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A STUDY OF THE OPTIMUM CAPACITY OF A FLUID MILK PROCESSING PLANT

A THESIS

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by

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A STUDY OF THE OPTIMUM CAPACITY OF A FLUID MILK PROCESSING PLANT

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SUMMARY

The purpose of this study was to develop a general mathematical model that could be used for determining the optimum plant capacity of a milk processing installation. The criterion for optimum capacity was per cent return on investment. The primary aim throughout the thesis was to develop the requirement of profitability into a practical and workable expression.

Initially, the fluid milk processing operation was broken down into its major elements of sales, expenses and investments. An analysis of these various segments was made and where necessary, these segments were further reduced to their more basic components. Each element was formulated into a mathematical expression that was the function of a single, common variable. This variable represented some value of plant capacity in gallons of milk processed per day. When all the elemental expressions of sales, expenses and investments were developed and stated as a function of plant capacity, they were consoliated into a per cent return on investment equation for the fluid milk industry.

Of course, it was not possible to formulate the expression of per cent return on investment to such a degree that it would be ready for immediate use for any condition or situation. Constants used in the various relationships in the formula must satisfy the specific market

conditions, individual manufacturing needs and varied managerial policies. Thus it was necessary to define the operating characteristics of the enterprise, i.e. type of machinery, packaging methods and market conditions. With these conditions established, it was a relatively easy matter to find the appropriate values of constants.

Various graphical and tabular examples are provided. Some of the data contained in these figures and tables are used to illustrate the practical values the constants may assume. Finally, a hypothetical milk plant proposal was presented to help provide a more comprehensive understanding of the method of plant site selection based on per cent return on investment.

CHAPTER I

GENERAL SURVEY OF MILK INDUSTRY IN THE UNITED STATES

The history of dairying goes back many centuries (1). Mention of milk and butter is made in Hindu writings of 2,000 B. C. There are numerous references to cattle, milk, butter and cheese in the Old Testament. Not only was the milk of cows used for human food, but sheep, goats, camels and other animals were kept for this purpose. Even today people in many parts of the world depend upon these animals to supply them with their basic food needs.

The pattern of the dairy industry from ancient times to the eighteenth century changed little. It consisted of a cow or some milk producing animal for each family. When excess milk was produced it was made into butter and cheese.

The dairy industry in America began when cows arrived with the Jamestown colonists in early 1600. Cows were of great importance to the welfare of the colonists because they were a dependable source of food. Until the beginning of the factory system the family cow persisted, even in some of the larger towns of early America. With the growth of cities and the separation of the city dweller from the farm, the city dweller became less self-sufficient, and large herds of dairy cows were developed to supply fresh milk to the cities and towns. As the herds continued to grow, it became increasingly difficult for the farmer to produce the milk and also prepare it for the market. More stringent health standards and consumer demand for better service and milk of a higher quality finally forced the farmer to become a milk producer only. By 1900 this separation in the United States between milk producer and milk processor had become well established.

Since 1900 the dairy industry has grown into one of the largest and most important industries in the United States. In 1955 the total value of all dairy products sold was approximately nine billion dollars (2). The industry is highly diversified with a method of collection, transportation, processing and distribution which has made the United States the leading dairying country in the world.

The scope of the industry is far reaching. Including those in associated and allied industries and the families of employees, it has been estimated that ten million people are dependent upon the dairy industry for their livelihood (3). This country has some 50,000 fluid milk distributors and about 40,000 processing plants. These plants prepare milk, butter, cheese, ice cream and other milk products for consumption. Over 250,000 workers are employed by these distribution and processing firms.

Market milk, the term used when referring to milk delivered to the consumer in liquid form, is the most important product of the dairy industry. There are more plants processing market milk than any other dairy product. Approximately one-third of all the milk produced in this country is used for direct consumption in its normal liquid state. Probably the most important reason for placing fluid milk first in importance, aside from its food value, is that it brings the highest price on the market. Though the price varies in different parts of the country, it is always higher than that paid for the milk used for butter, cheese, ice cream and other manufactured products.

Per capita consumption of dairy products from 1900 through the late thirties, although showing a yearly fluctuation, demonstrated no great change in trend (4). An uptrend appeared in the early forties, probably reflecting scarcities in other foods, such as meats and certain beverages. The peak was reached in 1945, after which consumption fell for a number of years and then remained fairly constant from 1948 to 1954. There has been some upturn in the past three years.

Fresh whole milk, which normally comprises about three quarters of the retail weight of all dairy products, has essentially followed the overall consumption trend. Despite fluctuation in the purchasing power of consumers, per capita consumption of milk has remained relatively constant. Increases in total consumption depend primarily on population growth and secondly on gains in the general standard of living.

This study is not to any great extent concerned with the detailed engineering phases of the market milk industry. However, it may be well to review the entire operation of a typical fluid milk processing installation. The scope of activities of many processing plants, especially the larger firms, consists of more than the immediate plant operations and delivery of the milk to the customer. The initial work, in many cases, begins on the farm and ends when the customer becomes a regular purchaser. The processor must observe and inspect the methods and practices of the farmers and advise them how to produce a more suitable product. Also, to insure continuous customer satisfaction, methods of processing, packaging and delivery must be constantly surveyed and all faults promptly corrected.

Many of the larger processing companies maintain their own milk collection systems, while the smaller firms generally rely upon raw milk carriers to supply them with their daily milk requirements. But regardless of who moves the milk from the "shed" collecting stations to the plant, it will arrive for processing in either the familiar 40-quart milk can or more likely in insulated stainless-steel tank trucks. It is not unusual for milk to be transported daily by these trucks for distances up to 300 miles from farm to city. Movement of milk by railway is steadily declining in the United States.

The processing of fluid milk involves *receiving*, clarification, homogenization, pasteurization, cooling, bottling or packaging, capping or sealing and finally delivery to the customer (5).

Receiving: When milk is initially received at the processing plant, three separate operations are performed upon it, namely: grading, weighing and sampling. It is graded for any abnormal colors or flavors and in addition, periodic tests are made for temperature, sediment and bacteria. When milk is below standard, it is excluded from the acceptable supply. The milk is weighed and a sample is taken to determine its butterfat content. The weighing and butterfat sampling is important, for the price paid the farmer is based upon the weight and butterfat content of the milk. The milk is next moved or pumped from the receiving tank to a cooler and then to a storage tank. It is now ready for clarification.

Clarification: The purpose of clarification is to remove foreign material and sediment from the milk. This is *accomplished* by a clarifier machine, which uses centrifugal means to force heavier-than-milk material to accumulate at the outermost part of its rapidly revolving bowl.

Homogenization: If the milk is to be homogenized, it goes from the clarifier to the homogenizer, passing through a pre-heater, which elevates its temperature to 130° F. The homogenizer is a machine which is capable of exerting pressure up to 3,000 pounds per square inch upon the milk. The purpose of this pressure is to reduce the size of the butterfat globules to approximately one-eighth of their former diameter, thereby preventing cream formatio in the milk. This results in a final product with a more uniformly creamy taste. The familiar milk - cream separation line also disappears after milk is homogenized.

Pasteurization: Following clarification or homogenization, the milk is pasteurized. Pasteurization can be accomplished by using any one of three methods: by heating the milk to 142° F and holding it at that temperature for 20 to 30 minutes; by heating it to 160° F and holding it at that temperature for a short time (about 15 seconds); or by exposing the milk to bacteria destroying rays which kill the bacteria as the fluid flows in a thin film over the exposed surface. The first two methods are the ones most commonly used today, with the high temperature especially popular with large capacity installations.

The principal reason for pasteurization is to provide a health safeguard for the public. The temperatures used are sufficient to destroy all harmful bacteria, especially the tuberculosis organisms, while the flavor of the milk is virtually unchanged.

Cooling: Immediately after pasteurization the milk is cooled to 50° F or lower and is ready to be placed into its final container.

Bottling or packaging: If the final milk containers are glass, the bottles are washed and sterilized and conveyed to the filler where the milk is either gravity or force fed into them. In the paper container operation, the procedure is essentially the same as with the bottles with the exception of washing and sterilization, which of course is unnecessary. One type of paper container comes into the milk plant flat and is waxed, formed and filled by a special paper machine.

Other types of containers are bought formed and ready for filling. Plant capacity, dealer preference and needs will dictate the packaging method used. After capping or sealing, the milk is moved into the cold storage rooms to await truck loading early the next morning.

Delivery: The final phase of the milk processing operation is the delivery of the product to the consumer. While daylight deliveries prevail in some areas, generally speaking milkmen are the early risers. In many cases, the milkman must pick up empty milk bottles, collect bills and in addition, on wholesale routes, collect and return leftover milk and other dairy products to the plant. Every effort is made to place the milk in the hands of the consumer in the freshest condition. Ice or other means of refrigeration is used during transit to insure that products of the highest quality are delivered. Few other foods are handled with such attention to freshness, wholesomeness and sanitation.

The future of the market milk industry appears to be well established. There will be a steady but not spectacular increase in total production, the output following the total consumption increase due to the rising population in the United States. Plants will tend to increase in production capacity, with smaller independent firms being taken over more and more by national concerns. Since milk processing is so well adapted to a continuous flow operation, automation will continue to make inroads into the industry.

In many areas of the country the distribution methods of the past are slowly changing. Together with these changes new forms of packaging are emerging. To summarize these changes, Market Research Report Number 135, August 1956, of the United States Department of Agriculture states:

> Long established methods of fluid milk distribution have been giving way to new developments in marketing, as distributors try to keep abreast of consumers' changing tastes and buying habits.
>
> Homogenized milk is rapidly replacing regular milk in nearly all of the markets included in this study.
>
> Milk dealers' sales on home delivery routes continue to lose ground to the dealers' wholesale outlets, including retail stores. Most of the wholesale sales reach consumers through stores.
>
> Sales of milk in glass containers still exceed sales in fiber or paper containers. However, in all markets for which data are available sales in glass are declining relative to sales in other containers. In some markets the gallon and half gallon glass jug has a firm position, with the size of the container appearing to be the determining factor.
>
> Changes in milk purchases by size of container have been related to the changes in types of milk sold, types of sales and types of containers used in the market. The quart container is still the most widely used, although it is losing ground.

Dairy product plants buy a wide variety of materials and equipment in addition to the raw material which they process. It is estimated that the total annual market is 500 million dollars. The 1954 Census of Manufacturers notes that the dairy industry throughout the United States invested about $163,116,000 in capital expenses of which $130,507,000 was for new equipment and machinery.

CHAPTER II

THE COSTS OF OPERATION OF A FLUID MILK PROCESSING PLANT AS A FUNCTION OF CAPACITY

A milk processing plant that is operating at more or less its rated capacity will incur various expenses. These expenses are generally of four types: raw material cost, processing and bottling costs, administration and general costs, and the costs of selling and delivery (6). These expenses are discussed in detail in this and the following chapters.

In all cases, whether specifically stated or not, a number of basic assumptions have been made. Plant output and capacity are assumed to be the same. Daily production is in gallons per day, on a eight-hour daily basis, with a 26-day production month (312 days a year). It has also been assumed that the factors of production were employed economically under the conditions of the prevailing state of technology. The consumer preferences were also assumed to be constant.

By far the largest single cost is the amount that is paid for the raw milk. This expense varies directly with the production rate of the installation. Thus, for every unit of milk that is processed, a certain constant cost will be incurred. As subsequently explained, there are a number of conditions that will cause this constant value to change.

Most of the major milk producing and consuming areas are dealer price controlled, either by federal, state or local milk commissions. For instance, heavily populated New York City is under both federal and state control, while the San Francisco - Los Angeles area is under state control. In many cases the control applies both to processors' cost price and wholesale - retail selling prices of market milk. In a controlled area the role of supply and demand is negligible. The price a dealer must pay for his raw material is constant relative to the quantity that he purchases. Whether a dealer buys 100 or 10,000 gallons of milk a day, the unit cost that he must pay does not change. Factors that affect unit cost are the butterfat constant of the milk and the usage for which the milk is destined. There is an allowance made per 1/10 per cent butterfat content whereby the dealer pays above, below or the exact amount established by the milk commission from a basic butterfat test price, depending upon the fat content of the milk received at the plant.

If a dealer buys raw milk and sells the whole amount as market milk, he will pay a premium, or class one price for his raw material. If he sells only part of it as market milk, he need pay only class one price on that per cent that he sells as regular market milk. Milk used for the manufacture of butter, cheese or ice cream has a cost classification of its own.

If a milk processing plant buys its raw material and sells it as 100 per cent market milk, the following cost equation may be written:

$$C_m = 26.7 \text{ m Q} \quad (1)$$

Where C_m = Total annual cost of raw milk, in dollars

26.7 = conversion factor

m = a constant, denoting average annual price, in dollars, per 100 pounds of raw milk

Q = quantity of milk processed per day, in gallons

In order to use the terminology and pricing practices common to the milk industry, it is necessary to use a conversion factor in Equation (1). This factor converts the various units of measure into a dollar expression of annual raw milk cost. The conversion factor taken as 26.7 has been derived as follows:

$$C_m = (\text{lb/gal}) \quad (\text{days/year}) \quad (\text{dol/100 lbs}) \quad (\text{gal/day})$$

$$= (8.59) \quad (312) \quad (m/100) \quad (Q)$$

$$= 26.7 \text{ m Q}$$

Figure 1 illustrates the annual cost of raw milk in two areas of the United States. The figure is based on the following two assumptions: All raw milk is sold as market milk and each installation operates 312 days a year. The prices are based on the average cost of raw milk

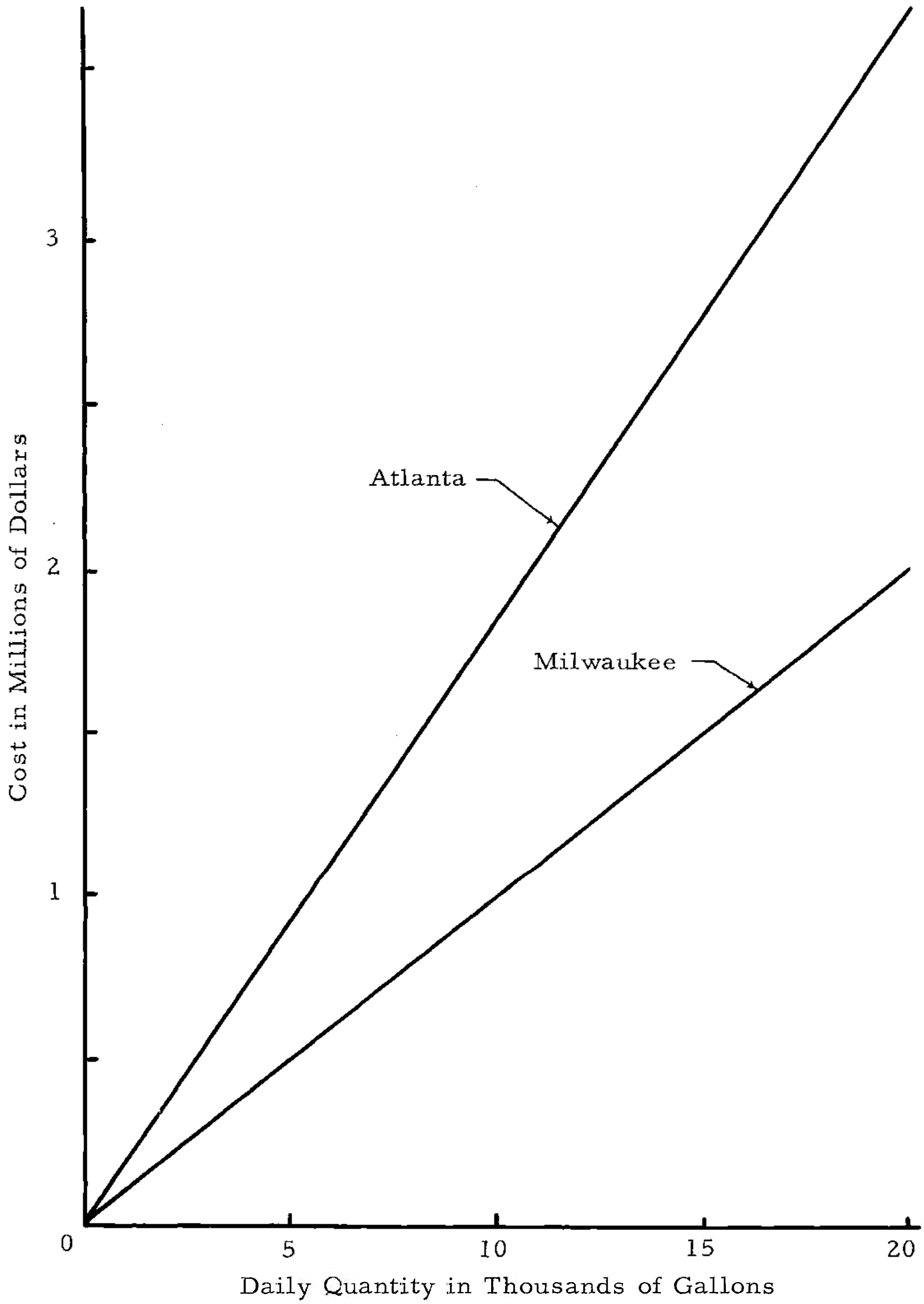

Figure 1. Annual Raw Milk Cost in Two Marketing Areas

for 1957 with the monthly average equal to the April 1957 price.

Table 21 in the Appendix gives additional raw milk cost figures in major marketing areas. It shows the wide price differences existing in ten selected markets. It is interesting to note that the dealers' buying prices shown in this table follow closely the dealers' selling prices (see Table 33).

The expenses of receiving, processing and bottling market milk may be reduced to a great many components. However, many of these cost components would have very little effect on the overall expenses of the firm. The portions of receiving, processing and bottling that are of major consequences are plant labor charges, building and equipment depreciation charges, bottle and container costs and the expense for fuel and water. Some of these costs, like labor, fuel and water, are of the variable type, while others, like depreciation of equipment and building, are fixed type expenses.

The number of plant employees to operate different capacity installations vary considerably with each plant. However, a relation between output and personnel does follow a pattern. This relationship was investigated by Bartlett in a study of 261 milk processing firms (7). The results of this study indicated that labor can be more efficiently utilized with a higher plant output. The findings of Bartlett are summarized in Table 1.

Table 1. Relation Between Plant Output and Plant Personnel Employed

Gallons Milk Handled Daily	Plants (Number)	Atlanta Survey (Number)	Milk Handled Daily Per Plant Employee (Gallons)	Atlanta Survey
500 or less	43		103.3	
501 to 1,000	37		161.4	
1,001 to 2,000	33	1	206.9	200.
2,001 to 3,000	25		232.7	
3,001 to 5,000	39	1	264.5	301.
5,001 to 10,000	38	3	340.2	397.
10,001 to 20,000	20	5*	341.0	406.
Over 20,000	26		344.4	

* Colburg Dairy, Charleston, South Carolina - Southern Dairy Products Journal, November 1957.

A survey of milk processing firms in the Atlanta, Georgia, area was made to determine whether or not the plants would follow the pattern shown in Table 1. The results of this survey appear in the Atlanta survey column of the above table. Since the sample size is small, no definite conclusions can be based on it. However, it does not appear to contradict to any great extent the 261 plant survey. The installation of new equipment and improved methods probably account for the higher efficiency of the plants surveyed in the Atlanta area.

Figure 2 is based on the results of the 261 plant survey. It illustrates graphically the number of plant employees required to operate

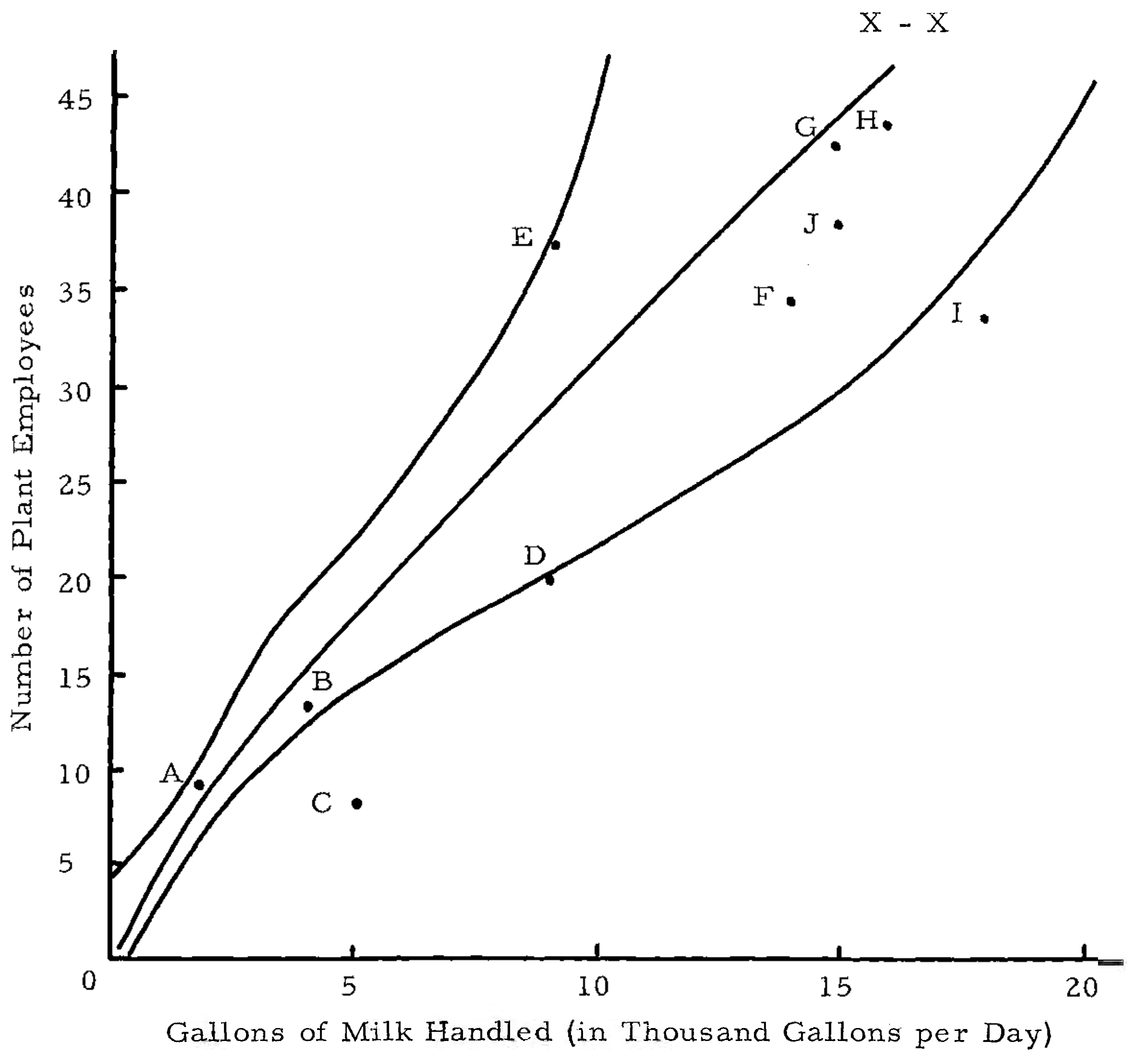

Figure 2. Plant Personnel Employed in Various Size Milk Processing Installations

milk processing installations of various outputs. The letter coded points are the plants in the Atlanta area, plus the South Carolina concern. A curve denoted by X - X is obtained if the average of each output range is plotted against the number of plant personnel. The equation of this curve is:

$$N_e = (.0197\, Q^{.803}) \tag{2}$$

Where N_e = number of plant employees

Q = quantity of milk processed, in gallons per day

The derivation of this equation is explained in the Appendix (Table 34).

The annual labor cost for plant employees thus becomes:

$$C_1 = N_e\, s \tag{3}$$

Where s = average yearly salary per plant employees, in dollars

By substituting Equation (2) into Equation (3), annual labor cost becomes:

$$C_1 = (.0197\, Q^{.803})\, s \tag{4}$$

The equipment and building expenses are major cost items. Of the two charges, equipment costs are generally the larger amount. It has been established by the Bureau of Internal Revenue that the average productive life of most milk processing machines is 15 years. Therefore, if the cost of new machines is known, it becomes a relatively simple matter to compute the annual cost. By dividing the equipment cost by the number of years of expected life, an annual cost of equipment expression may be determined.

The cost of milk processing machines of similar design and capabilities will vary between manufacturers. The cost will also vary according to the capacity of the machine desired. This capacity variation, however, will usually follow the six tenth factor rule (8). The cost - capacity relationship for one type of equipment is illustrated in Figure 3. The curve shown is the total cost for various capacity machines made by one of the leading dairy processing machine manufacturers in the United States. Table 23 in the Appendix gives a more detailed breakdown of the components making up the full installation.

The curve in Figure 3, expressed in algebraic terms, is of the type:

$$C_{et} = e\, Q^{n} \tag{5}$$

Where C_{et} = Total cost of equipment

e = constant, depending on type of equipment, in dollars

n = exponential factor, depending on type of equipment

Q = capacity of equipment, in gallons per day

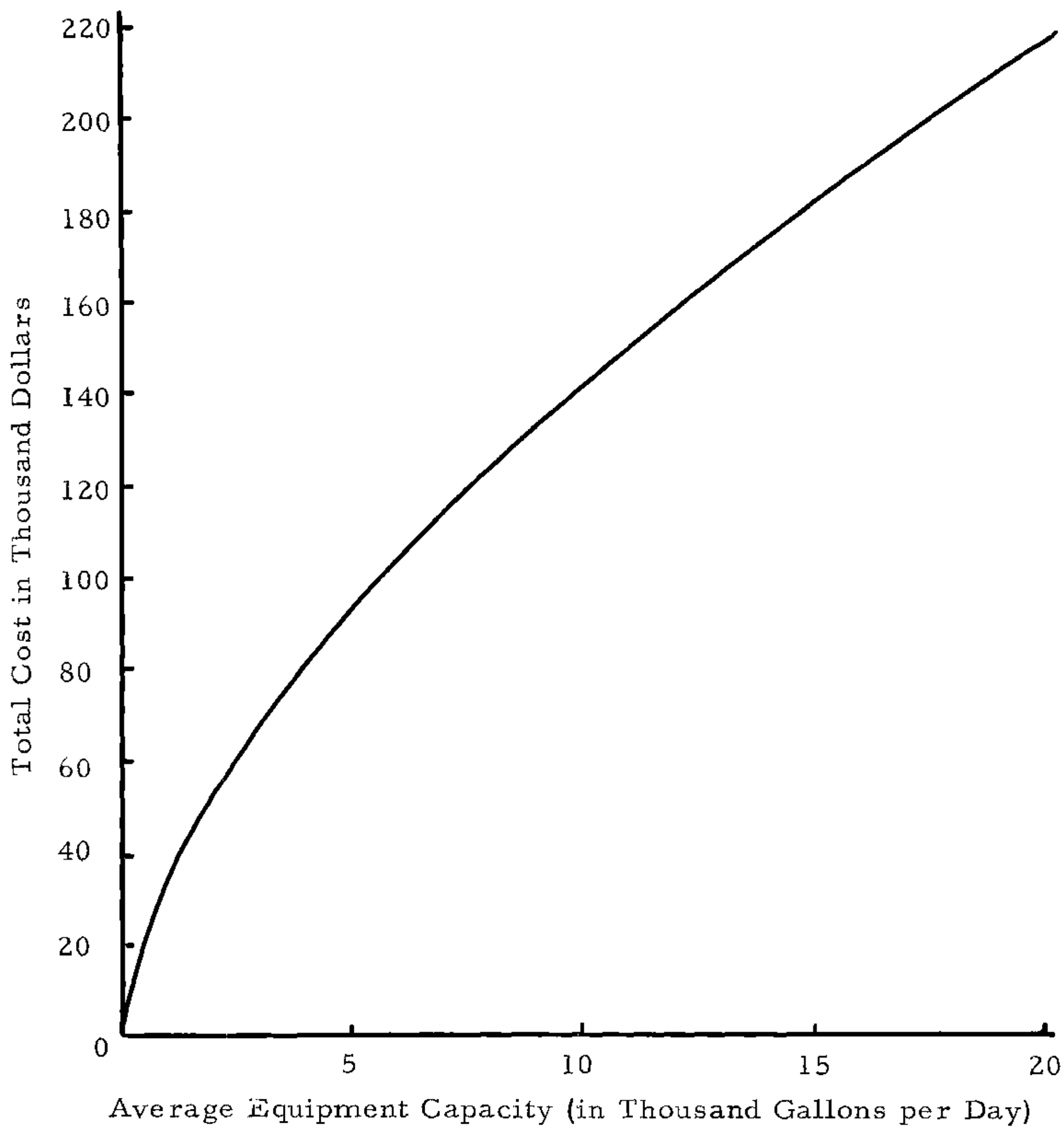

Figure 3. Cost of One Type of Milk Processing Equipment for Various Size Plants

Equation (5) for the curve in Figure 3 may be solved and becomes:

$$C_{et} = 702\, Q^{.57}$$

Although the constant e = 702 and factor n = 0.57 are based on the results pertaining to one manufacturer, perusal of similar relationships in other lines of processing plants indicates that the equation of the form $C_{et} = e\,Q^n$ is of general type. Of course, e and n may vary within limits.

The yearly cost of equipment, using a straight line 15 year depreciation value (with zero salvage value) thus is:

$$C_e = \frac{e\,Q^n}{15} \qquad (6)$$

Paper container machines used by the market milk industry are generally acquired on a rental basis. When a machine of this type is rented, the material used is included in the cost. A wide variety of equipment is available so that all standard container sizes may be utilized.

The total annual rental cost expression for machine and material for paper packaging of fluid milk is:

$$C_{ep} = cQ^p \qquad (7)$$

Where C_{ep} = total annual cost of paper equipment and material, expressed in dollars c = constant, depending on type of machine, installation output and container size, in dollars

Q = quantity of plant output, in gallons per day

p = exponential factor, depending on type of machine, installation output and container size

Equation (7) solved by the method of averages from values contained in Table 25 in the Appendix becomes:

For 1 quart containers:

$$C_{ep} = (312) \quad (15.6) \quad Q^{.89}$$

For 1/2 gallon containers:

$$C_{ep} = (312) \quad (18.6) \quad Q^{.862}$$

This equipment can be used in conjunction with any dairy processing machines. If a plant is engaged in all paper operations certain equipment used with glass is unnecessary. For instance, bottle washers and fillers are no longer needed. Firms which package in glass and paper will use a combination of machines which will fulfill the total output requirements. Regardless of the installation, Equation (6) will hold true if the constants have been properly computed.

Paper container machines may be purchased outright up to certain sizes. The price of such machines are included in Table 27 of the Appendix. Cost of blanks and other material is also listed in this table.

Space requirements for milk plants vary with every installation. Only by studying the local plant situation can an accurate size be determined for a specific case. However, a general relationship between plant output and the physical size of the establishment is suggested by Mitten in a study at Michigan State University (9). For an ordinary milk plant, the total area should be from one to two square feet per gallon of milk handled daily. For volumes under 20,000 pounds (2300 gallons) daily, as much as three square feet per gallon should be used.

Mitten further suggests that buildings be of brick, stone or concrete construction, with a processing room floor to ceiling clearance of 12 to 15 feet and equipment so arranged as to permit one floor processing.

Based on the previous statements, the following assumptions are now made. The plant should vary from a unit area of three square feet for each gallon of milk handled daily for a low capacity installation to one square foot for a large capacity plant. These conditions can be approximated by an algebraic expression. Written in such a form the equation is:

$$A_t = 308\,Q^{.42} \qquad (8)$$

Where A_t = the total building area, in square feet

Q = the quantity of milk processed, gallons per day

The most practical method of calculating the erected cost of buildings without resorting to a detailed construction estimate is based upon the cost per foot of floor area (10). If the area of a plant is based upon Equation (8), the cost of the building for a milk processing enterprise can be stated as:

$$C_{bt} = f A_t \qquad (9)$$

Where C_{bt} = total cost of the building, in dollars

f = constant, depending upon type of construction, in dollars per square foot

By substituting Equation (8) into Equation (9), the total cost expression becomes:

$$C_{bt} = 308 f Q^{.42} \qquad (10)$$

The yearly cost of the building, using a straight-line 50 year depreciation plan (with zero salvage value) is:

$$C_b = 6.16 f Q^{.42} \qquad (11)$$

Table 26 in the Appendix lists the erected unit costs of various types of construction. Constant f in the above equations may be chosen from this table.

To deliver milk to the consumer it must be placed in a suitable container. Many different types, styles and sizes are used. The glass bottle and paper carton are the most common containers used for regular retail selling (11). On home delivery routes, the glass bottle prevails, while retail stores generally handle milk packaged in paper cartons. Container sizes used vary widely with the marketing area and individual customer needs and desires. The quart container is the most commonly used, with the half-gallon size second in popularity. A small portion of fluid milk is sold in half-pint, pint and gallon sizes, but these sales are relatively small.

The cost of the container may be a considerable part of the total cost of a unit of milk. Paper is usually more expensive than glass. Theoretically, glass can be infinitely cheaper than paper, for it can be used over and over. However, in actual practice the life of a bottle is limited by breakage and chipping. The average life of a bottle is considered by many milk dealers as 25 trips between consumer and the milk plant 12). The larger the container, whether it is glass or paper, the lower the cost relative to the quantity of product it will hold, i.e., $11.87 per gross for quart bottles as compared to $21.00 per gross for half-gallon containers.

An equation for annual container costs relative to quantity of milk processed may take the form:

$$C_c = 312 \ c' Q \tag{12}$$

Where C_c = total annual cost for containers and sealing material, in dollars

c' = average cost per container per gallon and sealing material, in dollars

Q = quantity of milk processed daily, in gallons per day

A more detailed equation(based on bottle life of 25 trips) which would yield the same results as the above expression is:

$$C_c' = Q \Big[(1248\, P_{pq}\, P_1) + (624\, P_{ph}\, P_2) + (49.8\, P_{gq}\, P_3) + (24.9\, P_{gh}\, P_4) + (1248\, P_{gqc}\, P_3) + (624\, P_{ghc}\, P_4)\Big] \qquad (13)$$

Where C_c' = total annual cost of containers and sealing materials, in dollars

P_{pq} = unit cost, paper container, quart size, in dollars

P_1 = portion of total milk processed packaged in one quart containers, decimal value

P_{ph} = unit cost, paper container, half-gallon size, in dollars

P_2 = portion of total milk processed packaged in half-gallon paper containers, decimal value

P_{gq} = unit cost, quart bottle (glass), in dollars

P_3 = portion of total milk processed bottled in one quart glass containers, decimal value

P_{gh} = unit cost, half-gallon bottle, in dollars

P_4 = portion of total milk processed bottled in half-gallon glass containers

P_{gqc} = unit cost, hood and disc, quart glass bottle, in dollars

P_{ghc} = unit cost, hood and disc, half-gallon glass bottle, in dollars

Q = quantity of milk processed daily, in gallons per day

The values of 1248, 624, 49.8, 24.9, 1248 and 624 (appearing in that order) in the above equation are derived as follows:

$$1248 = \text{(days per year) (paper cartons per gallon)}$$
$$= (312)\ (4)$$

$$624 = \text{(days per year) (paper cartons per gallon)}$$
$$= (312\ (2)$$

$$49.8 = \frac{\text{(days per year) (glass bottles per gallon)}}{\text{bottle life}}$$
$$= \frac{(312)\ (4)}{25}$$

$$24.9 = \frac{\text{(days per year) (glass bottles per gallon)}}{\text{bottle life}}$$

$$= \frac{(312)\quad(2)}{25}$$

$$1248 = (\text{days per year})\ (\text{hoods and discs per gallon})$$

$$= (312)\quad(4)$$

$$624 = (\text{days per year})\ (\text{hoods and discs per gallon})$$

$$= (312)\quad(2)$$

The unit cost of bottles and cartons may decrease with large purchases. What discounts are given for such purchases are not known by this writer. Some typical values of various types and sizes of containers are listed in Table 27 of the Appendix.

The water supply for a processing plant is very important. It is essential that an adequate supply of pure water be available for washing equipment and heating and cooling purposes. The actual amount of water needed by a milk plant depends upon many factors. If the supply is plentiful and inexpensive, more water may be used than is necessary. However, in dry areas where water costs are high, a plant will make every effort to conserve water. The type of equipment used, its age and state of maintenance will also affect the water requirements. Dealers who use the bulk handling method require less water for milk can washing than dealers who use the ten gallon cans for receiving. Finally, the packaging method employed is of great importance. A plant using glass containers for milk packaging will need more water than a plant primarily engaged in paper carton operations.

A basis for computing approximate water requirements is suggested by the work of Farrall (13). The quantity of water for washing equipment may vary from 20 gallons to 50 gallons per 1000 pounds of milk handled. Refrigeration machinery usually requires about two gallons of water per minute per ton of refrigeration. The quantity of water for supplying the boiler may be considerable in certain cases, but for economical and efficient operation, a boiler should recirculate the same water many times.

Values of monthly water requirements of major operations for various plant outputs have been compiled in Table 2. The table is based on Farrall's estimated water needs per volume of milk handled and refrigeration machinery size in operation. In climates where there are sharp seasonal temperature variations, allowances may be made for refrigeration machinery water requirements.

Table 2. Approximate Average Monthly Water Requirements for Milk Processing Plants (26 Days Per Month)

Milk Handled Per Day (Gallons)	Refrigeration Size (Tons)	Water Requirements (Gallons)		
		Washing	Refrigeration	Total
560	1.8	4380	165000	169380
1125	3.9	8950	358000	366950
2500	9.0	19300	825000	844300
10000	18.3	77200	1670000	1747000
20000	28.5	144400	2590000	2734000

An equation that approximately satisfies the conditions of Table 2 is:

$$G = 934 \; Q^{.82} \qquad (14)$$

Where G = water per month, in gallons

Q = quantity of milk processed per day, in gallons

Milk plants, especially those located in and near cities, generally buy their water from public utilities. The amount that they must pay for this commodity is usually computed on a sliding scale basis. Small users will pay more per unit for their total requirements than large water users.

In equation form, the cost of water will be of the type:

$$C_w = G \; r \; 12 \qquad (15)$$

Where C_w = total annual cost of water, in dollars

r = average price of water per gallon, per month, in dollars

By substituting Equation (14) into Equation (15), the annual cost for water, in terms of milk output, will be:

$$C_w = (11218) \; r \; Q^{.82} \qquad (16)$$

Table 28 in the Appendix gives the cost of water for home and industrial users in the Atlanta area.

A fluid milk processing plant uses a large amount of fuel. The fuel supplies the necessary heat for milk pasteurization, equipment and container washing and other equally important heat consuming plant operations. The most commonly used fuels are coal, oil and gas. Each has its advantages and the choice of fuel will depend upon the particular conditions and needs of the individual installation.

The heat obtained from the fuel is generally used to generate steam, which is the most popular source of heat for general use in the milk plant. Steam is economical, flexible and has properties which allows it to convey large quantities of heat from a source to the product which is being processed.

The amount of heat, and consequently the fuel expense, required by a fluid milk plant will vary with every installation. The type of equipment used, methods of receiving, pasteurizing and packaging will determine the heat needed per unit of milk handled. For instance, low temperature vat pasteurization requires more total heat for the same amount of milk processed than does high temperature, regenerative type of pasteurization. Water of different temperature is recommended for washing wooden milk bottle cases than for aluminum wire cases. Even individual milk plant superintendents will disagree on the optimum temperature for any particular operation.

It is difficult to write a general expression for heat required for various capacity milk plants. However, for a more specific condition, a relationship between heat needed and plant capacity is indicated by the recommended boiler sizes for a number of installations of varying sizes. For an all glass operation of 250, 1100, 2250, 12500 and 20000 gallons of milk processed a day, boiler horsepower sizes of 6, 20, 40, 100 and 200 respectively are suggested. It should be noted that some differences exist between installations (Table 23). The smaller ones use low temperature vat pasteurization while the larger plants use the high temperature short time method. The larger plants also employ the bulk method of handling milk. But regardless of these differences, a heat-required-relative-to-milk-output pattern exists. This relationship, expressed algebraically is of the type:

$$BHP = i\,Q^{s} \tag{17}$$

Where BHP = total boiler horsepower

i = constant, expressed in boiler horsepower per gallons of milk processed daily

s = exponential factor, depending upon installation type

Q = capacity of installation, in gallons per day

Converting boiler horsepower to heat required per month, Equation (17) becomes:

$$BTU_m = 7220000\,i\,Q^{s} \tag{18}$$

Where BTU_m = total heat required per 26 day month, eight hour per day operation, in BTU (one boiler horsepower is equivalent to 33349 BTU per hour)

Equation (18) may be solved from the values contained in Table 23. It becomes:

$$BTU_m = 7220000 \ (.133) \ Q^{.73}$$

The yearly expense for fuel may thus be written:

$$C_f = Y \ (BTU_m) \ 12 \qquad (19)$$

Where C_f = total annual expense for fuel, in dollars

Y = average monthly cost of a unit of heat, depending upon type of fuel and local rate formula, expressed in dollars per BTU's

By substitution Equation (19) becomes:

$$C_f = 8.65 \times 10^7 \ Y \ i \ Q^s \qquad (20)$$

Table 29 of the Appendix gives data on heat requirements for certain operations in the dairy plant and suggests a method of formulating more comprehensive expressions of fuel requirements for different situations and conditions. Table 30 gives additional data of fuel costs on a comparative basis.

There are many more components of processing and bottling that could be considered in estimating the cost of operation of a fluid milk processing plant. However, the elements that have been discussed are generally the most important and the results obtained by calculating and combining these elements will yield a relatively accurate value of manufacturing costs.

Administration and general expenses were investigated by Bartlett (14) for over 192 specific market milk dealers. The results of these studies are not on a cost-relative-to-output basis, but they do provide a means for estimating these expenses on a percentage to other costs. The following table summarizes these studies and gives administration and general expenses as a percentage of the various cost items.

Table 3. Cost of Administration Compared to Cost of Receiving, Processing, Bottling and Delivery

Average 117 Unit Costs	Cost Per Gallon (Dollars)			
	Administrative and General	Receiving, Processing and Bottling	Selling and Delivery	Total
Average 117 Unit Costs*	.0154	.0732	.07256	.16128
Percentage of	...	21.7%	20.6%	9.56%
Average 75 Unit Costs**	.0260	.0620	.16128	.2548
Percentage of	...	41.8%	16.1%	10.2%

* Delivery of milk to stores
** Delivery of milk to homes

Thus the cost of administration and general expenses may be estimated as a percentage of receiving, processing and bottling; selling and delivery or total operating costs. In this study these expenses will be based on a per cent of receiving, processing and bottling costs.

Therefore, the annual cost of administration and general expenses will be:

$$C_{ag} = .217 \text{ to } .418 \; (C_I + C_e + C_b + C_c + C_w + C_f) \tag{21}$$

Where C_{ag} = total annual cost of administration and general expenditures, in dollars

The remaining symbols are from Equations (4), (6), (11), (12), (16) and (20).

CHAPTER III

THE DELIVERY COST OF MILK AS A FUNCTION OF PLANT CAPACITY

The success of a market milk enterprise largely depends upon the efficient distribution of the product. The costs of delivery systems represent, in most cases, the largest single area of cost over which management has any appreciable control (15). Many studies of milk operations have been made and all of the investigations clearly reveal this state of conditions.

A study made by Dr. Leland Spencer, Professor of Marketing at Cornell University, of the operations of six milk companies in the New York City area covering the years 1941 to 1946, inclusive, showed that one of the major cost items was the delivery expense (16).

When this survey was made, milk was selling for 20 cents a quart. The report said:

> Of the 20 cents a quart of standard milk at stores, two cents is retained by the grocer and 18 cents goes to the milk dealer. The dealer pays a little more than 12 cents a quart for the milk at his country plants. His operating costs total about 5.6 cents, including 2.4 cents for delivery service to the store.
>
> Operating costs of all kinds on milk delivered to the consumer's doorstep come to nearly ten cents, and of this amount more than six cents goes for delivery service.

The effect of volume of milk processed upon cost of distribution was investigated by Dr. Roland Bartlett (17). Two groups were studied. One group of 12 dealers included those engaged in 100 per cent wholesale selling, while the other group of 25 companies delivered milk exclusively to the home.

Total unit cost of the wholesale operators averaged 2.72 cents per quart for the six low volume dealers to 2.99 cents for the high volume operators. The average of the low group was 2670 gallons of milk processed per day compared with 8114 gallons daily for the high volume operators.

In the second group of 25 companies delivering milk to homes, the 12 low volume companies averaged 5.97 cents per quart compared with 6.27 per quart for the high volume companies.

In these studies by Bartlett, distribution cost is used as an all inclusive term. It includes processing, bottling, administrative, selling and delivery expenses. This situation does not allow positive conclusions concerning the effect of plant volume on costs. However, it is not unreasonable to suspect that one of the causes of increased unit costs of the larger plants was due to increased delivery expenses, i.e., having routes that are sub-marginal or marginal in order to dispose of total plant output.

Additional studies have established one basic fact. In nearly all cases it is more expensive to maintain a retail home delivery system than a store delivery wholesale type operation. Plant output does little to alter this situation. Although milk companies still operate many home delivery routes, numerous firms are discontinuing certain retail routes because of the big differential between wholesale and retail delivery unit expenses. To compensate for the lost sales, these firms attempt to increase sales on their other remaining routes.

It is extremely difficult to have delivery service which will yield optimum results on all the routes included in the system. Even a firm that has a virtual monopoly within an area cannot expect each route to maintain an ideal minimum delivery unit cost. The decrease in load carried rather than increased route expenses have a greater effect on unit costs because important cost items for each delivery route are constant regardless of the quantity of products delivered. Therefore, each vehicle must be used to full capacity in order to attain the lowest delivery cost per unit of product.

As stated by Sommer (18), the capacity of the delivery route may be limited by the vehicle, but more commonly the driver is the limiting factor. Aside from the differences in the capabilities of the route men, the amount of milk each driver can deliver depends upon such factors as route mileage, customer density, average amount of milk sold per customer, the use of paper or glass containers, and competition. All the vehicles in a fleet could possibly be loaded to capacity but this would not always reduce unit cost because it may take a much longer period to service some of the routes. Extra compensation would be necessary for those drivers working over the regular number of hours and any gain from the 100 per cent load would be offset by these additional expenses.

Many individual situations may be encountered in practice that will affect unit delivery costs. For instance, a fluid milk plant may be located in a constant density, homogeneous population center. Its competition is negligible and it therefore delivers milk to the entire surrounding area. Each driver is expected to work eight hours a day. If he works more than the standard eight hours, he must be compensated for the extra time with overtime pay. As it takes more and more time to get to the outlying areas, the vehicles must carry fewer products in order that the drivers can finish their deliveries in the allotted time. Since the major cost items are relatively constant, the unit cost of delivery is affected largely by the decreasing load, which itself is caused by the distance traveled. The factors or combination of factors mentioned previously would have the same affect on load carried as increasing route mileage.

Thus an equation for unit delivery cost may be expressed as:

$$C_{ud} = \frac{TC_r}{Q\,P\,N} \qquad (22)$$

Where C_{ud} = total average unit cost on a route, in dollars per gallon

TC_r = total annual expenses of route, in dollars

Q = total plant output, gallons per day

P = decimal fraction of plant output delivered on route

N = number of deliveries per year (usually 156 or 312)

An equation of total delivery cost relative to total plant output may be formulated in a number of ways. In this study the cost of delivery of one unit of milk for each route is computed from Equation (22). These values are first arranged in a least-cost-first order. Each unit cost is then multiplied by the annual quantity of milk delivered at that cost. The summation of the products results in an equation of the type:

$$C_d = d\ (TQ)^h \tag{23}$$

Where C_d = total annual cost for deliveries on all routes, in dollars

d = a constant, depending on specific delivery system, in dollars per gallon

T = decimal fraction of plant output delivered on system

Q = total output of plant, in gallons per day

h = exponential factor, depending upon specific delivery system

For an operating plant it is relatively simple to solve the delivery cost equations. The data that are available in accounting records, plus other pertinent information, are generally sufficient. An enterprise that is being planned presents a more difficult problem. A thorough study must be made of the market situation and an expected volume of sales and expenses must be estimated for each part of the market area in which the firm expects to operate.

The direct costs to operate a milk delivery route consists of a number of major elements (19). Some of these elements are of fixed type and depend upon the availability of service on the route. The variable type expenses depend upon the actual operation of the route and its particular characteristics. The following are the expense items considered in this study. The total of these items, computed on a yearly basis, equals TC_r, the numerator of Equation (22).

Fixed type expenses:

Route drivers' wages

Truck and related equipment depreciation

Truck license, taxes and insurance

Variable type expenses:

Gasoline and oil

Maintenance and repairs

Material for refrigeration

Drivers' commissions (if applicable)

A retail and wholesale delivery system of a fluid milk processing firm was investigated. This concern operated throughout the Atlanta area. The retail volume accounted for approximately 20 per cent of its business, the wholesale trade the remaining amount. Home deliveries were on an every-other-day basis while wholesale routes were maintained daily. About 95 per cent of total sales was market milk.

The average number of units of milk delivered daily on each retail route, total annual cost of delivery and total unit costs are summarized in Table 31 of the Appendix. Total costs include the previously listed fixed and variable type expenses. However, commissions paid the drivers are not included. Although maintenance, repairs and material for refrigeration may vary from truck to truck, these expenses were distributed uniformly to each vehicle by the accounting policies of the firm.

Figure 4 illustrates geometrically the values contained in Table 31. The curve shows the relationship of unit cost to accumulated total quantity of milk delivered on all the routes of the retail system. The total quantity of milk delivered is for a two day period because this concern maintained every other day retail service. The various points to establish the curve were obtained by using Equation (22). It is interesting to note that the curve that has been drawn is similar to the curve that results from using the bulk-line cost method for pricing raw milk (20).

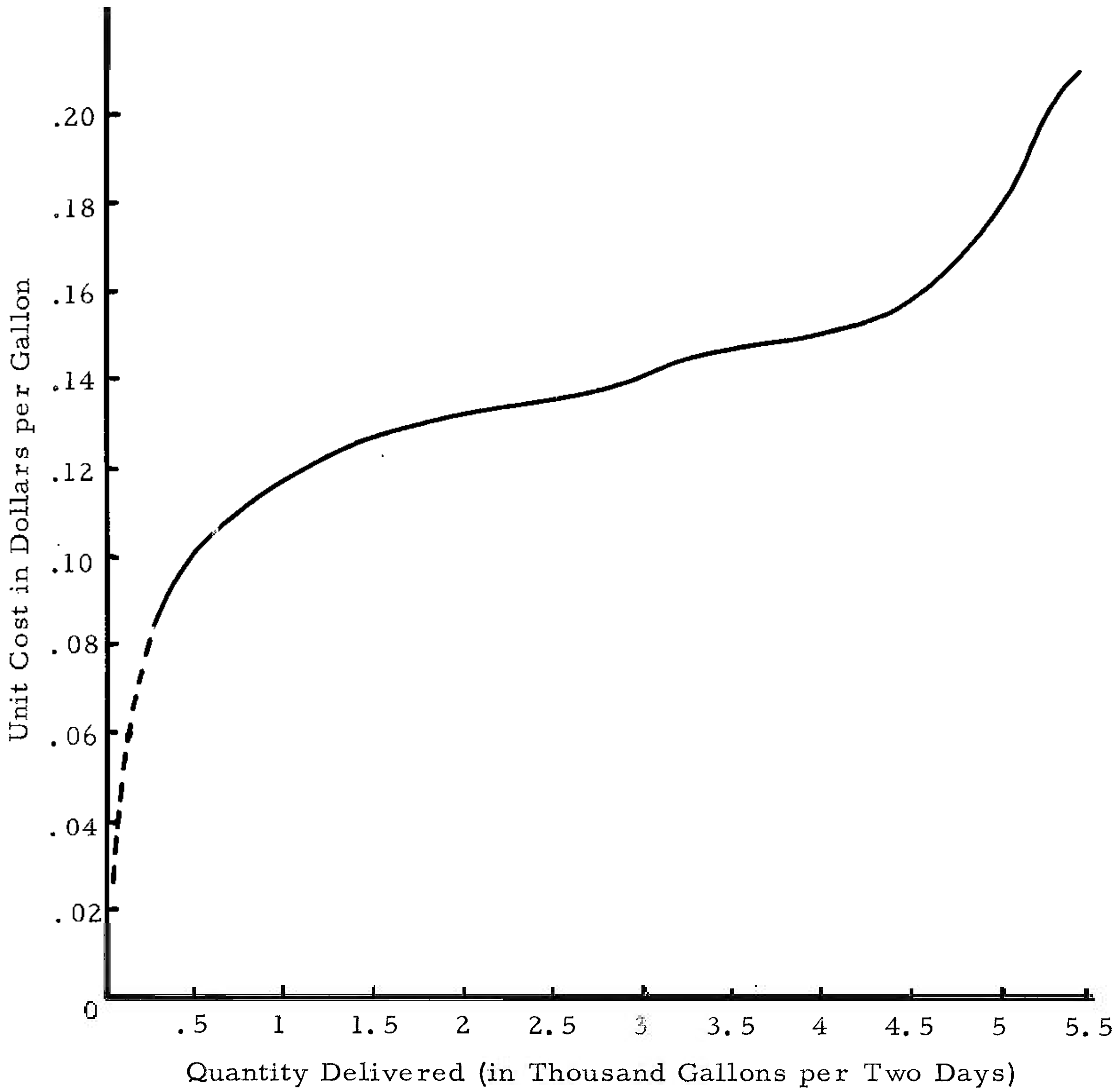

Figure 4. Total Home Delivery Unit Cost for a Certain Fluid Milk Processing Plant

Figure 5 has been derived from Figure 4, with the horizontal axis representing average amount of milk delivered daily and the vertical axis representing total annual accumulated cost for all the retail routes. The slope of the curve can be seen increasing with higher values of accumulated quantity of milk delivered. This indicates that it costs more to deliver each additional increment of product. One advantage of using this method of formulating the delivery cost equation is that all the characteristics of each route are included. Otherwise, separate plots would be necessary, each curve relative to a certain route characteristic; customer density against total cost; miles of delivery against total cost, etc. Thus in Figure 5 the portion of the curve that has a slope considered excessive by management may be studied in a greater detail and each individual route may be examined for factors contributing to its higher cost of operation.

The expression of the total annual cost of home deliveries as a function of quantity of plant output is given by Equation (23). For the curve in Figure 5, the equation becomes:

$$C_d = 7.64\, Q^{1.210}$$

The data for the wholesale delivery system for the Atlanta milk processing concern is summarized in Table 32 of the Appendix. The average number of units delivered daily, total annual cost and total unit costs are listed for each route. With one major exception all expense

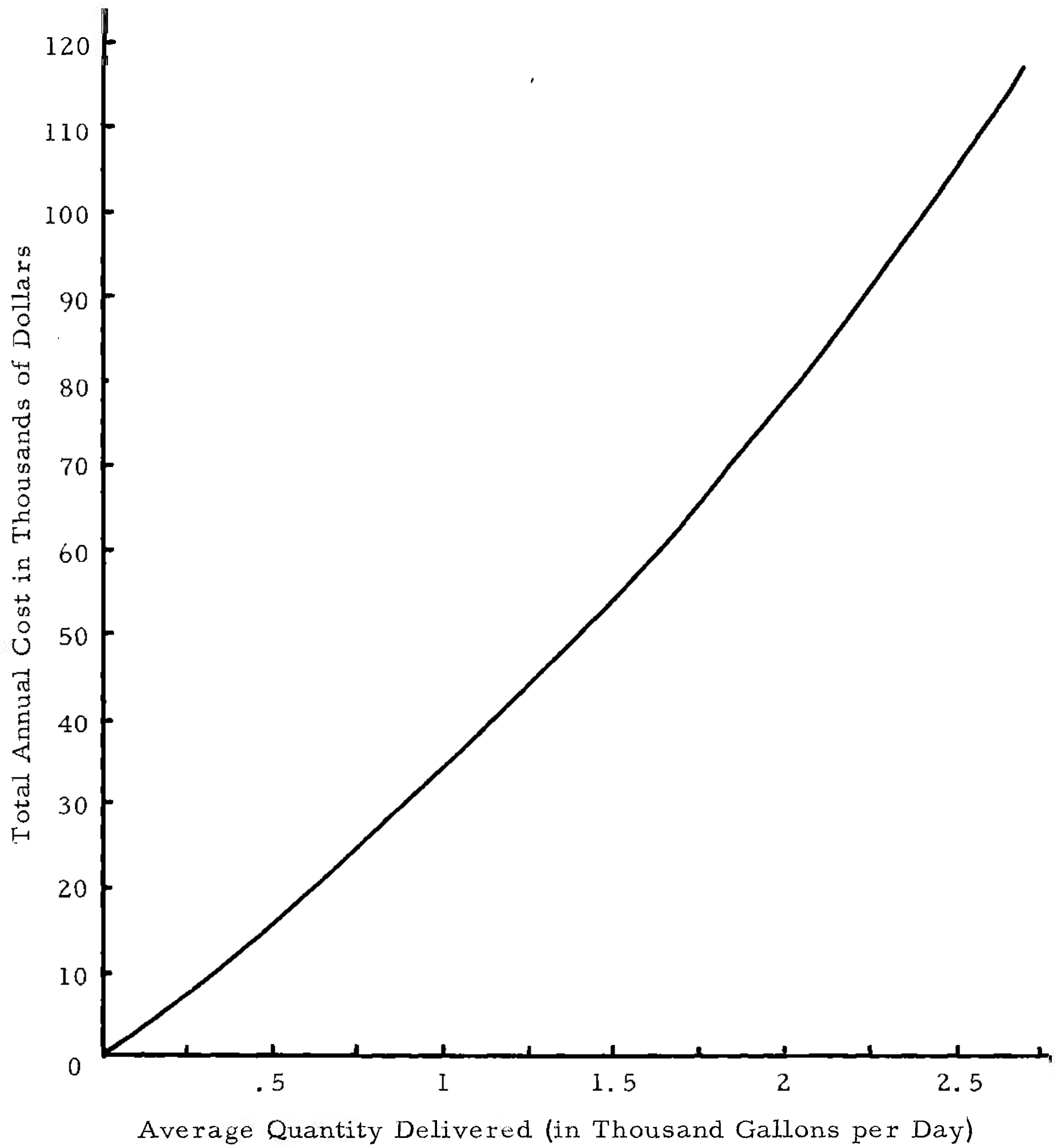

Figure 5. Total Annual Home Delivery Cost for a Certain Fluid Milk Processing Plant

items used in computing costs for the retail routes were used in finding the values of costs for the wholesale system. For the wholesale routes the wages and all commissions paid the drivers are included in the expenses.

The equipment and methods used to deliver milk to stores and institutions are similar to the equipment and methods employed on home delivery routes. However, it is generally easier to utilize men, vehicles and equipment more efficiently on a wholesale delivery basis. This accounts for the lower wholesale delivery unit costs, as compared to home delivery expenses, calculated for this plant. Figure 6 illustrates total unit costs relative to the quantity of milk delivered. As previously done, the various points of the curve were established by using Equation (22).

The curve of total annual cost relative to total daily quantity of milk delivered is shown in Figure 7. The method of obtaining this curve is similar to the method used in formulating the curve in Figure 5 (retail delivery). The algebraic expression for this curve is again Equation (23). Solved by the method of averages it becomes:

$$C_d = 13.8\, Q^{1.06}$$

If the unit cost of wholesale delivery for each individual route varied as much as the unit cost of home delivery, the total cost expression shown above would have a larger value for its exponent and

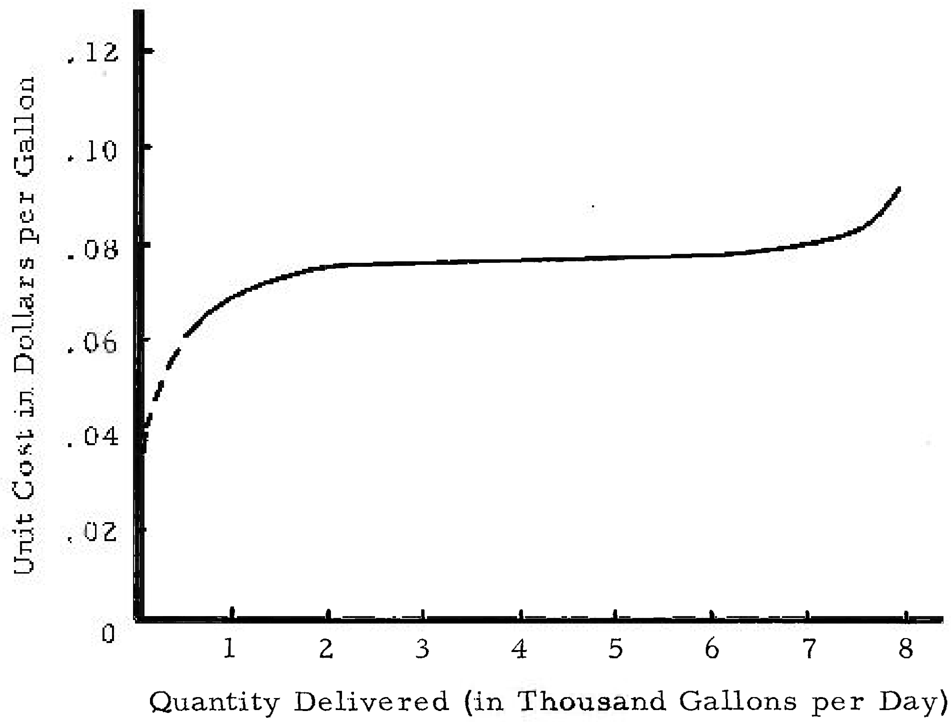

Figure 6. Total Wholesale Delivery Unit Cost for a Certain Fluid Milk Processing Plant

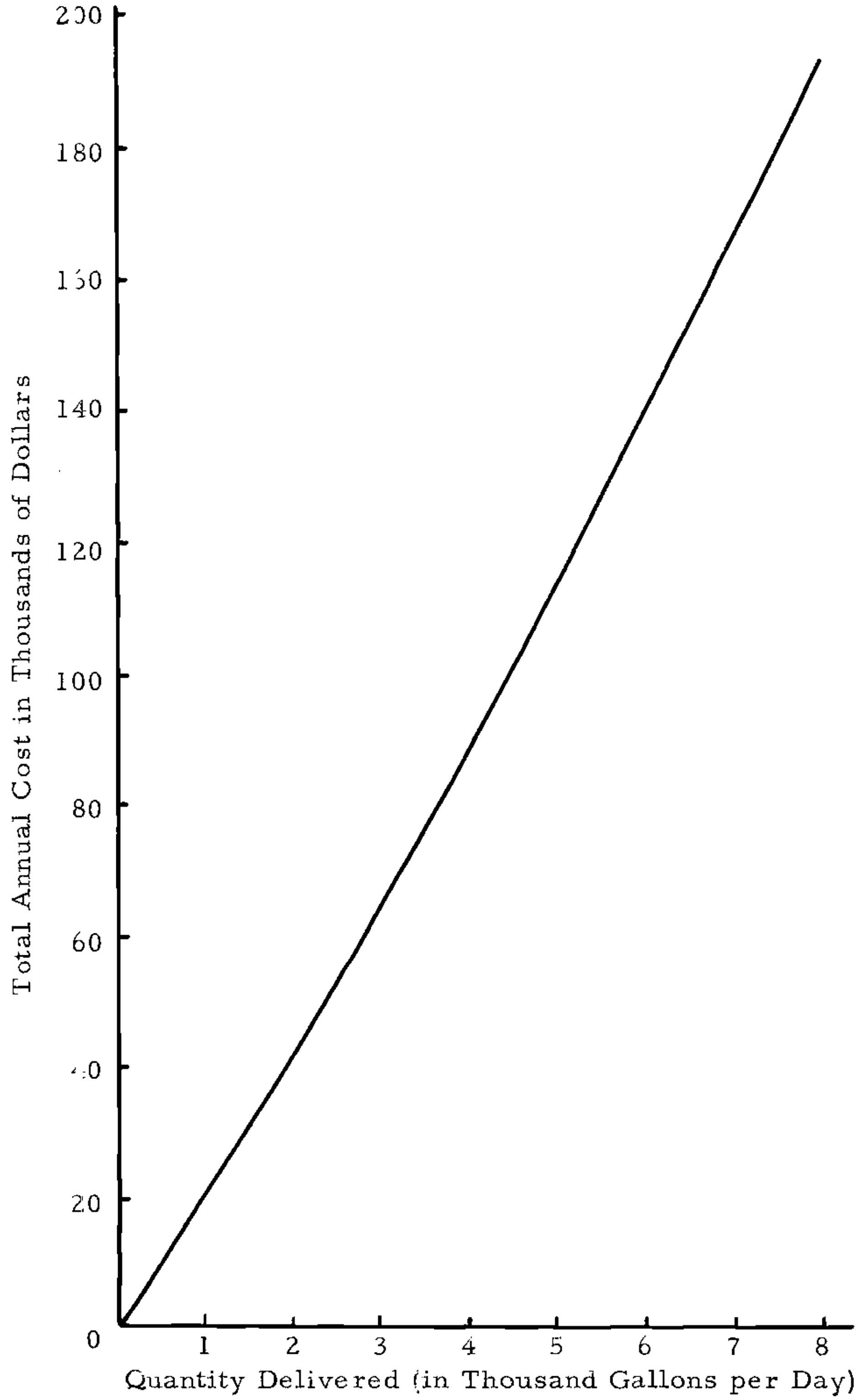

Figure 7. Total Annual Wholesale Delivery Cost for a Certain Fluid Milk Processing Plant

the approximate straight line with its near constant slope would become a line with a faster changing slope.

The retail and wholesale delivery costs may be combined into a single expression. In this combined form, it will be:

$$C_{dt} = d_1 (T_1 Q)^{h_1} + d_2 (T_2 Q)^{h_2} \qquad (24)$$

Where C_{dt} = total annual cost for retail and wholesale delivery, in dollars

d_1 = constant for retail delivery routes

d_2 = constant for wholesale delivery routes

T_1 = decimal fraction of plant output delivered on retail routes

T_2 = decimal fraction of plant output delivered on wholesale routes

h_1 = exponential factor for retail routes

h_2 = exponential factor for wholesale routes

Q = total plant output, gallons per day

CHAPTER IV

PER CENT RETURN ON INVESTMENT AS A FUNCTION OF PLANT CAPACITY

The market milk industry follows the pattern of most manufacturing and business enterprises. Their primary objective is to make a profit on their operations. In order to maintain and increase their earnings, processing plants and dealers continuously strive to improve their production and service efficiency. New equipment is installed and better methods of marketing are instituted. The trend toward strategically located high capacity installations is slowly gaining momentum. As shown in Chapter II, the larger plants can have a lower unit cost of production than their smaller rivals. However, it was also shown that these advantages could be offset by increasing delivery expenses. Thus the problem of selecting the plant size that will yield the optimum profit must take into account all the major aspects of the milk processing and distribution.

Capacity or plant size selection should be based on maximum profitability over a long period of time. To ascertain the correct size, an analysis of various capacity installations must be made. The values of sales, costs and investment calculated and properly related for varying capacities will give an answer that will indicate the plant size of optimum profitability.

Profitability may be defined as the measure of attractiveness of every new venture and every change in an established enterprise expressed in some monetary form (21). Per cent return on investment is the most common way of relating this profitability to a prospective or operatin firm. It is the annual rate at which profits will return on the investment. It may be defined as the ratio, expressed as a per cent, of the annual profits to the capital investment. Per cent return may be on a before or after tax basis and may employ fixed capital only. Any expression that satisfies the specific conditions or circumstances is considered equally correct.

In equation form, per cent return on investment is:

$$R = \frac{P_t}{I_c}(100) \tag{25}$$

Where R = per cent return on investment, before taxes

P_t = total annual profit, before taxes, in dollars

I_c = total capital investment, in dollars

Capital investment may be said to be the monetary outlay required for the erection of productive facilities and their ultimate operation (22). It may further be reduced to two classifications, fixed and working capital. Fixed capital represents the amount that is invested in production and supporting facilities. Working capital is the funds needed for the normal conduct of business. Capital investment therefore may be stated as the sum of the fixed capital and working capital, or $I_c = I_f + I_w$.

Total annual profit is equal to the difference of total annual sales and total annual costs. This may be written as TS - TC.

Therefore, by substitution Equation (25) becomes:

$$R = \frac{TS - TC}{I_f + I_w} (100) \quad (26)$$

Each component of the above equation may be expressed as a function of plant output. Major cost items have been so expressed in the previous chapters. Certain fixed investments have also been expressed as a function of plant capacity. If Equation (26) is thus solved for various plant capacities, corresponding values of per cent return on investment will result for each size. At some certain value of capacity, per cent return will reach a maximum amount. Therefore, if Equation (26) is the criterion for investment, it is most advantageous to build a new plant or enlarge an existing plant to the value of capacity which yields the highest per cent return.

For the market milk industry total annual sales, expressed as a function of the plant output, are generally of the type:

$$TS = 312\,a\,Q \quad (27)$$

Where TS = total annual sales, in dollars

a = a constant, the average price received, in dollars per gallon

Q = total output of plant, in gallons per day

The value of constant "a" depends upon the particular marketing area in which the milk plant is located, the number of units sold wholesale and the number sold retail, the size and form of the container and the type of milk that is sold. For the Atlanta market area, the following are but a few of the values that "a" can assume.

1. Condition: 100 per cent milk output sold retail, in four one-quart glass containers, all milk homogenized

   a = $1.04

2. Condition: milk sold in paper containers, 50 per cent retail, 50 per cent wholesale (to stores) in four one-quart containers, all milk homogenized

   a = $1.01

Generally no price reduction is made to stimulate the sale of milk that is in danger of spoilage. It is usually sold at one set price or not at all. Where possible, leftover milk is made into some other dairy product and sold as such. In some cases milk that has not been sold or that cannot be converted into another form is merely discharged into the sewer. Thus a straight line relationship usually exists between number of units sold and the income from each class of sales.

The price of the raw material, the processing costs and the delivery expenses were discussed in detail in the preceding chapters. These major cost items were further reduced to their more important elements. The following table summarizes these cost elements. The sum of these expressions are equal to TC in Equation (26).

Table 4. Total Annual Cost of Various Items as a Function of Plant Capacity

Item	Annual Cost Equation	Equation Number
Raw milk	$C_m = 26.7 \, m \, Q$	(1)
Plant labor	$C_l = (.0197 \, Q^{.803}) \, s$	(4)
Equipment (glass)	$C_e = \frac{e \, Q^n}{15}$	(6)
Equipment (paper)	$C_{ep} = c \, Q^p$	(7)
Building	$C_b = 6.16 \, f \, Q^{.42}$	(11)
Containers *	$C_c = 312 \, c' \, Q$	(12)
Water	$C_w = 11218 \, r \, Q^{.82}$	(16)
Fuel	$C_f = 8.65 \times 10^7 \, Y \, i \, Q^s$	(20)

(Continued)

Table 4 (Continued). Total Annual Cost of Various Items as a Function of Plant Capacity

Item	Annual Cost Equation	Equation Number
Administration	$C_{ag} = .217 \text{ to } .418\ (C_l + C_e + C_b + C_c + C_w + C_f)$	(21)
Delivery	$C_{dt} = d_1\ (T_1 Q)^{h_1} + d_2\ (T_1 Q)^{h_2}$	(24)

*See Equation (13).

The most important capital investment components of a fluid milk plant are the purchase cost of milk processing machines, buildings, land and delivery equipment. In addition to these basic costs, the expense of installation, piping and instrumentation which transforms a piece of machinery into a productive unit must be considered. Table 5 lists the major fixed cost items which comprise capital investment. The sum of these items is equal I_f of Equation (26).

Table 5. Major Fixed Cost Items of a Market Milk Processing Firm

Item	Expression
Process equipment (including storage room)	$C_{et} = e\,Q^n$

(Continued)

Table 5 (Continued). Major Fixed Cost Items of a Market Milk Processing Firm

Item	Expression
Buildings	$C_{bt} = 308 f Q^{.42}$
Delivery Units	$\frac{C_{dt}}{TC_r}$
Process installation cost (23) (24)	Up to $.43\ C_{et}$
Land (25)	$.01$ to $.02\ (C_{et} + C_{bt})$
Cost of engineering	Up to $.3\ (C_{et} + C_{bt} + *)$
Contractor's fee	$.04$ to $.10\ (C_{et} + C_{bt} + **)$
Contingency	$.10\ (C_{et} + C_{bt} + **)$

*Process installation cost and land

**Process engineering cost, land and cost of engineering

In general, it will be found that working capital is equal to an amount approximately 10 to 15 per cent of the fixed capital investment. Working capital includes the value of raw material stocks, material in process, finished products on hand, extended credit and money available for payment of salaries and other charges (26).

The following expression may be used for estimating I_w of Equation (26).

$$I_w = R_m (C_{mu} + 4 C_p + .5 C_{mu} P_c) \qquad (28)$$

Where I_w = working capital

R_m = monthly production rate

C_{mu} = raw milk cost, per gallon, in dollars

C_p = total processing costs, dollars per gallon

P_c = production cycle, months

Each element of the above equation may be written as follows. The notations and symbols used are the same as those used throughout this study.

$$R_m = 26\ Q$$

$$C_{mu} = .0856\ m$$

$$C_p = \frac{C_I + C_e + C_b + C_c + C_w + C_f}{312\ Q}$$

$$P_c = .0384$$

The major components of Equation (26) are now available as functions of plant capacity and the expression may be solved for various plant sizes. The results will be per cent return on investment for each plant size.

The following example will serve to illustrate the properties and usefulness of per cent return on investment method of measuring the attractiveness of a proposed milk processing venture. Five plant sizes will be considered. The sizes will be 1,000, 5,000, 10,000, 15,000, and 20,000 gallons of fluid milk processed per day. It should be remembered that the enlargement of a present plant to the mentioned sizes could just as easily be calculated and expressed as a per cent return on additional investment or total investment.

A market milk processing plant is proposed for the Atlanta area. A home delivery type of operation is planned because it is generally easier to secure steady customers for this type of sales outlet. Wholesale store sales would be inaugurated at some future date. A thorough market investigation indicates that customers are available throughout the city. The cost pattern for deliveries is estimated as $C_d = 3.82\, Q^{1.3}$. Packaging will be in glass containers.

The estimated annual sales, annual costs and total investment required for each rate of output is as follows:

Annual sales: Sales are based on the April 1957 price received by dealers in Atlanta for milk sold on retail routes. It is estimated that 50 per cent of the total volume of milk processed will be sold in one quart glass containers. The rest of the output will be sold in half-gallon bottles. Constant "a" thus is equal to $1.03.

Table 6. Total Annual Sales of Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Sales in Dollars
1000	TS = 312 a Q (27)	$ 321360.00
5000	"	1606800.00
10000	"	3213600.00
15000	"	4820400.00
20000	"	6427200.00

Annual cost of raw material: Raw milk costs are based on the April 1957 price paid by dealers in Atlanta for milk of four per cent butterfat content.

Table 7. Total Annual Cost of Raw Milk for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_m = 26.7\ m\ Q$ (1)	$ 185000.00
5000	"	925000.00
10000	"	1850000.00
15000	"	2775000.00
20000	"	3700000.00

Annual plant labor costs: Average salaries for all plant employees are considered to be $3000.00 per year. This is the value of constant "s".

Table 8. Total Annual Plant Labor Cost for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_1 = (.0197\ Q^{.803})s$ (4)	$ 13700.00
5000	"	50400.00
10000	"	88900.00
15000	"	126500.00
20000	"	166500.00

Annual equipment cost: The annual equipment cost is based on equipment of the type listed in Table 25 of the Appendix. Hence, constant "e" is equal to $702.00 and exponential factor "n" is .57.

Table 9. Total Annual Equipment Cost for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_e = \frac{e\,Q^n}{15}$ (6)	$ 2420.00
5000	"	6490.00
10000	"	8950.00
15000	"	11100.00
20000	"	14100.00

Annual building costs: Cost per square foot (m) of floor area is equal to $6.29 (Table 26). Building depreciated over 50 year period.

Table 10. Total Annual Building Cost for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_b = m\,308\,Q^{.42}$ (11)	$ 700.00
5000	"	1400.00
10000	"	1800.00
15000	"	2200.00
20000	"	2580.00

Annual container cost: One half of the volume of output will be bottled in one-quart glass containers and the rest of the output will be in half-gallon jugs. The container costs, including caps, are based on prices listed in Table 27. Life of the bottles are considered as 25 trips between plant and consumer. Therefore, P_{gq} is \$.0825; P_{gh} is \$.146; P_{gqc} is \$.00276; P_{gnc} is \$.00276; PC_3 is .5; and PC_4 is .5.

Table 11. Total Annual Cost for Containers and Caps for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	* (13)	$ 5352.00
5000	"	26760.00
10000	"	53520.00
15000	"	80280.00
20000	"	107040.00

* See Page 24. It should be noted that since PC_1 and PC_2 are zero, the remaining components in Equation (13) disappear.

Annual water cost: The price of water is taken from Table 28. The value of constant "r" is .000262; .000215; .00208; .000198; and .000191 dollars per gallon of water for values of plant output of 1000, 5000, 10000, 15000, and 20000 gallons of milk per day, respectively.

Table 12. Total Annual Cost of Water for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_w = 11218\ r\ Q^{.82}$ (16)	$ 842.00
5000	"	2580.00
10000	"	4340.00
15000	"	5800.00
20000	"	7750.00

Annual Fuel Cost: The values of constants in Equation (20) are based upon heat requirements for equipment listed in Table 23 and the price of natural gas in Atlanta on the SN - 8 rate. Thus "i" is .133; exponential factor "s" is .73; "Y" is $.428 \times 10^{-5}$, $.326 \times 10^{-5}$, $.314 \times 10^{-5}$, $.301 \times 10^{-5}$, $.297 \times 10^{-5}$ dollars per BTU of fuel for 1000, 5000, 10000, 15000, and 20000 gallon per day milk output, respectively. Fuel required for purposes other than milk processing and related factory operations is not included in these computations.

Table 13. Total Annual Fuel Cost for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_f = 8.65 \times 10^7 \ YfQ^s$ (20)	$ 762.00
5000	"	1870.00
10000	"	3000.00
15000	"	3820.00
20000	"	5100.00

Annual administration and general costs: These expenses are calculated as a percentage of estimated receiving, processing and bottling expenses of each plant size. The per cent assumed is 30.

Table 14. Total Annual Administration and General Expenses for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_{ag} = .3\ (C_1 + C_e + C_b + C_c + C_w + C_f)$ (21)	$ 6900.00
5000	"	26500.00
10000	"	47400.00
15000	"	68000.00
20000	"	91110.00

Annual retail delivery costs: Market estimates indicate that the delivery expenses will follow the pattern set by Equation (23). Constant "d" will equal 3.82 dollars per gallon per year, exponential factor "h" will equal 1.30, and P will equal 1. Commissions paid the drivers are not included in these figures. It is also estimated that each route will average approximately $4500.00 in annual expenses. This value will be used subsequently in computing the fixed capital investment in vehicles.

Table 15. Total Annual Delivery Costs for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	$C_{dt} = d\,PQ^h$ (23)	$ 30600.00
5000	"	241000.00
10000	"	606000.00
15000	"	1030000.00
20000	"	1490000.00

<u>Annual commissions paid drivers</u>: The drivers on the retail routes will be paid a five per cent commission on their total sales. This expense is calculated as a per cent of sales on all the routes.

Table 16. Total Annual Commissions Paid Retail Delivery Drivers for Various Size Plants

Gallons Per Day	Expression and Equation Number	Annual Cost in Dollars
1000	Commission = .05 (TS) (27)	$ 16068.00
5000	"	80340.00
10000	"	160680.00
15000	"	241020.00
20000	"	321360.00

Total annual profit: The following table summarizes the sales and cost figures given in the previous tables. The difference between these values results in the total annual profits.

Table 17. Total Annual Profits of Various Size Plants

Gallons Per Day	Annual Sales	Total Annual Costs	Total Annual Profit
1000	$ 321360.00	$ 262344.00	$ 59016.00
5000	1606800.00	1362340.00	244460.00
10000	3213600.00	2824590.00	389010.00
15000	4820440.00	4343720.00	476720.00
20000	6427200.00	5905540.00	521660.00

Total capital investment: The capital investment required is equal to the sum of the items listed in Table 5. Process equipment installation is considered as 30 per cent of equipment cost; land as two per cent of equipment and building cost; cost of engineering as ten per cent; contractor's fee as five per cent; and contingency as ten per cent. Investment in delivery units is estimated as the quotient of total annual delivery costs divided by $4500.00 (the average fixed expense per route) times the price of each vehicle. This price of each truck is taken as $3200.00.

Table 18. Total Capital Investment for Various Size Plants

Item	Plant Size - Gallons Per Day				
	1000	5000	10000	15000	20000
Equipment	$36300.00	$97350.00	$134250.00	$166500.00	$211500.00
Building	35000.00	70000.00	90000.00	110000.00	129000.00
Vehicles	22400.00	172800.00	432000.00	732800.00	1081600.00
Installation	10890.00	29200.00	40275.00	49950.00	63450.00
Land	1426.00	3347.00	4485.00	5300.00	6810.00
Engineering	8361.00	19989.00	26949.00	33175.00	41076.00
Contractor Fee	4598.00	10993.00	14821.00	18246.00	22591.00
Contingency	9197.00	21987.00	29643.00	36492.00	45183.00
Total	$128172.00	$425666.00	$772423.00	$1152463.00	$1601210.00

Total working capital: Expression $.5\,C_{mu}\,Pc$ in the following equation need not be used, for it has little influence on results.

Table 19. Total Working Capital for Various Size Plants

Gallons Per Day	Expression and Equation Number	Total Working Capital
1000	$I_w = R_m (C_{mu} + 4C_p + .5C_{mu} P_c)$ (28)	$ 23342.00
5000	"	105586.00
10000	"	207428.00
15000	"	307866.00
20000	"	409240.00

Per cent return on investment: All the values are now available for calculating the estimated per cent return on investment.

Table 20. Per Cent Return on Investment for Various Size Plants

Gallons Per Day	Expression and Equation Number	Per Cent Return on Investment
1000	$P = \frac{TS - TC}{I_f + I_w}$ (26)	38.95
5000	"	46.02
10000	"	39.70
15000	"	32.64
20000	"	25.94

Figure 8 shows graphically the unit sale price and the unit costs of operating plants of various capacities. Sale price and raw milk costs

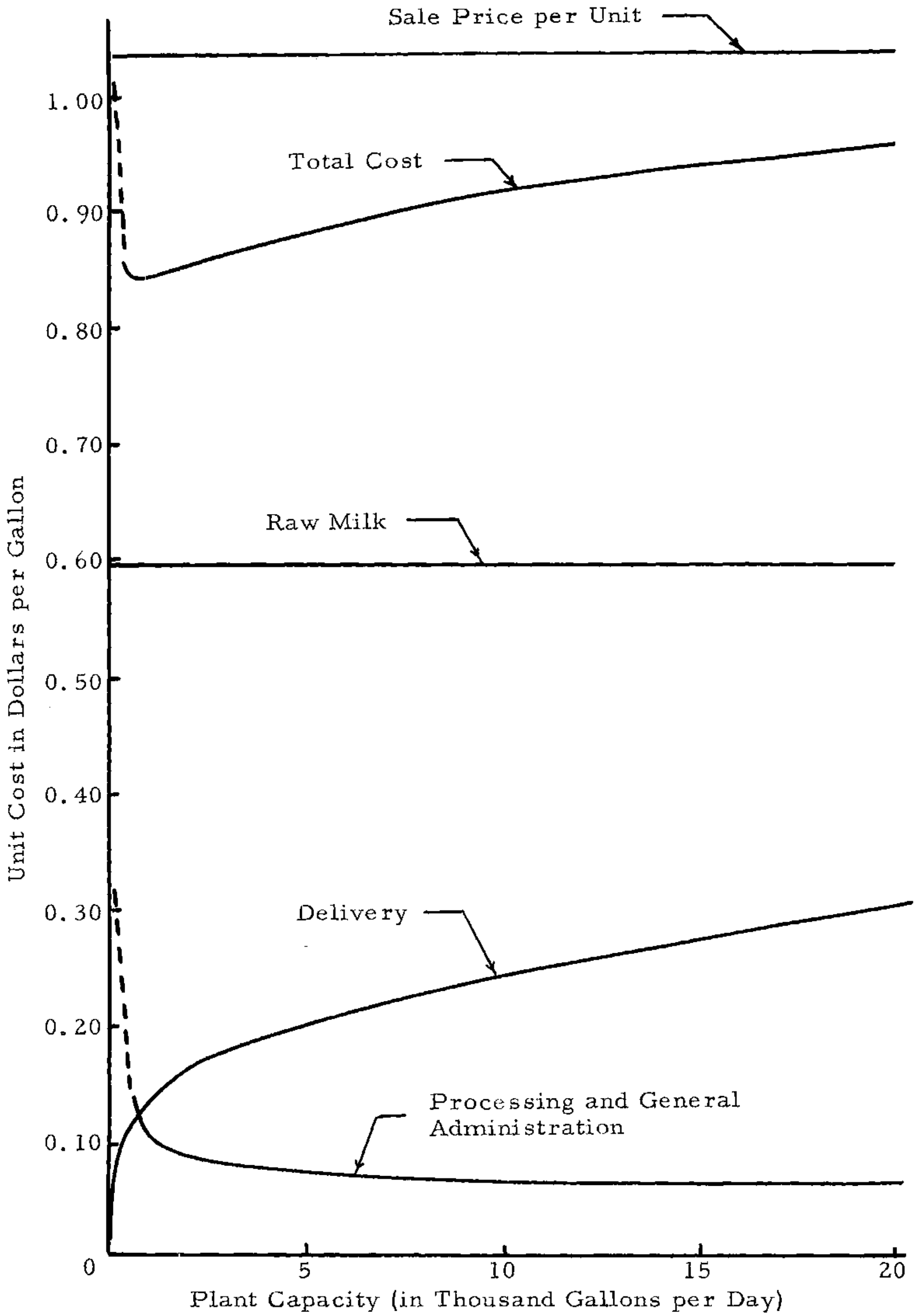

Figure 8. Unit Costs for Various Size Plants

are constant for all plant sizes. However, it can be clearly seen that delivery costs and processing and administration expenses vary considerably with installation size. Relative to each other, delivery and processing expenses behave in an opposite manner. As capacity increases, unit processing costs decrease. Unit delivery cost meanwhile increases with higher plant capacity. On the basis of the total unit cost, it appears that optimum plant capacity is below 1000 gallons per day. Figure 9 presents the information discussed above on a total sales and costs relative to plant capacity.

Figure 10 shows the curves of per cent return on investment and total investment required for various size plants. Thus the plant size that should be selected on a per cent return on investment basis is an installation of approximately 5000 gallons daily capacity. Further computations for sizes in the 5000 gallon per day capacity range would yield the more exact value. It is obvious that the cost of delivery and the related investment in vehicles is the expense and investment items having the greatest limiting effect on the size of the plant. Meanwhile, delivery expenses are generally the most difficult to control and reduce because of the factors influencing delivery operations. Some of these factors affecting deliveries have been discussed in Chapter III.

The figures show that the plant capacities at which unit profit, total profit and per cent return on investment are each at their respective maximum ar · not the same. Whether a plant should be built

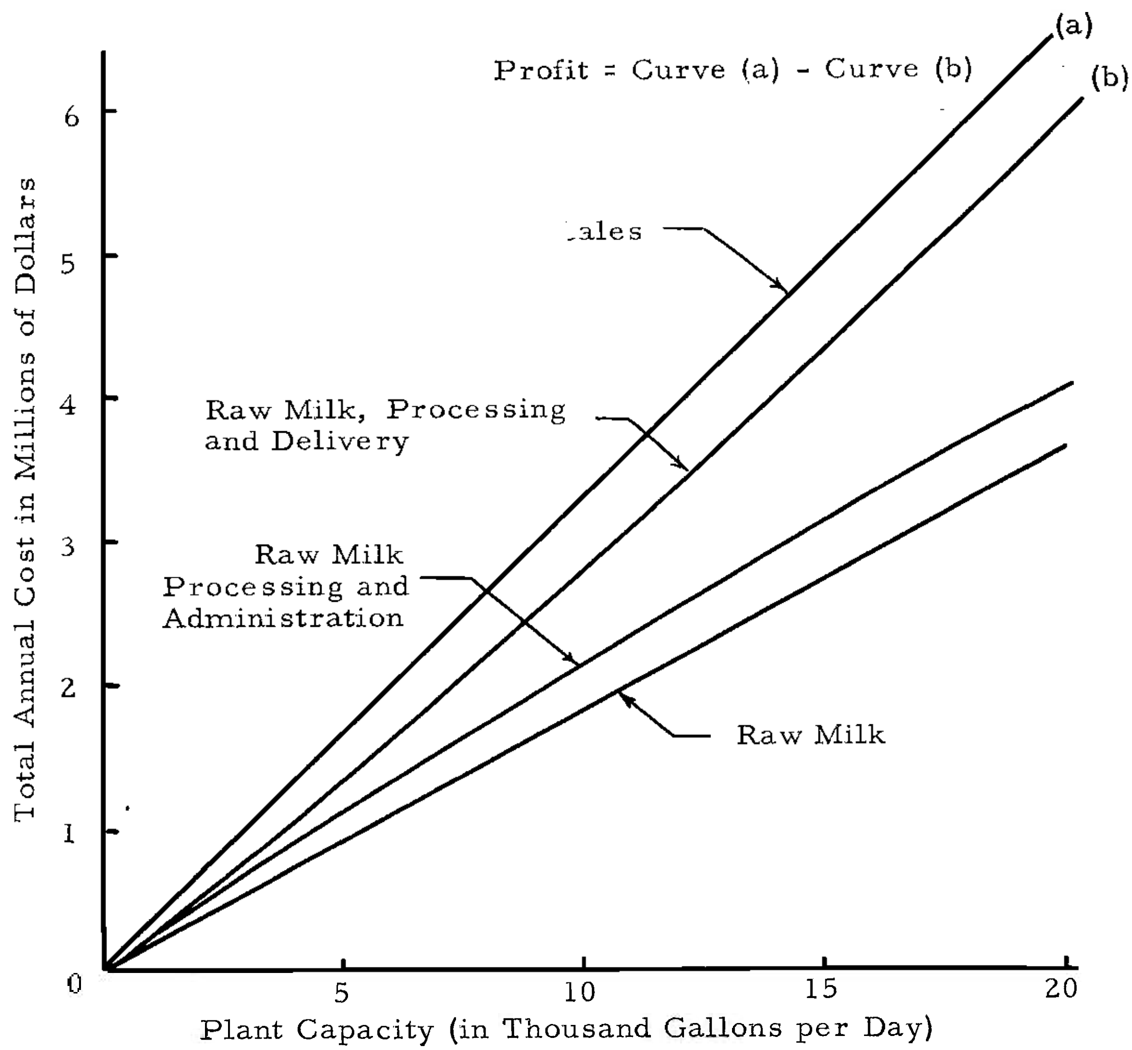

Figure 9. Total Annual Sales and Expenses of Various Size Plants

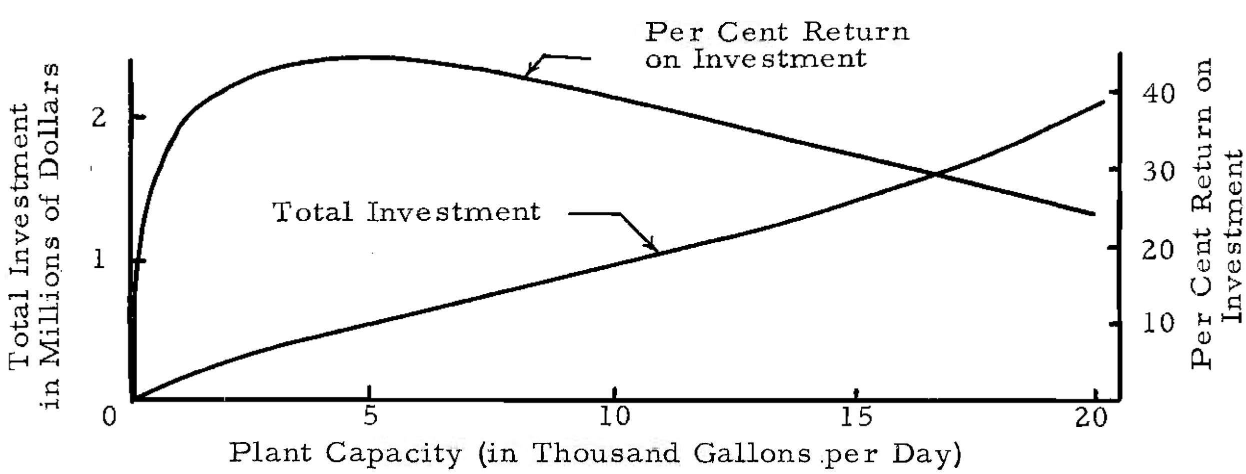

Figure 10. Total Investment and Per Cent Return on Investment for Various Size Plants

or expanded to satisfy one or another of these conditions will finally depend upon the decision of management. However, the criterion of the maximum return on investment appears to be the most logical.

The foregoing may serve as a pattern in calculating the optimum size of an enterprise engaged in any production or business endeavor. Of course, the proper mathematical expressions and their related constants would have to be established. These expressions and constants would depend upon the type of operation contemplated, the conditions encountered and the general overall management policies.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The primary purpose of this study was to establish a mathematical model of the fluid milk processing industry for use in determining the plant capacity that would yield optimum return on investment. With the establishment of this expression the study has attempted to show how it could be used in a specific case. Although the study deals with only the fluid milk industry, it is the writer's firm conviction that this type of analysis of other industries would be very useful. Not only would prospective entrepreneurs be assisted in making wise investment decisions, but anyone interested or concerned with manufacturing, business or economy at large would be given a better insight and understanding into the many problems of industry.

The sales, costs and investment components of the fluid milk industry follow a well defined pattern. The following may be said of these components:

1. If similar units of goods sold are considered (i.e. same type, style and size container of a standard milk), the expression of sales is generally of the type:

$$S = a\,Q$$

Where S = total sales

a = unit price per gallon

Q = quantity in gallons

2. Raw milk to be processed and sold as standard market milk generally has a cost expression of the type:

$$C = bQ$$

Where C = total cost of raw milk

b = unit cost per gallon

Q = quantity in gallons

3. Operational costs, which include receiving, processing and bottling are generally of the type:

$$C = cQ^m$$

Where C = total operational cost

c = unit cost per gallon

Q = quantity in gallons

m = exponential factor, where $0 < m < 1$

4. Delivery costs, including retail and wholesale distribution, are generally of the type:

$$C = dQ^n$$

Where C = total delivery cost

d = unit cost per gallon

Q = quantity in gallons

n = exponential factor, where $n > 1$

5. Capital investment in buildings and the necessary processing equipment is generally of the type:

$$I_c = e\,Q^p$$

Where I_c = total capital investment

e = unit investment per gallon

Q = quantity in gallons

p = exponential factor, where $0 < p < 1$

6. Investment in delivery units is generally of the type:

$$I_v = h\,Q^r$$

Where I_v = investment in delivery units

h = unit investment per gallon

Q = quantity in gallons

r = exponential factor, where $r > 1$

7. After consolidating the formulas written in the previous statements, the general expression for the return on investment R is of the following type:

$$R = \frac{(a-b)\,Q - c\,Q^m - d\,Q^n}{e\,Q^p + h\,Q^r}$$

It can be seen that in order for R to give a range of positive values, the following condition should be satisfied at all times:

$$(a-b)\,Q > c\,Q^{m} - d\,Q^{n}$$

When the above condition is satisfied, it will be found that R reaches a maximum between certain critical values of Q_1 and Q_2. At Q_1 and Q_2, R is equal to zero. For the conditions discussed in this thesis, it appears that R reaches the optimum value closer to Q_1 than Q_2.

8. The lowest total unit cost is often taken as the basis of plant size selection. However, it was found in this study that the above criterion is not very realistic because the plant capacity at which the total unit cost is at a minimum is not necessarily the same as the capacity resulting at the maximum return on investment.

9. A high capacity installation should not be the only aim of the entrepreneur until all aspects of the milk processing operation are carefully studied and analyzed. It may be better to consider a number of small or medium size, strategically located installations to one large capacity plant.

10. The possibilities for greatest reduction in cost lie in the delivery phase of the fluid milk processing operation. The

continued serving of marginal and sub-marginal routes in a delivery system may, in many cases, cause a marked increase in overall delivery expenses and, consequently, less profit or even loss will be realized.

Recommendations: Although the major cost and investment aspects of the fluid milk industry have been considered, additional studies would be valuable in determining those components that were not covered fully by this study. In particular, the author feels that while the factors affecting the processing costs are reasonably well established, a great deal of research would be advisable in the area of delivery costs. In general, the pattern of processing costs is governed by the tec nological status of the industry and is not too difficult to determine. On the other hand, delivery costs depend on such factors as density of population, competition, size of the community, topographical features, racial composition of population, and other characteristics of a particular market. Finally, as stated previously, this type of analysis of other industries would be of great value in deciding on the optimum size of an enterprise.

APPENDIX

Table 21. Dealers' Buying Prices in April 1957 for Selected Markets

Market (By Cities)	Used for Fluid Milk Dealers' Buying Price (FOB City): Paid for Milk of Basic Fat Test Per cwt (Dollars)	Basic Fat Test (Per Cent)	Allowance 1/10% Butterfat (Cents)	Paid for or Adj. to 3.5% Fat Per cwt (Dollars)
Boston F	5.73	3.7	7.4	5.58
Trenton S	5.87	3.5	6.0	5.87
Milwaukee F	3.69	3.5	7.1	3.48
Asheville, Charlotte, NC S	6.25	4.0	6.0	5.95
Atlanta-Aug.-Col.-Macon S	6.93	4.0	7.0	6.58
Birmingham S	6.43	4.0	5.0	6.18
New Orleans F x	5.90	4.0	7.1	5.54
Kansas City, Mo. F	4.53	3.8	7.72	4.30
Dallas F	5.32	4.0	7.4	4.95
Los Angeles S	5.48	3.8	10.14	5.18

F = Federal order

S = State order

x = New Orleans 61-70 mile zone

Source: U. S. Dept. of Agriculture, Fluid Milk & Cream Report, April 1957.

Table 22. Plant Personnel Employed in Various Atlanta Fluid Milk Processing Plants

Dealer*	Average Plant Output, Gallons Per Day	Number of Plant Employees
A	1800	9
B	4000	13
C	5000	8
D	9000	20
E	9000	37
F	14000	34
G	15000	42
H	16000	43
I	18000	34
J**	15000	38

* Some dealers requested their names not be used and all names have, therefore, been coded.

** Colburg Dairy, Charleston, South Carolina - Southern Dairy Products Journal, November 1957.

Table 23. Estimated Basic Cost of New Equipment for Various Size Plants (All Glass Operations)

Average Capacity 250 gals/day		Average Capacity 1100 gals/day	
Pasteurizer	$2300.	Testing equipment	$ 500.
Homogenizer	2000.	Scales	1200.
Pump	125.	Storage vat	2500.
Cooling (sweet water)	1000.	Pump	125.
Sweet water system	1200.	Clearifier	2500.
Filler	600.	Pasteurizer (2 past. vats) (LTLT vat past.)	4600.
Washing equipment	300.	Homogenizer (includes pump)	3000.
Boiler (steam), 6 HP	500.	Plate cooler	2000.
Cooler compressor	500.	Filler (auto. 7 valve fil.)	4500.
Milk storage	2000.	Pump (for cream line milk)	300.
Total	$10525.	Washer	4000.
		Conveyors	1000.
		Storage room (includes compressor	6250. *
		Sweet water system	1500.
		Boiler (steam), 20 HP	2500.
		Can washer	2000.
		Stainless steel tubing for piping	2000.
		Total	$40475.

(Continued)

Table 23 (Continued). Estimated Basic Cost of New Equipment for Various Size Plants (All Glass Operations)

Average Capacity 2250 gals/day	
Testing lab equipment	$1000.
Weighing equipment	3000.
Storage coolers	10000.
Pump	125.
Clearifier and standardizer	4500.
Pasteurizer (HTST)	8500.
Heating & cooling (clean-up pump)	600.
Homogenizer	4000.
Filler	6000.
Roller converter	500.
Washer	9000.
Conveyor (washer to filler)	2000.
Storage room	11500. *
Sweet water system	[illegible]000.
Boiler (steam), 40 HP	4000.
Can washer	5000.
Stainless steel tubing for piping	8000.
Total	$80725.

Average Capacity 12500 gals/day **	
Lab equipment	$4000.
Storage tanks	25000.
Clearifier, standardizer and separator	4500.
Pasteurizer (HTST)	12000.
Clean-up pump	600.
Homogenizer	8000.
Surge tank	3500.
Filler	10000.
Power conveyor (to storage room)	25000.
Storage room	23000. *
Bottle washer	12000.
Conveyor (washer to filler)	5000.
Sweet water system	7000.
Boiler (steam), 100 HP	7000.
Piping	12000.
Total	$143500.

(Continued)

Table 23. (Continued). Estimated Basic Cost of New Equipment for Various Size Plants (All Glass Operations)

	Average Capacity 20000 gals/day**
Lab equipment	$6000.
Storage tanks	40000.
Clearifier, standardizer and separator	7000.
Pasteurizer (HTST)	20000.
Clean-up pump	600.
Homogenizer	10000.
Surge tank	7000.
Filler	20000.
Power conveyors	12000.
Storage room	30500. *
Bottle washer	24000.
Conveyor (washer to filler)	6000.
Sweet water system	12000.
Boiler (steam), 200 HP	7000.
Piping	14000.
Total	$216100.

* As estimated from information supplied by York Corporation, York, Pennsylvania.

** Probably tank truck operation.

Source: Sales Representative, Cherry Burrell Corporation, Atlanta, Georgia.

Table 24. Comparative Data on Milk Storage Rooms

	Installation				
	A	B	C	D	E
Room Dimensions (feet)					
Length	17.5	17.0	42.7	40.0	56.0
Width	13.0	15.0	21.5	23.5	55.0
Height	7.5	7.8	7.7	9.7	9.2
Product Load (gallons)	700	625	1120	2500	10800
Total Refrigeration (tons per 20 hours of operation)	1.64	1.73	3.9	10.8	21.6

Cost may be computed as approximately $1065.00 per ton of refrigeration required.

Source: Condensed from tables of York Corporation, York, Pennsylvania.

Table 25. Estimated Annual Machine and Material Cost for Paper Carton Operations on Rental Basis

Average Output (Gallons of Milk Daily)	Daily Cost	Annual Cost (312 Day Per Year Operation)
One-Quart Container Operation		
375 *	$ 31.20	$ 9734.40
500 *	38.58	12036.96
650 *	45.80	14289.60
750 *	54.15	16894.80
4850 **	304.00	94848.00
8100 ***	508.00	158496.00
Half-Gallon Container Operation		
250 #	$ 25.40	$ 7924.00
500 #	39.33	12270.96
1000 #	67.22	20972.64
3456 #	207.00	64584.00
7128 ##	415.00	129480.00
10800 ###	636.00	198432.00

* Based on rental cost of Midget Model "E" Pure-Pak
** Based on rental cost of Junior Model "N" Pure-Pak
*** Based on rental cost of Senior Model "Q" Pure-Pak

Based on rental cost of Midget Model "S" Pure-Pak
Based on rental cost of Junior Model "R" Pure-Pak
Based on rental cost of Senior Model "C" Pure-Pak

Source: Pure-Pak Division, Ex-Cell-O Corporation, Detroit, Michigan.

Table 26. Total Erected Cost of Buildings

Type of Building	Cost Per Square Foot of Floor Area
Office*:	
Steel frame, brick and concrete walls, concrete floors and roof, heating, lighting, plumbing, sprinklers	$16.00
Manufacturing, 15 foot floor clearance*:	
Steel frame, walls and roof, concrete floors, lighting, plumbing, sprinklers	14.00
Industrial, one-story masonry**:	
Brick walls, concrete floors, heating, lighting, plumbing - 30,000 to 40,000 sq.ft.	6.70
Industrial, one-story masonry**:	
Brick walls, concrete floors, lighting, plumbing, heating - 7,000 to 9,000 sq.ft.	6.29

* Source: Building Cost Manual, The Joint Committee on Building Costs of The Chicago Chapter of The American Institute of Architects and The Appraisers Division of The Chicago Real Estate Board, New York: John Wiley & Sons, Inc., 1957.

** Source: Aires and Newton, Chemical Engineering Cost Estimation, New York: McGraw-Hill Book Company, Inc., 1955.

Table 27. Cost of Machines and Supplies for a Fluid Milk Processing Plant

Item	Cost in Dollars	Quantity
One-quart glass bottle	$11.87	per gross
Half-gallon glass bottle	21.00	per gross
Caps (including hood and disc)	2.67	per thousand
Wooden cases (12-quart capacity)	4.00	each
Ten-gallon cans	12.00	each
Five-gallon dispenser	12.00	each
Dispenser sealing wire	6.50	per thousand
Dispenser tube	25.00	per 250
Dispenser parchment paper	3.65	per thousand
One-quart paper container		
(including preforming costs)	25.00	per thousand
Half-gallon paper container		
(including preforming costs)	45.00	per thousand
Paper machines		
(standard 28 quart per minute)	4000.00	each
(hand operated 10-12 quart per minute)	2000.00	each

Source: Courtesy of Sewell Simpson Dairy Supply Company, Atlanta, Georgia, November 1957.

Table 28. Monthly Water Rates for Domestic, Commercial, and Industrial Consumers in Atlanta, Georgia

Water Used Per Month (Cubic Feet)	Net Charge (Dollars)
Minimum billed, 800 cu. ft. per month	$1.25
Next 4200 cu. ft. per month	.33 per 100 cu. ft.
Next 5000 cu. ft. per month	.25 per 100 cu. ft.
Next 5000 cu. ft. per month	.20 per 100 cu. ft.
Next 5000 cu. ft. per month	.18 per 100 cu. ft.
Next 100000 cu. ft. per month	.15 per 100 cu. ft.
Next 200000 cu. ft. per month	.14 per 100 cu. ft.
Next 200000 cu. ft. per month	.13 per 100 cu. ft.
All over 520000 cu. ft. per month	.11 per 100 cu. ft.

Source: Atlanta, Georgia, Water Department, December 1957.

Table 29. Approximate Daily Heat Requirements for Certain Milk Processing Operations (a)

Output (Gallons of Milk Daily)	Heat Requirements in 100,000 BTU's		
	Vat Pasteurization (b)	Bottle Washing (c)	Can Washing (d)
250	2.5	....	....
1000	10.0	6.7	....
5000	50.0	31.8	15.2
12500	125.0	77.0	38.1
20000	200.0	112.0	61.2

a) For plant using one-quart glass, ten-gallon receiving cans and pasteurizing at low temperature. An efficiency of 80 per cent considered throughout.

b) Heat for vat pasteurization based on raising temperature of milk from 42 to 142 degrees Fahrenheit and holding for 20 minutes. Heat losses considered in 80 per cent efficiency.

Example: For 250 gallons of milk processed daily -

$$\text{Required heat} = \frac{\text{(lbs of milk) (specific heat) (temperature change)}}{\text{efficiency}}$$

$$= \frac{(250)\ (8.6)\ (.93)\ (100)}{.80} = 250000 \text{ BTU's}$$

(c) Based on Cherry Burrell Model K Soaker Washers, operating at average speed for required time at suggested temperature; 5-wide, 7-wide, 11-wide, and 12-wide washers considered for 1000, 5000, 12500, and 20000 gallon daily milk output, in that order.

(d) Based on Damrow Brothers Company Type ss-8 single line can washers at suggested boiler horsepower for required time.

Table 30. Comparative Cost Data for Various Fuels

Fuel	Current Unit Cost	BTU Per Unit	Required Natural Gas Rate to Equal Current Fuel Cost
Residential Use:			
#1 Fuel Oil	17.8¢/gal.	137,000/gal.	13.9¢
#2 Fuel Oil	16.2¢/gal.	139,000/gal.	12.5¢
Stoker Coal	$18.40/ton	14,000/#	7.3¢
Lump Coal	$16.65/ton	14,000/#	9.5¢
LP Gas	17.5¢/gal.	91,500/gal.	19.0¢
Natural Gas	7.6¢/th.	100,000/th.	7.6¢
Small Commercial and Industrial Use:			
#2 Fuel Oil	12.3¢/gal.	139,000/gal.	8.8¢
N&S Stoker Coal	$10.40/ton	14,350/#	4.1¢
LP Gas	17.5¢/gal.	91,500/gal.	19.0¢
Natural Gas	4.78¢/th.	100,000/th.	4.8¢
Large Commercial and Industrial Use:			
#2 Fuel Oil	12.3¢/gal.	139,000/gal.	8.8¢
#5 Fuel Oil	11.0¢/gal.	147,000/gal.	7.5¢
#6 Fuel Oil	9.7¢/gal.	152,000/gal.	6.4¢
Steam Coal N&S	$8.15/ton	14,400/#	2.8¢
Steam Coal (Carbon)	$7.60/ton	14,200/#	2.6¢
Plant Atkinson	$7.54/ton	12,500/#	2.9¢
LP Gas	8.3¢/gal.	91,500/gal.	9.0¢
Natural Gas (Part Firm)	2.3¢/th.	100,000/th.	2.3¢
Natural Gas (Inter.)	2¢/th.	100,000/th.	2.0¢

Source: Atlanta Gas Light Company, September 19, 1957.

Table 31. Individual Route Cost of a Home Delivery System

Route Number	Average Gallons Delivered Per Route (a)	Total Annual Cost (b)	Average Unit Cost
1	167	$2299.	$.088
2	153	2175.	.091
3	150	2174.	.092
4	138	2298.	.106
5	132	2226.	.111
6	129	2283.	.113
7	131	2381.	.116
8	122	2257.	.118
9	120	2341.	.125
10	112	2216.	.126
11	108	2155.	.127
12	118	2341.	.127
13	110	2217.	.129
14	104	2218.	.131
15	117	2423.	.132
16	107	2237.	.134
17	105	2196.	.134
18	110	2309.	.134
19	108	2278.	.135
20	109	2309.	.135
21	102	2178.	.136
22	105	2237.	.136
23	112	2421.	.138
24	105	2280.	.139
25	102	2230.	.140
26	96	2174.	.143
27	98	2227.	.145
28	98	2237.	.146
29	104	2381.	.146
30	98	2262.	.147
31	105	2342.	.147
32	105	2424.	.148
33	99	2295.	.148
34	94	2175.	.148

(Continued)

Table 31 (Continued). Individual Route Cost of a Home Delivery System

Route Number	Average Gallons Delivered Per Route (a)	Total Annual Cost (b)	Average Unit Cost
35	95	$2216.	$.149
36	96	2257.	.150
37	100	2341.	.150
38	92	2245.	.156
39	89	2175.	.156
40	91	2240.	.157
41	90	2216.	.157
42	90	2276.	.162
43	86	2258.	.168
44	88	2338.	.170
45	80	2165.	.173
46	84	2374.	.181
47	74	2134.	.184
48	71	2135.	.192
49	69	2132.	.198
50	71	2257.	.203
51	68	2175.	.205
52	68	2200.	.208
Total	5375	$117330.	

(a) Every-other-day route deliveries

(b) Includes:

Truck and equipment depreciation
Drivers' salary
License, insurance and taxes
Ice for refrigeration during summer
Maintenance and repair
Gasoline and oil

Source: Based on figures supplied by a leading milk processing firm in Atlanta. Firm name is withheld by request.

Table 32. Individual Route Cost of a Wholesale Delivery System

Route Number	Average Gallons Delivered Per Route (a)	Total Annual Cost (b)	Average Unit Cost
1	660	$13489.00	.0655
2	495	10994.00	.0710
3	550	12394.00	.0724
4	425	9934.00	.0748
5	450	10684.00	.0760
6	410	9784.00	.0767
7	425	10264.00	.0771
8	385	9299.00	.0774
9	375	9099.00	.0776
10	410	9904.00	.0776
11	375	9110.00	.0779
12	385	9414.00	.0784
13	350	8624.00	.0790
14	370	9150.00	.0796
15	370	9170.00	.0797
16	350	8754.00	.0801
17	340	8480.00	.0803
18	310	8009.00	.0828
19	275	7297.00	.0850
20	250	7130.00	.0920
Total	7960	$190983.00	

(a) Average daily quantity for 312-day year

(b) Includes:
Truck and equipment depreciation
Drivers' salary and commissions
License, insurance and taxes
Ice for refrigeration during summer
Maintenance and repair
Gasoline and oil

Source: Based on figures supplied by a leading milk processing firm in Atlanta. Firm name is withheld by request.

Table 33. Dealers' Selling Prices in April 1957 for Selected Markets

Market by Cities	Selling Prices for Standard Milk					
	Wholesale b		Retail			
			Home Delivery		Stores	
	Bulk/gal. (¢)	Bottled/ qt. (¢)	Single qt. (¢)	2 - qt. cont. (¢)	Single qt. (¢)	Mult. qt. cont. (¢)
Boston	84	21.5	25	51	23-25	fg 41-45
Trenton	86	23.5	26	-	f24.5-28	f 48
Milwaukee	61-64	18.	22	40	19-21	g 35-37
Asheville	86-94	24.	26	-	26	-
Charlotte	-	22	26	47	26	-
Atlanta	91	e 23.5-24.5	e26-27	e 51-53	e26-27	e 51-53
Birmingham		23.75	26	51	z 26	51
Kansas City, Mo.	74-78	19	23	44	19-21	g 39
Dallas	88	-	26	51	-	-
Los Angeles	66-72.5	18.75	s 25.5	s 45.5	20.5	40.5

b - published list prices subject to unknown discounts
e - higher prices for paper containers
f - paper container
g - gallon price not included in table as follows:
Boston - 79¢
Milwaukee - 72¢-78¢, home; 65¢-69¢, store
Kansas City, Mo. - 68¢
s - includes service charges for first unit each single delivery
Los Angeles - 5¢
z - 1¢ sales tax not included

Source: U. S. Department of Agriculture, Fluid Milk & Cream Report, April 1957.

Table 34. Number of Plant Personnel Employed in Various Size Plants

Plant Output Gallons Per Day Q	Number of Employees N_e	Log Q	Log N_e
750	4	2.8751	0.6021
1500	7	3.1761	0.8451
2500	10	3.3979	1.0000
4000	15	3.6021	1.1761
7500	25	3.8751	1.3979
15000	44	4.1761	1.6435

The plot of the number of plant employees against daily plant output is not linear (see Figure 2). Instead, the curve is of the exponential type and its algebraic equation takes the form of:

$$N_e = kQ^x \qquad \text{(a)}$$

To solve constant "k" and exponential factor "x" in the above equation, the data have been arranged as shown in Table 34. The logs of N_e and Q were obtained from a table of logarithms. The equations then becomes:

$$\log N_e = \log k + x \log Q \qquad \text{(b)}$$

By substituting the data from the above table into the log equation, the following six equations can be written.

$$\begin{array}{rcl} 0.6021 & = & \log k + x\, 2.8651 \\ 0.8451 & = & \log k + x\, 3.1761 \\ 1.0000 & = & \log k + x\, 3.3979 \\ \hline 1.1761 & = & \log k + x\, 3.6021 \\ 1.3979 & = & \log k + x\, 3.8751 \\ 1.6435 & = & \log k + x\, 4.1761 \end{array}$$

Adding the first three and the last three equations,

$$\begin{array}{rcl} 2.4472 & = & 3 \log k + x\, 9.4491 \\ 4.2175 & = & 3 \log k + x 11.6533 \end{array} \quad \text{(c)}$$

which yield, on subtraction,

$$\begin{array}{rcl} 1.7703 & = & x\, 2.2042 \\ x & = & .803 \end{array}$$

Substituting for "x" in Equation (c),

$$\begin{array}{rcl} 3 \log k & = & 2.4472 - (.803)\, 9.4491 \\ & = & -\ 5.1404 \\ k & = & .0197 \end{array}$$

Equation (a) thus becomes

$$N_e = .0197\, Q^{.803}$$

The remaining exponential equations used in this study were solved in a similar manner.

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