competitors.

**Table 8.** Percentage change in costs for each cost category from 1993 to 2000 (2000 $).

| | 1993 | 2000 | Total change % | Annual rate % |
|---|---|---|---|---|
| Operating capital | $34,297 | $94,164 | 175% | 15.5% |
| Land and building | $1,475,906 | $1,920,522 | 30% | 3.8% |
| Product loss | $172,943 | $177,466 | 3% | 0.4% |
| Equipment | $1,505,063 | $3,101,635 | 106% | 10.9% |
| Fuel oil | $127,755 | $174,565 | 37% | 4.6% |
| Supplies | $5,121,108 | $4,135,125 | −19% | −3.0% |
| Water and sewer | $160,949 | $157,314 | −2% | −0.3% |
| Labor | $3,666,298 | $4,714,420 | 29% | 3.7% |
| Electricity | $736,196 | $824,291 | 12% | 1.6% |
| Total | $13,002,507 | $15,299,502 | 18% | 2.4% |

This model has indicated an important shift in processing costs. Labor costs now exceed the cost of packaging and plant supplies. Labor costs have increased due to economy-wide wage inflation, plus dramatic increases in health care premiums paid by employers. Labor costs also have increased due to the addition of highly educated plant employees with skills in computer-driven plant automation and information technologies. Secondly, processing technology continues to evolve, and more sophisticated technology is more expensive to implement. Equipment costs have increased as a percentage of total costs and may indicate a wider trend in industry practices to reduce human handling and labor costs.

Consistent with these trends are clear economies of size in production facilities. In order for firms to reduce per-unit production costs, a higher volume of products must be processed by the dairies in order to distribute fixed-production investment over more products. Under the state regulatory framework motivating this research, it has been determined that cost savings, due to economies of size, are not fully realizable. The wholesale margin is composed partly of milk processing costs and partly of distribution costs. Due to the geographic distribution of consumption throughout the state, and the cost of distributing milk from one large, low-cost processing facility, the delivered wholesale price of milk increases to Maine consumers. Additional distribution costs linked to transportation from the dairy to small-scale distribution depots erases *cost savings due to economies of size*. On a region-wide basis, cost savings could be realized by larger firms exporting milk outside of the state. Increased export of milk to the greater Northeast region could also justify investment in larger plant capacity and ones that include on-site blow molding of gallon and half-gallon containers.

Comparisons of models over time have yielded important insight into the evolution of the industry. In 1966, 74 dairies existed in the state of Maine. Four exist today. The models presented in this article indicate that economic efficiency in milk processing is increased by processing higher volumes of milk, but that this efficiency requires enormous investment in processing technology and facilities. In comparison with previous models, labor costs are increasing in absolute terms and are relative to the total cost of production, due to higher wage costs and the requirement of specialized workers with technical skills. This comparison shows that had a 400,000-gallon/wk plant been modernized from 1993 to 2000, it would have had to increase volume of milk processed to 600,000-gallons/wk in order to gain the economies of size sufficient to offset technology and industry cost increases. Dairies that are unable to respond to increased labor costs through capital investment and expansion will likely find it more difficult to remain competitive in the milk-processing industry.

The findings demonstrate that milk-processing costs can be accurately captured through a detailed breakdown of the technical and economic factors used in dairy processing. The modeling approach is also useful in characterizing the current state of dairy processing technology, highlighting past trends, and describing future directions in dairy-processing cost management.

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