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## OPTIMUM NUMBER AND LOCATION OF MANUFACTURING MILK PLANTS TO MINIMIZE MARKETING COSTS

Robert L. Beck and J. Don Goodin

Historically, the manufacturing milk sector has been treated as the residual segment of the dairy industry. Milk for fluid consumption has always had first claim on Grade A milk production and any excess milk has been available for manufactured products. The pricing system for milk reflects the dependence on manufactured products as the residual outlet for excess milk. On-farm quality standards for production are lower for manufacturing milk and thus the farm price is lower. The proportion of whole milk produced as manufacturing grade milk is declining as producers shift to Grade A production. The decline in supply has been accelerated to some extent also by the upgrading of on-farm quality standards in recent years. Many small producers left the industry rather than make the necessary expenditures to upgrade on-farm facilities. In addition, the movement of Grade A milk into the expanding fluid milk markets in the South has resulted in a declining quantity of excess Grade A milk. Consequently, there is excess processing capacity in the manufacturing milk sector.

The residual nature of the manufacturing milk sector has posed problems for manufacturing milk processors. The variability of the supply milk available for manufactured products, caused by the fluid milk market having first claim on Grade A milk, affects plant operating efficiency. Manufacturing plants have not been very innovative because of their declining and variable supply of raw milk.

Recent locational studies of the dairy industry by Ashley and Alexander, Boehm and Conner, Buccola and Conner, and Hinton indicate a potential for increased efficiency in the market system through coordination of raw milk assembly and product processing.

The manufacturing milk industry in Kentucky currently faces some critical adjustment decisions. After a period of expansion from the 1930s to the early 1950s, it now has a declining supply of raw milk and excess processing capacity. Because of the adjustments taking place and the need by management for decision-making information, a study was initiated to determine the number and location of manufacturing plants that would minimize the total assembly and processing costs of manufac-

ting the milk into finished products. The results of that study by Goodin are reported herein.

### RESEARCH PROCEDURES.

#### Method of Solution

During the past two decades, substantial research effort has been directed toward the determination of minimum cost location of various types of economic activity. The model developed by Stollsteimer continues to be the most widely used complete enumeration method for analyzing plant location problems. Because the solution calls for the complete enumeration of all possible combinations of locations, the feasibility of its use diminishes as the number of potential plant sites increases. Extensions of the Stollsteimer model, however, have enabled additional realism to be incorporated into applied research.

A modification of the linear programming transportation algorithm, the Grange method (Woolsey and Swanson), was used to locate the optimum number of manufacturing milk plants in Kentucky and simultaneously minimize assembly costs. The procedure seeks the best one-plant system, the best two-plant system, etc., up to a specific number of plants designated by the user. Each successive solution is based on the previous solution, i.e., the procedure selects the best  $n + 1$ -plant system, given the previous  $n$ -plant solution. For our study, plants were added until total plant capacity could handle the supply of milk available for manufactured products.

Given the optimum plant locations, the procedure permits the identification of least-cost movement patterns from supply areas to processing centers to minimize assembly and processing costs.

Data needed are: (1) locations of plant sites (processing centers), (2) transportation cost from production to processing centers, (3) processing cost functions, (4) volumes of milk available from various supply centers, and (5) plant capacities. The supply of milk available includes both the manufacturing grade milk and excess Grade A milk produced in the state.

The procedure allows the retention of the current structure of the market as a framework

for the analysis through the use of present plant locations as processing centers and current individual plant capacities. This approach adds a dimension of reality to the results.

### Milk Sources

The county was used as the basic unit for identifying sources of raw milk. Counties were identified in which either manufacturing or Grade A producers were operating. An estimate of the amount of milk available from each county included the manufacturing grade milk and excess Grade A. The movement of any of the state's milk supply into markets in adjoining states was assumed to be offset by the inflow of milk from those states. Also, because cooperatives coordinate the movement of 90 to 95 percent of all Grade A milk from the farm to processing centers, the excess Grade A milk was assumed to move directly from each county to the processing centers.

Ninety-nine counties were identified as supply centers with a total volume of 1,129 million pounds of milk available for manufactured products in 1977.

### Processing Centers

At the time of the study, 14 manufacturing milk plants were processing hard dairy products. These plants, located in the central milk-producing area of the state, were identified as processing centers for the study. Operating capacity figures were also available. Use of present locations and actual plant capacities was believed to add a degree of acceptability to the results.

### Assembly Cost Function

Assembly costs include the costs of all functions from the loading of milk at the farm to the unloading of the milk at the processing center. A hauling cost function developed by Boehm and Conner was used. The function was developed primarily from engineering cost data and was adjusted for inflation. The following cost function was used to estimate assembly costs:

$$SHC = \$0.22 + (\$0.002) \quad (SHM)$$

where

SHC = cost in dollars per hundredweight milk, 40,000-lb tanker, loaded,

SHM = short haul miles, one way.

This function includes the return-empty costs in the loaded milk costs. The intercept in the

function includes the cost of route assembly as well as other actual fixed costs.

Use of this cost function required road mileages from each source to destinations. Mileages were computed from each supply center to each processing center via the shortest all-weather road. Application of these mileage estimates to the cost function gave the cost of transporting milk from each of the counties to processing plants.

### Processing Cost Functions

The processing cost functions were likewise adapted from the Boehm and Conner study. Functions were updated to account for the inflationary pressures on processing costs by applying an annual inflation rate of 5 percent.

The adjusted total linear cost functions are:

$$(1) \quad TCC = \$561,828 + \$0.58347 (q)$$

$$(2) \quad TCP = \$657,924 + \$0.527899 (q)$$

where

TCC = total cheese processing cost (dollars/year),

TCP = total butter/powder processing cost (dollars/year),

q = quantity of raw milk processed (cwt/year).

## RESULTS

The optimum number and location of plants to minimize total cost of assembling and processing the supply of milk used for manufactured products in Kentucky vary under different sets of conditions and/or assumptions.

In Solution I, a linear programming transportation model was used to determine the assignment of milk when all of the plants currently operating in the state were kept in the system. Only assembly costs were minimized. However, the system had excess plant capacity with only 57 percent of total capacity being utilized. The amount of excess capacity indicates that a cost saving could be achieved by a system of fewer plants.

In Solution II, the Grange method was used to locate the optimum number of plants needed to process the current supply of milk with the plants operating at 85 percent of capacity. Because of seasonal variations in the supply of milk, it is not practical to expect a plant to operate year-around at full capacity. Thus, in all solutions except Solution I, the optimum was based on 85 percent of actual operating capacity.

Because of declining production of manufacturing milk and the expanding market for

fluid milk in the South, a decline in milk available for manufactured products was assumed to continue. Solution III was based on a 10 percent reduction in the supply and Solution IV

was based on a 20 percent reduction in supply. Table 1 summarizes the results obtained from each solution. Figures 1-4 show the optimum location and number of plants for each solution.

TABLE 1. PLANT NUMBERS, PROCESSING COSTS, TRANSPORTATION COSTS, AND TOTAL COSTS FOR DIFFERENT LEVELS OF SUPPLY, KENTUCKY'S MANUFACTURING MILK INDUSTRY

| Solution                                     | Number Plants | Total Annual Processing Cost | Total Annual Transportation Cost | Total Annual Cost |
|--|---------------|------------------------------|----------------------------------|-------------------|
| Solution I                                   | 14            | \$14,461,011                 | \$3,070,933                      | \$17,531,944      |
| Solution II<br>(Current Supply)              | 6             | \$ 9,948,829                 | \$3,680,369                      | \$13,629,198      |
| Solution III<br>(10% Reduction<br>in Supply) | 6             | \$ 9,290,337                 | \$3,140,723                      | \$12,431,060      |
| Solution IV<br>(20% Reduction<br>in Supply)  | 4             | \$ 7,508,188                 | \$3,057,273                      | \$10,565,461      |

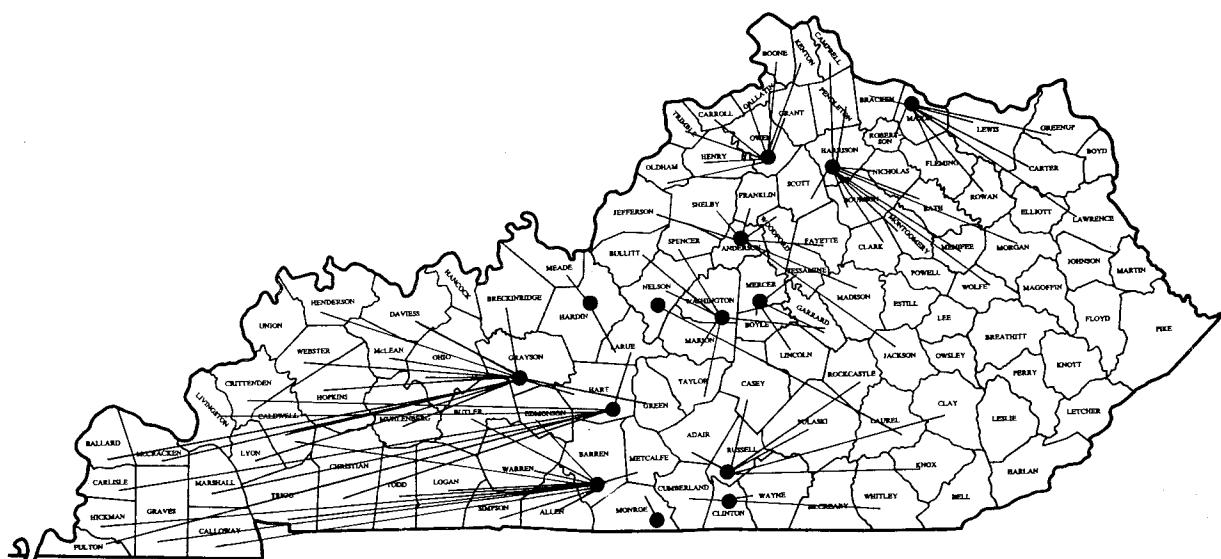


FIGURE 1. SOLUTION I: LEAST-COST ASSEMBLY, MILK FOR MANUFACTURED PRODUCTS, KENTUCKY, 1977

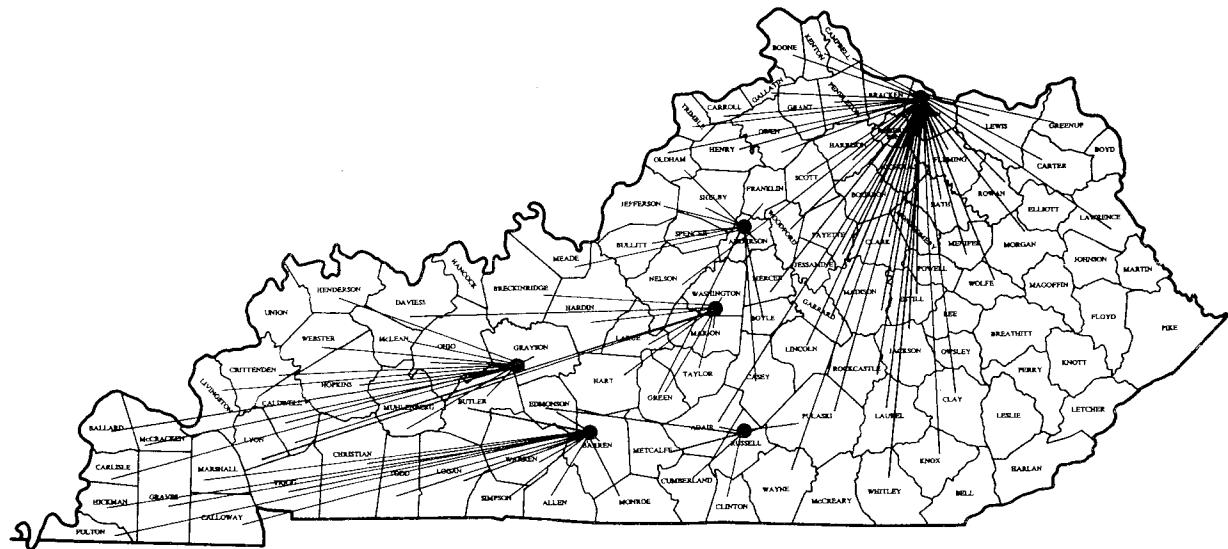


FIGURE 2. SOLUTION II: OPTIMUM PLANT LOCATIONS AND SOURCES OF MILK FOR MANUFACTURED PRODUCTS, CURRENT SUPPLY, KENTUCKY, 1977

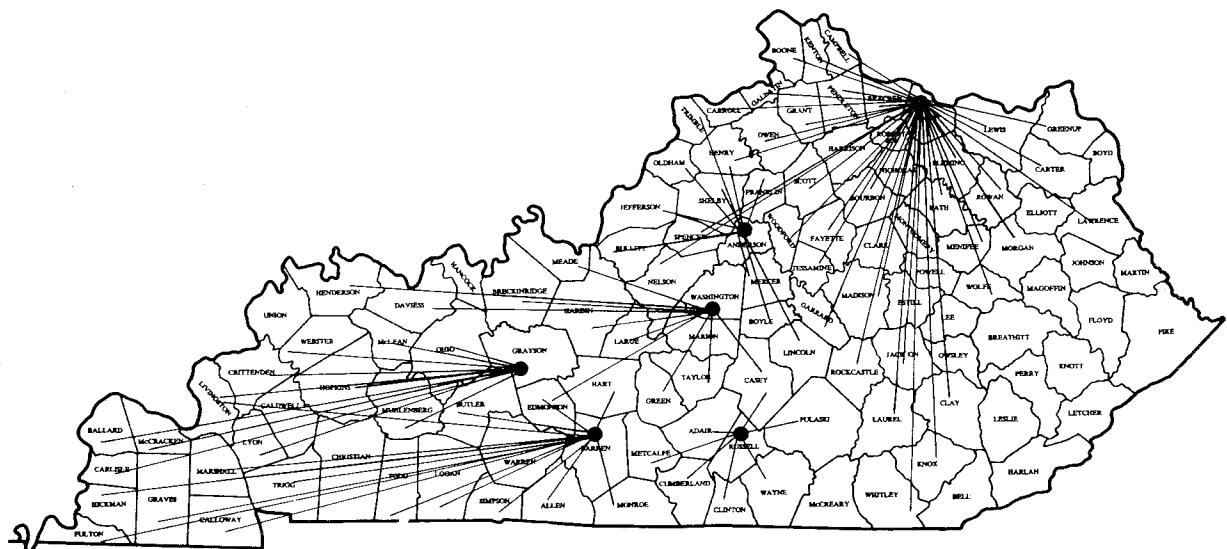


FIGURE 3. SOLUTION III: OPTIMUM PLANT LOCATIONS AND SOURCES OF MILK FOR MANUFACTURED PRODUCTS, 10% REDUCTION IN MILK SUPPLY, KENTUCKY

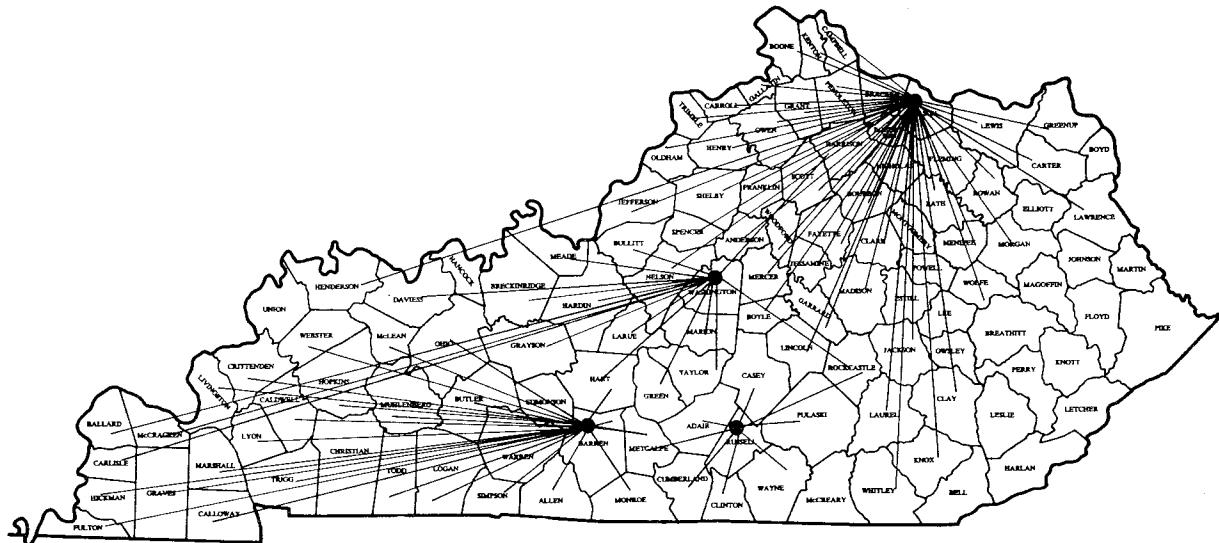


FIGURE 4. SOLUTION IV: OPTIMUM PLANT LOCATIONS AND SOURCES OF MILK FOR MANUFACTURED PRODUCTS, 20% REDUCTION IN MILK SUPPLY, KENTUCKY

## CONCLUSIONS AND IMPLICATIONS

The findings of this study agree with the conclusions of Boehm and Conner, Buccola and Conner, Hinton, and others who found that significant economies appear to be associated with the coordination of milk assembly and processing. In general, the results show that movement toward fewer manufacturing facilities would result in substantial cost reductions (Table 1). Additionally, the high proportion of cost reductions attributable to the processing sector indicates a potential for achieving economies of scale in processing while eliminating some of the excess capacity in the system.

Although results of the study may be useful to managers involved in short-run, day-to-day decisions, the long-run adjustments necessary to achieve an optimum system are crucial and have potentially far-reaching effects on the industry. The likelihood of these adjustments occurring may be questioned, but there are noticeable trends in the state's dairy industry which, if continued, will not only increase the probability of their occurrence but will tend to shorten the adjustment period.

One major trend is the changed role of cooperatives in the procurement and management of the supply of milk available for manufactured dairy products. The least-cost solutions identified clearly require a high degree of coordination in the allocation and movement of milk from supply sources to processing centers. Cooperatives are increasingly assuming that coordinating role. Cooper-

atives have historically taken the responsibility of disposal of excess Grade A milk in the market. In recent years they have become more aggressive in organizing manufacturing milk producers and thus gaining control over that portion of the milk supply also. Control of the milk supply by cooperatives is likely to have a greater impact on the speed with which adjustments are made than any other single factor involved. Thus, cooperatives are in a position to effect changes and adjustments indicated by this study through (1) the ownership and operation of product processing plants and/or (2) the coordination and management of the total supply of milk available for use in manufactured dairy products. Cooperatives are currently involved in both types of activities. Continued and increased involvement will tend to hasten the adjustment process.

Some significance should be attached to the incorporation of current plant capacities and locations into the analysis. There are several reasons for retaining the current structure as a framework for the analysis: (1) it tends to add a real-world dimension to the results, (2) any least-cost location study that suggests new, large facilities located at neutral points only imparts a certain degree of impracticality because adjustments are made from current structure rather than from point zero, and (3) manufacturing plants have historically been located near the source of supply because of the cost benefits of shipping finished products that are less bulky than milk. Any new structure would be likely to locate processing facilities similarly with respect to the milk supply.

Finally, Solutions III and IV inject a long-run time frame into the analysis by the assumption of a 10 percent and 20 percent reduction in supply, respectively. For reasons dis-

cussed heretofore, processors of manufactured dairy products will continue to face a declining supply situation.

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