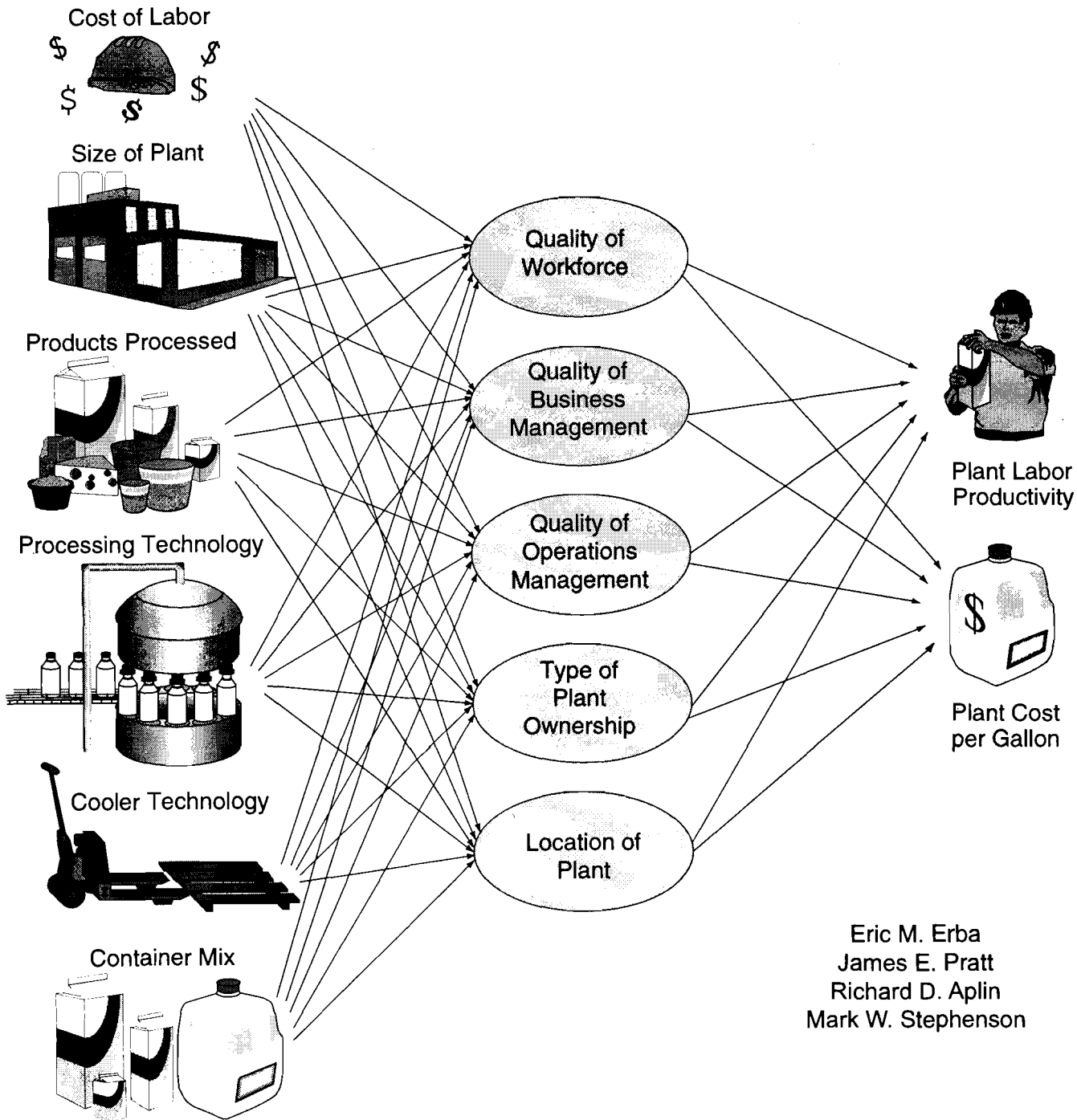


Comparisons of Costs and Efficiencies Between Cooperative, Proprietary, and Captive Fluid Milk Processors: A Neural Network Approach



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HIGHLIGHTS

Labor Productivity and Costs in 35 Fluid Milk Plants

This report focuses on labor productivity and costs in 35 fluid milk plants in 15 states. We targeted medium and large plants that are well-managed and have a significant market presence. The 35 operations are highly respected in the industry and are thought to be among the best fluid milk plants in the country. Of the 35 plants in the study, 8 are owned and operated by supermarket companies (i.e., captive plants), 5 are owned and operated by farmer-owned milk marketing cooperatives, and the remaining 22 are independently owned and operated. Participating plants submitted data from a recent 12-month period. Most plants submitted data from 1993 or 1994 calendar years.

Key Characteristics of Survey Plants

The following table allows for comparisons of key characteristics among all plants in the study. The figures in the column labeled "High 3 Average" ("Low 3 Average") represent the average values of the three highest (three lowest) plants calculated for each characteristic. High and low averages for each characteristic were computed independently. For example, the plants that comprise the "High 3 Average" for the number of pounds of fluid products processed are not necessarily the same three plants that comprise the "High 3 Average" for SKUs processed, labor cost per hour, or any other category.

<u>Plant Characteristic</u>	<u>Average of 35 Plants</u>	<u>Low 3 Average</u>	<u>High 3 Average</u>	<u>Details On Page No.</u>
All fluid products, million lbs. per month	27.8	13.3	51.4	5
SKUs processed ¹	148	26	367	6
SKUs in cooler	250	40	539	7
Number of labels	11	2	34	7
Labor cost, including benefits, \$ per hour	20.19	13.12	27.92	12
Electricity, ¢ per kwh	6.7	2.2	13.2	13
Natural gas, ¢ per therm	42.6	18.1	66.0	13
Level of processing & filling technology (1 to 10; 10 = highest)	7.4	4	9	7
Level of cooler & load out technology (1 to 10; 10 = highest)	5.9	1	10	7

¹SKUs are stock keeping units, and each SKU denotes a different product. For example, skim, 2% milkfat, and whole milk packaged in half-gallon paperboard and gallon plastic jugs under 4 different labels constitute 3x2x4 = 24 SKUs.

Labor Productivity and Costs

This report contains detailed reporting of the following measures of performance on a per gallon basis:

- plant labor productivity
- plant labor costs
- utility costs
- total plant costs excluding depreciation
- total plant costs including depreciation

We offer the following reminders and caveats:

- The productivity and unit costs were calculated on a gallon equivalent basis which included ALL beverage products processed and packaged in the plant. Items other than fluid milk products included creamers, juices, drinks, bottled water, and ice cream mixes.
- Labor hours and labor costs reflect direct labor from the raw milk receiving bays through the cooler and load out area. Labor from the following areas was also included: maintenance, plant quality control, plant office support, and plant management. The blow mold area was excluded from plant cost and productivity measures.
- Labor hours and labor costs did NOT include any labor dedicated to production of soft products (e. g., cottage cheese, sour cream, and yogurt). Raw milk procurement, distribution, selling, and general and administrative expenses were also excluded.
- The plant with the highest labor productivity or the lowest cost per gallon is not necessarily the most profitable. Many factors affect profitability, and we have not attempted to analyze profitability in this report.

The following table enables comparisons of labor productivity and plant costs for all plants in the study.

<u>Plant Characteristic</u>	<u>Average of 35 Plants</u>	<u>Low 3 Average</u>	<u>High 3 Average</u>	<u>Details On Page No.</u>
Labor productivity, gallons/hr	174	107	286	11
Labor cost, ¢/gallon	12.3	7.7	17.1	13
Cost of utilities, ¢/gallon	2.6	1.7	4.2	14
Plant cost (depreciation excluded), ¢/gallon	18.2	11.5	24.0	15
Plant cost (depreciation included), ¢/gallon	21.2	13.1	27.3	15

Comparisons of Plant Descriptors and Plant Performances by Type of Ownership

When grouped by type of ownership, (i.e., plant is owned by vertically integrated supermarket company, milk marketing cooperative, or independently owned and operated), we found that there were significant differences among the three groups. The following table allows for comparisons of means of basic plant descriptors, such as plant size, cost of labor, and number of products processed by the plant.

<u>Averages by Plant Ownership Type</u>				
<u>Descriptor</u>	<u>Captive</u>	<u>Proprietary</u>	<u>Cooperative</u>	<u>Details On Page No.</u>
Volume, 10 ⁶ gallons/month	3.55	3.36	2.28	16
Plant capacity utilized, %	77	76	77	16
Labels processed	3	13	18	16
SKUs processed	48	178	160	16
SKUs in cooler	70	299	332	16
Labor cost, \$/hr	22.42	19.83	19.05	16
Electricity, ¢/kwh	7.2	6.4	7.4	16
Natural gas, ¢/therm	47.2	45.4	32.4	16

We also found that plants owned by supermarket companies were more productive and lower cost than either proprietary plants or cooperative plants. Although cooperative plants and proprietary plants typically operate as full-line plants, proprietary plants were slightly more productive and lower cost than cooperative plants. The following table allows for comparisons of means of cost and labor productivity measures grouped by type of plant ownership.

<u>Averages by Plant Ownership Type</u>				
<u>Descriptor</u>	<u>Captive</u>	<u>Proprietary</u>	<u>Cooperative</u>	<u>Details On Page No.</u>
Labor productivity, gallons/hr	261	153	128	20
Cost of utilities, ¢/gallon	2.7	2.7	3.1	20
Cost of labor, ¢/gallon	8.6	13.1	15.1	20
Variable costs, ¢/gallon	13.8	18.9	22.2	21
Total plant costs, ¢/gallon	17.1	22.3	24.1	21

A Neural Network Approach to Determining the Effects of Various Factors on Labor Productivity and Cost per Gallon

Neural network methods encompass a broad class of flexible nonlinear regression and discriminant models, data reduction models, and nonlinear dynamical systems. Neural networks "learn" from examples and can exhibit some capability for generalization beyond the training data. The "learning" in this context is analogous to "estimation" in more traditional statistical analysis. Similarly, "training" data is analogous to "observed" data. Neural networks are useful for classification and function approximation problems which are tolerant of some imprecision, but to which strict rules cannot be easily applied. For example, neural networks are well-suited for pattern recognition, trend prediction, and image analysis. We used a neural network model to predict the effect of different factors on plant labor productivity and cost per gallon and to determine if factor effects differed by type of plant ownership. Our analysis revealed that:

- Plant size, as measured by actual monthly volume processed, was predicted to increase labor productivity and decrease cost per gallon for the three types of plant ownership.
- Higher labor cost per hour was expected to increase labor productivity for the three types of plant ownership but with an associated increase in cost per gallon.
- Regardless of type of ownership, plants were predicted to be more productive and lower cost without unionized labor.
- Increases in percent of products packaged in gallon and half-gallon containers and percent of plant capacity utilized were predicted to increase labor productivity and decrease cost per gallon.
- Plants with more advanced equipment in the processing and filling area had slightly higher labor productivity with little impact on costs per gallon. Plants with more advanced equipment in the cooler and load out area had significantly higher labor productivity and slightly lower costs per gallon.
- More intensive use of pallets was predicted to increase labor productivity and decrease cost per gallon, but a large increase in the percent of volume handled on pallets was necessary to produce these effects.
- Processing more stock keeping units was predicted to decrease labor productivity and increase plant cost per gallon, but a large increase in the number of products processed was necessary to produce these effects.
- Without exception, changes in the various inputs impacted labor productivity in cooperative plants considerably less than what was predicted for captive or proprietary plants.
- Labor productivity and cost per gallon in cooperative plants were predicted to respond well to increases in plant capacity utilization, decreases in the number of products processed, increases in the volume of product handled on pallets, and improvements in cooler technology.

INTRODUCTION

Objectives

This report details the findings of a survey of 35 fluid milk plants believed to be among the best operations in the United States. The objectives of the study were to determine the costs of processing and distributing fluid milk products and to identify and to quantify the factors which contribute to differences in labor productivity and costs among plants under different ownership categories.

Research Justification

The fluid milk industry is the largest single-product sector of the U.S. dairy industry, representing about 37% of the usage of U.S. milk production. Approximately 500 companies and 645 plants produce fluid milk products which have an annual wholesale value of about \$23 billion. As is generally true in the dairy industry, the number of products processed and handled by fluid milk plants shows tremendous variability.

The main (perceived) role of milk marketing cooperatives has been to balance milk supply, but changing market conditions have resulted in cooperative ownership of fluid processing facilities. In 1992, 29 cooperatives owned fluid milk plants, and about one-third of the cooperatively owned fluid milk plants accounted for about 90% of total fluid milk volume processed by cooperative plants (15). Thus, although most butter/powder plants are owned and operated by cooperatives, a small number of fluid milk operations are also owned and operated by cooperatives. Since 1980, the volume of packaged fluid milk products distributed by cooperatives relative to all fluid milk processors has held constant at about 16% (15).

Uncertain impacts of the Dairy Title of the 1995 farm bill leaves cooperatives concerned about the future. Cooperative ownership of fluid milk plants may become increasingly important as the dairy industry moves toward less governmental intervention and regulation. It is necessary to understand the differences in productivity and cost of processing between ownership types – cooperative, proprietary, and vertically integrated supermarket plants – if cooperatives are to be successful owner/operators of fluid milk plants.

Outline of Report

The report is divided into three major sections, each with subsections detailing specific topics. The first section addresses general characteristics of the plants studied, including the reported volume of milk and other beverage milk products processed, percent plant capacity utilization, number of labels and stock keeping units (SKUs) processed, plant and cooler evaluations, filling equipment, and product handling.¹ Plant labor productivity, labor costs, cost of utilities, and processing costs are also reviewed. The second section reviews differences among the 35 plants based on type of plant ownership. The third section uses a neural network model to quantify the effects of various factors on labor productivity and cost per gallon.

¹ Stock keeping unit (SKU) was defined as a specific product with a specific label in a specific package size.

Background Information On Fluid Milk Plants

In 1857, Louis Pasteur, a French chemist and bacteriologist, discovered that heating milk postponed milk spoilage. Not coincidentally, commercialized firms that processed and marketed fluid milk products began to emerge soon after Pasteur's findings. Before the times of commercialized fluid milk processing and packaging, dairy farmers prepared and distributed milk. As they became more involved in milk production, these tasks became the responsibility of organizations specializing in milk processing and marketing (10).

In the mid to late 1800s, fluid milk processing and packaging was a relatively new industry, and improved techniques or mechanical innovations were rare. The introduction of returnable glass quart milk bottles marked the beginning of several technologies introduced to increase the efficiency and safety of fluid milk processing. In 1886, automatic filling and capping equipment was developed for milk bottlers, and in 1911, automatic rotary bottle filling and capping equipment was perfected for large scale use which further increased the speed and efficiency of bottling plants (22). Between 1930 and 1950, high temperature-short time (HTST) continuous flow pasteurization replaced vat pasteurization as the primary method of preparing fluid milk for bottling. As bottling plants soon discovered, automation of fluid milk processing and filling equipment led to substantial increases in labor productivity and plant efficiency. The relatively recent developments of plastic-coated paper containers, plastic jug containers, clean-in-place (CIP) systems, case stackers, conveyors, and palletizers contributed further to efficiency gains of fluid bottlers.

Although fluid milk processing plants may differ in size and in form, the functional aspects are relatively consistent. As with any manufacturing plant, raw materials are transformed into finished products through process applications as the products "flow" through the plant. The raw material in this case is milk which arrives at the plants via bulk milk trucks or tractor-trailers. In the receiving bays of the plant, the milk is pumped from the bulk transport tanks and passes through a plate cooler which reduces the temperature of the milk to 35° F before it reaches the raw milk storage tanks or silos. From the silos, HTST processing, which passes milk through a heat exchange plate, pasteurizes the milk. The process heats the milk to temperatures of 163° F to 170° F for 15 to 18 seconds, killing most of the microorganisms the milk may contain. After pasteurization, a separator removes the milkfat component from the skim portion of the milk. Excess cream may be stored for future processing, but it is often sold in bulk to ice cream or butter manufacturing plants. In-line standardization allows the removed cream to be added back to the skim portion as the milk continues to flow from the pasteurization area to the homogenizer. A homogenizer contains a series of high-speed pistons that break down milkfat particles; this process prevents cream from separating from the skim portion of milk. After homogenization, milk flows to pasteurized storage tanks. From these tanks, milk is either pumped or gravity-fed to filling equipment where it is packaged in plastic-coated paper containers, plastic jug containers, or polybags. Packaged milk is placed (usually automatically) into plastic, wire, or cardboard cases for further handling. The traditional milk case has been a 16-quart plastic case, but the introduction of disposable, nonreturnable corrugated cardboard cases has allowed for growth of one-way shipments of milk. After the packaged milk has been placed in cases, the product must move immediately into a cooler to prevent rapid spoilage. Most plants use equipment to automatically form stacks of 5 to 7 cases. The stacked cases travel on a track conveyor which transports the product to the cooler where it is stored temporarily until it is loaded on a delivery vehicle for distribution to retail outlets.

In an attempt to use the facility as efficiently as possible, most fluid milk plants process other products which might include juices; flavored drinks; light, medium, and heavy creams; half and half; buttermilk; ice cream mixes; and bottled water. Generally, these items use the same plant equipment as fluid milk products. Some plants may also have soft dairy product processing capabilities and produce cottage cheese, yogurt, sour cream, and ice cream in addition to the beverage products.

Previous Studies of Fluid Milk Plants

Results from fluid milk processing and distribution cost studies have a variety of uses. Fluid milk plant management and executive personnel may apply the results to their own operations to gauge or bench mark the performance of their operations against other similar milk plants. Such studies may also reveal which aspects of fluid milk operations offer the most benefit from internal restructuring or capital investments. The results may also be useful for regulatory purposes, especially for states that regulate milk prices at the wholesale or retail level. At the academic level, cost of processing and distribution studies have been an invaluable component for modeling the dairy industry and projecting structural changes in milk markets.

In the past 35 years, the cost of processing fluid milk has been analyzed several times. Studies by Blanchard et. al. (5) and Bond (6) partitioned plants into separate cost centers and used cost data to analyze differences in efficiencies among participating plants. Other research has investigated processor sales, costs of goods sold, operating costs, and gross and net margins for moderate-sized fluid milk plants (1, 13, 14, 18). Because of difficulties encountered in recruiting participants for processing cost studies or lack of an adequate number of representative plants, economic engineering studies have served as an alternative method of estimating minimum achievable processing costs per gallon and investigating the consequences of various plant volume capacities on per unit processing costs (8, 11, 12, 17, 20).

Studies that attempt to identify the factors that affect plant productivity and the cost of processing are less common. Thraen et. al. (21) estimated a functional relationship between total plant cost and plant volume based on data from 15 cooperatively owned and operated fluid milk plants, suggesting that per unit costs decrease with increases in plant processing volume. Metzger (16) found that, among 21 Maine dealers, plants with larger processing volumes were associated with lower per unit costs of processing and distributing fluid milk products. Aplin (2, 3) indicated that economies of scale, utilization of plant processing capacity, product mix, and level of technology in the processing and cooler areas were expected to influence the cost of processing as well as plant labor productivity.

Profile of Fluid Milk Operations Studied

This study targeted medium and large fluid milk operations that are well-managed, have high labor productivity, and maintain a significant market presence. Our list of "benchmark" operations was constructed by consulting with fluid milk industry executives and Federal Milk Marketing Order Administrators to identify the fluid operations that are highly respected. Thus, the plants did not represent a random sample of all fluid milk plants throughout the country. A high percentage of the plants identified for the study agreed to participate.

Data Collection Period

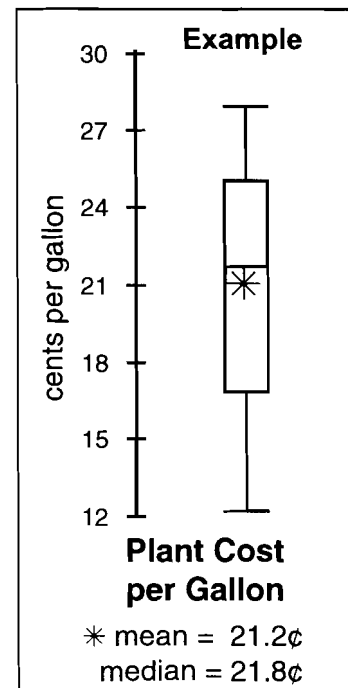
Plants were requested to submit data on plant operations for a recent 12-month period. The data collection period spanned just over 2 years, with the oldest data representing plant activities in January 1993 and the most recent representing activities in March 1995. Although most plants submitted data for 12 consecutive months, a few plants submitted quarterly or annual data.

Much of the data submitted were aggregated into monthly averages to simplify the report. Some plants submitted information based on different time frames (for example, 13 4-week periods or 12 weekly periods with a 4-4-5 week allocation). These data were converted to corresponding monthly figures to allow for comparisons among all plants. In several of the plants, soft manufactured dairy products (e. g., sour cream, cottage cheese, and yogurt) were produced in addition to the fluid beverage products. These plants reported neither the monthly production of these products nor their associated production costs.

Using Boxplots to Report Results

Boxplots are used as descriptors of data points in many instances in this report. The following explanation regarding the information that they contain may help to interpret their meaning. The boxplot to the right illustrates plant cost per gallon for the 35 plants in the survey. Plant cost includes the costs of direct processing and filling labor, cooler and load-out labor, and all other plant labor, electricity, gas, water and sewage, building and equipment depreciation (excluding any depreciation charged to blow mold equipment), leases, repairs, parts, cleaners and lubricants, plant supplies, pest control, refuse collection, taxes, and insurance.

Boxplots are a method of displaying the central point and dispersion of data. The information is broken down into quartiles (25% of the ranked observations fall into each quartile). The center "box" which is composed of the two middle quartiles outlines the middle 50% of the observations. The horizontal line within the box indicates the median value of the data set. The median is the midpoint of the data. In other words, 50% of the observations lie above the median, and 50% of the observations lie below the median. Here, the median plant cost is 21.8¢ per gallon. The sample mean, the location of which is represented in the boxplot by the starburst (*), is the average value of the collected data. For this data set, the sample mean is 21.2¢ per gallon. The mean and the median are close in magnitude for this example which implies that the mean plant cost per gallon is not unexpectedly skewed toward a higher or lower cost per gallon. The sample mean and median need not be closely matched in magnitude as will be encountered in some of the following analyses.



Correlation Coefficients

Correlation is a measure of the degree of association between two variables. Correlations range from -1 to +1 and are denoted by the symbol "r". A correlation of +1 indicates a perfect linear relationship, i.e., the "movement" of the two variables matches precisely in direction, but not necessarily in magnitude. A correlation of -1 indicates that the variables are "moving" in exactly opposite directions. A correlation of 0 means that no linear relationship exists between the two variables. Correlations imply nothing about the causal relationship between two variables. For example, a correlation coefficient of 0.8 between plant labor productivity and average employee height would not necessarily imply that taller employees increase plant labor productivity. It merely indicates that the two variables are positively related in a relatively strong manner.

GENERAL CHARACTERISTICS OF PLANTS STUDIED

Plant Location and Ownership

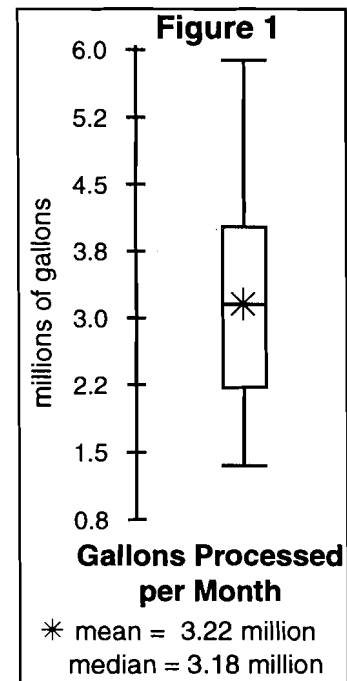
The plants participating in the study were widely dispersed throughout the United States. Although 14 of the plants were located in the Northeast, 7 plants were located in Western and Mountain states, 7 were located in the Middle Atlantic and Southeast, and 7 were located in the Upper Midwest. Of the 35 plants in the study, 5 were owned and operated by milk marketing cooperatives, 8 were owned by vertically integrated supermarket chains (i. e., captive plants), and the remaining 22 were owned and operated by proprietary firms.

Volumes Processed

Figure 1 shows the average monthly volume of beverage milks and other fluid products processed by the 35 plants. Fluid products included all white and flavored milk products, half and half, heavy cream, buttermilk, ice cream mix, juices, drinks, and bottled water. Other products, such as sour cream, yogurt, cottage cheese, and carbonated drinks were not included. Participating plants processed an average of 3.22 million gallons (27.8 million pounds) of products per month with a median of 3.18 million gallons (27.4 million pounds). Processing volume for all plants ranged from 1.36 million gallons to about 5.97 million gallons per month (11.7 million pounds to 51.4 million pounds).

Plant Capacities

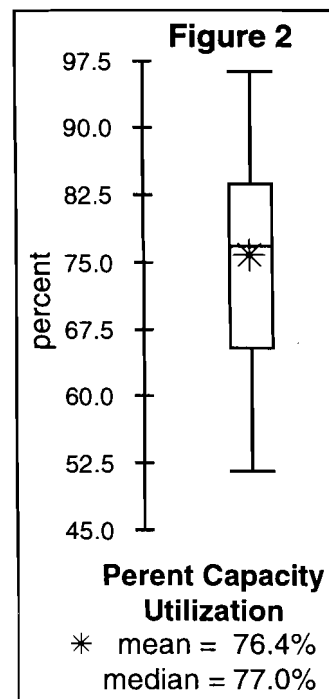
The maximum capacity rating of each plant was defined as the level of processing that could be sustained without changing the existing equipment, buildings, product mix, or customer mix. Additional shifts of labor or additional processing days were allowed. Using the maximum capacity rating and the actual gallon equivalents of fluid products processed each month, a measure of capacity utilization was estimated. All monthly estimates for plant capacity utilization were averaged to produce a single number (Figure 2). Capacity utilization ranged from about 51.8%



to 96.5% with an average of 76.4%. It was evident that a number of facilities were operating far below their maximum sustainable capacity, and as a consequence, had excess plant capacity for several months throughout the year. Consistently low capacity utilizations were calculated for plants that process large amounts of non-beverage products because only beverage products were considered when determining gallon equivalents processed each month. Consequently, plants that processed large volumes of soft products were not included in the calculation of plant capacity utilization.

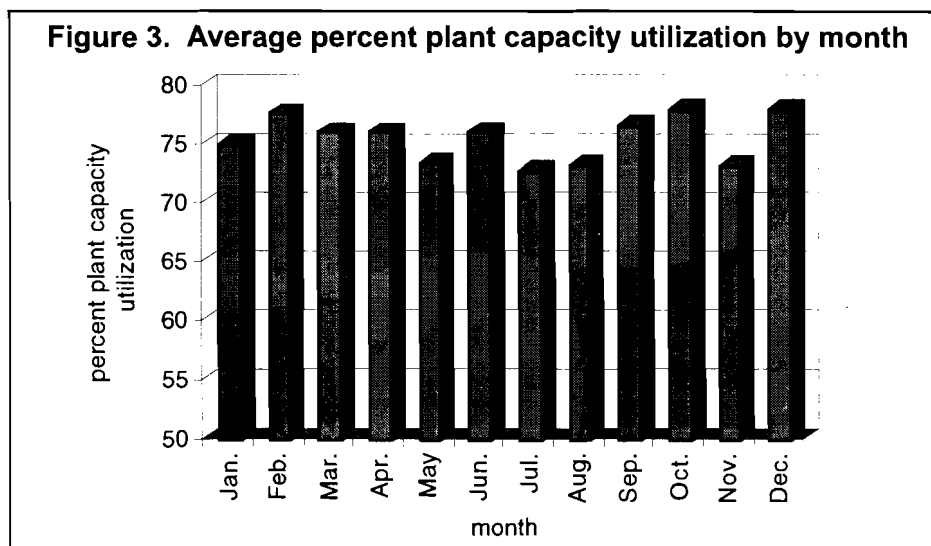
We compared plant capacity utilization by month. We calculated daily productions for each plant and then standardized all production data to 30.5 days to avoid potential bias encountered by comparing months of unequal lengths. The results revealed that there were small differences in average monthly plant capacity utilization (Figure 3).

Plant capacity utilization was not expected to be high during the summer months. Milk supply typically increases during the spring and early summer, but demand for beverage dairy products tends to be lower. Although farm milk production typically drops off during the late fall and early winter, high capacity utilization was anticipated because of increased consumption of beverage milk products and production of seasonal beverages. This hypothesis was supported by the results. On average, plant capacity utilization was highest in December, followed by October, February, and September. Plant capacity was utilized the least in July, May, and August.

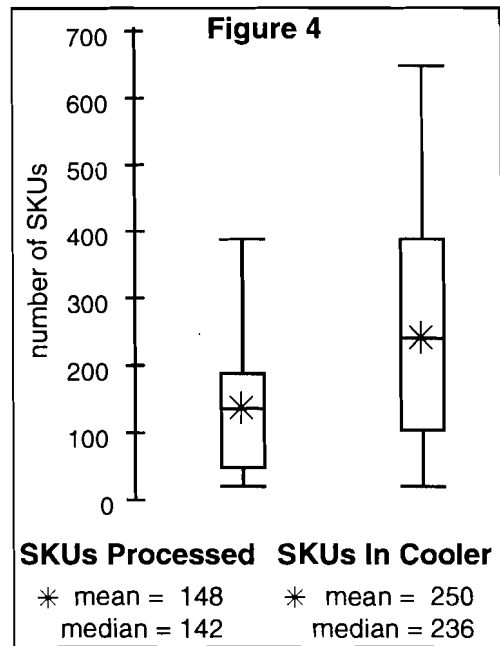


Number of Products, Labels, and SKUs Processed

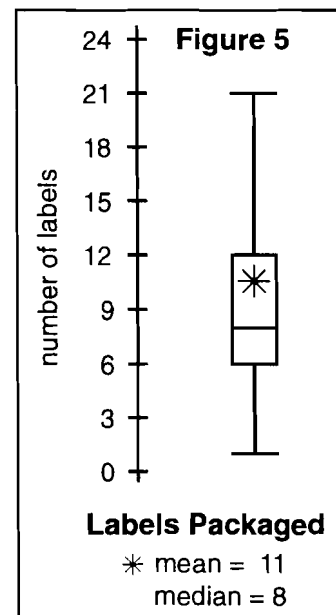
None of the plants in the study was strictly a fluid milk plant, i. e., a plant that only processed beverage milk products. Many products were processed, packaged and stored



along with the variety of beverage milk products. Very few plants processed and packaged UHT products, and the most common products processed with UHT technology were coffee creamers; half and half; and light, medium, and heavy creams. A few plants processed and packaged soft dairy products, such as sour cream, cottage cheese, and yogurt. Nearly all plants brought finished products into their coolers from other food manufacturers which were then distributed to wholesale or retail outlets with the products processed by the plant. However, a few plants did not bring any finished purchased products into their coolers. Figure 4 illustrates the range of stock keeping units (SKUs) that were plant-processed and the range of SKUs handled in the cooler. On average, plants processed 148 SKUs and stored about 250 SKUs in the cooler. The data for each category was quite disperse with SKUs processed ranging from about 20 to nearly 400. The number of SKUs stored in the cooler ranged from 25 to 650.



Most plants indicated that they packaged products under multiple labels (Figure 5). Seven plants processed four or fewer labels, and six plants processed twenty or more labels. On average, the plants packaged beverage products under 11 labels. The number of SKUs processed was influenced by the number of labels processed. The correlation coefficient for labels and monthly volume processed was weak ($r = 0.17$), indicating that plants processing and packaging beverage products for a large number of labels were not necessarily large operations. The correlation coefficient for SKUs processed and monthly volume processed was also weak ($r = 0.27$), indicating that large facilities were not necessarily the plants processing and packaging a large number of SKUs.



Plant and Cooler Evaluation

A number of questions were posed in the survey to characterize the level of technology and automation. Automation and technology in the processing and filling area and in the cooler and load-out were evaluated by the plant manager at each plant. The managers were asked to use a 10-point scale to self-assess the levels of technology in the two areas of the plant (1 = the lowest level of technology, and 10 = the latest, most innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales (1 = too small; poor layout, and 10 = spacious; convenient design).

Automation and technology in the processing and filling area averaged 7.4 and ranged from 4 to 9 (Table 1). About 83% of the plants rated the technology and automation in their processing and filling area 7 or better. Automation and technology in the cooler and load-out area was more variable, ranging from 1 to 10 and averaged 5.9.

Table 1. Ratings of plant and cooler characteristics by plant managers¹

<u>Characteristic rated:</u>	<u>Mean</u>	<u>Median</u>	<u>Minimum</u>	<u>Maximum</u>
Processing and filling area	7.4	8	4	9
Cooler and load-out area	5.9	7	1	10
Cooler size	5.7	6	1	10
Cooler design and layout	6.3	7	2	10

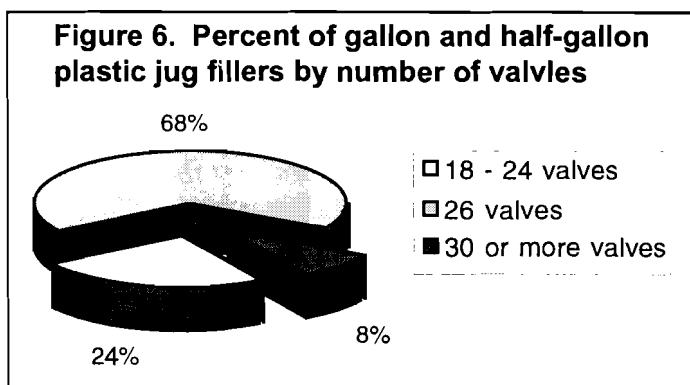
¹ Automation and technology, cooler size, and cooler layout were evaluated by the plant manager at each facility. The managers were asked to use a 10-point scale to assess the levels of technology ("1" = older technology, and "10" = innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales ("1" = too small; poor layout, and "10" = spacious; convenient design).

About 50% of the plants rated the automation and technology in their cooler and load-out area 7 or better. The correlation between processing and filling technology and cooler and load-out technology was surprisingly low ($r = 0.20$), indicating that high ratings for technology in the processing and filling area were only weakly associated with high ratings for technology in the cooler and load-out area.

Ratings for cooler size and cooler design followed the same dispersed pattern as shown by cooler and load-out technology (Table 1). Among the 35 participating plants, cooler size averaged 5.7, and cooler design averaged 6.3. About one-third of the plants rated both the size and layout of their coolers 4 or less. Correlation coefficients among cooler and load-out technology, cooler size, and cooler design ranged from mildly strong to strong. The correlation between cooler size and cooler design indicated that larger coolers were also likely to be more conveniently designed ($r = 0.63$). The correlation between cooler and load-out technology and cooler design indicated that coolers with more automation were very likely to be more conveniently designed ($r = 0.81$). The correlation between cooler and load-out technology and cooler size indicated that coolers with more automation were likely to be more spacious ($r = 0.62$).

Plastic Jug Filling Equipment

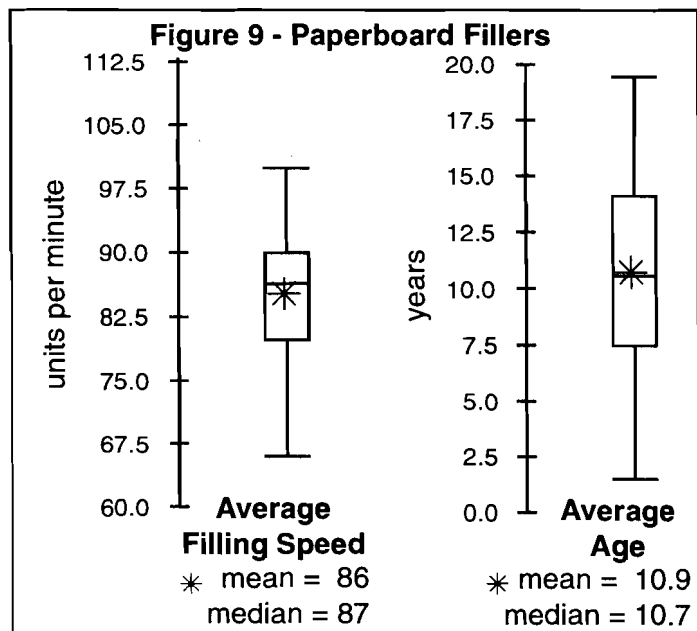
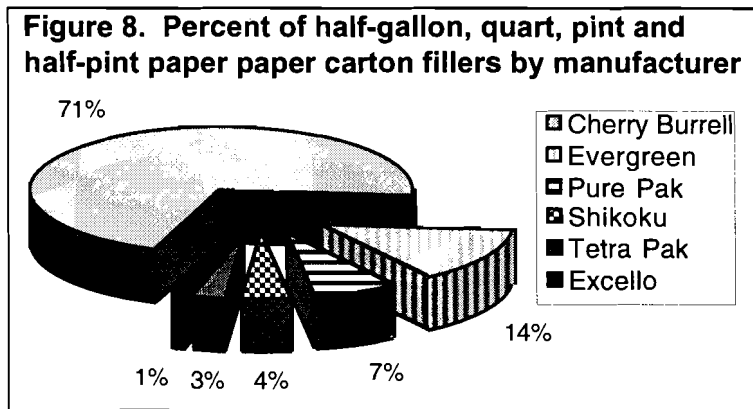
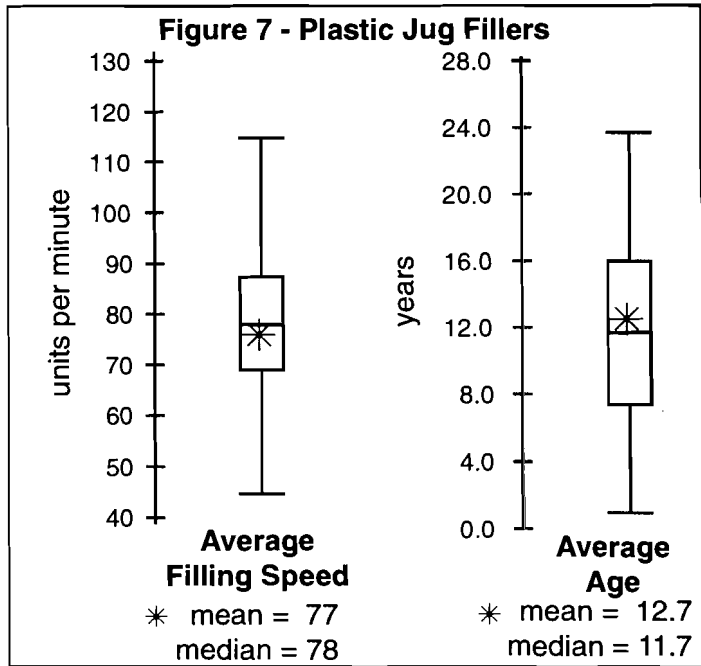
All plants operated plastic jug filling equipment and most operated paperboard container filling equipment as well. Plastic jug fillers were almost exclusively manufactured by Federal, although a small percentage of jug fillers were manufactured by Fogg. The size of plastic jug fillers, as measured by the number of valves per machine, was variable, but over two-thirds of jug fillers were equipped with 26 valves (Figure 6). Fillers with 18-valves were generally reserved for filling half-gallon jugs, but it was not unusual for plants to fill gallon and half-gallon jugs on a single machine. The average age of



all plastic jug fillers was 12 years and ranged from 1 year to 24 years (Figure 7). Actual filling speeds, as opposed to manufacturers' ratings, were reported for machinery used to fill gallon jugs. Plastic gallon jug filling equipment averaged 77 units per minute and ranged from 45 units per minute to 115 units per minute (Figure 7). The correlation coefficient for gallon jug filling speed and age of plastic gallon jug fillers indicated that older machines were somewhat more likely to operate at slower rates ($r = -0.43$).

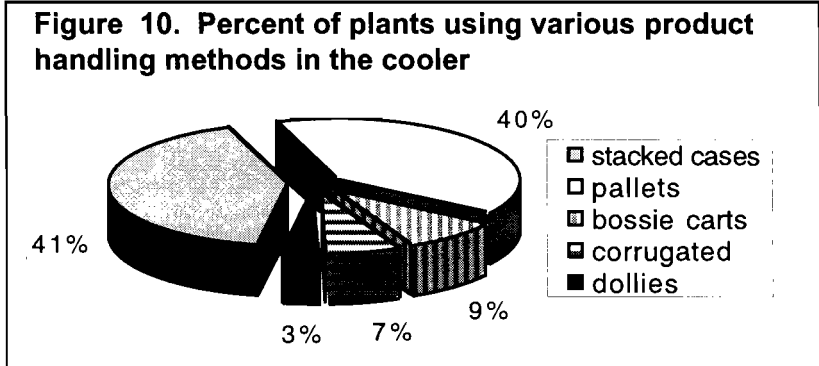
Paperboard Filling Equipment

Manufacturers of paperboard fillers were more numerous than plastic jug fillers, but Cherry Burrell was clearly the dominant manufacturer of paperboard filling equipment in the participating plants (Figure 8). Forty-three percent of paperboard fillers were used exclusively for filling half-gallon containers. The other fillers were capable of handling a variety of package sizes. About 45% were capable of filling quart, pint, and half-pint containers, and the remaining 12% were used to package half-pint and 4-ounce NEP containers. The average age of all paperboard filling equipment was 10.9 years and ranged from 1 year to 19 years (Figure 9). Actual filling speeds, as opposed to manufacturers' ratings, were reported for half-gallon paperboard filling equipment. The average filling speed was 86 units per minute, and the range was 65 units per minute to 100 units per minute (Figure 9). The correlation coefficient for half-gallon paperboard filling speed and age of half-gallon paperboard fillers indicated that older machines were somewhat more likely to operate at slower speeds ($r = -0.47$).



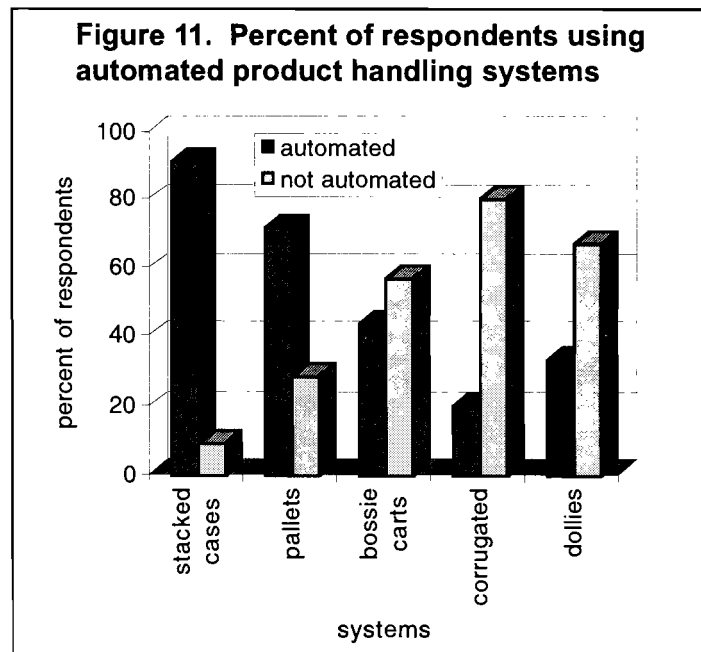
Product Handling In the Cooler and Loading

A wide variety of product handling systems were used in the coolers of the 35 participating plants: stacked cases, corrugated boxes, bossie carts, dollies, and pallets. All but five of the plants used two or more of these product handling systems in their coolers. Product handled on pallets was packed in plastic cases, wire cases, or corrugated boxes prior to loading on a pallet. To eliminate any confusion with these different product handling systems, stacked cases or corrugated boxes placed on pallets were classified as pallets. Stacked cases and corrugated boxes refers only to the product handled in individual stacks. Pallets and stacked cases accounted for the largest shares of volume handled by the various systems (Figure 10). On average, 41% of the plants' volumes were handled using stacked cases, and 40% were handled on pallets. Bossie carts accounted for about 9% of the volume handled, and corrugated boxes and dollies combined for about 10% of the volume handled.

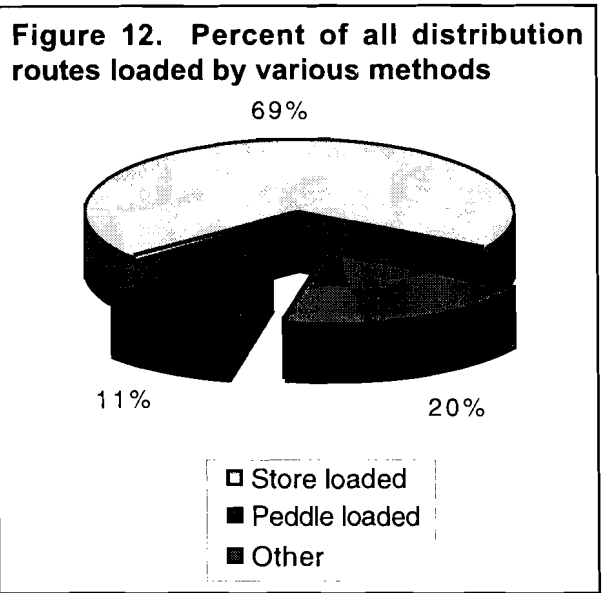


To characterize the handling systems and associated assembly processes, each product handling system of each plant was categorized as "automated" or "not automated". For example, case stackers and palletizers indicated automated product handling processes. Ninety percent of the plants using stacked cases to handle product indicated that mechanical case stackers were used (Figure 11). Three-fourths of the plants using pallets to handle product indicated that pallets were loaded by automated equipment. More than 55% of the plants using bossie carts responded that the carts were loaded manually. Similarly, corrugated boxes and dollies were less likely to be automated processes. For the less popular product handling systems, automation appeared to be associated with the volume of product handled. In other words, a plant that handles 5% of its volume on bossie carts may find it difficult to justify purchasing an automated cart loader whereas another plant that handles 30% of its volume on bossie carts may be able to justify an automated cart loader.

When placed into the delivery vehicles, product is organized largely by customer (store loaded) or by product (peddle loaded). "Store loaded" means that orders are pre-picked in the cooler and then arranged on



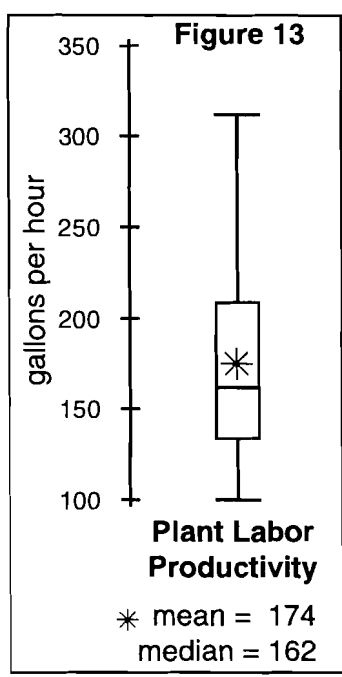
delivery vehicles by the customers receiving orders on the route. "Peddle loaded" means that orders are not pre-picked, and the driver is responsible for assembling the order at the time of delivery. As such, products are arranged on the delivery vehicle to simplify order filling at the time of delivery. About 89% of all routes operated by the 35 plants were either store loaded or peddle loaded (Figure 12). The remaining 11% of the routes were loaded by other methods. The most popular alternative method was bulk loading, usually reserved for trucks and trailers destined for warehouses or other drop points.



Plant Labor Productivity

Plant labor productivity is one measure of plant efficiency. Plant labor productivity for the 35 plants reflected the volume processed, in gallon equivalents, relative to the hours worked by direct plant, cooler, and all other plant labor. All milks, creams, buttermilks, juices, drinks, bottled water, and ice cream mixes were included in the calculation of volume processed. Direct processing labor included all processing plant employees from the receiving bay to the cooler wall, and cooler labor included employees in the cooler and load-out areas as well as any jockey labor.² "All other plant labor" was a general plant labor category that included maintenance, engineers, plant quality control, plant office support, and plant management. Plant labor productivity did not include any labor from the blow mold area, nor did it include any labor used in producing soft dairy products (e. g., cottage cheese, sour cream, and yogurt). Hours worked in milk procurement, research and development, distribution, selling, and general and administrative personnel were also excluded.

Plant labor productivity ranged from about 100 gallons per hour to over 320 gallons per hour (Figure 13). The top ten plants, eight of which were captive supermarket plants, averaged more than 210 gallons per hour. These highly productive plants influenced the average plant labor productivity as evidenced by the large difference between the mean and median (174 gallons per hour versus 162 gallons per hour). Twenty-two of the 35 plants fell in the range of 100 gallons per hour to 170 gallons per hour.



² Jockey labor moves distribution trucks and trailers into and out of the loading bays.

Plant Labor Costs

Hourly Cost of Labor

Labor cost per hour (wages and fringe benefits) was calculated by dividing the sum of the direct plant, cooler, and all other plant labor costs by the total number of hours worked in the plant. Labor assigned to the blow mold, research and development, distribution, selling, general and administrative personnel was not included in this category.

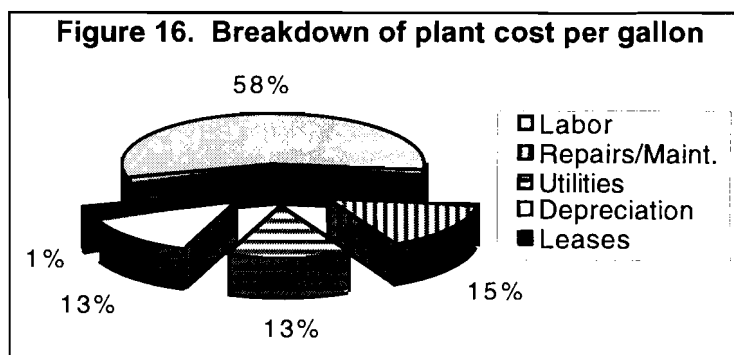
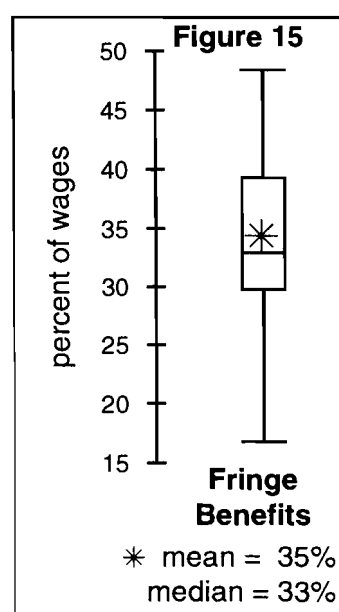
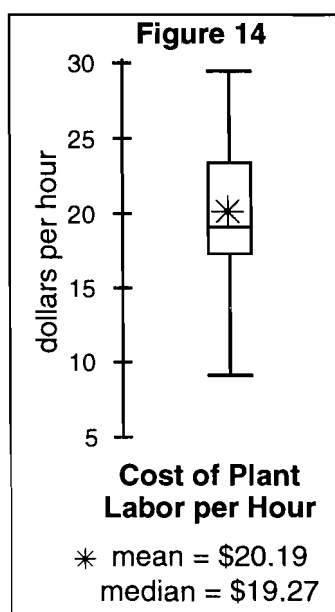
Cost of plant labor averaged about \$20.19 per hour, but there was a tremendous range among plants (Figure 14). Plant location and the availability of other competitive occupational opportunities may explain some of the variation in cost of labor per hour. For example, New York City Metropolitan Area plants paid an average of \$24.88 per hour for plant labor while the cost of labor in all other plants averaged \$19.42 per hour.

Fringe Benefits

Fringe benefits included employer contributions to medical insurance, employees' pension fund, vacation, and gifts as well as the mandatory contributions to FICA, workman's compensation, and unemployment insurance. Not all plants contributed to all benefit categories. Benefits as a percentage of labor wages ranged from about 17% to 48% with an average of 35%, but 85% of the plants fell in the range of 18% to 40% of wages (Figure 15).

Labor Cost per Gallon

The cost of labor was the largest single factor in determining plant cost per gallon (Figure 16). The percent of plant cost per gallon attributable to labor costs ranged from 41% to 70% with a mean of 58%. The average labor cost was 12.3¢ per gallon of fluid products processed, and the median labor cost was 12.8¢ per gallon (Figure 17). Labor cost per gallon was influenced by a number of factors, including plant location. For example, plants in and around New York City tended to have higher labor costs per gallon than plants in other parts of the country. Plants around the New York City Metropolitan Area averaged 14.3¢ per gallon for labor costs, and all of the plants outside this area averaged 12.1¢ per gallon.

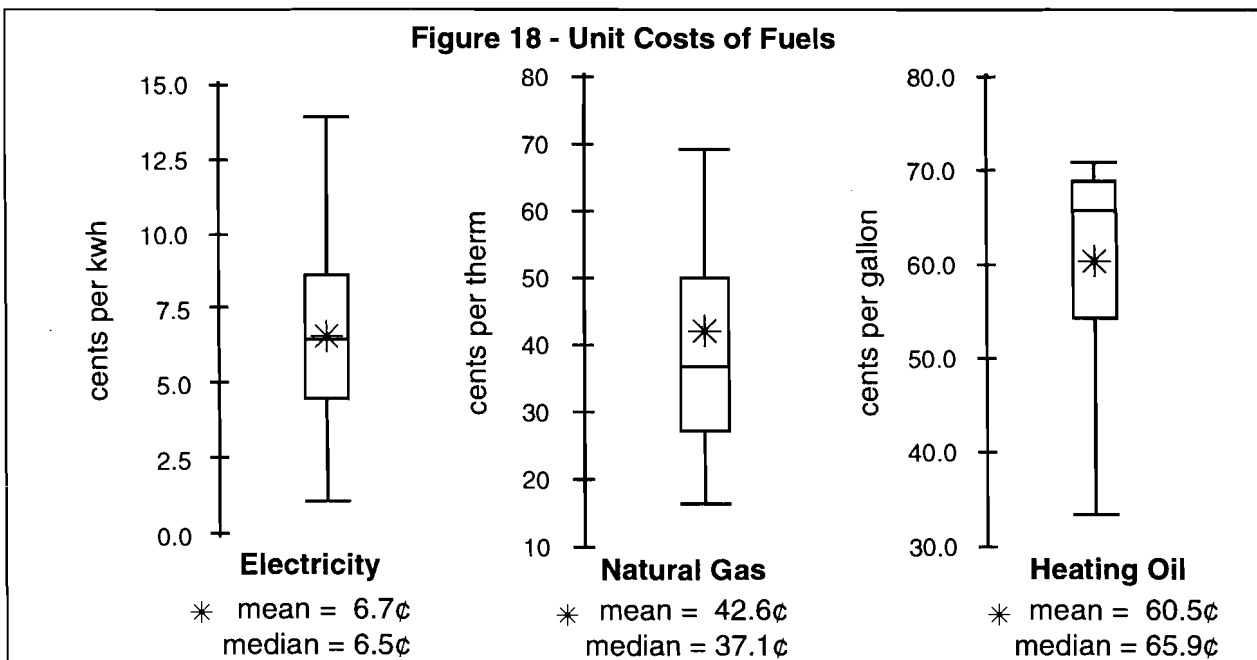
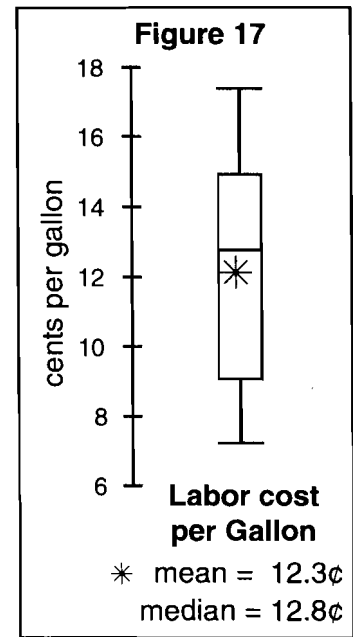


Cost of Utilities

All 35 participating plants reported per unit electricity and natural gas costs. Heating oil and liquid propane were also used as fuels but far less frequently than electricity and natural gas. The common unit of measure of electricity was kilowatt-hour (kwh), but natural gas was measured in therms, decitherms, hundred cubic feet (ccf), and thousand cubic feet (mcf). To make meaningful comparisons, all unit costs for natural gas were converted to cents per therm.

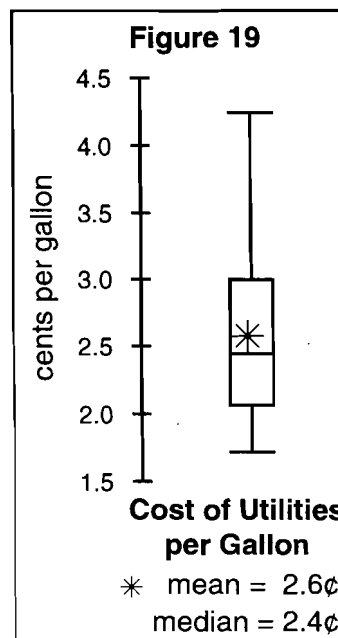
There were substantial differences among the lowest and highest per unit costs for electricity and natural gas (Figure 18). Cost of electricity averaged 6.7¢ per kwh with a median of 6.5¢ per kwh. About 85% of the plants reported units costs between 3.5¢ per kwh and 10.0¢ per kwh. Natural gas costs ranged from 17¢ per therm to 70¢ per therm. The average cost of natural gas was 42.6¢ per therm with a median of 37.1¢ per therm. The data was uniformly distributed around the median, i. e., reported per unit costs did not tend to cluster around any certain costs. Plants that paid high per unit costs for electricity were likely to pay high per unit costs for natural gas ($r = 0.60$).

Unit costs for electricity and natural gas were dependent on plant location. For example, plants in and around New York City reported higher unit costs than plants in other parts of the country. Plants around the New York City Metropolitan Area averaged 9.9¢ per kwh and 53.4¢ per therm, and all of the plants outside this area averaged 6.2¢ per kwh and 36.8¢ per therm.



Only a handful of plants used fuel oil, and the majority of those plants did not specify which grade of fuel oil was used in the plant. Therefore, the average and median prices paid per gallon reflected the reported costs of all grades of fuel oil. Oil prices averaged 60.5¢ per gallon and were influenced by plant location as well as grade. The use of fuel oil in fluid milk plants was generally limited to late fall and winter months, and other fuel sources were used in plant operations during the remainder of the year.

The total cost of utilities per gallon processed varied widely (Figure 19). Cost of utilities per gallon was calculated as the 12-month average cost of utilities divided by the 12-month average volume processed by the plant. Utilities included electricity, natural gas, heating oil and other fuels, water, and sewage. Cost of utilities ranged from 1.7¢ per gallon to 4.3¢ per gallon and averaged 2.6¢ per gallon of product processed. Two-thirds of the plants had utility costs between 2.0¢ per gallon and 3.7¢ per gallon.



Plant Costs

Two measures were developed to assess the cost of operating each of the 35 fluid plants. Both measures represented plant cost per gallon of fluid product processed, but while one measure included the cost of depreciation, the other did not. Depreciation is an expense, albeit a non-cash expense, and it could be argued that depreciation costs should be included to paint a more accurate and complete portrait of plant costs and asset replacement. On the other hand, including reported depreciation costs in the calculation may be misleading because depreciation costs as reported in this study are based on bookkeeping methods. For older equipment and older plants, depreciation costs are low if the building and much of the equipment is fully depreciated. In addition, depreciation costs for new equipment and new plants may be determined on an accelerated basis which shows up as a higher depreciation cost than the actual consumption of capital in the early stages of the useful life of the assets.

The true economic cost of the investment in these fluid milk plants is not the accounting depreciation that was reported. Rather, it is the economic depreciation of the assets based on current replacement costs and the cost of capital tied-up in the assets (opportunity cost of capital). Unfortunately, neither economic depreciation nor opportunity cost information lent itself well to straightforward assessments by accounting personnel or controllers at the participating plants.

To avoid bias associated with bookkeeping depreciation in plant cost comparisons, we included two separate measures of plant cost per gallon. Specifically, one measure of plant cost accounted for the costs of labor, electricity, gas, water, sewage, building and equipment depreciation (excluding any depreciation charged to blow molding equipment), leases, repairs, maintenance, parts, cleaners, lubricants, plant supplies, pest control, refuse collection, taxes, and insurance relative to the volume processed in gallon equivalents. The second measure summarized variable costs and included all of the above items except depreciation expenses. The true plant cost per gallon would likely be bounded from below by the plant cost which excludes depreciation and from above by the plant cost which includes depreciation.

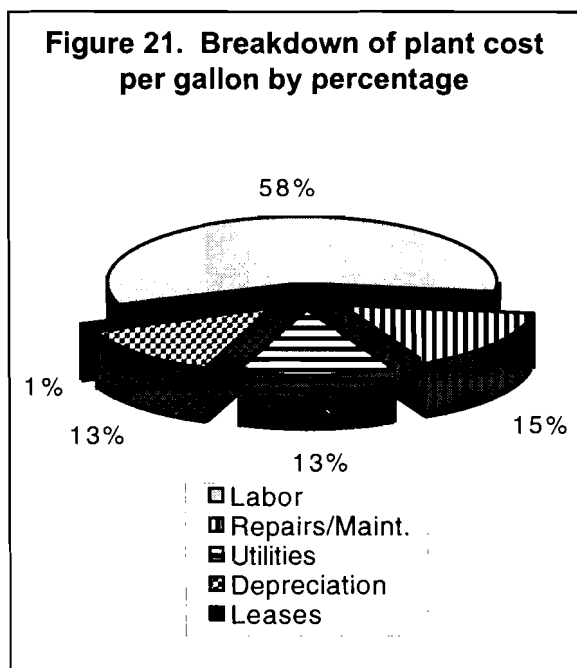
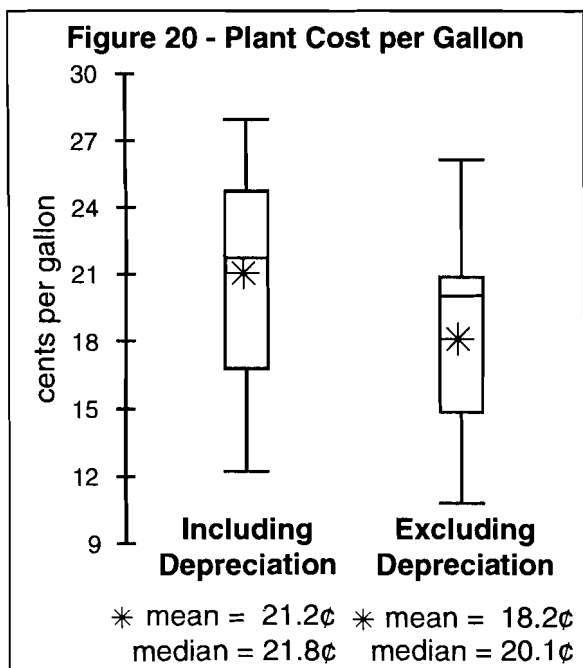
Ingredient costs were not included in either the calculation of total plant costs per gallon or variable costs per gallon. We excluded packaging costs from both of the plant cost measures because we found that unit purchase prices followed a time-series progression, i.e., the plants that submitted plant data in the early stages of the study had significantly lower packaging material prices than the plants that submitted plant data toward the end of the study. Any labor used in producing soft dairy products (e. g., cottage cheese, sour cream, and yogurt) was also excluded, as well as the costs of milk procurement, research and development, distribution, selling, and general and administrative personnel.

Plant Cost per Gallon

Among the 35 plants, plant cost per gallon, including depreciation, showed large variability, ranging from 12.3¢ per gallon to 28.0¢ per gallon (Figure 20). The average cost was 21.2¢ per gallon. About 65% of the plants fell within the range of 15¢ per gallon to 25¢ per gallon. One-third of the plants had calculated plant costs of less than 18¢ per gallon.

When depreciation expenses were excluded, variable costs per gallon dropped to an average of 18.2¢ per gallon and ranged from 10.9¢ per gallon to 26.2¢ per gallon (Figure 20). About three-fourths of the plants fell within the range of 13¢ per gallon to 23¢ per gallon.

When depreciation expenses were included, labor costs constituted 58% of plant cost per gallon (Figure 21). Building and equipment depreciation accounted for 13%, and the cost of water, sewage, electricity, and other fuels accounted for an additional 13%. As a group, repairs, maintenance, parts, cleaners, lubricants, plant supplies, pest control, refuse collection, taxes, and insurance totaled 15% of plant cost per gallon. Leases accounted for about 1% of plant cost per gallon.



COMPARISONS BASED ON TYPE OF PLANT OWNERSHIP

Overview

The second objective of this study was to investigate differences among the participating plants based on type of plant ownership. Although the majority of the plants in the study were independently owned and operated (63%), 14% of the plants were owned and operated by milk marketing cooperatives, and 23% of the plants were owned and operated by supermarket companies.

In this section, we present comparisons of basic plant information and efficiency measures by plant ownership with the appropriate statistical tests for differences among means. We emphasize comparisons of captive and proprietary plants against cooperative plants.

Statistical Test

We used heteroscedastic Student's t-Tests to evaluate differences among plants by type of ownership. Each test requires two distinct samples and assumes that the variances of both samples of data are unequal. Because we were investigating the profiles and performances of cooperative plants relative to other plants, we used two t-tests. One test compared captive plants and cooperative plants, and the second test compared proprietary plants and cooperative plants.

The results of the test are given in the form of probabilities. For example, $P = 0.05$ means that there is a 5% chance that the samples come from two underlying populations with the same mean. Conversely, $P = 0.05$ indicates that there is a 95% probability that the true means of all plants in each type of ownership class, including those plants not sampled, are different.

General Plant Comparisons

Comparing captive plants and cooperative plants revealed many statistically significant differences (Table 2). However, comparing cooperative plants and proprietary plants revealed few statistically significant differences.³ Although we found few statistically significant differences between means of cooperative and proprietary plants, most of the comparisons favored proprietary plants.

To summarize Table 2, we provide a brief description of the results of the pairwise comparisons. On average, captive plants and proprietary plants were significantly larger than cooperative plants as measured by gallon equivalents of product processed per month. There were only small and insignificant differences among the means for plant capacity utilization among the three types of plant ownership. On average, captive plants processed many fewer labels and SKUs than cooperative plants and proprietary plants. Furthermore, captive plants stored very few SKUs in their coolers as compared to plants under different ownership. Relative to cooperative plants, proprietary plants processed

³ By convention, $P=0.05$ is chosen as the level to indicate "statistical significance". If the computed probability is 0.05 (or less), then there is a 95% (or greater) chance that the means are different.

Table 2. Comparisons of means of basic plant information by plant ownership

Descriptor	Captive plant mean	Proprietary plant mean	Cooperative plant mean	<i>P</i> cap:coop ¹	<i>P</i> pro:coop ¹
Volume, x10 ⁶ gal/mo	3.55	3.36	2.28	0.05	0.01
Plant capacity utilized, %	77	76	77	0.96	0.83
Labels processed	3	13	18	0.03	0.34
SKUs processed	48	178	160	0.03	0.67
SKUs in cooler	70	299	332	0.04	0.74
Labor cost, \$/hr.	22.42	19.83	19.05	0.16	0.71
Electricity, ¢/kwh	7.2	6.4	7.4	0.91	0.66
Natural gas, ¢/therm	47.2	45.4	32.4	0.09	0.18

¹Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

fewer labels and stored fewer SKUs in their coolers, but they processed slightly more SKUs than cooperative plants. The comparisons of SKUs and labels among proprietary and cooperative plants were not statistically significant. Labor cost per hour was higher in captive plants than proprietary or cooperative plants on average. These differences may be a function of plant location, rather than an intrinsic feature of captive plants. Proprietary plants paid employees slightly more per hour than cooperative plants. Cost of electricity and natural gas was mixed for the three plant types. Cooperatives had the highest unitary cost for electricity, but the lowest unitary cost for natural gas. Unit electricity and natural gas costs for captive plants were curiously high relative to other plants, but, again, this may be a function of plant location.

Plant and Cooler Comparisons

Although the plants in the study were considered to be among the best in the U.S., differences in plant age and capital investments in processing equipment and cooler machinery were evident. We attempted to assess technology and automation as well as obtain some measures of satisfaction with cooler design and layout. We asked the plant manager at each plant to use a 10-point scale to assess plant and cooler technology ("1" = the lowest level of technology, and "10" = the latest, most innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales ("1" = too small; poor layout, and "10" = spacious; convenient design). Table 3 summarizes the comparisons of the mean responses to four plant and cooler evaluation questions.

Comparing captive plants and cooperative plants revealed three statistically significant differences. However, comparing cooperative plants and proprietary plants revealed no statistically significant differences (Table 3). Although the differences among cooperative plants and proprietary plants were not large enough to be statistically significant, all of the comparisons favored proprietary plants.

While we found only small differences in processing technology ratings among the groups of plants, cooler evaluations were much more varied. On average, captive plant

Table 3. Comparisons of means of plant and cooler ratings by plant ownership

<u>Descriptor</u> ¹	<u>Captive plant mean</u>	<u>Proprietary plant mean</u>	<u>Cooperative plant mean</u>	<i>P</i> <u>cap:coop</u> ²	<i>P</i> <u>pro:coop</u> ²
Processing technology	7.3	7.4	7.0	0.74	0.37
Cooler technology	7.5	5.5	4.8	0.01	0.42
Cooler size	6.8	5.5	4.4	0.10	0.39
Cooler design & layout	8.3	5.8	5.0	0.03	0.53

¹ Automation and technology, cooler size, and cooler layout were evaluated by the plant manager at each facility. The managers were asked to use a 10-point scale to assess the levels of technology ("1" = older technology, and "10" = innovative technology). Similarly, cooler size and cooler design were assessed on 10-point scales ("1" = too small; poor layout, and "10" = spacious; convenient design).

² Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

managers appeared more satisfied with cooler technology, cooler size, and cooler layout and design than managers of other plants. When comparing evaluations for the three cooler characteristics, responses by managers of captive plants were higher and statistically different (when using reasonable levels of significance) than those of cooperative plant managers. Cooperative plant managers appeared to be the least satisfied with cooler size when compared to the responses given by managers of proprietary or captive plants.

Comparisons of Filling Machinery

When constructing the survey, we chose not to collect much descriptive data on specific processing equipment used in each plant. We did, however, obtain data on the filling machinery used by the plants (Table 4). We compared actual filling speeds in units per minute and age of equipment in years for both plastic gallon jug fillers and half-gallon paper carton fillers. These two types of fillers were used by nearly every plant. In general, other types of filling machinery, such as quart, pint, and half-pint paper carton fillers and plastic half-gallon jug fillers were not used by captive plants and did not allow us to make comparisons based on type of plant ownership.

Age of equipment did not show much variation among the three groups of plants, and comparing means among the three groups of plants led to mixed results. However, none of the paired comparisons was statistically significant. Captive plants and proprietary plants operated the oldest plastic jug filling equipment on average, and cooperative plants operated newer plastic jug filling equipment. However, a comparison of age of paper half-gallon carton fillers revealed that these positions were reversed - cooperative plants operated the oldest fillers on average, and captives and proprietary plants operated newer fillers.

While age of filling equipment was not greatly different among the three groups, filling speed varied considerably. Captive plants operated both plastic jug and paper carton fillers at speeds that were considerably higher (and statistically different) than those of cooperative plants. For example, captive plants filled an average of 24 plastic gallon jugs and 32 half-gallon paper cartons per minute per machine more than cooperative

Table 4. Comparisons of means of filling machinery age and speed by plant ownership

<u>Descriptor</u> ¹	<u>Captive plant mean</u>	<u>Proprietary plant mean</u>	<u>Cooperative plant mean</u>	<i>P</i> <u>cap:coop</u> ²	<i>P</i> <u>pro:coop</u> ²
Age of plastic jug fillers	12.6	12.4	11.2	0.78	0.75
Age of paper carton fillers	10.8	10.6	12.0	0.65	0.59
Plastic jug filling speed	89	75	65	0.06	0.37
Paper carton filling speed	97	88	65	0.04	0.09

¹Comparisons were based on plastic gallon jug fillers and half-gallon paper carton fillers. Actual filling speeds in units per minute and age of equipment in years were compared.

²Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

plants. Proprietary plants also operated both types of filling equipment at faster speeds than cooperative plants. On average, proprietary plants filled 10 plastic gallon jugs and 23 half-gallon paper cartons per minute per machine more than cooperative plants. Although the speed of operation for plastic gallon jug fillers was not statistically significant, the speed of operation for paper half-gallon carton fillers was.

Product Loading

When placed into the delivery vehicles, product was organized largely by store (store loaded) or by product (peddle loaded). As a reminder, "store loaded" means that orders are pre-picked in the cooler and then arranged on delivery vehicles by the customers receiving orders on the route, and "peddle loaded" means that orders are not pre-picked, and the driver is responsible for assembling the order at the time of delivery. Although store loading and peddle loading were the most frequently used methods, most plants used bulk loading as an alternative method when delivering to warehouses or other drop points.

An average of 93% of all orders were store loaded by captive plants (Table 5). Because a captive plant usually serves only the stores owned by the supermarket com-

Table 5. Comparisons of means of product loading methods by plant ownership

<u>Descriptor</u>	<u>Captive plant mean</u>	<u>Proprietary plant mean</u>	<u>Cooperative plant mean</u>	<i>P</i> <u>cap:coop</u> ²	<i>P</i> <u>pro:coop</u> ²
Store loaded orders, %	93	68	36	0.02	0.08
Peddle loaded orders, %	0	22	43	0.04	0.17
Other loading, %	7	10	21	0.28	0.36

¹Store loading refers to orders that are pre-picked in the cooler and then arranged on delivery vehicles by the stores receiving orders on the route. Peddle loading refers to orders that are not pre-picked, and the driver was responsible for assembling the order at the time of delivery.

²Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

pany, this result was not a surprise. On average, proprietary plants used store loading for about 68% of their orders, but cooperative plants used store loading for only 36% of the orders. Conversely, peddle loading was the loading method of choice for an average of 43% of the orders filled by cooperative plants. While proprietary plants peddle-loaded their delivery vehicles on about one-fifth of all orders filled, captive plants reported no use of peddle loading for any of the orders. Cooperative plants reported an average of 21% of their orders were loaded by other methods, but bulk loading was the most common alternative to store or peddle loading. Proprietary plants and captive plants used other methods of loading for only a small percentage of the orders.

Comparison of Costs and Labor Productivity

Overview

We present five measures for comparison of plant costs and labor productivity: gallon equivalents processed per hour of labor, cost of utilities per gallon, labor cost per gallon, variable costs per gallon, and total plant costs per gallon. We used the same definitions presented earlier for each measure.

As might be suspected given the results of the previous comparisons by plant ownership, captive plants bettered the other plants in every cost and labor productivity category (Figure 22 and Table 6). While proprietary plants and cooperative plants were closer in magnitude for each pairwise comparison, proprietary plants had, on average, lower costs per gallon and higher productivity per hour of labor.

Plant Labor Productivity

Labor productivity in captive plants far exceeded that of proprietary or cooperative plants. On average, captive plants processed and packaged 108 gallons per hour more than proprietary plants, and 133 gallons per hour more than cooperative plants. The difference in means of captive plants and cooperative plants was highly significant from a statistical viewpoint. Although proprietary plants outperformed cooperative plants by 25 gallons per hour, the difference in means was not statistically significant at the 5% level.

Cost of Utilities and Cost of Labor per Gallon

In combination, the cost of labor and utilities accounted for 55% to 75% of plant cost per gallon, including depreciation. Labor cost was clearly the dominant cost and accounted for 40% to 70% of plant cost per gallon. Although the com-

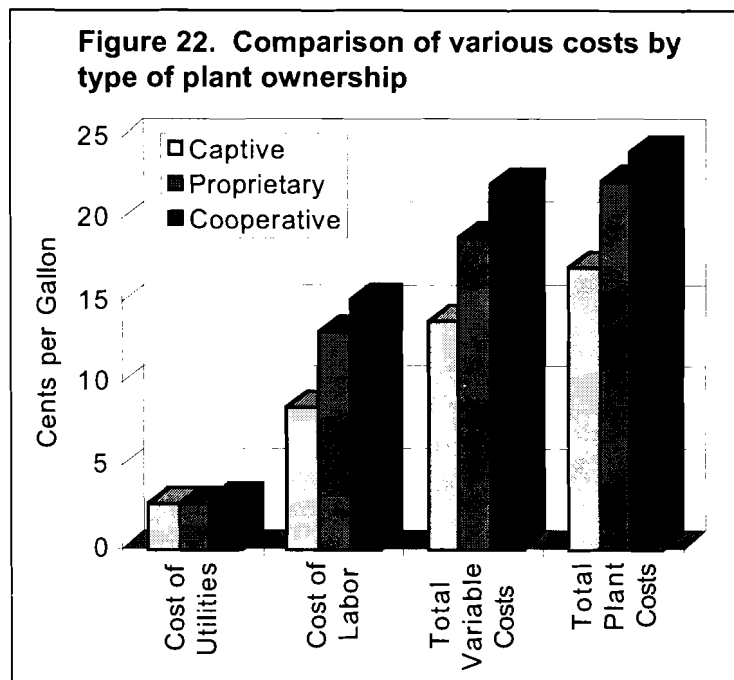


Table 6. Comparisons of means of cost and labor productivity by plant ownership

<u>Descriptor¹</u>	<u>Captive plant mean</u>	<u>Proprietary plant mean</u>	<u>Cooperative plant mean</u>	<u>P cap:coop²</u>	<u>P pro:coop²</u>
Plant labor productivity, gal/hr	261	153	128	<0.01	0.18
Cost of utilities, ¢/gal	2.7	2.7	3.1	0.52	0.52
Cost of labor, ¢/gal	8.6	13.1	15.1	<0.01	0.08
Variable costs, ¢/gal	13.8	18.9	22.2	<0.01	0.04
Total plant costs, ¢/gal	17.1	22.3	24.1	<0.01	0.23

¹Plant labor productivity reflected the total volume processed, in gallon equivalents, relative to the hours worked by direct plant, cooler, and all other plant labor. Cost of utilities per gallon included the cost of electricity, natural gas, heating oil and other fuels, water, and sewage relative to the total volume processed. Labor cost per gallon reflected the cost of wages and benefits for direct plant, cooler, and all other plant labor relative to the total volume processed. Variable costs per gallon included the cost of labor, repairs, maintenance, cleaners, lubricators, and other supplies, and utilities relative to the total volume processed. Total plant cost included all variable costs as well as equipment leases and building and equipment depreciation for the plant and the cooler relative to the total volume processed.

²Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

Comparisons of utility costs revealed no statistical differences, cooperative plants had higher utility costs per gallon than captive plants or proprietary plants. On the other hand, comparisons of labor cost per gallon showed that captive plants and proprietary plants had advantages over cooperative plants. For example, labor cost per gallon in captive plants was 60% lower than that of cooperative plants, and labor cost per gallon in proprietary plants was 15% lower than that of cooperative plants. Both of these differences were statistically significant.

Variable and Total Plant Costs per Gallon

Variable costs included the cost of labor, repairs, maintenance, cleaners, lubricators, and other supplies, and utilities relative to the total volume processed. Total plant cost included all variable costs as well as equipment leases and building and equipment depreciation for the plant and the cooler. Variable costs for captive plants averaged 13.8¢ per gallon, far less than cooperative plants (22.2¢ per gallon) and proprietary plants (18.9¢ per gallon). The differences among means of plants were statistically significant. When leases and depreciation expenses were included, captive plants were still significantly lower cost operations than cooperative plants. Although proprietary plants had lower total plant costs per gallon than cooperative plants, the difference was not statistically significant.

Comparisons of Cost Breakdowns by Percentage

As a final comparison among plants under different ownership, we present a breakdown of total plant costs per gallon for each group (Table 7 and Figure 23). Relative to cooperative plants, the cost of labor in captive plants makes up a smaller percentage of total plant cost, but, on an individual category comparison basis, depreciation, utilities, repairs and maintenance, and leases accounted for a larger percentage of total plant cost. Similarly, labor cost and repairs and maintenance costs in proprietary plants contributed to

Table 7. Comparisons of means of plant cost categories by plant ownership

Descriptor ¹	Captive plant mean	Proprietary plant mean	Cooperative plant mean	<i>P</i> cap:coop ²	<i>P</i> pro:coop ²
Labor cost, %	51.0	60.2	63.1	0.03	0.52
Utilities cost, %	15.8	12.3	12.4	0.15	0.99
Repair & Maint. cost, %	17.2	13.8	16.4	0.82	0.45
Cost of leases, %	1.3	0.8	0.8	0.65	0.97
Cost of depreciation, %	14.7	12.9	7.4	<0.01	<0.01

¹ Labor cost per gallon included the cost of wages and benefits for direct plant, cooler, and all other plant labor. Cost of utilities per gallon included the cost of electricity, natural gas, heating oil and other fuels, water, and sewage. Repairs and maintenance included any expenses for purchased labor and parts, supplies, laundry and uniforms, cleaners, and lubricators, pest control, refuse collection, and property taxes. Cost of leases included all equipment leases maintained by the plant on processing, filling, or cooler equipment. Depreciation included costs of all building and equipment (except depreciation on blow mold equipment) depreciation reported during the 12 month data collection period.

² Probability of equal group means associated with a Student's t-Test assuming unequal variances. Test for each descriptor compares captive or proprietary plants with cooperative plants.

a smaller percentage of total plant costs per gallon, but depreciation costs accounted for a higher percentage of total plants costs, relative to cooperative plants.

Describing Captive Plants

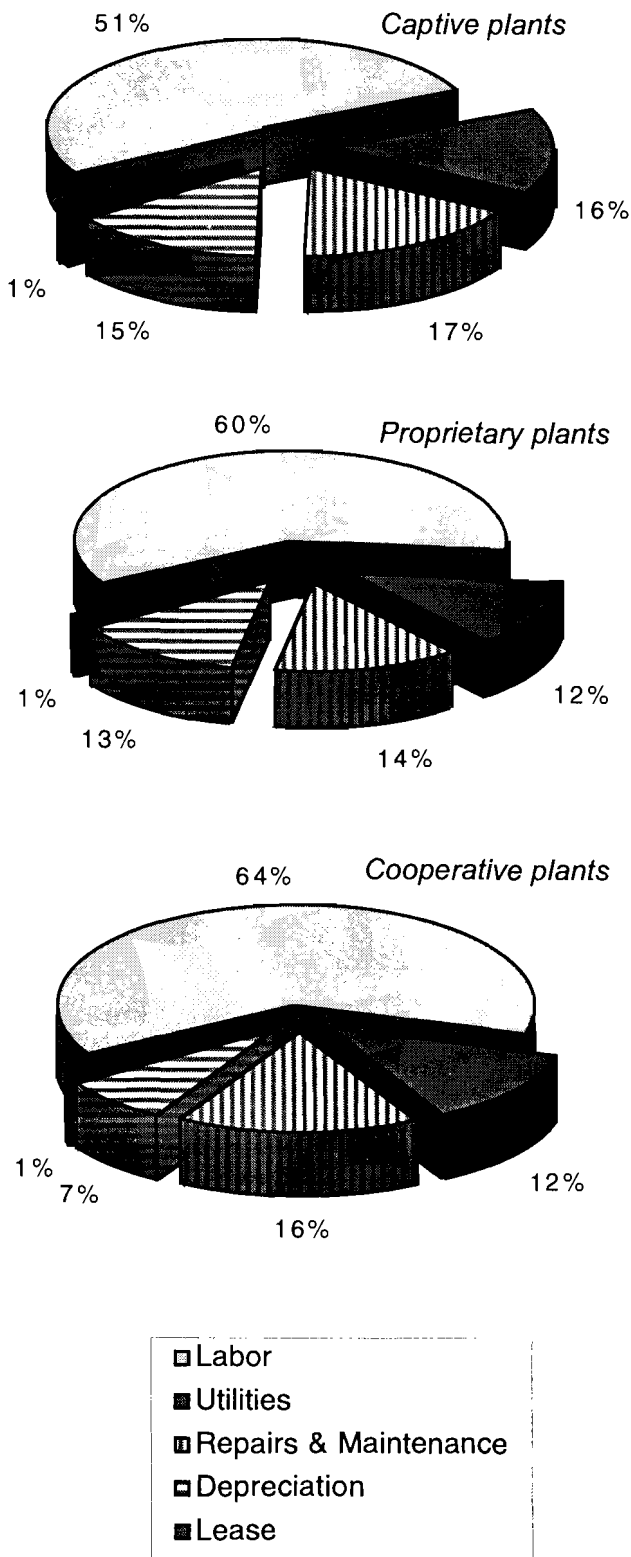
For those who are not familiar with captive plants, it may be insightful to review some of the differences between captive plants and full-line dairies. Some of the differences in how these plants operated may help to explain why they have lower costs per gallon and higher labor productivity.

Captive plants typically maintain narrower product mixes, i. e., they process fewer products under fewer labels and use fewer packaging sizes. Furthermore, most products are packaged in gallon and half-gallon containers, and only a small percentage of products are packaged in quart, pint or half-pint containers. Because captives only serve their own stores, there is a greater opportunity to handle products on less labor intensive systems, such as bossie carts and pallets. Relative to the total number of products handled, few (if any) finished products from outside sources are brought into the coolers of captive plants for distribution, reducing the number of products in the cooler and simplifying filling of orders and load-out procedures. On the distribution side, captives serve supermarket stores that place orders for similar mixes of products with little variation in order size. In combination, the characteristics described point toward operations with high product turnover and high labor productivity, which are inherently, less complex and easier to manage.

Describing Cooperative Plants

Like proprietary plants, cooperative plants tend to operate as full-line processing facilities, but the analysis of the 35 participating plants suggested that cooperative plants achieved lower labor productivity and higher costs per gallon than proprietary plants. Several reasons may offer insight as to why the disparity existed. The structure of a cooperatively owned and operated business may not be a valid reason; some of the top food processing businesses in the U. S. are cooperatives, such as Sunkist, Ocean Spray and Welch's.

Figure 23. Total cost per gallon breakdown by percentage



Moreover, some of the most efficient and well-run cheese plants and butter/powder plants throughout the U. S. are owned and operated by dairy cooperatives. Consequently, other explanations must be sought to offer some insight as to why cooperative plants were found to be less labor efficient and more costly on a unit basis than plants under different ownership.

Several reasons may help to address the lower labor productivity and higher unit costs experienced by cooperative plants. First, cooperative plants tend to be smaller than proprietary plants and captive plants. Although we have not specifically investigated the effect of plant size on labor productivity and plant costs per gallon, economic theory contends that larger plants realize economies of size. Second, cooperative plants tend to process more products and handle more products in their coolers. We propose that the more SKUs processed, the more complicated the logistics of changing processing lines, switching labels, and changing container sizes and types. We also contend that plants that stored a large number of SKUs in the cooler experience a decrease in cooler and load-out labor productivity because of the logistics involved in coordinating the storage and retrieval of a large number of products. These added complications would lead to lower labor productivity and higher labor costs per unit. Third, because the primary owners of a dairy cooperative are dairy farmers, raising equity capital to invest in new equipment and increased automation in fluid milk facilities can be difficult. This seems to be supported by the lower levels of satisfaction with plant and cooler facilities expressed by cooperative plant managers. Lastly, cooperatives typically undertake milk supply balancing functions in a given market for the economic benefit of their members, and performing this balancing function results in additional costs, and perhaps, less efficient use of labor and facilities.

NEURAL NETWORK MODELS

Introduction

Differences among plants based solely on type of plant ownership, as shown in the previous section, spawn questions about the effects of the factors on labor productivity and cost per gallon. For example, how much effect does increasing the number of SKUs processed have on labor productivity and cost per gallon? Does the magnitude of the factor effects differ by type of plant ownership? Traditional statistical methods are available to answer these type of questions, but such methods also have limitations, such as selecting an appropriate functional form and specifying a (parsimonious) model. Neural networks, a form of data mining, do not have these restrictions.

Neural network methods encompass a broad class of flexible nonlinear regression and discriminant models, data reduction models, and nonlinear dynamical systems. Precise (and disparate) definitions for neural networks abound, but most researchers who use this method of data analysis would agree that a neural network is a collection of many simple and highly interconnected processors or "neurons" that process information in parallel. The communication channels ("connections") that link the neurons carry numeric as opposed to symbolic data. The neurons operate only on their local data and on the inputs they receive via the connections.

Most neural networks have an input layer, an output layer, and an unspecified number of "hidden layers", ranging from one to many (Figure 24). The hidden layer is so named because it has no direct connection to the outside world. The function of the hidden layers is to make the associations between the inputs and the outputs. Each layer of neurons receives its input from the previous layer or, in the case of the input layer, from outside the network.

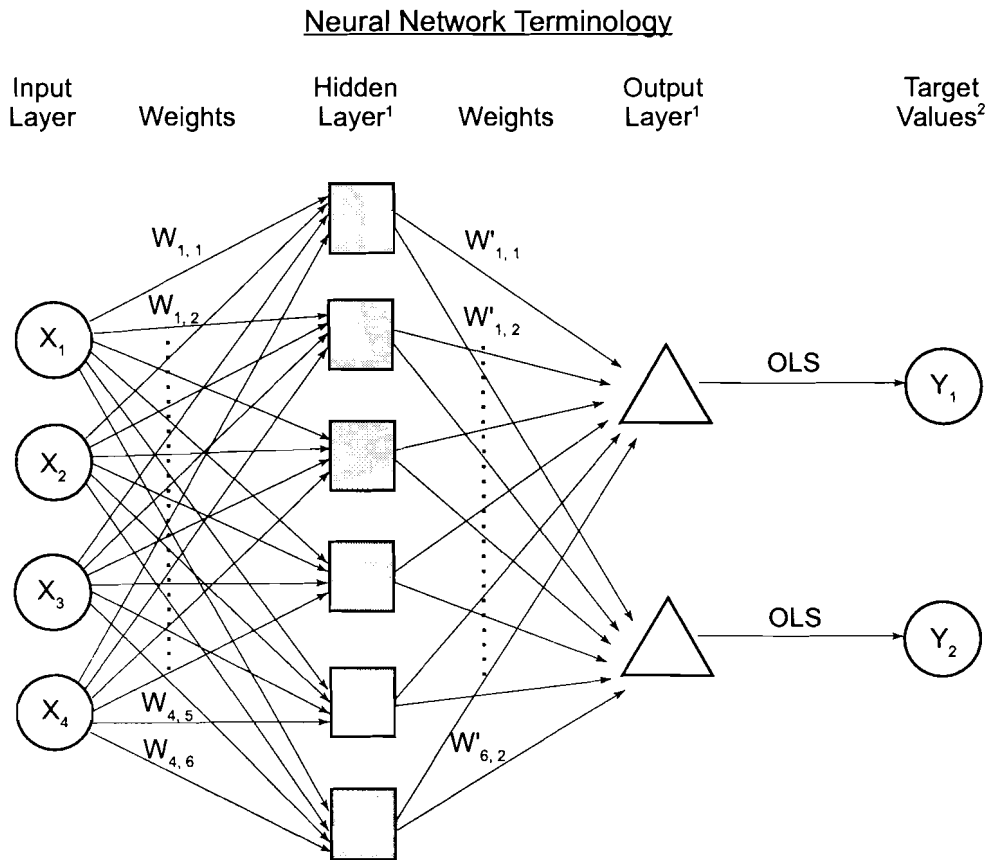
Neural networks "learn" from examples and can exhibit some capability for generalization beyond the training data. The learning in this sense is analogous to "estimation" in more traditional statistical analysis. Similarly, "training" data is analogous to "observed" data. Most neural networks have a training rule whereby the weights of connections are adjusted on the basis of data. The network learns (estimates) by adjusting the weights to minimize the sum of the squared error of the outputs (predicted values) relative to the target values (observed data). The schematic in Figure 24 may help to clarify the relationships of the various neural network components.

Although the name "neural networks" seems to imply a biological connection, neural networks are not limited to modeling biological phenomenon. Neural networks are useful for classification and function approximation problems which are tolerant of some imprecision, but to which strict rules cannot be easily applied. For example, neural networks are well-suited for pattern recognition, trend prediction, and image analysis. These applications may appear unrelated, but they all share the ability to make associations between known inputs and outputs.

Classification and Description

Neural network models are especially appealing when there is little knowledge about the form of the relationship between the independent and dependent variables. Part of

Figure 24. Conceptual framework of a 3-layer neural network with 4 input neurons, 6 hidden layer neurons, and 2 output neurons



¹ The hidden layer(s) and output layer contain activation functions which are usually sigmoidal or linear.

² Ordinary least squares (OLS) is typically used to fit the values generated by the output layer to the target values.

the reason for the flexibility of neural network models is explained by the hidden layer(s). Activation functions for the units in the hidden layer(s) are used to introduce nonlinearity into the network, making them less restrictive and more useful as universal approximators (25). The capability to represent nonlinearity makes neural networks with hidden layers powerful. Almost any nonlinear function can be used for the activation function although it must be differentiable for back propagation learning. Sigmoidal functions (i.e., logistic and Gaussian functions) are the most common choices for activation functions. Activation functions for the output units should be selected based on the distribution of the target values. For example, bounded activations functions are more useful when the target values have a bounded range.

Neural networks may be classified into two broad categories — feedforward and feedback. A feedforward network is such that a neurons' output does not depend on the output of subsequent neurons. Signals only flow in one direction, and outputs are dependent on only the signals incoming from the neurons in the previous layer. On the other hand, feedback networks have looping features built into the system.

Feedforward networks are a subset of the class of nonlinear regression and discrimination models. Feedforward networks with one hidden layer are closely related to projection pursuit regression. Many results from the statistical theory of nonlinear models apply directly to feedforward networks.

Neural Networks and Statistics

There is considerable overlap between the fields of neural networks and statistics. Many neural network models are similar or identical to popular statistical techniques such as generalized linear models and polynomial regression, especially when the emphasis is on prediction of complicated phenomena rather than on explanation (23, 24). Despite the overlap between statistical models and neural network models, the terminology prevalent in neural network discussion differs considerably from that used in statistics. Table 8 provides a brief list of corresponding terms.

With the tremendous number of tried-and-true statistical models available, there may be some question as to why neural network models would be used. Standard regression models start out with a specified functional form (e.g., linear, polynomial, logarithmic) which may include interaction terms in addition to the independent variables. Ordinary least squares (OLS) seeks to minimize the sum of the squared differences between the

Table 8. Corresponding terms between statistics and neural networks.

<u>Statistics Jargon</u>	<u>Neural Networks Jargon</u>
independent variable	input
predicted value	output
dependent variable	target (or training) value
residual	error
estimation	training, learning, or adaptation
parameter estimates	(synaptic) weights
observations	patterns
hold-out sample	test set
iteration	epoch
interpolation or extrapolation	generalization
prediction	forward propagation
computation of the error gradient for a feedforward network by use of derivatives	back propagation
a category of neural networks in which connections flow in one direction	feedforward network

regression line (or curve) and the data points. In other words, after the functional form is specified, OLS tries to find estimates for the model parameters that produce the best fit to the line or curve. With neural network models, a similar process is used with the exception of specifying a functional form; there are no assumptions concerning the form of the model. Simply put, neural network models let the data reveal the shape that best fits the data rather than forcing the data to fit a pre-specified shape. In general, regression analysis requires that the researcher theorize how a variable enters a model and guess as to which variables are relevant for the model. Neural network models do not require these tasks of the researcher. The network decides which variables are important and how best to use each relevant variable. Works by Cheng and Titterington (7) and Ripley (19) provide a more comprehensive discussion of neural networks viewed from a statistical perspective.

Speed of Calculation

Nonlinear regression algorithms can fit most neural network models orders of magnitude faster than the standard neural network algorithms. Part of the difference in speed of calculation has to do with data storage (23). Neural network algorithms are often designed for situations where the data are not stored, but each observation is available transiently in a real-time environment. In statistical applications, the data are usually stored and are repeatedly accessible so statistical algorithms can be faster and more stable than neural network algorithms. Many neural networks converge to a set of weights slowly or not at all, depending on the restrictions imposed by the operator.

Polynomial regression models are linear in the parameters, and, as a results, they can be fit quickly. However, numerical accuracy problems can result with fourth degree (or higher) polynomial models. Multiple layer neural networks with nonlinear activation functions are genuinely nonlinear in the parameters, and therefore take much more computer time to fit than polynomial models.

Neural Network Model of Fluid Milk Plants

Our objective was to obtain quantitative measures of the effects of various factors on labor productivity and cost per gallon. We used Windows Neural Network (WinNN), a Windows-based neural network simulator with back propogation learning to find the weights which best described the data set (9). We specified three layers for our neural network model – an input layer, one hidden layer, and an output layer. We selected 11 factors to serve as input neurons and 2 factors to serve as output neurons (Table 9). Three of the input neurons were used as identification inputs to distinguish captive plants, cooperative plants, and plants with unionized labor.

Set Up

WinNN accepts a variety of activation functions to transfer data from the hidden layer to the output layer (9). We selected logistic activation functions in the hidden layer and the output layer because bounded activations functions are more appropriate when the target values have a bounded range. The logistic activation function was described as

$$\text{act}(x) = (1 + e^{-x})^{-1}$$

Because we included both labor productivity and cost per gallon as outputs and used logistic activation functions, our model was the statistical equivalent of a multivariate

multiple nonlinear simultaneous regression model (23).

Normalizing (rescaling) input data is fairly common when working with multilayer neural network models. The reason is that data sets often contain numbers that are out of the effective range of the activation functions. The logistic activation functions in the hidden and output layers required that the target values fall within a meaningful range. We normalized the input data so that all of the elements fell between -3 and 3 and the output data such that all observations fell between 0 and 1.

Table 9. Inputs and outputs for neural network model

<u>Inputs</u>	<u>Outputs</u>
Plant size	Labor productivity
Captive plant	Plant cost per gallon
Cooperative plant	
Labor cost	
Unionization of workforce	
Plant capacity used	
Product in gallon and half-gallon containers	
Processing technology	
Cooler technology	
SKUs processed	
Product on pallets	

Another relatively common practice is to assign a small amount of error randomly to input data when training the network to help avoid local minima in the weight surface and to make the trained network less sensitive to changes in the input values. The assignment of random error also helps to avoid the problem of "inconsistent" data where two or more identical sets of inputs generate different outputs. We assigned a "noise" of 0.05 to the normalized input values.

The training of the network and associated adjustments of the weights necessitates specification of a convergence criterion. Although it is theoretically possible to specify an allowable error of zero, speed of convergence is adversely affected as the allowable error is reduced. We made a compromise between speed of convergence and accuracy of the solution weights when setting the convergence criteria. We specified that an acceptable solution was obtained when all of the output values were within 4% of their corresponding target values.

Results and Discussion of Neural Network Model

Model Plants

One of the challenges we encountered was to explain the results of a neural network application in meaningful economic terms. The solutions obtained from neural network models are in the form of synaptic weights. These weights are definitionally similar to parameter estimates in traditional statistical models, but neural network models do not quantify the effects of the inputs explicitly. Furthermore, interaction among the input variables and the basic nonlinearity of the activation functions introduce additional complications when interpreting the meaning of the weights.

Our approach to the problem of interpreting results was to train the network using monthly observations for each of the 35 plants. After obtaining the weights, we constructed model plants for the three types of plant ownership (Table 10). The model plants

Table 10. Numerical description of model plants by type of ownership

<u>Descriptor</u>	<u>Type of Ownership</u>		
	<u>Captive</u>	<u>Proprietary</u>	<u>Cooperative</u>
Plant size, x10 ⁶ gal/month	3.0	3.5	2.5
Labor cost, \$/hr	25	20	18
Plant capacity used, %	85	75	77
Product in gallon and half-gallon containers, %	91	84	72
Processing technology, score	8	7	7
Cooler technology, score	7.5	5.5	4.5
SKUs processed	40	165	180
Product on pallets, %	80	50	20

were based on profiles of actual plants, but none of the model plants duplicated an actual plant. Using the model plants as a guide, we built a test data set by varying each of the inputs listed in Table 10 by 10% (+ and -). We standardized the results to produce coefficients which indicated the impact of changing the input by one-half of a standard deviation (Table 11). This standardization process allowed us to draw conclusions about the relative importance of changing input variables over "equally likely" ranges of input variables. As such, the figures represented the expected change in labor productivity or plant cost per gallon for a small change in the input for each type of plant ownership. For example, a \$2.23 per hour increase labor cost in captive plants, a one-half standard deviation change, increased labor productivity by 18.89 gallons per hour and increased plant cost by 0.74¢ per gallon.

The exception to this type of interpretation of the results reported in Table 11 was the impact of non-unionized labor. All three model plants were constructed under the assumption of a unionized workforce. The figures reported in Table 11 for non-unionized workforce reflected the expected change in labor productivity and plant cost per gallon with a non-unionized workforce in place of the unionized workforce. For example, a non-unionized workforce was expected to increase labor productivity in captive plants by 15.05 gallons per hour and decrease plant cost by 0.49¢ per gallon.

Overview of Results

In general, the effects of each factor varied appreciably across type of plant ownership. Plant size, as measured by actual monthly processing volumes, had similar implications for all model plants — increasing plant size was predicted to increase labor productivity and decrease cost per gallon. Higher labor cost per hour was expected to increase labor productivity in all model plants but with an associated increase in cost per gallon. All model plants were predicted to be more productive and have lower costs without unionized labor. Increases in percent of products packaged in gallon and half-gallon containers and percent plant capacity utilization were predicted to increase labor productivity and decrease cost per gallon simultaneously. Plants with more advanced equipment in the processing and filling area had slightly higher labor productivity with little associated change

in cost per gallon. Plants with more advanced equipment in the cooler and load out area had significantly higher labor productivity and slightly lower in costs per gallon. The large variation in use of pallets and SKUs processed helped to amplify their effects on labor productivity and cost per gallon. More intensive use of pallets was predicted to increase labor productivity and decrease cost per gallon, but processing more SKUs was predicted to decrease labor productivity and increase plant cost per gallon.

Although most of the coefficients followed what intuition would suggest, a few of the results appeared counter-intuitive and invited discussion. One such unexpected result was the estimated effect of labor cost on cost per gallon. Hiring plant labor at \$2.23 per hour more than the model plants increased labor productivity but had a small impact on cost per gallon. A \$2.23 per hour increase in labor cost was expected to increase cost per gallon in captive plants by 0.74¢ per gallon, by 1.13¢ per gallon in proprietary plants, and by 1.00¢ per gallon in cooperative plants. It is likely that the neural network discerned some other subtle and hidden interactions between wages, labor productivity, and cost

Table 11. Predicted performance measures and calculated coefficients for various plant descriptors by type of ownership¹

Descriptor	Type of Ownership					
	Captive		Proprietary		Cooperative	
	Productivity (gal/hr)	Cost (¢/gal)	Productivity (gal/hr)	Cost (¢/gal)	Productivity (gal/hr)	Cost (¢/gal)
Plant performance	300.07	13.05	153.19	18.15	125.58	20.74
Plant size, 0.66 million gal/month	12.19	-0.02	7.40	-0.03	4.42	-0.02
Labor cost, \$2.23/hr	18.89	0.74	11.50	1.13	6.87	1.00
Non-unionized labor ²	15.05	-0.49	9.88	-0.71	5.99	-0.61
Plant capacity used, 5.3%	7.42	-0.23	4.50	-0.36	2.69	-0.31
Product in gallon and						
half-gallon containers, 5.4%	0.36	-0.31	0.22	-0.47	0.13	-0.42
Processing technology, 0.66 score	1.31	-0.01	0.79	-0.01	0.47	-0.01
Cooler technology, 1.33 score	5.67	-0.03	3.43	-0.05	2.05	-0.04
SKUs processed, 50 SKUs	-7.78	0.32	-4.71	0.49	-2.81	0.43
Product on pallets, 21.4%	11.18	-0.54	6.80	-0.82	4.05	-0.73

¹Each coefficient represents the expected change in labor productivity or plant cost per gallon for the specified change in the input for each type of plant ownership. The specified changes reflect a one-half standard deviation increase in the input value. For example, a \$2.23 per hour increase in labor cost increased labor productivity by 18.89 gallons per hour and increased plant cost by 0.74¢ per gallon in captive plants, increased labor productivity by 11.50 gallons per hour and increased plant cost by 1.13¢ per gallon in proprietary plants, and increased labor productivity by 6.87 gallons per hour and increased plant cost by 1.00¢ per gallon in cooperative plants.

²All model plants were constructed with unionized labor. The reported number reflects the impact of non-unionized labor on labor productivity and plant cost per gallon. For example, the effect of a non-unionized workforce on captive plants was an increase of 15.05 gallons per hour in labor productivity and a decrease of 0.49¢ per gallon in plant cost. Similar results were obtained for proprietary and cooperative plants. These results were not induced by a change in cost of labor per hour. Simply put, if all factors listed in Table 11 were held constant, including labor cost per hour, then a nonunionized workforce would increase labor productivity and decrease cost per gallon.

per gallon such that cost per gallon did not increase as much as one might expect naively. A second unexpected result was the minor effect of packaging more product in gallon and half-gallon containers. Although the results indicated that more volume packaged in gallon and half-gallon containers decreased cost per gallon appreciably, the associated increase in labor productivity was negligible. Perhaps the neural network detected some interactions between plant capacity utilization, percentage of volume packaged in gallon and half-gallon containers, and labor productivity such that labor productivity did not increase as one might anticipate.

Two other factors gave results which were not unexpected but warrant mentioning nonetheless. The results suggested that plants that process a large number of SKUs were adversely affected by their diverse product mix. Not only was cost per gallon higher in the model plants that processed a larger number of SKUs, but labor productivity was lower as well. The model captive plant, which had a very narrow product mix, was affected more than the proprietary plant or cooperative plant. Specifically, by adding another 50 SKUs to the product mix of the captive plant, labor productivity decreased by 7.8 gallons per hour and cost increased by 0.32¢ per gallon.

A second result suggested that plants without unionized labor were more productive and had lower cost per gallon than plants with unionized labor. Unionized labor has been criticized for defining narrow job descriptions, imposing jurisdictional limitations, developing work rules, and reducing workforce flexibility, all of which would lead to decreased labor productivity and increased cost per gallon. However, labor unions also lead to lower job turnover rates, to more experienced and skilled workers, and to more stability and order in the work environment. On the management side, unions may compel company executives to become better managers. Although the negative effects of unionized labor are probably true and are highly publicized, the more positive aspects of labor unions are not well-known. We expected that the effect of unionized labor encompassed a combination of both the positive and the negative effects. However, the results indicated that the negative effects apparently outweighed the positive effects in this study. Captive plants realized the largest gains in labor productivity by using non-unionized labor (15.1 gallons per hour), and proprietary plants realized the largest decrease in cost per gallon (0.71 ¢ per gallon).

Factor Effects and Type of Plant Ownership

We recognize that the "model" cooperative plant described in Table 10 had the lowest values for all input variables except SKUs processed. These values were chosen in an attempt to represent the profile of the cooperative plants in the study accurately. However, without exception, changes in the various inputs impacted labor productivity in cooperative plants in the same direction but with considerably less magnitude than what was predicted for captive or proprietary plants. From Table 11, increasing plant size by 0.66 million gallons per month over and above that specified for the model plants was predicted to increase labor productivity by 12.2 gallons per hour for captive plants, 7.4 gallons per hour in proprietary plants, and only 4.4 gallons per hour in cooperative plants. Hiring plant labor at \$2.23 per hour more than that specified for model plants was predicted to increase labor productivity by 18.9 gallons per hour in captive plants, by 11.5 gallons per hour in proprietary plants, and only 6.9 gallons per hour in cooperative plants. A 5.3% increase in the percentage of plant capacity utilized was predicted to increase

labor productivity by 7.4 gallons per hour in captive plants, 4.5 gallons per hour in proprietary plants, and only 2.7 gallons per hour in cooperative plants.

Similar comparisons of the coefficients for cost per gallon did not reveal the same systematic differences. Furthermore, the coefficients appeared to be more similar for proprietary and cooperative plants. For example, replacing unionized labor with non-unionized labor was predicted to decrease cost per gallon by 0.49¢ per gallon in captive plants, 0.71¢ per gallon in proprietary plants, and 0.61¢ per gallon in cooperative plants. Increasing plant capacity utilization and the percent of product packaged in gallon and half-gallon containers were also expected to have the larger impacts on cost per gallon for proprietary plants and cooperative plants than for captive plants.

Cooperative Plant Performance Under A Captive Plant Profile

The results presented in Table 11 generate questions concerning the performance of cooperative plants relative to captive plants and proprietary plants. We specified a second model cooperative plant with characteristics identical to those of the captive plant with the exception of type of ownership (Table 10). Although none of the cooperative plants in the study were similar operationally to a captive plant, the exercise was revealing (Table 12). Efficiency measures for the model cooperative plant improved remarkably. Labor productivity increased by 37.8%, and plant cost per gallon decreased by 8.9%. Despite the impressive gains in plant performance, the model cooperative plant did not match the efficiency measures predicted for the model captive plant.

Differences in the effects for the individual coefficients also persisted. When comparing the calculated coefficients, the captive plant was predicted to realize larger changes in labor productivity than the cooperative plant for identical changes in the inputs. For example, increasing plant size by 0.66 million gallons processed per month was predicted to increase labor productivity by 12.2 gallons per hour in the captive plant, but by only 9.1 gallons per hour in the cooperative plant. Furthermore, a \$2.23 increase in labor cost per hour was expected to increase labor productivity by 18.9 and 14.2 gallons per hour in the captive plant and the cooperative plant, respectively.

The same systematic differences were not evident when comparing the coefficients for cost per gallon. The increase of \$2.23 in labor cost per hour was expected to increase cost per gallon by 0.74¢ per gallon and 0.97¢ per gallon in the captive plant and the cooperative plant, respectively. Increasing plant capacity utilization by 5.53% decreased plant cost by 0.23 and 0.31¢ per gallon in the captive plant and the cooperative plant, respectively. We expect that the differences in the effects of the inputs for the two nearly identical plants were attributable to differences in immeasurable plant characteristics, such as quality of workforce, and operations and business management. It is also likely that different business objectives for cooperatively-owned and privately-owned plants are contributing factors.

Table 12. Predicted performance measures and calculated coefficients for various plant descriptors for a cooperative plant under captive plant profile¹

Descriptor	Type of Ownership			
	Captive		Cooperative	
	Productivity (gal/hr)	Cost (¢/gal)	Productivity (gal/hr)	Cost (¢/gal)
Plant performance	300.07	13.05	173.07	18.90
Plant size, 0.66 million gal/month	12.19	-0.02	9.13	-0.02
Labor cost, \$2.23/hr	18.89	0.74	14.18	0.97
Non-unionized labor ²	15.05	-0.49	12.06	-0.60
Plant capacity used, 5.3%	7.42	-0.23	5.56	-0.31
Product in gallon and half-gallon containers, 5.4%	0.36	-0.31	0.27	-0.41
Processing technology, 0.66 score	1.31	-0.01	0.98	-0.01
Cooler technology, 1.33 score	5.67	-0.03	4.23	-0.05
SKUs processed, 50 SKUs	-7.78	0.32	-5.82	0.49
Product on pallets, 21.4%	11.18	-0.54	8.39	-0.82

¹Each coefficient represents the expected change in labor productivity or plant cost per gallon for the specified change in the input for captive plant ownership and cooperative plant ownership. The specified changes reflect a one-half standard deviation increase in the input value. For example, a \$2.23 per hour increase in labor cost increased labor productivity by 18.89 gallons per hour and increased plant cost by 0.74¢ per gallon in captive plants and increased labor productivity by 6.87 gallons per hour and increased plant cost by 1.00¢ per gallon in cooperative plants.

²Both model plants were constructed with unionized labor. The reported number reflects the impact of non-unionized labor on labor productivity and plant cost per gallon. For example, the effect of a non-unionized workforce on captive plants was an increase of 15.05 gallons per hour in labor productivity and a decrease of 0.49¢ per gallon in plant cost.

CONCLUSION

Labor productivity and plant operating costs are determined in a complex system of interrelated variables. Input variables undoubtedly have complex and nonlinear relationships with the output variables, and the levels of some input variables impact the importance of others. For example, labor cost per hour impacts labor productivity and cost per gallon, but labor cost per hour is also likely to determine the degree of mechanization in labor-intensive areas of the plant and the extent to which the plant's capacity is utilized. Labor cost per hour may also play a role in determining the extent of subsequent investments in plant expansions and renovations.

Traditional regression analysis requires the researcher to explicitly specify the functional form of the model and interactions among the variables prior to the analysis. Neural network methods use a "data mining" approach to numerical analysis and rely on observations to reveal these intricacies. While the input variable weights are not as directly usable as their counterparts from regression analysis, they capture much more of the potential complexities hidden in a system such as fluid milk processing operations.

Although the research revealed a number of differences in plant profiles across type of ownership, the neural network model showed that only a subset of those characteristics had any meaningful impact on plant labor productivity or cost per gallon for equally likely changes in the various inputs. For example, cooperatives and proprietary plants packaged a smaller percentage of product in gallon and half-gallon containers than captive plants, but the predicted effect on labor productivity and cost per gallon of doing so was small.

The results also showed that differential effects were predicted for some characteristics and were dependent on the type of plant ownership. For example, the predicted effect of increasing plant size by an equal amount for the three types of ownership increased labor productivity in all plants but by different amounts with the cooperative plant realizing the smallest gains. This result is particularly intriguing considering that a 0.66 million gallon increase in processing capacity represented a 26% increase in plant size for the model cooperative plant and only a 19% and 22% increase in plant size for proprietary plants and captive plants, respectively. Furthermore, when a model cooperative plant was constructed using a captive plant profile excepting of type of ownership, the predicted labor productivity and cost per gallon did not match those predicted for the captive plant. This suggests that cooperative plants are deleteriously impacted by variables not explicitly included in the analysis.

Opportunities for cooperative plants to decrease plant cost per gallon and increase labor productivity were evident from the analysis. Increasing the percentage of plant capacity utilized, decreasing the number of SKUs processed, increasing the percentage of product handled on pallets, and de-unionizing plant labor stand out as a potential means of simultaneously increasing labor productivity and decreasing cost per gallon. Investments in the cooler area may also increase labor productivity without affecting cost per gallon adversely.

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