An economic study of milk produced and processed for manufacturing purposes in selected Montana areas

by James Harold Cothern

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Agricultural Economics
Montana State University

Abstract:
This dissertation is a study of the production, processing, and transportation of milk for manufacturing purposes in selected areas in Montana. These areas for the most part are located in Lake, Gallatin, and Ravalli counties. The study is primarily concerned with the economic analysis of changes in efficiency in the production and processing of milk as volume produced and processed changes.

The areas considered have in the past been sites of dairy activity. However, dairying as a source of income in these areas has been declining. This study examines some of the alternatives available to existing operators in view of available resources.

Data made available by the Experiment Station, the Cooperative Extension Service, the Montana Crop and Livestock Reporting Service as well as personal interviews provide the basis for determining the optimum number, size, and site of processing plants that would most efficiently process the volume of milk available for manufacturing purposes in Montana in 1970.

The tools used for this purpose are linear programming, budgeting, and a derivation of the linear programming transportation model, the Stollsteimer model.

Based on the use of the Stollsteimer model a plan for more efficient utilization of plants' existing volume is advanced. This plan could result in economic improvement to the producer and processor. Other recommendations are made that conceivably could help existing plants alleviate the problem of declining volume.

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AN ECONOMIC STUDY OF MILK PRODUCED AND PROCESSED FOR MANUFACTURING PURPOSES IN SELECTED MONTANA AREAS

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ABSTRACT

This dissertation is a study of the production, processing, and transportation of milk for manufacturing purposes in selected areas in Montana. These areas for the most part are located in Lake, Gallatin, and Ravalli counties. The study is primarily concerned with the economic analysis of changes in efficiency in the production and processing of milk as volume produced and processed changes.

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CHAPTER I

INTRODUCTION

Background Information

The production, processing, and marketing of milk and milk products in the United States has undergone many of the same changes that have taken place in much of United States agriculture during the past 50 years.

The changes in production of milk on farms has gone from one or two cows on almost every farm to many cows, in some cases thousands, on few farms. The adoption of new technology in the production of milk has been significant. From herringbone milking systems and parlors in the production of milk to huge bulk systems to transport milk, the industry bears little resemblance to that of 50 years ago.

Along with this adaptation of new technology have come other changes. The number of farms reporting milk cows has declined. The total number of cows reported has been decreasing. The decline in cow numbers has been offset by a large increase in production per cow. The competitive position of dairy products with other foods has also changed. Substitutes for a great many dairy products now exist. This transition has caused specific problems for the Montana dairy farmer and processor.

Changes in the Dairy Industry in Montana

Looking at a 10-year period from 1956 to 1965 illustrates some changes that have taken place. During this time period, milk production in Montana has shown some substantial changes in number of dairy farms, cow numbers, milk used on farms and amounts and methods used to market milk off the farms. The number of milk cows on farms has followed a general decline from 95 thousand in 1956 to 57 thousand in 1965.

Production per cow has also increased. This is particularly evident when a comparison is made of all cows with those in efficient segments illustrated by Dairy Herd Improvement Association Units. Table 1.1 illustrates this change. A comparison of cow numbers for the years 1960 and 1965 indicates that dairy cow numbers in Montana have decreased by approximately 26 percent.

Production over this same period is illustrated in Table 1.2. Production of milk for Grade A purposes has increased by nearly 8 percent from 1960 to 1965. Over this same period Grade B production has decreased 8 percent but total production has increased 5 percent.

Several conclusions can be drawn from the data presented in these two tables. Total production of milk over the 1960 to 1965 period has increased with 26 percent fewer cows. The increase has come in the milk produced for Grade A purposes which over this period has accounted for approximately 84 to 86 percent of total milk produced in the state. There are several reasons for this. The fluid market's requirements for sanitation and the level of efficiency necessary to exist in the industry has required that new technology and large amounts of capital be expended by the producer. This has forced the producer to make large investments in milking parlors, pipeline milkers, and bulk coolers. To justify this

TABLE 1.1. MILK COWS AND PRODUCTION OF MILK, GALLATIN COUNTY DAIRY HERD IMPROVEMENT ASSOCIATION AND THE STATE OF MONTANA, 1956-1965.

Year	Milk Cows on Farms a/	Production Per Cow a/		Gallatin County D.H.I.A. b/	
		Milk	Butterfat	Milk	Butterfat
	Number	Pounds	Pounds	Pounds	Pounds
1956	95,000	5,260	195	10,698	390
1957	92,000	5,320	197	10,770	387
1958	88,000	5,510	204	10,803	391
1959	84,000	5,600	207	10,863	391
1960	77,000	5,990	222	11,464	412
1961	72,000	6,210	230	11,362	409
1962	67,000	6,330	234	11,223	409
1963	63,000	6,440	235	11,649	415
1964	60,000	6,600	241	11,939	420
1965	57,000	6,630	242	12,315	432

a/ Montana Department of Agriculture, Montana Agriculture Statistics, Helena: Vol. XI, August, 1967.

b/ Earl J. Peace, Montana Dairy Herd Improvement Association Annual Report, Cooperative Extension Service (Bozeman: 1956-66).

TABLE 1.2. TOTAL MILK PRODUCTION FOR GRADE A AND MANUFACTURING PURPOSES, 1960-1965. a/

Year	Total Milk	Grade A	For Manufacturing b/
	1,000 Pounds	1,000 Pounds	1,000 Pounds
1960	232,000	194,880	37,120
1961	240,000	199,200	40,800
1962	240,000	199,200	40,800
1963	240,000	201,600	38,400
1964	245,000	210,700	34,300
1965	244,000	209,840	34,160

a/ Unpublished data released by Statistical Reporting Service, Helena, Montana, 1967.

b/ Manufacturing or Grade B milk is defined as that milk purchased from dairy farms not licensed to sell Grade A milk. Grade A milk is that milk purchased from dairy farms that are licensed to sell Grade A milk that is eligible for fluid consumption, including any surplus used for manufacturing purposes.

investment in these facilities along with the investment required for cows, shelter and land for feed production, the producer must have some reasonable assurance of a market and a stable pricing program. This has caused the efficient producer, exemplified by the Gallatin County D.H.I.A. data, to attempt to enter the Grade A market with its associated higher prices and stability of demand. Therefore, the manufacturing market's principal source of supply are those producers who are unwilling or unable to convert to Grade A production.

The Problem

The changes discussed in the previous section have brought about several problems. In the past, Montana has had a much larger industry producing milk for manufacturing purposes. Apparently, profitability of producing milk for manufacturing purposes has been declining. Manufacturing prices are geared to government support prices. Prior to 1967 these have been quite low in relation to fluid milk prices in Montana. Apparently more attractive opportunities exist as a Grade A milk producer or outside dairying completely. These factors have also had an adverse effect on plants processing milk for manufacturing purposes. This decrease in volume, low price support levels, and increasing costs of labor and other factors have caused excess plant capacity, lower profit levels, and a decrease in the residual that can be paid the producer.

These pressures have caused the exodus of a great number of producers and processors. Many people believe that in Montana milk cannot be economically produced for the Grade B market at all.

The increase in the production of Grade A milk has not been without problems. One of these difficulties has been that of efficient utilization of surplus which is the residual beyond the normal product mix associated with fluid milk that is used for manufacturing purposes.

Unfortunately this residual is utilized principally in the manufacture of butter which has not been an item of high return for the producer. Consequently production is held quite close to the Grade A base. Producing strictly for the Grade A base can cause shortages in certain parts of the state at certain times of the year and surpluses in these same areas during the spring and early summer. This is primarily due to seasonal variation in production. In the past this surplus has not existed in a sufficient quantity at individual plant sites to process it into more profitable products such as American cheddar. If there is a sufficient volume of milk in a producing area an alternative might be the manufacture of such a product. While this type of alternative does not offer as high a price as the fluid market offers, the market for this type of product is relatively steady. The major metropolitan areas in Southern California and Western Washington all import a large volume of manufactured products which include cheese and butter.

In summary, three problems in the area of production and processing exist. First, there is a real question if the dairyman producing milk for the Grade B market can continue to produce milk for this market. Both the processor and producer need to have more information about the relative competitiveness of this enterprise at various price levels related to other agricultural opportunities. Second, there is a problem of excess capacity in existing Grade B plants. If the prospect for continuing the production of milk for manufacturing under existing price levels is dim the problem will get worse. Third, there is the problem of utilization of milk beyond the normal plant mix processed by the Grade A plant.

Scope and Purpose of the Study

In view of these problems there are four major objectives of this study. First, to determine the relative competitiveness of the dairy enterprise with that of other alternatives available to a typical Montana producer and to determine at what production and price levels a processor or producer could expect the enterprise to enter a farm program. Second, to determine how the cost structure of a model manufacturing plant varies as the volume of milk increases. If excess capacity in plants is to be a continuing problem in the manufacturing industry and there are economies of scale present in the manufacture of milk, one possibility is to consolidate the volume of milk at the various sites into larger quantities in order to utilize these economies associated with processing these larger volumes at fewer sites. Third, to determine some least cost methods and associated costs of transporting milk between these sites. Fourth, to determine if there are economies associated with transporting and processing volumes of surplus Grade A milk from cities in the state. This volume of milk would be in excess of that needed for the normal plant mix processed by the Grade A plants in those cities.

History and Administration of the Present Pricing Program 1/

The government has been active in the purchase of milk and its products since 1933. Their purchases have never been great as a percent of total milk produced; but market prices have been closely allied with support levels.

Since some selected price support levels will be used throughout the thesis, a brief discussion will be devoted to the organization and administration of this program. The government programs have ranged from direct price supports during the depression to incentive type programs administered during World War II and the Korean War.

After World War II a "clean the market" concept has come into being. The present dairy program is authorized under the Agricultural Act of 1949. In the wording of this act,

> . . . the price of whole milk, butterfat, and the products of such commodities, respectively, shall be supported at such a level not in excess of 90 percentum of the parity price therefore as the Secretary determines necessary in order to assure an adequate supply. . . .

Table 1.3 illustrates the relationship between percentage of parity, support price, and market price since 1949. Table 1.3 serves to illustrate the close correlation of market price to support price. This is not to say that the support price is the market price but in the past has been closely related to it.

1/ A good account of the government's role in the pricing of dairy products is outlined in Anthony S. Rojko's The Demand and Price Structure for Dairy Products, USDA Tech. Bul. 1168 (Washington: May 2, 1957) pp. 149-159.

TABLE 1.3. MANUFACTURING MILK: COMPARISON OF ANNOUNCED SUPPORT PRICES AND UNITED STATES MARKET PRICES PAID TO PRODUCERS 1949-1966. 1/

	Manufacturing of Milk				
	Support Level		Market Level		
Marketing Year Beginning April 1	Percentage of Parity Equivalent Prior to Marketing Year a/	Price Per 100 Pounds	Price Per 100 Pounds	Parity Equivalent in Month Prior to Marketing Year a/	Average Parity Equivalent During Marketing Year
1949 b/	90 c/	3.14	3.14	90 c/	89
1950 d/	81 e/	3.07	3.35	88 f/	85
1951	86	3.60	3.97	94	93
1952	90	3.85	4.00	93	95
1953	89	3.74	3.46	83	84
1954	75	3.15	3.15	75	80
1955	80	3.15	3.19	81	82
1956	82	3.15			
	84	3.25 f/	3.31	86	84
1957	82	3.25	3.28	83	82
1958	75	3.06	3.16	77	77
1959	77	3.06	3.22	81	81
1960	76	3.06 g/			
	80	3.22 h/			
	85	3.40 i/	3.31	83	83
1961	83	3.40	3.38	83	83
1962	75	3.11	3.19 j/	76	77
1963	75	3.14	3.24	77	77
1964	75	3.15	3.30	77	77
1965	75	3.24	3.45	81	77
1966	78	3.50			
	89.5	4.00 k/	4.10	92	90
1967	87	4.00			

a/ Figures listed are the actual percentage of parity or parity-equivalent prices published near the end of March before the beginning of the marketing year.

b/ Calendar year.

c/ Based on parity equivalent published in March 1949.

d/ January 1, 1950 - March 31, 1951.

(Footnotes continued on following page.)

e/ Percentage of parity equivalent and parity prices, based on modernized parity published in January 1950.

f/ Effective April 13, 1956.

g/ Effective April 1 - September 16, 1960.

h/ Effective September 17, 1960 - March 9, 1961 (Public Law 86-799).

i/ Effective March 10, 1961.

j/ Beginning November, 1962, parity equivalent is based on prices for all manufactured milk instead of "3-product" price for American cheese, evaporated milk, and butter-nonfat dry milk combination used before.

k/ Effective June 30, 1966.

l/ Economic Research Service, Dairy Situation (Washington, D. C.: May, 1967), p. 8.

Administration of the Program

Prior to each marketing year, the Secretary of Agriculture announces the specific support levels that will be in effect for the coming marketing year. Under the purchase program the Secretary announces that the Commodity Credit Corporation will stand ready to buy at the specified support levels any butter, cheddar cheese, and nonfat dry milk of the specified grades offered it in carlots. (Section 201)

Although only butter, cheese, and nonfat dry milk are purchased under the support program prices of other products are indirectly supported through the program. The average prices received by farmers have equaled or exceeded the support levels during most of the period since 1949.

Previous Research Related to Economic Adjustment of Dairy Firms in Montana

The purpose of this section is to review some of the literature associated with plant organization, optimal dairy farm organization, and some of the research related to supply response in Montana.

A 1955 Montana State College study indicated that the dairy picture in Montana was a continually changing one due to technological advance. 2/

2/ Edward H. Ward, The Influence of Technological and Legal Changes on the Operation of the Montana Milk Control Law, Montana Agr. Expt. Sta., Mimeo Cir. 90 (Bozeman: July, 1955), pp. 8-10.

It also pointed out that markets overlapped and were becoming increasingly competitive. Even at that time Ward noted there was not a stable marketing situation but that some areas suffered deficits at certain periods during the year while in surplus at other times. Improvement of transportation facilities and other advances also made the total market much more overlapping than it had been in the past.

Also in 1955, Davidson used budgeting techniques and a synthesizing process to derive a supply response model for the upper Flathead Valley. 3/ By this technique Grade A milk supply response within the limited range of alternatives presented by the budgeting-synthesizing method were analyzed. Various alternative adjustments to price changes were analyzed. Davidson noted that the number of possible alternatives that could be analyzed were limited by the budgeting technique and suggested the possible use of linear programming to expand the number of alternatives.

Further research on utilization of surplus through manufacture of cheddar cheese, butter, and cottage cheese was accomplished by Jones in 1957. 4/

Minimum daily requirements of milk necessary for manufacture of cottage cheese, cheddar cheese, and butter were determined. Alternatively,

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3/ J. R. Davidson, Supply Response of Grade A Milk Production in Upper Flathead Valley, Mimeo Cir. 91 (Bozeman: October, 1955).

4/ Donald F. Jones, Marketing Alternatives for Surplus Grade A Milk in Montana, Mimeo Cir. 100 (Bozeman: February, 1957).

net returns for the three commodities were compared when processed by an individual plant.

Bucher hypothesized that a cheese plant could improve income for Billings dairy farmers through a better utilization of surplus. 5/ Bucher synthesized a model plant handling from 5,000 to 40,000 pounds of milk per day and analyzed the returns at these varying levels.

Several other studies exist in the area of plant efficiency. Johnson, Clarke, and Forker did a rather detailed study of the manufacturing industry in California. 6/ Using the synthesizing technique model plants were constructed and compared in terms of efficiency to 200 plants. Cost schedules were computed for the actual plants and compared to the model. These estimates became part of a broader investigation of the pricing mechanism for milk in California.

Synthesizing and budgetary techniques have been completed in areas similar to Montana. Hammond and Cox's study of the structural changes in the North Dakota dairy industry related some of the same problems that exist in the Montana dairy industry. 7/

5/ Robert F. Bucher, Can a Cheese Plant Improve Income for Billings Milk Producers, Agricultural Economics Research Report No. 20 (Bozeman: October, 1962).

6/ Aaron C. Johnson, Jr., Olan D. Forker, D. A. Clarke, Jr., Operations and Costs of Manufacturing Dairy Products in California, Giannini Foundation, Research Report No. 272 (Berkeley: January, 1964).

7/ Jerome W. Hammond and Rex W. Cox, Structural Changes in the North Dakota Dairy Industry, Bulletin No. 454 (Fargo; June, 1965).

There are many good studies of efficiency problems in the production of dairy products. The dairy industry at the farm level has experienced the same general type of problems whether it be in Mississippi or Montana. More production per cow, fewer cows, bigger herds, fewer cheese plants, lower volume to these cheese plants--this is the trend that has been followed in the past few years. It is probably an understatement to say that linear programming has become a significant research tool in determining optimizing levels in the production process. 8/

The Problem Area

Over 90 percent of the milk used for manufacturing purposes is currently produced in three areas in Montana and the study is concentrated,

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8/ Iowa State has published two good studies since 1960 dealing with problems encountered in resource use on Iowa dairy farms. See Randolph Barker and E. O. Heady, Economy of Innovations in Dairy Farming and Adjustments to Increase Resource Returns, Research Bulletin No. 478 (Ames: May, 1960). See also Earl O. Heady, Ross V. Bauman and Frank Orazen, Adjustments to Meet Changes in Prices and to Improve Incomes on Dairy Farms in Northeastern Iowa, Research Bulletin No. 480 (Ames: June, 1960). Colyer's study emphasized the importance of strategic use of capital on Wisconsin dairy farms. A major conclusion was that on most Wisconsin dairy farms dairying could only be justified as a continuing enterprise, not as a new one. See Dale K. Colyer, Adjustments in Dairy Farming in Western Wisconsin Under Alternative Capital Limitations, Bulletin 578 (Madison: February, 1966). James G. Hamill noted the importance of high production, management, and proper use of capital in a study completed in Mississippi which used the linear programming technique. See Hamill, Costs and Returns to Producers of Milk for Manufacturing, Bulletin 672 (Oxford: October, 1963).

for most purposes, in these areas. 9/ The areas that were chosen specifically for purposes of the linear programming model were Gallatin County, Ravalli County, and Lake County. The principal agricultural areas within those counties are the Gallatin Valley, the Bitterroot Valley, and the Lower Flathead Valley, respectively.

It was felt that these areas typify the major portion of the dairy industry devoted to the manufacture of cheese in Montana. Other areas such as the Yellowstone Valley could be included but it was felt that the models derived from this study could apply to those areas with very little modification.

Characteristics of the Problem Areas

Weather and type of crops grown vary considerably in the three areas. Ravalli County averages about 112 frost-free days, Gallatin County averages about 107 frost-free days while Lake County averages 120 frost-free days. Precipitation in all three areas is light, limiting farming without irrigation. 10/ Water availability and the type of climate limit the types of

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9/ Unpublished data released by the Montana Crop and Livestock Reporting Service, Helena, Montana.

10/ Climatological and geological characteristics of the three areas are summarized in: Charles T. Hash and Jack R. Davidson, Economics of Vegetable Processing in Ravalli County, Montana, Agr. Econ. Research Report 25 (Bozeman: May, 1966). O. M. Hackett et al., Geology and Ground Water Resources of the Gallatin Valley, Gallatin County, Montana, Geological Survey Paper 1482, U. S. Government Printing Office (Washington, D. C.: 1960), pp. 12-13. Willaim DeYoung and R. C. Roberts, Soil Survey of the Lower Flathead Valley Area, Montana, Montana Agricultural Experiment Station (Washington: 1929).

crops that can be grown. Ravalli County and Lake County both appear to be capable of raising vegetable crops, sugar beets, legume crops, and grains. The shorter growing season in Gallatin County limits the types of crops to primarily legumes and grains.

All three areas have supported milk producers and manufacturers in the past. However, the volume and cost situation has caused the demise of a considerable number of plants and producers. Dairying still contributes heavily to Gallatin County's economy. Most of the milk is produced for Grade A purposes. At present there is one plant in this area that produce cheese and nothing else. A plant at Bozeman manufactures cheddar out of its surplus but fluid milk is its principal product.

Lake County is adaptable to raising legumes and winter wheat. Some corn is grown, a few sugar beets, oats, barley, and potatoes. The acreages of corn, sugar beets and potatoes are insignificant. Lumbering and livestock are also important segments of the valley's economy. Dairying is also an important activity. There is a manufacturing plant located in Ronan and Grade A milk is shipped to Missoula and Kalispell.

Crops that can be grown in Ravalli County are vegetable crops, sugar beets, legume crops, and grains. The valley in the past has supported dairying. At one time several processing plants existed in the valley. Now only two are in operation--one at Hamilton and the other at Stevensville. Increased costs and low volume were given as reasons for their closure. Some milk is shipped out of the valley to Grade A markets in Missoula.

Analytical Methods

Three different analytical tools were employed to accomplish the objectives of this study. These were (1) linear programming, (2) budgeting or cost-synthesis, and (3) the Stollsteimer location model.

Linear Programming.--The determination of an optimal farm organization with the possibility of the inclusion of a dairy enterprise can be arrived at in several ways. The farm budgeting technique has been used for many years but its major shortcoming is that of the burden involved in handling a large number of price variations, yield variables, or management variables applied as revisions to the basic model. With the development of linear programming and the high speed computer operations that would ordinarily take days can now be performed in minutes. Loomba defines linear programming as:

> a method of determining an optimum program of interdependent activities in view of available resources. The term linear implies that all relationships involved in the particular problem which can be solved by this method are linear. The term programming refers to the process of determining a particular plan of action. 11/

Several good references outline the theoretical procedure involved in the use of linear programming in farm management. 12/

11/ N. Paul Loomba, Linear Programming, An Introductory Analysis (New York: McGraw-Hill, June, 1964), p. 1.

12/ Earl O. Heady and Wilfred O. Candler, Linear Programming Methods (Ames, Iowa: Iowa State College Press, 1958).

The device was used in this study to test the feasibility of dairying under the following sets of possibilities. First, since the market price for milk is quite closely correlated with support levels, revisions were made in the basic model for changes in support levels. Secondly, since the ability to manage a dairy herd can vary quite drastically, revision was made in the basic model for differences in management. This was accomplished by programming four different dairy production levels. The advantage of the use of linear programming in this study now becomes apparent. These budget changes in the basic model can quite easily be analyzed by revision of the program. The linear program also yields the added bonus of the computation of the marginal value productivities for the various inputs.

The climatological differences in the areas under consideration necessitated the construction of two different linear programs for the milk production problem. For convenience these will be referred to as Basic Model One and Basic Model Two. Basic Model One included a system of 28 activities and 21 equations. Alternatives were more limited in the construction of Basic Model Two so it included a system of 24 activites and 14 equations.

The Synthesis Model: The Manufacturing Plant.--This study also made use of the budgetary or synthetic model approach which has been developed by Bressler and others. 13/ The cost structure of manufacturing plants changes as the volume of milk processed increases. There are several methods used in determining costs of different sized plants. Surveys are often made and existing plants' costs compared with these plants. However, there are differences in input rates and efficiency levels among plants of the same scale. Hence it is difficult to accurately ascertain the exact nature of these costs either by interplant or intra-industry comparison. The synthetic model attempts to overcome these obstacles by applying the same standards to all firms within the series to be studied. The synthetic model can also easily be revised. Since the number of product alternatives appears to be quite limited in Western Montana it was easier and probably more accurate to apply this method than alternative methods.

The Stollsteimer Location Model.--One of the considerations involved in this study is the possibility of merging the existing operations into various sizes and number of plants so as to more efficiently utilize the volume. Processing of surplus Grade A is also considered. The problem is not only that of the economies of scale associated with an increasing

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13/ R. G. Bressler, Economies of Scale in the Operation of Country Milk Plants with Special Reference to New England (Boston: New England Council on Marketing and Food Supply), 1942. Also see M. C. Connor, Leland Spencer and C. W. Pierce, Specifications and Costs for a Milk Pasteurizing and Bottling Plant, Virginia Agricultural Experiment Station Bulletin 463, Northeast Regional Publication 16 (Blacksburg, 1953), p. 48. For a detailed discussion of the theoretical basis for this technique and its adaption to cost analysis of plant operations, see B. C. French, L. L. Sammet, and R. G. Bressler, "Economic Efficiency of Plant Operations with Special Reference to Marketing of California Pears," Hilgardia, Vol. XXIV, No. 19, July, 1956, pp. 544-591.

size of plant but also the increasing transportation cost associated with fewer plants and greater distances. The general problem of location theory has been dealt with extensively by many theorists. Results of their work are incorporated into the study. The broad theoretical framework in which the problem of location theory rests will not be considered extensively here. 14/ The main discussion will be concerned with the specific theoretical model used in this thesis and some specific research related to this model.

Researchers in the past few years have become increasingly dissatisfied with the Loschion or Weberian approach to the economics of location. The applicability of these models is severely limited by the assumptions on which it is based. First of all, generally all points in the plans in the Weberian model are considered as potential plant sites. In actuality this is seldom the case. Normally plant locations are restricted to a selected number of points adjacent to an existing transportation network. The distance functions then are normally discontinuous which precludes the use of the marginal calculus in solving for optimum plant sites. The model is also restricted in that the number of plants is not considered a variable.

14/ Isard discussed the history and development of location theory quite well. See W. Isard, Location and Space Economy (Cambridge, Mass.: M.I.T. Press, 1956). Also specifically in the area of assembly and processing of milk see R. G. Bressler and D. O. Hammerburg, "Efficiency of Milk Marketing in Connecticut, No. 3, Economics of the Assembly of Milk," Storrs Agr. Expt. Sta. Bul. 239 (Storrs, 1942); and F. L. Olson "Location Theory as Applied to Milk Processing Plants," Journal of Farm Economics, Vol. XLI, No. 5, (December, 1959), pp. 1546-1555.

The linear programming model deals with problems of discontinuities in the distance function. We can note that first of all such a problem consists of three components: (1) a linear objective function, (2) a set of linear structural restraints, and (3) a set of nonnegativity restraints. We might visualize such a problem in the following manner. The linear objective function to be minimized represents the total shipping cost of goods to be sent from some origins to some corresponding destinations. Second, we can write a set of linear structural restraints which might, for example, give the relationships between the origin capacities and the goods to be received by different destinations (origin capacity restraints) and the relationship between the location capacities and the goods to be shipped (destination requirement restraints). Finally, we select a set of nonnegative constraints for the structural variables. They will state that no negative shipment is permitted. Mathematically the relationship can be expressed as:

Minimize

$$Z = f(x_1, x_2, \ldots, x_n) = c_1 x_1 + c_2 x_2 + \ldots + c_n x_n$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \leq b_i \qquad \begin{array}{l} i = 1,2,\ldots,n \\ j = 1,2,\ldots,n \end{array}$$

and

$$x_{ij} \geq 0 \qquad \begin{array}{l} i = 1,2,3,\ldots,n \\ j = 1,2,3,\ldots,n \end{array}$$

The linear programming transportation model, however, does not deal with problems involving economies of scale nor does it cope with problems involving variation in plant numbers.

Stollsteimer recognized the weaknesses of the basic linear programming transportation model and in 1961 introduced a model that was in essence an extension of the linear programming transportation model but one in which economies of scale could be considered. Plant number and locations could also be introduced as variables. The particular model will simultaneously determine the number, size, and location of plants which will minimize the combined assembly and processing costs of a particular raw material over a given time period produced at scattered production points.

Basically the model is as follows: Given I origins or raw material sites at which there is a quantity of X_i of a material produced to be transferred to one of L possible locations to be processed; the problem is to determine that number, size, and site of these locations that simultaneously minimizes the combined cost of transferring and processing the quantity of raw material produced at that origin. 15/ Algebraically the problem can be stated as:

15/ J. F. Stollsteimer, "A Working Model for Plant Numbers and Location," Journal of Farm Economics, Vol. 45, No. 3 (August, 1963), pp. 631-645.

"Minimize

$$(1) \quad TC = \sum_{j=1}^{J} P_j X_j \mid L_k + \sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} C_{ij} \mid L_k$$

with respect to plant numbers ($J \geq L$) and locational pattern $L_k = 1, \ldots, \binom{L}{J}$ subject to

$$(2) \quad \sum_{j=1}^{J} X_{ij} = X_i$$ = quantity of raw material available at origin i per production period.

$$\sum_{i=1}^{I} X_{ij} = X_j$$ = quantity of material processed at plant j per production period

$$\sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} = X$$ = total quantity of raw material produced and processed $X_{ij}, X_j \geq 0$ and $C_{ij} > 0$

where: TC = total assembly and processing cost

P_j = unit processing costs in plant j ($j = 1, \ldots, J \leq L$) located at L_j

X_{ij} = quantity of raw material shipped from origin i to plant j located with respect to L_j

C_{ij} = unit cost of shipping material from origin i to plant j located with respect to L_j

L_k = one locational pattern for J plants among the $\binom{L}{J}$ possible combinations of locations for J plants given L possible locations

L_j = a specified location for an individual plant ($j = 1, \ldots, J$)" 16/

16/ Ibid., pp. 632-633.

As Stollsteimer points out the procedure varies with the presence or absence of economies of scale and whether the plant costs are influenced by the plant site.

There are several possible combinations of these circumstances. Only one will be discussed here. It will be assumed that plant costs are independent of plant site and that there are economies of scale in operation.

A basic assumption is that the form of the long run plant cost function is linear with respect to output and to have a positive intercept. As Stollsteimer points out, "this particular functional form simplifies solution of the problem and appears to be applicable . . . within the relevant range to many plant operations." 17/ If factor costs are equal at all plant locations, the long run plant cost function will also be invariant with respect to location. In this case plant costs will be a function of plant size.

The process of minimizing equation (1) with respect to plant numbers (J) and a locational pattern (L_k) can be accomplished in two steps. The first step is to obtain a total transfer cost function minimized with respect to plant location and plant numbers. Secondly, the addition of these minimized transfer costs for varying numbers of plants to the total processing costs for these plants yields a combined transfer and

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17/ Theoretical support of this argument is advanced by S. C. French, L. L. Sammet, and R. G. Bressler, Jr., op. cit., pp. 545-557. Olson, however, assumes the processing cost function to be curvilinear. See Olson, op. cit., pp. 1548-1549.

processing cost function minimized with respect to plant location for varying numbers of plants.

The transfer function will be concave in shape. 18/ The number of plants that minimize these combined transfer and processing costs depend on the relative slopes of the minimized transfer cost function and the total processing cost function. As Stollsteimer points out, "in order that the total costs fall with an increase in plant numbers, the decrease in minimized total transfer costs must be greater than the increase in total processing costs." 19/

Sources of Data

The Linear Programming Production Models.--The necessary data for the linear programming models consisted of:

(1) Net cost coefficients for the objective function

(2) Input-output coefficients

(3) The necessary resource restrictions

(4) Prices for the buying and selling activities.

Net cost coefficients and input-output coefficients. -- Previous research by the Montana Cooperative Extension Service in the Yellowstone

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18/ Stollsteimer, Ibid., p. 636. Hoch, in a later article states that the second differences are not necessarily positive. See Irving Hoch, "Transfer Cost Concavity in Stollsteimer's Plant Location Model," Journal of Farm Economics, Vol. 47, No. 2 (May, 1965), pp. 470-472.

19/ Ibid., p. 638.

Valley as well as studies completed in the Bitterroot Valley and the Upper Flathead were utilized as principal sources of data for the cropping enterprises. 20/ These data consisted of input requirements in terms of cultural, harvest, miscellaneous costs, and fixed costs. Primary components of the variable costs were labor, fertilizer, and materials.

Much of the physical data in the Extension study appeared to be directly applicable to the current problem. Time and labor requirements for each of the cultural and harvesting operations for the enterprises should be capable of achievement under a reasonably efficient set of operating conditions. Total cultural harvest and fixed costs are included in Appendix I. These costs are included in detail and referenced as to source in Chapter II.

Requirements for a cow-calf enterprise were taken from sources completed by the Economic Research Service. 21/

20/ As can be noted in Appendix I, Sample Costs: Irrigated Crops Yellowstone County, Montana, Cooperative Extension Circular (Bozeman, 1964) was used for synthesizing costs related to the Bitterroot Valley as well as Charles Hash and Jack Davidson, Economic Feasibility of Vegetable Processing in Ravalli County, op. cit., also Jack R. Davidson, Supply Response in the Upper Flathead Valley, op. cit.

21/ Economic Research Service, Resource Situation: Non-Irrigated, 1370 Acre Grain-Livestock Farm, Economic Research Service Circular 1970 (Bozeman, 1964).

Input requirements and the derivation of net cost coefficients for the dairy enterprise came from several sources. 22/ Some estimates were made based on the author's experience as a dairyman. Thumb rules for feeding concentrates and hay were used. These costs and requirements are specified in Appendix I, Table I-IV.

Price Data. -- Montana Agricultural Statistics was consulted for this data as well as the monthly reports of the Statistical Reporting Service. Previous work at Montana State University was also consulted. 23/

Resource Restrictions. -- Federal programs dictate allotments in certain crop areas and the maximum acreage devoted to that specific crop. Typical allotments held with sugar companies also determined the maximum amount of sugar beets to be grown. Another determining factor was the amount of land available for cropping activity. These were determined from survey data in the areas involved. 24/ Since specialized dairying was not considered, a constraint was placed on the maximum number of cows

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22/ Cooperative Extension Service, Twin Falls County Dairy Herd Improvement Association Annual Report (Twin Falls, Idaho: 1960-64). Interviews with Floyd Olson, Manager, Consolidated Dairies, Ronan, Mont., Shane and Joe Heap, Managers, Glacier Mountain Cheese Factory, Gallatin, Montana helped determine the used value of much of the physical equipment.

23/ Vesterby compiled seasonal indices of inputs used a formula pricing plan for Grade A milk in Montana. These also were consulted. See Marlow Vesterby, "The Development of a Milk Pricing Formula at the Processor-Distributor Level for Montana", (Unpublished Master's Dissertation: Montana State University, August, 1966).

24/ Hash-Davidson, op. cit., p. 14.

to be milked. One of the objectives was to test the competitiveness of the dairy enterprise with existing activities. To consider a large, specialized dairy operation also means the consideration of large quantities of specialized equipment and capital. 25/

Budgetary Data.--The necessary data for the model constructed at the processing level was selected from several sources. Secondary data was consulted when applicable for such items as the physical plant, equipment, and utilities. 26/ Actual survey data was used for such items as labor, supplies, fuel costs, and other consumable items.

Survey Description.--Visits were made to four plants in Idaho, one in Utah, and one in Wyoming as well as initial visits and surveys conducted in four plants in Montana. The first three areas contained

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25/ Colyer found that dairying was only justified as an enterprise at Wisconsin Grade B prices only with present facilities. Certainly a major decision is involved to expand the dairy operation to a full scale specialized operation. Capital and labor requirements can cause a reluctance to increase such activity. The assumption here was that the farmer in a diversified farming area would keep it as only one of the activities.

26/ F. V. Kosikowski, "Cost of Manufacturing Cheese in New York State," Milk Products Journal, (May, 1954). Also see Hugh L. Cook and Kenneth J. Little, Marketing Costs and Margins for Selected Lots of Wisconsin Cheddar Cheese, Wisconsin Agr. Expt. Sta. and USDA Research Bulletin 210 (Madison: May, 1959). An earlier Wisconsin study was Hugh L. Cook and LaVerne Schaller, Costs for Manufacturing American Cheese in Wisconsin Factories of Two Vat Size, Univ. of Wisconsin, Dept. of Agr. Econ. (Madison: May, 1959). Two other studies were G. A. Rowe, Economics of Cheese Manufacturing in Tillamook County Oregon, Oregon Agr. Expt. Sta. Bul. 529 (Corvallis: December, 1952) and Christian Jensen, "Want A Cheese or Milk Drying Plant in Your Community?", North Dakota Farm Research Bulletin, Vol. 21 (Fargo: July, 1960). Bucher's work was also used. See Bucher, Can a Cheese Plant Improve Income for Billings Milk Producers?, op. cit.

plants that processed much larger volumes than those in Montana. Some of these plants were also different in makeup. Two of the plants were butter-powder operations while two were Swiss Cheese operations. Initial visits to these plants were made to become acquainted with the type of operation that the plant had at that time. Although some of the technology employed did not apply to the area in Montana, other phases of the operations did. This was particularly true for the Swiss operation which in many respects is similar to a cheddar operation. Plant organizations were observed and particularly the labor force necessary to operate the various stages in the plant. Interviews were held with the managers. Of particular interest was the emphasis by these managers on increasing producers' volume. Four of the six plants in Idaho, Wyoming, and Utah used some type of incentive program. All of the plants in this area were paying on a hundredweight basis. These initial visits were general in nature. Five of the six managers agreed to cooperate if further information was needed. Initial visits to the American Cheddar operations in Montana were also made. Managers in these areas also agreed to cooperate. Although the scale of operation was much larger in all of the plants in Idaho, Utah, and Wyoming than those in Montana many of the same problems were encountered.

A second visit was made to three of the plants in Western Montana. This visit was of a much more detailed nature. Economic engineering techniques were employed to derive stage times at the various processing stages. Cost of consumable items were obtained from the managers. This information is listed as to source throughout the study. Profit and Loss statements were analyzed where the managers permitted. The managers were all quite willing to cooperate although several expressed fear that some confidential information could cause them harm if disclosed.

In dealing with the transportation phase another problem was encountered. A large volume of information pertaining to milk transportation does not exist in Montana. Interviews with the H. F. Johnson Petroleum Company were conducted. This company transports gasoline, diesel fuel, and other petroleum products throughout the state. Interviews were held to determine repair costs, fuel, and labor costs, and operating times. Interviews with long distance milk haulers from Havre and Great Falls were also conducted. Much of the data pertaining to the stage operations in loading and transporting milk came from the review of these operations.

The state milk production data was gathered from the Statistical Reporting Service. These data were not broken into manufacturing and Grade A components. The state office secured permission to divide the information into these two components. Written permission to analyze their respective operations was obtained from plant owners. Once this permission was obtained the Statistical Reporting Service was most cooperative in supplying information related to the utilization of milk by these plants.

An analysis of data made available by the State of Montana Milk Control Board yielded the figures used in the computation of milk available for manufacturing in five cities. Officials and personnel at this office were cooperative in supply these data.

Limitations to the Data.--Bias can be present in any study due to the data utilized in making this analysis. This bias sometimes cannot be avoided but it should be recognized. It was felt that the variable cost estimates used in the alternative models were quite reliable. These were estimated over a fairly broad range of data and were checked against existing studies where available. However, estimates of fixed costs are another item. Since these estimates represent some return on investment, the calculation of these estimates can be influenced by the rate of return chosen. Operators are investing increasingly large amounts of capital and rates of returns that were considered adequate in the past might not interest present investors at all. The interest rates chosen represent those that constitute almost a sure return in terms of alternatives such as high grade bonds or investments of similar nature. Consequently, a downward bias in the calculation of fixed costs might be introduced once the element of uncertainty is introduced. An individual operator might be unwilling to invest in the cheese or milk transportation industry unless a return of 12 to 15 percent on his capital can be foreseen. What this return should be is debatable. An alternative to this problem would be to consider various interest rates and calculate the fixed costs using these rates. This problem was not undertaken in this study.

The data on the production of milk utilized in the processing phase of the study was computed over a short time period. This was particularly true in the analysis of the Grade A surplus component. However, this represented the best data available.

It is also important to emphasize two other limitations. In the ultimate long run all costs become variable. This would alter the shape of the long run average cost curve. In this dissertation the length of run considered was that long enough so that planning considerations could be instituted. Secondly, the Stollsteimer model chosen assumed that costs were independent of plant site. Some differences in costs at plant sites in fact did exist. Natural gas was not available at all sites and insurance and power rates might possibly fluctuate with location. Although these differences did not represent a significant portion of total costs, they should be recognized.

CHAPTER II

THE PRODUCTION MODELS

The success of a dairy manufacturing plant in the long run is dependent to a large degree on the stable production of milk in the areas concerned. The production of milk must provide returns which are competitive with other enterprise alternatives available in the area.

To determine if it would be profitable for farmers in the Lake, Ravalli, Gallatin area to produce milk rather than other farm products at varying manufacturing prices for milk and specified prices for other farm products, linear programming analyses were conducted.

Basic Model I

Two basic models were used. The first model was of a representative farm that might be considered an intensive row crop operation. The operation was derived from the results of research of Hash and Davidson in Ravalli County 1/ and also the work of the Cooperative Extension Service in Yellowstone County. 2/ This does not suggest that the model measures all farms existing in the area but merely serves as a basis of measuring the efficiency of one enterprise or activity against another. Enterprise activities not only included crops that are grown in the area but also crops that could be grown in the area. The Bitterroot Valley

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1/ Hash-Davidson, op. cit., pp. 12-14.

2/ Cooperative Extension Service, Sample Costs, loc. cit.

or the Yellowstone Valley would come closest to approximating the conditions outlined in the following section.

Thus, the different enterprise activities which were included in the first basic programming model were:

Corn	Wheat
Beans	Barley
Sugar Beets	Dairy
Alfalfa	

The only livestock activity was the dairy activity in this model. The total size of the dairy activity, if it were to come in at all, was restricted. The assumption was that any operation beyond 40 cows would become much more specialized and would require an additional investment in the physical plant. An individual operator would conceivably be very reluctant to undertake such specialization.

No restrictions were placed on the total amount of labor available. Seasonal labor could be hired as well as a considerable amount of custom work substituting for labor. The wage rate selected was $1.50 per hour. 3/

Some comments about the construction of the actual dairy model are warranted at this point. Since corn silage was included in the cropping activity, an intensive silage feeding program was utilized. Home grown barley was utilized as the grain ration with enough protein supplement added to make a 14 percent grain ration. The pasture activity was not utilized in the production of milk. It was used for the pasture of young animals. The dairy operation then was strictly a dry lot operation.

3/ *Ibid*.

Grain was fed at the rate of one pound of grain for each three pounds of milk produced. Silage was substituted for hay at the rate of three pounds of silage for a pound of hay to a maximum of 60 pounds of silage per day.

Land classes relating to the operation were restricted. The land was divided into two classes, that suited for row crop (Land Class I) and that suited for pasture (Land Class 4).

Rotational activities were such that at least two years of hay was required and that sugar beets were only grown one out of five or six years depending on whether the bean activity came into the solution or not.

It was also assumed that silage could be contracted to be grown in the spring and thus could be considered as a buying activity. Hay could be purchased as well as barley. Protein supplement was also included as a buying activity to be fed with the home grown barley as a dairy ration.

There were nine selling activities included in the matrix. There were hay selling, barley selling, wheat selling, sugar beet selling, silage selling, and four milk selling activities included. The milk selling activity was included at four different levels. Milk level one was \$3.00. This was about 71 percent of parity. Milk level two was \$3.50 which is about 80 percent of parity. Milk level three was \$4.00 which is about 91 percent of parity and the highest milk level was \$.50 higher at \$4.50 per hundredweight.

There were four different milk production levels. Milk level one was about the present statewide average for all producers. This was about 6,000 pounds of milk per cow per year. Milk level two was 9,000 pounds which was above the statewide average but slightly under the state Dairy Herd Improvement Association average. Milk level three was approximately the state D.H.I.A. average. Milk level four represented a high management level at 15,000 pounds of milk per cow. This is still an attainable level.

The difference in the various management and capital requirements for the four milk levels was also accounted for by placing different values on the animals and different labor requirements for the four production levels. The derivation of these capital and labor requirements is outlined in Appendix I-A.

Production and price levels for the other enterprises are presented in Table 2.1.

It can be noted from Table 2.1 that acreage allotments were assumed for sugar beets and wheat. An additional cropping restriction was imposed on the amount of hay to be included in the rotation. Due to rotational activities 26 acres of hay was the maximum to be included in the rotation at one time.

In total then there were 28 activites and 21 equations in the matrix. Cost and return budgets were prepared for each enterprise and are included in Appendix I.

TABLE 2.1. PRICE AND YIELD COEFFICIENTS USED IN BASIC MODEL ONE.

Activity	Requirements a/	Selling Price b/	Buying Price b/
		Dollars	Dollars
Sugar Beets (T/A)	16.5	15.00	
Barley (Bu/A)	65	.80	.90
Wheat (Bu/A)	50	1.50	
Silage (T/A)	20	6.00	6.50
Beans (Cwt/A)	15	6.50	
Alfalfa (T/A)	4	22.00	23.00
Land 1 (A)	126		
Land 4 (A)	24		
Protein Supplement (Cwt)			4.20
Sugar Beet Allotment (A)	27		
Wheat Allotment (A)	16		
Cow Allotment (No)	40		

a/ Yields, wheat allotments, and land requirements were taken from Cooperative Extension Service, Sample Costs: Irrigated Crops, Yellowstone County, Montana, op. cit., and Hash-Davidson, op. cit., p. 14.

b/ Prices are 1964 average prices received by farmers as reported by the Montana Crop and Livestock Reporting Service with adjustments made for federal programs where appropriate.

Optimal Farm Organization: Model I

The results of the linear programming analysis of the first type of farm are reported in Tables 2.2, 2.3, 2.4, and 2.5.

Net returns on this type of farm varied from -$618 to over $10,000 depending on the production and price levels. Net returns is here defined as returns after all costs have been deducted including 6 percent charged to equipment, land, and buildings. Variable costs were those only associated with the production of the activity (see Appendix I). Using variable costs as an optimizing function and a production level of 6,000 pounds per cow, the minimum price for milk could be $3.28 and still include dairying as an activity. Thus it was not included at the price of $3.00. A look at the data included in the tables indicates that the crop activities stay constant. Since the relationship is linear, after the optimum was reached, the acreages remain constant and only the buying and selling activities change as different production and prices were introduced. For example, the dairy activity does not enter the organization at the lowest production and price level (Table 2.2). After the dairy activity enters, returns vary with the change in the price of milk. Internal change of the organization that might occur in the long run due to an increase in the price of milk was not considered.

In terms of total costs including a 6 percent return on investment, land, equipment, and buildings, negative returns were obtained in three of the four production levels assuming a $3.00 price.

TABLE 2.2. MODEL I: OPTIMAL ORGANIZATION OF A MODEL 150 A. IRRIGATED FARM WITH A MILK PRODUCTION AVERAGE OF 6,000 POUNDS OF 3.5 PERCENT B.F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Sugar Beets (A)	21	21	21	21
Hay (A)	13	13	13	13
Wheat (A)	16	16	16	16
Silage (A)	21	21	21	21
Pasture (A)	20	20	20	20
Barley (A)	5	5	5	5
Beans (A)	37	37	37	37
Dairy (No)	0	40	40	40
Milk Selling (Cwt)	0	2,400	2,400	2,400
Silage Selling (T)	420	240	240	240
Sugar Beet Selling (T)	346.5	346.5	346.5	346.5
Bean Selling (Cwt)	555	555	555	555
Wheat Selling (Bu)	800	800	800	800
Barley Buying (Bu)	0	1,275	1,275	1,275
Hay Buying (T)	0	16	16	16
Protein Supplement Buying (Cwt)	0	16	16	16
Labor Using (Hrs)	1,341	3,181	3,181	3,181
Capital Use (Dol)	6,856	9,195	9,195	9,195
Total Revenue Minus Total Variable Cost	7,927	8,577	9,777	10,977
Total Revenue Minus Total Cost	-229	-618	582	1,782

TABLE 2.3. MODEL I: OPTIMAL ORGANIZATION OF A MODEL 150 A. IRRIGATED FARM WITH A MILK PRODUCTION AVERAGE OF 9,000 POUNDS OF 3.5 PERCENT B.F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Sugar Beets (A)	21	21	21	21
Hay (A)	13	13	13	13
Wheat (A)	16	16	16	16
Silage (A)	21	21	21	21
Pasture (A)	20	20	20	20
Barley (A)	5	5	5	5
Dairy (No)	40	40	40	40
Beans (A)	37	37	37	37
Milk Sold (Cwt)	3,600	3,600	3,600	3,600
Sugar Beets Sold (T)	346.5	346.5	346.5	346.5
Beans Sold (Cwt)	555	555	555	555
Wheat Sold (Bu)	800	800	800	800
Barley Bought (Bu)	2,075	2,075	2,075	2,075
Hay Bought (T)	36	36	36	36
Protein Supplement (Cwt)	24	24	24	24
Labor Used (Hrs)	3,273	3,273	3,273	3,273
Capital Used (Dol)	9,356	9,356	9,356	9,356
Total Revenue Minus Total Variable Cost	9,243	11,043	12,843	14,643
Total Revenue Minus Total Cost	-113	1,687	3,487	5,287

TABLE 2.4. MODEL I: OPTIMAL ORGANIZATION OF A MODEL 150 A. IRRIGATED FARM WITH A MILK PRODUCTION OF 11,000 POUNDS OF 3.5 PERCENT B. F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Sugar Beets (A)	21	21	21	21
Hay (A)	13	13	13	13
Wheat (A)	16	16	16	16
Silage (A)	21	21	21	21
Barley (A)	5	5	5	5
Pasture (A)	20	20	20	20
Dairy (No)	40	40	40	40
Beans (A)	37	37	37	37
Milk Sold (Cwt)	4,400	4,400	4,400	4,400
Silage Sold (T)	180	180	180	180
Sugar Beets Sold (T)	346.5	346.5	346.5	346.5
Beans Sold (Cwt)	555	555	555	555
Wheat Sold (Bu)	800	800	800	800
Barley Sold (Bu)	0	0	0	0
Barley Bought (Bu)	2,875	2,875	2,875	2,875
Hay Bought (T)	56	56	56	56
Protein Supplement (Cwt)	32	32	32	32
Labor Used (Hrs)	3,341	3,341	3,341	3,341
Capital Used (Dols)	9,916	9,916	9,916	9,916
Total Revenue Minus Total Variable Cost	9,884	12,084	14,286	16,486
Total Revenue Minus Total Cost	-32	2,168	4,370	6,570

TABLE 2.5. MODEL I: OPTIMAL ORGANIZATION OF A MODEL 150 A. IRRIGATED FARM WITH A MILK PRODUCTION LEVEL OF 15,000 POUNDS OF 3.5 PERCENT B. F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Sugar Beets (A)	21	21	21	21
Hay (A)	13	13	13	13
Wheat (A)	16	16	16	16
Silage (A)	21	21	21	21
Barley (A)	5	5	5	5
Pasture (A)	20	20	20	20
Dairy (No)	40	40	40	40
Beans (Cwt)	37	37	37	37
Milk Sold (Cwt)	6,000	6,000	6,000	6,000
Silage Sold (T)	140	140	140	140
Sugar Beets Sold (T)	346.5	346.5	346.5	346.5
Beans Sold (Cwt)	555	555	555	555
Wheat Sold (Bu)	800	800	800	800
Barley Bought (Bu)	3,675	3,675	3,675	3,675
Hay Bought (T)	76	76	76	76
Protein Supplement (Cwt)	40	40	40	40
Labor Used (Hrs)	3,713	3,713	3,713	3,713
Capital Used (Dols)	10,436	10,436	10,436	10,436
Total Revenue Minus Total Variable Cost	12,278	15,278	18,278	21,278
Total Revenue Minus Total Cost	1,842	4,842	7,842	10,842

The amount of labor employed varied from 1,341 hours per year where no livestock activity was included to 3,713 hours per year at a production level of 15,000 pounds of milk per cow per year. Thus labor employed in most cases would appear not to be a prohibitive factor.

The amount of capital required in these various operations varied from a low of $6,856 in the operation where dairying was not included to over $10,000 at the highest milk production level.

Table 2.6 illustrates the relationship between total revenue, total variable cost, and total cost as related to the dairy enterprise.

TABLE 2.6. COST AND REVENUE RELATIONSHIPS AT THE FOUR PRODUCTION AND PRICE LEVELS--MODEL I.

Production Level	Total Revenue Minus Total Variable Cost				Total Revenue Minus Total Cost			
Pounds of Milk Per Cow	Milk Price Per Hundredweight				Milk Price Per Hundredweight			
	3.00	3.50	4.00	4.50	3.00	3.50	4.00	4.50
	Dollars				Dollars			
6,000	--	3,527	4,728	5,928	--	- 618	- 471	729
9,000	4,194	5,994	7,794	9,594	-1,163	634	2,434	4,234
11,000	4,835	7,035	9,236	11,435	-1,082	1,115	3,317	5,517
15,000	7,229	10,229	13,229	16,229	789	3,789	6,759	9,789

Assuming a price of $3.00 per hundredweight the dairy enterprise showed a positive return over total cost at the highest production level only. It also showed this positive relationship at the highest price with a production of 6,000 pounds. This indicates that although costs may be covered in the short run, the long run total cost picture can be quite different.

Table 2.6 also shows the profitability of the high producing herd. Total costs were covered even at the lowest price level.

The minimum prices that milk could fall to and still include dairying as an activity under variable cost optimization were:

6,000 pound herd average	$3.28
9,000 pound herd average	2.67
11,000 pound herd average	2.58
15,000 pound herd average	2.30

Since this does not consider returns to management, no prediction can be made about which herd owner would exit from the industry first. The owner of the herd with the 15,000 pound average could conceivably be the first to exit. This could be due to better management and an expectation of a higher return elsewhere.

Relationship to Other Enterprises

A primary conclusion to be gained from this phase of the study was the economic comparison of dairying with other enterprises included in the model. Since this model was designed to test the relative profitability of the dairy enterprise against other alternative enterprises, a composite picture can be obtained. This is illustrated by comparing Table 2.6 with Table 2.7.

TABLE 2.7. COSTS AND RETURNS FOR THREE ENTERPRISES ON A MODEL 150 A. IRRIGATED FARM.

Activity	Revenue	Total Revenue Minus Total Variable Cost	Total Revenue Minus Total Cost
Sugar Beets	5,197	2,614	1,480
Wheat	1,200	752	- 112
Beans	3,607	1,683	- 315

Under the conditions of this model, the 40 cow herd producing 6,000 pounds of milk annually per cow per year would not produce as much revenue as the 21 acre sugar beet enterprise and the 9,000 pound herd would only produce as much revenue when milk was $4.00 per hundredweight or higher. The herd averaging 15,000 pounds of milk would yield more revenue than that particular enterprise at $3.50 or higher. The 16 acre wheat enterprise yielded more revenue than the 6,000 pound herd up to $4.00 per hundredweight for milk and yielded more revenue than both the 9,000 and 11,000 pound herd at $3.00.

Similar statements about the bean enterprise could be made by comparing it with the dairy herd in the same manner. The livestock enterprise did make more efficient utilization of the rest of the feed crops than by selling them, thus its inclusion in the program after the minimum price of $3.28 per hundredweight was reached.

Basic Model II

The variation in types of farming from Gallatin to Ravalli county warranted construction of a second type of model. Because of climatological differences most of the area in Gallatin County is not adaptable to growing corn, beans, or sugar beets.

This model then contained the following activities:

Alfalfa	Barley
Wheat	Dairy or Cow-Calf Activity

Net returns on a dairy versus a cow-calf operation were compared. The total size of the dairy activity as well as the size of the cow-calf activity was restricted. The cow-calf activity was limited to 80 calves marketed yearly. The amount of irrigated pasture and fall pasture available limited the activity to this maximum.

No restrictions were placed on the total amount of labor available. Seasonal labor could be hired as well as custom work.

Restrictions were placed on the total amount of land suitable for alfalfa, barley, and wheat. A restriction was also placed on the amount of pastureland available.

A strict rotational procedure was not followed except that wheat was restricted by the allotment and the total amount of alfalfa did not exceed 25 percent of the total Class I cropland. This was primarily for rotational reasons.

The buying activities included hay, barley, and protein supplement.

The selling activities included milk, hay, barley, wheat, and calves. The same procedure was followed as in the first basic model related to varying milk production and price levels.

The selling activity for the cow-calf enterprise was varied in three steps. The first level assumed a 450 pound calf being marketed at $22 per hundredweight. The second level assumed a price of $25 and the third level a price of $28. 4/

Production and price levels for the enterprises are presented in Table 2.8.

TABLE 2.8. PRICE AND YIELD COEFFICIENTS USED IN BASIC MODEL II.

Activity	Requirements a/	Selling Price b/	Buying Price b/
		Dollars	Dollars
Barley (Bu/A)	60	.80	.90
Wheat (Bu/A)	45	1.50	
Alfalfa (T/A)	3	22.00	23.00
Land 1 (A)	360		
Land 4 (A)	40		
Wheat Allotment (A)	80		
Hay Allotment (A)	72		
Cow Allotment (No)	40		
Protein Supplement (Cwt)			4.20
Cow-Calf (No)	80		

a/ Yields, wheat acreage, and land requirements derived from Cooperative Extension Data on an Irrigated Farm in Gallatin County, 1960.

b/ Prices are 1964 average prices received by farmers as reported by the Montana Crop and Livestock Reporting Service.

4/ Prices for calves as reported by the Montana Crop and Livestock Reporting Service varied from $24.70 to $28.60 per cwt. in 1965 and 1966; while the three year 1947-1949 average was about $21.00. A high level was represented by the $28.00 price, a medium level by the $25.00 price and the low price level was represented by the $22.00 price.

In total there were 24 activities and 14 equations for this model. Additional cost and return data necessary for the second matrix are presented in Appendix I.

Optimal Farm Organization: Model II
Dairy Operation Included

The results of the linear programming analysis for the second basic type of farm organization are reported in Tables 2.9, 2.10, 2.11, and 2.12.

A different picture was obtained from analyzing the second model. Negative net returns were obtained in all but the two highest production and price levels. This can be attributed to the value of the fixed costs associated with the firm, particularly land.

Analyzing the firm from the standpoint of variable costs indicates that returns varied from $10,161 to over $23,000. This presents a somewhat deceptive picture. If interest on investment is charged as it should be, then net returns for cropping enterprises would be negative. So in a sense one is looking at enterprise combinations that minimize loss.

Table 2.13 illustrated the relationship of total revenue to total variable cost and to total cost in terms of the dairy enterprise.

The dairy enterprise covered variable costs at any price and production level above 6,000 pounds of milk per cow per year. The additional restriction was that the minimum price of milk was at least $3.27 per hundredweight. At any price below $3.27 the dairy enterprise exited from the organization and all crop activities were sold. Returns over variable costs ranged from $3,455 to $17,573. Total returns were not

TABLE 2.9. MODEL II: OPTIMAL ORGANIZATION OF A 400 A. IRRIGATED FARM WITH A MILK PRODUCTION LEVEL OF 6,000 POUNDS OF 3.5 PERCENT B.F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Hay (A)	72	72	72	72
Wheat (A)	80	80	80	80
Barley (A)	208	208	208	208
Wheat Sold (Bu)	3,600	3,600	3,600	3,600
Barley Sold (Bu)	12,480	10,880	10,880	10,880
Hay Sold (T)	216	36	36	36
Dairy (No)	0	40	40	40
Pasture (A)	40	40	40	40
Milk Sold (Cwt)	0	2,400	2,400	2,400
Protein Supplement (Cwt)	0	16	16	16
Labor Used (Hrs)	1,332	3,172	3,172	3,172
Capital Used (Dols)	19,584	21,904	21,904	21,904
Total Revenue Minus Total Variable Cost	10,161	10,714	11,914	13,114
Total Revenue Minus Total Cost	-9,493	-11,190	-9,990	-8,790

TABLE 2.10. OPTIMAL ORGANIZATION OF A 400 A. MODEL FARM WITH A MILK PRODUCTION LEVEL OF 9,000 POUNDS OF 3.5 PERCENT B. F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Hay (A)	72	72	72	72
Wheat (A)	80	80	80	80
Barley (A)	208	208	208	208
Wheat Sold (Bu)	3,600	3,600	3,600	3,600
Barley Sold (Bu)	10,080	10,080	10,080	10,080
Hay Sold (T)	9.6	9.6	9.6	9.6
Dairy (No)	40	40	40	40
Pasture (A)	40	40	40	40
Milk Sold (Cwt)	3,600	3,600	3,600	3,600
Protein Supplement (Cwt)	24	24	24	24
Labor Used (Hrs)	3,266	3,266	3,266	3,266
Capital Used (Dols)	22,065	22,064	22,064	22,064
Total Revenue Minus Total Variable Cost	13,260	15,060	16,860	18,660
Total Revenue Minus Total cost	-8,804	-7,004	-5,204	-3,404

TABLE 2.11. MODEL II: OPTIMAL ORGANIZATION OF A 400 A. MODEL FARM WITH A MILK PRODUCTION LEVEL OF 11,000 POUNDS OF 3.5 PERCENT B.F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars 3.00	3.50	4.00	4.50
Hay (A)	72	72	72	72
Wheat (A)	80	80	80	80
Barley (A)	208	208	208	208
Wheat Sold (Bu)	3,600	3,600	3,600	3,600
Barley Sold (Bu)	9,280	9,280	9,280	9,280
Dairy (No)	40	40	40	40
Hay Bought (T)	24	24	24	24
Pasture (A)	40	40	40	40
Milk Sold (Cwt)	4,400	4,400	4,400	4,400
Protein Supplement (Cwt)	32	32	32	32
Labor Used (Hrs)	3,336	3,336	3,336	3,336
Capital Used (Dols)	22,263	22,263	22,263	22,263
Total Revenue Minus Total Variable Cost	14,319	16,519	18,719	20,919
Total Revenue Minus Total Cost	-8,304	-6,104	-3,904	-1,704

TABLE 2.12. MODEL II: OPTIMAL ORGANIZATION OF A MODEL 400 A. IRRIGATED FARM WITH A MILK PRODUCTION LEVEL OF 15,000 POUNDS OF 3.5 PERCENT B.F. PER COW.

Activity	Milk Price Per Hundredweight--Dollars 3.00	3.50	4.00	4.50
Hay (A)	72	72	72	72
Wheat (A)	80	80	80	80
Barley (A)	208	208	208	208
Wheat Sold (Bu)	3,600	3,600	3,600	3,600
Barley Sold (Bu)	8,480	8,480	8,480	8,480
Dairy (No)	40	40	40	40
Hay Bought (T)	56	56	56	56
Pasture (A)	20	20	20	20
Milk Sold (Cwt)	6,000	6,000	6,000	6,000
Protein Supplement (Cwt)	40	40	40	40
Labor Used (Hrs)	3,704	3,704	3,704	3,704
Capital Used (Dols)	23,143	23,143	23,143	23,143
Total Revenue Minus Total Variable Cost	14,561	17,561	20,561	23,561
Total Revenue Minus Total Cost	-8,582	-5,582	-2,582	418

positive for the dairy enterprise at any production or price level at the 6,000 pound production level.

TABLE 2.13. COST AND REVENUE RELATIONSHIPS AT FOUR PRODUCTION LEVELS--MODEL II.

Production Level: Pounds of Milk Per Cow	Total Revenue Minus Total Variable Cost: Milk Price Per Hundredweight 3.00	3.50	4.00	4.50	Total Revenue Minus Total Cost: Milk Price Per Hundredweight 3.00	3.50	4.00	4.50
	Dollars				Dollars			
6,000	--	3,455	4,655	5,855	--	-3,666	-2,466	-1,266
9,000	4,817	6,617	7,417	9,217	-3,676	-1,876	- 76	1,724
11,000	5,864	8,064	10,264	12,464	-4,086	-1,886	314	2,514
15,000	8,573	11,573	14,573	17,573	-2,620	380	3,380	6,380

They were positive only at the highest price level at the 9,000 pound production level. At 11,000 they were positive at $4.00 or $4.50 per hundredweight and at 15,000 they were positive above $3.50.

The minimum prices that milk could be and still include dairying as an enterprise activity were:

6,000 pounds per cow	$3.27
9,000	2.64
11,000	2.60
15,000	2.30

Dairying Versus the Cow-Calf Enterprise

As an alternative to dairying a cow-calf enterprise was introduced into the matrix. This enterprise assumed the capability of producing a 450 pound calf. The restriction was entered that the cow-calf enterprise could not exceed 80 calves a year. This was the amount of irrigated pasture and fall pasture available. 5/ It also assumed an 84 percent calf crop. 6/ (Appendix I)

The calves were sold at three prices--$22, $25, and $28 per hundredweight. The solution values are presented in Table 2.14.

TABLE 2.14. MODEL II: OPTIMAL ORGANIZATION OF A MODEL 400 A. IRRIGATED FARM WITH A BEEF PRODUCTION LEVEL OF EIGHTY 450-POUND CALVES YEARLY.

Activity	Beef Price Per Hundredweight--Dollars		
	22.00	25.00	28.00
Hay (A)	72	72	72
Wheat (A)	80	80	80
Barley (A)	208	208	208
Wheat Sold (Bu)	12,240	12,240	12,240
Hay Sold (T)	136	136	136
Pasture (A)	40	40	40
Labor Used (Hrs)	1,532	1,532	1,532
Capital Used (Dols)	23,311	23,311	23,311
Cow-Calf (No. Sold)	80	80	80
TR-TVC	14,005	14,969	15,933
TR-TC	-9,306	-8,342	-7,378

Returns, on a variable cost basis, ranged from $14,005 to $15,933. Returns, on a total cost basis, varied from -$9,306 at $22 to -$7,378 where the calves were sold at $28.

5/ Cooperative Extenstion Service, Sample Costs, op. cit., p. 11a, the above study assumed 1 AU per Acre, 2 AU's were assumed with supplemental feeding.

6/ Economic Research Service, Resource Situation, Non-Irrigated 1,370-Acre Grain Livestock Farm, op. cit., p. 7.

This type of operation utilized 1,532 hours of labor. This is over 1,100 hours lower than in the case where the most intensive dairy operation was included in the enterprise combination.

The cow-calf enterprise itself showed positive returns over total costs at all three prices. This occurrence is somewhat misleading in that the cow-calf enterprise does not make intensive use of the fixed factors. It also does not make intensive use of the variable factors. These are credited to the activity itself. What occurs is that greater losses are shown on the barley and hay activities while the cow-calf operation shows a net profit that is positive. This positive profit is based on abundant cheap pasture. As soon as the variable factors are used in this activity the profitability at these price levels diminishes rapidly. A livestock activity that utilizes these activities efficiently as an intermediate input will decrease the total cost of these activities over that of the outright sale of them.

The relationship between total variable, total cost, and revenue for the cow-calf enterprise is shown below.

Calf Activity Price Level	Total Revenue Minus Total Variable Cost	Total Revenue Minus Total Cost
Dollars	Dollars	Dollars
22.00	4,976	- 457
25.00	5,943	510
28.00	6,904	1,471

Comparison With the Dairy Operation

How does the cow-calf enterprise compare with the dairy enterprise as part of the total operation? Looking at Tables 2.9 - 2.12 and 2.14 allow us to make this direct comparison. On an individual basis the cow-calf activity appears to be more profitable than the dairy enterprise to price levels of $3.50 per hundredweight for milk. The dairy enterprise is more profitable than any of the cow-calf possibilities at production levels of 9,000 and a price of $4.00 per hundredweight, at 11,000 and $3.50 and finally at 15,000 and $3.50 or higher.

Looking at the net total revenue picture gives a somewhat different appraisal. (Tables 2.9 - 2.12 and Table 2.14). The operation as a whole yields more net revenue at all production levels of 9,000 and higher. That is, if the price of milk at the 9,000 pound level is at least $3.50. The 11,000 pound production level at $3.00 is approximately equal in net returns to the $25.00 calf operation. This is because of the previously explained fact that the beef enterprise uses less of the variable and fixed inputs than the dairy enterprise so the remainders are charged to the activity itself when they are sold.

Thus organization under the cow-calf operation and the dairy enterprise have certain weaknesses. Organization under the cow-calf enterprise is much more subject to the pasture limit available. It also does not utilize the operators labor to the degree that the dairy operation does. The dairy operation is a high labor user, under utilizes pasture, and makes high use of fixed inputs. This brings us to a discussion of a third possible type of enterprise combination.

Combination of Dairy and Beef

This combination is looked at only briefly. A price level of $3.00 per hundredweight for milk was assumed. The same four production levels were also used. A 450 pound calf was assumed produced and could be sold for $28.00. At production levels of 11,000 or lower the beef enterprise was included in the program. At the highest production level the dairy activity became more profitable than the beef activity. It was included at this maximum production level and the following results were recorded.

TABLE 2.15. MODEL II: OPTIMAL ORGANIZATION OF A MODEL 400 A. IRRIGATED FARM WITH A MILK PRODUCTION LEVEL OF 15,000 POUNDS OF 3.5 PERCENT B.F. AND A COW-CALF ACTIVITY.

Activity	Milk Price Per Hundredweight--Dollars			
	3.00	3.50	4.00	4.50
Hay (A)	72	72	72	72
Wheat (A)	80	80	80	80
Barley (A)	208	208	208	208
Dairy (No)	40	40	40	40
Wheat Sold (Bu)	3,600	3,600	3,600	3,600
Hay Bought (Bu)	96	96	96	96
Pasture (A)	40	40	40	40
Milk Sold (Cwt)	6,000	6,000	6,000	6,000
Protein Supplement Bought (Cwt)	40	40	40	40
Labor Used (Hrs)	3,804	3,804	3,804	3,804
Capital Used (Dols)	25,512	25,512	25,512	25,512
Calves Sold @ $28.00	40	40	40	40
TR-TVC	17,401	20,401	23,401	26,401
TR-TC	-8,111	-5,111	-2,111	889

Net revenue varied from -$8,111 to $889. Labor used increased to 3,804 hours. Because of the restriction imposed on hay acreage it was necessary to buy 40 more tons of hay which decreased the net revenue. This combination yielded the highest net revenue of any combination considered in the second basic model. It resulted in the highest utilization of available resources and resulted in the highest amount of labor being used. The minimum price that milk could fall and result in the continuation of the dairy operation was $2.77.

General Comments

The preceding discussion is based on models derived for the purpose of comparing dairying at various price and production levels against other enterprises typical to the areas considered. Several assumptions have been made that one should be aware of. Limiting the amount of hay acreage available due to rotational requirements weakens the profitability of the livestock enterprises. It does serve to point out the decreased profitability of the livestock enterprise once it is necessary to purchase feed. Dairying was compared only to one phase of beef raising. There are, of course, other alternatives within this enterprise. Raising an 84 percent live beef calf crop would probably be a better than average management function. However, the 11,000 and 15,000 milk production levels are also better than average management functions so it was felt this was a fair estimate without making more assumptions and additional revisions to the model. Assumptions made about yield figures could be adjusted upwards or downwards. The assumption concerning the dry lot feeding of the milking herd could be challenged and there could be a pasture activity included. This was particularly true in the second model. However, programming the activities using the dry lot method results in a very accurate method of accounting the feed consumed and hence was chosen.

Conclusions

Under the assumptions of this model dairying can be at least as profitable as the alternatives considered in the model. Herd averages as high as 11,000 pounds of milk per cow are even considered marginal in some areas today. The activity does make better use of some of the activities as intermediate inputs than by selling them under the price levels chosen.

With intermediate production levels the dairy activity can be at least as attractive as the small beef activity.

On the basis of the assumptions in the second model, the restriction on the size of the dairy herd limits the total profit picture for the farm operation. Much larger operations would make more effective use of such activities as barley and hay. However, consideration would have to be given to the capital and labor requirements which would accompany the increase in herd size.

A main conclusion reached under the conditions of this model was the relatively low profitability of the low producing herd. In all cases a price level of at least $3.27 per hundredweight for milk was necessary to continue the dairy enterprise in the short run. In the long run even higher prices would need to be considered if total costs were to be covered. Consequently at milk prices of $3.00 per hundredweight or less one could expect the continual exodus of producers from the industry if they conform to the assumptions of this model.

CHAPTER III

TRANSFER OPERATIONS

One of the possibilities of increasing plant volume considered in this thesis was the utilization of surplus in Grade A producing areas. Another possibility was the examination of the possibility of consolidation of existing plants into larger, more efficient units. To accomplish this, milk would have to be transported fairly long distances within the state. The purpose of this section was to examine some alternative means of transporting milk within the state. The costs of selected transportation methods were examined for the purpose of finding the least cost transportation method.

Introduction

Transfer of milk between plants can be accomplished by various forms of bulk transportation. The purpose of this section was to describe the handling procedure and to determine the total cost of handling this milk from origins located at varying distances to the prospective locations.

Bulk transfer of milk within the state at the present time is limited. Small trucks (from 1,800 to 3,000 gallon capacity) are used in local delivery situations but only a few larger units operate within the state. Cost data were obtained from companies transporting gasoline within and outside the state as well as from milk transporting units. Tanker sizes were similar to those to be analyzed for purposes of this study. Also due to the availability of tachometer readings fairly reliable estimates could be made of driving time, of fuel consumption per year, and of routine over-the-road maintenance performed yearly. This consisted of tire wear, oil change rates, chassis lubrication rates, and other miscellaneous charges. Insurance, taxes, building and equipment costs were estimated on a local basis from haulers, state licensing organizations, and insurance agencies and compared with existing studies.

A number of alternative bulk handling procedures can be used to transfer milk. The method used will have a direct effect on a cost comparison with various transfer methods. Those considered in this study were:

(1) A 3,000 gallon tandem axle diesel truck w/sleeper, with capabilities of pulling a 3,00 gallon, 4-wheel, "pup" trailer.

(2) A 4,000 gallon trailerized unit.

(3) A 5,700 gallon trailerized unit.

Selection of a particular unit for hauling is at best a difficult task. The trucking industry has also undergone a great transition in the past few years. Particular units can be selected with a variety of options available. Although there are many manufacturers, trucks from two different manufacturers can come equipped with the same engine, rear end, and transmission. For larger units, then, only the engine size, transmission option, length of wheel base and axle, and tire requirements may change from a unit hauling a fixed amount to a unit hauling several thousand pounds more. The particular engines and transmissions selected were not selected because of any apparent advantage over another but because maintenance records and services were available for units hauling milk or similar commodities equipped with these or similar power trains.

The cost estimates for these particular units appeared to be consistent with those made by Kerchner 1/ and Adams. 2/ Although some variation in cost estimates could occur it would not appear to be a serious source of error.

There are several features unique about the transportation of milk that warrant discussion. First of all, milk can be transported in tanks mounted on single axle or tandem axle tractors. It can be transported on this particular unit pulling a trailerized unit or "pup". It can be transported with a tractor pulling a trailer or even two trailers hooked in tandem. The advantages of the tandem units is flexibility. This is particularly true of any commodity whose production varies during the season. This type of transportation, however, is more expensive initially than a single unit containing the same volume. Although there are no "pup" units operating in the state, cost synthesis for this means of conveyance was analyzed as a possibility for transporting milk.

1/ Orville Kerchner, Costs of Transporting Bulk and Packaged Milk, Economic Research Service Market Res. Rep. No. 791 (Washington: May 1967). p. 5.

2/ J. A. Adams, "Intermarket Producer Price Relationships for Fluid Milk in California" (Unpublished Ph.D. Dissertation: University of California, 1962), p. 71.

Another unique feature of the transfer of milk is that the number of hours that the truck operates is not limited to the number of hours that the plant operates provided that there is bulk storage available. One cheese plant in the state has over 90,000 pounds of storage capacity available.

Table I, Appendix II, contains a listing of tractor requirements and costs for particular size of tank or trailer. It may be noted that there are 12 to 15 transmission options available for the truck alone, although only two are included.

To compare alternative transfer methods, labor and equipment requirements and costs were analyzed for these three types of tankers. This entailed an analysis of fixed and variable cost requirements for each type of vehicle. It also required the analyses of handling and pumping methods required for the particular vehicle concerned.

Milk Handling

The milk handling operation is quite similar for all types of units considered although the actual structure of the tank can vary. The tanks can be of welded stainless steel construction or as in the case of the very large units have a thin stainless outer shell, polyurethane insulation, and a thin welded inner shell to conserve weight. The tanks can also be single or multi-compartmented. The tanks can come equipped with or without pumps and the size of the pump generally varies from 50 to 90 gallons per minute. There are a few truck pumps available that have the capacity to deliver 125 to 140 gallons per minute. Unlike a large gasoline tanker the large milk tanker (5,700 gallon) does not contain baffles to eliminate "surging" or the milk forward and backward. The reason for this is that the baffles are quite difficult to keep clean. Multi-compartmented units take longer to clean in place than a single compartmented unit because the washer must be moved from one hole to the other. The length of time, then, depends on the number of compartments the tank contains. Regardless of the size or type of truck, the actual steps in milk handling are essentially the same for all units.

Handling consists of several steps. The tanker must be maneuvered into position to unload or load. The tank doors are opened and the hose is attached to the receiving tank. The driver then ascertains that the milk is ready for delivery or loading and pumping begins. This can be accomplished by a large pump within the plant "pushing" the milk into the truck tank, a technique that is quite often used with larger units for loading or unloading. Smaller units are often loaded by use of the tractor pump and unloaded by the plant pump. After loading is completed, the hose is detached, the back of the truck is rinsed out, and the pump washed in place. If the plant pump is used, the driver rinses the pump. The same process is repeated in unloading as described above except that the driver must wash the empty tank truck. This of course depends on the capabilities of the plant. If the plant has an in-place washer, the tank is washed by it. If the plant does not have an in-place washer, the tank must be scrubbed by hand, a process that takes longer. According to drivers 3/ a 5,700 gallon unit must be washed by hand because in-place washing units cannot effectively clean the tank due to its length.

Time requirements for this operation are outlined in Table 3.1.

After completing this operation, the driver secures his equipment and is ready to proceed to the destination. Comparison of different transports was accomplished with the use of the following model.

The Model

(1) Assumptions Concerning Truck Operation

a) All trucks are single compartment units.

b) All trucks are equipped with 70 g.p.m. pumps but can load or unload with a 250 g.p.m. pump located at the plant.

c) Drivers spend one hour daily regardless of size of unit in checking out the unit and .3 hour in maintenance. 4/

d) One driver per unit will be employed per unit to round trip mileages of 400 miles. At 400 to 600 miles a layover of 4 hours will be required. At mileages of 600 and over a second driver must be employed.

(2) Plant Specifications

a) Surplus or manufacturing milk is concentrated at one plant or receiving station.

b) Plant has 250 g.p.m. centrifugal pump to load and unload trucks.

c) Plant has an in-place washing system.

3/ Conversation with Larry Sterrett, driver of a 5,700 gallon tanker for Vita Rich Dairy, September 1967.

4/ Interview with H. F. Johnson Co.

TABLE 3.1. TIME REQUIREMENTS TO LOAD AND UNLOAD BULK MILK HAULING UNITS, 1967. a/

Element	Time (minutes)
Loading	
1. Maneuvering	1.0
2. Attaching hose and linking pipeline	5.0
3. Lost time between hose attachment and milk flow	5.5
4. Pumping time b/	
5. Detach hoses, wash pump, wash back of trailer	3.0
6. Rehook pump, stow gear	2.0
Total Time	16.5 Minutes + variable time
Unloading	
1. Maneuvering	1.0
2. Attaching hose	5.0
3. Lost time	5.5
4. Pumping b/	
5. Detach hoses, wash pump, wash back of trailer	3.0
6. Wash tanker unit c/	20.0
Total Time	34.5 Minutes + variable time

a/ Time and motion analysis conducted at Darigold, Bozeman, September, 1967.

b/ The pumping time is a function of pump capacity and volume available.

c/ Twenty minutes must be added to this time to wash trailer tank on 6,000 gallon unit.

(3) Highway Travel

a) Average rate of highway travel is assumed to be 40 miles per hour. 5/

b) Assumed to be private intra-state carrier. It will therefore not be necessary to observe 10 hour maximum driving regulation imposed by ICC.

Determination of Transfer Costs

Comparison of costs with different types of units must be made in order to determine the most efficient or "least cost" unit. Selection of this unit takes into account fixed costs, variable costs, and capacity of the particular unit. A small tanker is generally not used for long distance hauling due to the limited capacity of the unit.

Fixed equipment costs include depreciation, interest on investment, administrative costs, license fees, management, office salaries, and other administrative costs. These are costs that are incurred on an annual basis and are taken as constant over a wide range of output rates considered. Variable costs are those costs that are incurred with the level of operation of the equipment over a given time period. These include all the operating costs of the equipment and the labor charges related to output.

5/ According to interviews with personnel at H. F. Johnson Petroleum Company, insurance is issued on a maximum of 50 miles per hour and tachometers are checked frequently to insure this. Private milk carriers indicated that they could travel much faster than this. This speed was chosen on the basis of the insurance factor. This coincides with Kerchner's 1966 estimate. See Kerchner, op. cit., p. 3.

TABLE 3.2. EQUIPMENT COSTS, EQUIPMENT LIFE, SALVAGE VALUE, INTEREST, AND DEPRECIATION COSTS FOR THREE BULK DELIVERY UNITS.

Item	Cost a/	Life a/	Salvage Value a/	Depreciation	Interest b/
	Dol.	Yrs.	Dol.	Dol.	Dol.
Tractor	23,510	7	2,000	3,072	823
4,000 Gal. Tank	12,140	10	2,000	1,014	425
Tractor	23,772	7	3,000	2,967	832
5,700 Gal. Tank	15,240	10	2,000	1,324	533
Tractor	24,607	7	3,000	3,087	861
3,000 Gal. Tank	10,340	10	2,000	834	362
3,000 Gal. Trailer w/converter gear	11,500	10	2,000	950	403

a/ Interview with Owenhouse Hardware personnel, 1967.

b/ Seven percent of average value of investment.

Salvage Value and Life.--Determining the salvage value of a particular item is a somewhat difficult task. Some researchers use as short a period as three years while others may write a unit off over a 10-year period. Adams noted that transports were still being used in California that were 10 1/2 to 11 years of age. 6/ The life of a unit varies with the type of maintenance and the type of road that it is used on.

Kerchner noted that the firms in his study allowed about a 7-year length of life for the unit. 7/ Even if the tractor is completely "worn out" it can be rebuilt. Tank units are of somewhat the same nature.

6/ Adams, op. cit., p. 70.

7/ Kerchner, op. cit., p. 5.

Given proper maintenance and a decent surface to operate on, they can be kept operating for a good number of years. Metal failure due to aging can come about, however. It is with these reservations in mind that the above figures were chosen.

Interest.--Selection of a proper interest charge is also a difficult task. For the individual operator it is an important part of fixed costs. The interest rate was assumed to be 7 percent of the mid-life value of the equipment.

Depreciation.--A straight line method for determining depreciation was utilized based on a 7-year length of life for the tractors and a 10-year length of life for the trailers. Using this method, the difference between the new cost and salvage value is allocated evenly over the years of useful life of the equipment.

Fixed Costs

It was noted earlier that fixed costs are incurred regardless of the use of the vehicles. Table 3.3 illustrates fixed costs associated with the three units.

Variable Costs

The major variable costs associated with truck usage are fuel consumption, labor, and tire wear. However, other items such as overhauling can be expensive items. To complicate the problem, fuel consumption, tire wear, and engine life are also dependent on the type of surface the truck is operating on and how heavily the unit is loaded.

TABLE 3.3. FIXED COSTS ASSOCIATED WITH THREE HAULING UNITS.

Item	Delivery Unit 4,000	5,700	6,000
	Dollars	Dollars	Dollars
Depreciation			
Equipment a/	4,086	4,291	4,871
Building & Tools b/	225	225	225
Insurance c/	1,350	1,500	1,530
Interest	1,248	1,260	1,626
Taxes d/	1,186	1,365	1,400
Management & Office Salaries e/	1,000	1,000	1,000
Administrative Costs f/	700	700	700
Total	9,795	10,341	11,372

a/ From Table 3.2.

b/ From Kerchner's 1965 estimate.

c/ Subject to a wide range of discounts but compiled for 100/500 thousand bodily injury--Property damage $10,000 and $500 deductible collision.

d/ Weight fees, license fees, highway use fees.

e/ Supervision and clerical work--Kerchner.

f/ Office supplies, legal fees, auditing, and miscellaneous--Kerchner.

Fuel and Lubricants.--It was noted that fuel consumption varies with the road surface, speed, and total weight of the load. It also varies with the size and type of engine. Consumption estimates were made for each unit when it was operating one-fourth load, half loaded, three-quarters loaded, and at full capacity. This means a 4,000 gallon tanker carrying 34,400 pounds of milk would have a fuel consumption rate of six miles per gallon. A 5,700 gallon tanker carrying 49,020 pounds of milk would use fuel at the rate of 5.5 miles per gallon, and a 6,000 gallon tanker would use fuel at the same rate. 8/ The amount of oil a truck uses is dependent on the size of the crankcase and the number of miles between changes. When interviewing operators, it was noticed that a tremendous variation existed in the time length that oil was changed. Some operators changed every 2,000 miles while others would run the trucks as long as 6,000 miles between changes. A figure of 4,000 miles between changes was selected. Most of the operators greased the trucks every week or every 1,000 miles, whichever came first. Fuel costs are noted in Table 3.4. Lubricant costs are shown in Table 3.5.

Tire Costs.--Tire wear is also related to road surface and type of load. Kerchner's study indicated that two recappings per tire was about

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8/ Consumption rates for tankers fully loaded were obtained from H. F. Johnson. These rates were checked in interviews with drivers from Beatrice Foods and Vita-Rich Dairy. Estimates on partial loads were not so easy to obtain. These were obtained in interviews with the same drivers. The trucks fuel consumption rates when fully loaded conform quite closely to the Kerchner study. See Kerchner, op. cit., p. 5.

TABLE 3.4. FUEL COSTS FOR THREE MILK HAULING UNITS.

Unit	Volume Hauled	Miles Per Gallon	Cost Per Gallon a/ Dollars	Cost Per Mile Dollars	Cost Per Hour b/ Dollars
4,000	8,600	8.0	.325	.0406	1.6240
	17,200	7.5	.325	.0433	1.7320
	25,800	6.9	.325	.0471	1.8840
	34,400	6.0	.325	.0542	2.1680
5,700	12,255	7.5	.325	.0433	1.7320
	24,510	6.9	.325	.0471	1.8840
	36,765	6.0	.325	.0542	2.1680
	49,020	5.5	.325	.0591	2.3640
6,000	12,900	7.5	.325	.0433	1.7320
	25,800	6.9	.325	.0471	1.8840
	38,700	6.0	.325	.0542	2.1680
	51,600	5.5	.325	.0591	2.3640

a/ Interview with Gallatin Farmers, Bairs, and Enco Distributors. This figure is probably subject to a volume discount. Price includes 6 cent State and 9 cent Federal tax.

b/ Assuming a 40 m.p.h. driving rate.

TABLE 3.5. OIL AND LUBRICANT COSTS--THREE MILK HAULING UNITS.

Item	Service a/ Interval Miles	Cost Per Unit a/	Cost Per Mile	Cost Per Hour b/	Total Cost Per Hour 4,000	5,700	6,000
Oil							
40 qts.	4,000	$ .40	$.0040	$.1600	$.1600	$.1600	$
44 qts.	4,000	.40	.0044	.1760			.1760
Filter	4,000	2.00	.0005	.0200	.0200	.0200	.0200
Lubrifiner	4,000	2.00	.0005	.0200	.0200	.0200	.0200
Grease	1,000	3.00	.0075	.0200	.0200	.0200	.0200
Total					$.2200	$.2200	$.2360

a/ Interviews with H. F. Johnson. Their discount for the volume of oil purchased was greater than the figures chosen. However, they purchased several barrels at a time.

b/ Assuming a 40 m.p.h. driving rate.

standard with about 145,000 miles total usage per tire. 9/ Adams indicated that driver wheels would run 30,000 miles before recapping with about three recappings per tire. 10/ He also indicated the steering and trailer wheels were estimated to give 50,000 miles of service before recapping. He concluded that these tires would give about 150,000 miles total service assuming three recaps on all types of roads. For purposes of this study it was assumed that original tires would run about 50,000 miles on smooth surface roads. Recaps would run about 65,000. 11/ It was also assumed they could be recapped twice for heavy duty work (greater than one-half capacity) and three times for light duty work (less than one-half the capacity of the rig). The total life would then be 245,000 for light duty and 165,000 for heavy duty work. Tire costs are included in Table 3.6.

Repair and Maintenance.--Maintenance other than routine day-to-day maintenance consists mainly of the checking, adjusting, and relining of brakes, checking and replacing wheel bearings, and finally a major overhaul of the engine and transmission. Some engines run as long as 400,000 miles before it is necessary to overhaul them. This is also true of transmission work.

9/ Kerchner, op. cit., p. 7.

10/ Adams, op. cit., p. 68.

11/ It is not unusual for recaps to wear longer than originals. Kerchner also noted this. See Kerchner, p. 7.

TABLE 3.6. TIRE COSTS--THREE TANKERS, 1967. a/

Hauling Unit	Milk Volume Hauled	Total Number of Tires	Tire Cost	Recapping Cost	Total Cost Per Hour
	Pounds		Dollars Per Tire	Dollars Per Tire	Dollars
4,000	8,600	18 b/	90 b/	40 b/	.6174
	17,200	18 b/			
	25,800	18 b/			
	34,400	18 b/			.7416
5,700	12,255	18 c/	110 c/	45 c/	.7200
	24,510	18 c/			
	36,765	18 c/			
	49,020	18 c/			.8712
6,000	12,900	10 d/			.4000
	25,800	10 d/			.4840
	38,700	18 e/			.7584
	51,600	18 e/			.8136

a/ Interviews with H. F. Johnson and drivers for Beatrice and Vita-Rich.

b/ 10 x 30 tires on tractor and trailer.

c/ 11 x 20 tires on tractor and trailer.

d/ 11 x 20 tires on tractor.

e/ Ten 11 x 20 tires on the tractor and eight 10 x 20 tires on trailer.

It was assumed that a major overhaul of the engine would be necessary every 200,000 miles. Repair and maintenance costs are included in Table 3.7.

TABLE 3.7. REPAIR AND MAINTENANCE--THREE TANKERS, 1967. a/

Tanker	Brakes	Wheel Bearings	Overhaul	Total Cost Per Hour
4,000	$.0036	$.0060	$.1200	$.1296
5,700	.0036	.0060	.1600	.1696
6,000	.0036	.0060	.1600	.1696

a/ Interviews with H. F. Johnson and drivers from Beatrice and Vita-Rich Dairies.

Labor Costs.--The other principal variable cost is labor. The wage chosen was $3.63 per hour. This included $3.30 base wage, $.097 for social security, $.07 per hour retirement, $.07 per hour pension, and $.096 per hour unemployment. 12/

Adam's study indicated a $3.48 adjusted wage for 1960. It was felt that a $3.63 adjusted wage was not unreasonable for 1967.

12/ Teamsters Local Union No. 53 negotiates contracts on an individual basis. H. F. Johnson's drivers are paid on a "running" mile basis. Drivers for Darigold are paid a base wage plus 8 1/4 cents per mile. The few long distance drivers are paid a flat wage rate per hour. In an interview with a representative of Local No. 53 the agreed upon wage would be in the range of $3.44-$3.46 excluding unemployment and social security. Wage rates were determined from interviews with drivers and were checked with Teamster's Local Union No. 53 after the calculations were made.

Summary of Costs

Table 3.8 summarizes the various variable costs for the three types of tankers. The variable costs are computed for the four different capacities of operation that were mentioned previously.

TABLE 3.8. SUMMARY OF VARIABLE COSTS FOR THREE BULK DELIVERY UNITS, 1967.

Item	Delivery Units		
	4,000	5,700	6,000
	Dollars	Dollars	Dollars
Fuel			
1/4 capacity	1.6240	1.7320	1.7320
1/2 capacity	1.7320	1.8840	1.8840
3/4 capacity	1.8840	2.1680	2.1680
Fully loaded	2.1680	2.3640	2.3640
Lubricants	.2200	.2200	.2360
Maintenance and Repairs	.1296	.1696	.1696
Tires			
1/4 capacity	.6174	.7200	.4000
1/2 capacity	.6174	.7200	.4840
3/4 capacity	.7416	.8712	.7584
Fully loaded	.7416	.8712	.8136
Total Equipment Costs Per Hour			
1/4 capacity	2.59	2.84	2.54
1/2 capacity	2.70	2.99	2.77
3/4 capacity	2.98	3.43	3.33
Fully loaded	3.26	3.62	3.58
Labor Cost Per Hour	3.63	3.63	3.63

Milk Handling Costs with Different Volumes

The type of tanker selected for transporting milk from a selected origin to a prospective location depends on the cost of operating this unit and its capacity output for the route or routes considered. The least cost method has been determined in other studies by the use of regression analysis to determine a "break even" point for the various methods and then using the appropriate equation to predict costs with a given volume and distance. 13/

Adams' and Kerchner's research considered fixed routes and a constant volume per route. A problem arose in this research that warranted a slightly different approach. In this case not only could the routes be variable but the volume transported could be variable depending on the combination of routes selected. The allocation of fixed costs per hour would then depend on the number of hours operated during a given year. This can be illustrated by the following example. Assume that the potential site selected for processing is located at Gallatin Gateway. In addition, assume that the origin for the shipment of milk is located at Ronan. The determination of the appropriate unit or units for the transportation of this milk can be accomplished in the following steps:

(1) Determination of the volume of milk available on a seasonal basis from the origin or origins.

13/ Kerchner, op. cit., p. 10; J. A. Adams, op. cit., p. 111.

(2) Determination of the total time per trip required to transport this milk.

(3) Calculation of the costs involved to transport this milk.

(4) Selection of the least cost unit or units on the basis of a cost comparison between units.

The actual calculation of these costs for the previous example was accomplished in the following manner:

(1) Assume the volume of milk available in Ronan to be 9,978,000 pounds annually. Shipment of this milk would necessarily have to be in larger volumes in the spring months due to an increase in production brought about by good weather and succulent pasture. Volume transported could be transported on a fairly even basis throughout the rest of the year. The three month daily average was 34,998 pounds of milk. The nine months daily average was 25,102 pounds.

(2) Assume the unit to be used is a 5,700 gallon tanker. Total time per trip is calculated by the use of the following method. Time required to checkout the unit and perform routine maintenance is 1.30 hours. Fixed time to load and unload, 16.5 and 34.5 minutes, respectively (from Table 3.1) or .275 and .575 hours. Adding these three quantities yields 2.15 hours. The actual pumping time is computed and found to be 16.27 minutes per load for the three high months and 11.67 minutes per load for the nine remaining months. Total driving time per trip is obtained by dividing the total round trip distance by the driving rate ($546 \div 40 = 13.65$ hours). Adding this quantity to the previous quantities yields a total time per trip for the three high months of 16.34 hours per

trip for the three month period and 16.19 hours per trip for the nine month period.

(3) Costs are then calculated by computing the total number of hours operated per year (90 x 16.34 = 1,471) and (275 x 16.19 = 4,452). The appropriate variable cost per hour is then selected from Table 3.8. The tanker would operate at three-fourths of capacity for three months and at one-half capacity for nine months. The variable costs selected would be $7.06 per hour and $6.62 per hour. These quantities multiplied by the hours operated for the corresponding period results in total variable costs for the year (1,471 x 7.06 = 10,385) and (4,452 x 6.62 = 29,472). These quantities added to the fixed cost for the unit yields the total cost for the hours operated (10,385 + 29,472 + 10,341 = 50,198). Dividing this total by 9,978 results in the cost per thousand of transporting milk from Ronan to Gallatin Gateway. (50,198 ÷ 9,978 = 5.03).

(4) The same calculations are then carried out for the other units and a least cost unit selected.

The selection of the least cost unit depends on the route and combination of origins serviced along that route. The selection of the "route mix" and "input mix" to service these routes was deferred until Chapter V where all origins were considered and specific routes to service these origins were considered.

CHAPTER IV

PROCESSING OPERATIONS

Introduction

The analysis of Chapter II indicated that dairying could be at least as profitable an enterprise as some of the possible alternatives available to Montana farmers at a given set of prices. The fact remains that producing milk for manufacturing purposes as a source of income to Montana farmers has been declining. One of the reasons has been that production per cow has not been at these profitable levels discussed in Chapter II. Production per cow on a statewide basis has barely exceeded 6,000 pounds both in 1964 and 1965. Management skill necessary to obtain production levels about 11,000 pounds of milk per cow must be above average. Another fundamental reason for this decline has been insufficient volume at the plant level. This has tended to restrict payments to producers.

Montana's manufacturing plants are few in number and are characterized by low volume. There are 22 manufacturing plants in Montana. Products manufactured are cottage cheese, ice cream, butter, and American Cheddar. The first three commodities are generally marketed on a local basis. Only four plants exist that primarily process American Cheddar. These plants are located at Ronan, Stevensville, Hamilton, and Gallatin Gateway. These plants process from 25,000-40,000 pounds of milk daily. One of the four plants dealt in specialty packages of cheese. The volume this plant handled was less than these figures.

Consequently, this volume problem has tended to restrict prices paid to farmers. Until price supports were raised to 91 percent of parity in the summer of 1966, payments to the producer from these plants varied from $2.85 to $2.92 per hundredweight for cooled 3.5 percent butterfat milk. Since June 1966, there has been some improvement in prices paid to farmers due to the increase in support levels. The picture is somewhat discouraging when one looks at the results of analysis of plant operations in other areas. Estimates of minimum volumes necessary to successfully operate a cheese plant rarely drop below 40,000 pounds of milk a day and more often are higher than this. 1/ Other alternatives exist in the area of dairy manufacturing. However, minimum volumes necessary for operation are even greater for these products than for cheese. Jensen suggests a minimum daily requirement of about 290,000 pounds of milk for successful operation of a powder plant. 2/ Four powder operations were visited in the summer of 1966. 3/ None were below 300,000 pounds of milk

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1/ Bucher, op. cit., p. 3. This was also borne out in interviews with plant managers in Idaho, Utah, Wyoming, and Canada. Mr. Seeley, manager of Cache Valley Dairy Association, Smithfield, Utah indicated that he believed 100,000 pounds of milk was a breakeven level for cheese processing. Mr. Smith, manager of Ida-Gem Dairy Association, Jerome, Idaho, agreed that this was a breakeven point. Ernest Brog, manager of Star Valley Swiss Cheese Company, Thane, Wyoming, also concurred on this point.

2/ C. Jensen, "Want a Cheese or Milk Drying Plant for your Community," North Dakota Farm Research Bul., Vol. 21, July 1960, p. 13.

3/ These plants were located at Payette, Meridian, Caldwell, and Twin Falls in the state of Idaho. Cheese operations were visited at Smithfield, Utah, and Thane, Wyoming.

processed daily. The general consensus of the managers was that a plant would need to process at least 250,000 pounds of milk daily.

A cottage cheese operation can be a profitable operation. 4/ However, marketing problems arise. Consumption is limited to a somewhat local basis and the demand for the product must exist at that level because of the perishability of the product.

There are several attractive features of a cheddar operation. Capital requirements for a cheddar operation are not as high as a butter-powder operation. A ready market generally exists for the product from various marketing organizations. Representatives of Challenge Creamery and Butter Association indicated that affiliation can be readily obtained with them for the marketing of cheese from cooperative plants. Darigold is another cooperative marketing outlet that is a stable outlet for cheese. Kraft, Bordens, and Pet are examples of non-cooperative marketing outlets. Affiliation with the marketing organization releases the small plant of the responsibility of developing a retail outlet. Generally speaking, a retail outlet is interested in carrying the "full line", i.e., butter, cheese, cottage cheese, of the marketing organization. Affiliation with a larger marketing organization insures this.

The need for storage facilities to cure large volumes of cheese can be eliminated. If affiliation with a marketing outlet can be obtained, cheese is generally shipped out uncured and cured by this processor.

4/ Bob Bucher, Feasibility of a Milk Marketing Association for the Billings Area, Coop. Ext. Bul. 1501 (Bozeman: February 1967).

For purposes of analysis this chapter was broken into three main parts. The first section analyzed variable and fixed input requirements by stage in plants processing varying volumes of milk. The second section utilized data from the first section to develop cost requirements by stage with varying volumes of milk. This was accomplished through the cost-synthesis technique. The last section dealt with the development of fixed and variable cost prediction equations in order to obtain a total plant processing equation. This processing cost equation and the transfer cost equation when applied to appropriate production data form the basis for predicting the optimum number, size, and location of plants that minimize combined transfer and processing costs. This problem was dealt with in the next chapter.

The Cost Structure of a Model Cheddar Plant

A basic understanding of the process of cheese making is necessary before the various stages can be separated for the purpose of cost analysis.

The first stage is <u>receiving</u> the milk at the plant. If the plant receives milk in cans this means that the plant must have a conveyor, weigh tank, receiving tank, a can washer, and other small apparatus, for sampling, in order to handle the milk. If the plant is 100 percent bulk then this can be reduced to a pump to unload the truck and a receiving or refrigerated holding tank in which to store the milk. The next step is to standardize the milk at 3.5 percent butterfat. This is accomplished by means of a separator. The milk is then filtered or clarified and then <u>pasteurized</u> by running the milk through a pasteurizer.

The addition of the pasteurizer is an optional step in processing. However if unpasteurized milk is used in the manufacture of cheese the finished product must be in storage for 60 days in order to be safe for consumption. This operation also insures greater uniformity of product. Most operations studied used the pasteurizer in order to do away with elaborate and extensive cold storage facilities. If the milk is pasteurized the finished product can be shipped out immediately after cooling.

After pasteurizing the vat is then <u>filled</u> with the pasteurized, standardized product. The milk is generally pumped directly from the separator into the vat. Starter, one percent by weight is added to the milk that is now at 88°F. Colar and rennet are diluted with cold water and mixed in. 5/ The milk coagulates after which the curd is cut and the milk heated and agitated for about 70 minutes with the temperature rising slowly to 102°F. The whey is then drained off and the curd settled and packed, then cut into slabs that are piled upon each other. These slabs are then turned periodically as a part of a process that is called <u>cheddaring</u>. The curd is then milled (cut into small pieces) salt is added and stirred into the milled curd. The milled curd is then placed into square containers for <u>pressing</u>. After pressing and with

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5/ Starter contains the culture necessary to start the bacterial action in the milk in the initial stages of the cheesemaking process.

allowance for a cooling period, the cheese is packaged. Packaging can be accomplished in a variety of sizes and shapes. For purposes of this analysis the packaging was limited to 40 pound blocks wrapped in seran. 6/ The packages are then transported to temporary storage for loading or are loaded directly onto freight car or truck for shipment.

Processing Stages

For purposes of this analysis the overall manufacturer of cheese was broken down into eight stages. Costs were then determined for those stages for various plant capacities. These stages were:

Operational	Non-Operational
Receiving	Laboratory
Processing	Utilities
Hooping	Office
Packaging	
Whey and Butter	
In Plant Transportation	

Each of these operational phases has a handling or actual labor cycle and a processing cycle. The time requirements for each of these phases must be considered before costs can be considered.

Receiving--Cans

Receiving costs are functionally related to the amount of milk that is received in bulk and the amount in cans. Any appreciable amount of

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6/ Last year 40 pound blocks accounted for almost 30 percent of all cheese packaged in the U. S. Eighty-eight and one-half percent were packaged in large styles. See Economic Research Service, Dairy Situation (Washington: Sept. 7, 1967) p. 30.

milk received in cans greatly increases the amount of labor and fixed capital necessary to run this station. Cans are unloaded from trucks outside the plant. Conveyors bring the milk into an operator who dumps the producers cans, records the weight, and takes a sample. The milk is then released into a dump tank for pumping into a receiving tank. The empty can is placed back on the conveyor and moves through a washing machine where it is steam cleaned. The cans are then conveyed outside where they are stacked for reloading.

In checking plant operations at the receiving stations it was noted that there were many partially filled cans. These of course require just as much time for handling as the full cans. From a count of cans it was determined that for 6,375 pounds of milk received, 92 cans were required. Therefore, each can contained an average of 68.77 pounds of milk. Time requirements for 1,000 pounds of milk handled in cans can be computed by multiplying $\frac{1,000}{68.77}$ = 14.54 x 1.08 equals variable time per thousand. 7/ Time requirements of this cycle are included in Table 4.1. Equipment requirements are included in Appendix III, Table I.

Receiving--Bulk

Bulk receiving can be accomplished in a variety of ways depending on the time requirements and capacity of the plant. For plants of relatively low capacity milk can be unloaded by a direct hookup of a

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7/ The count was obtained by observing three days' can plant receipts at Ronan. Cans were counted and weights were recorded from the weighing station.

TABLE 4.1. RECEIVING--STAGE TIME REQUIREMENT PER 1,000 POUNDS MILK. a/

	Stage	Time
	Receiving--Cans	**Minutes**
1	Assembly of lines, placing of drop tank, weigh tank for day's operation.	10.000
2	Disassembly. Cleaning of lines, drop tank, weigh tank after day's operation.	20.000
	Fixed Time Total	30.000
3	Sampling, dumping, weighing, and placing of can on conveyor for washing per can.	.833
4	Recording weight per can	.250
	Variable Time Per Can	1.083
	Total Variable Time ($\frac{1,000}{68.77}$ = 14.54 x 1.08) (Variable time per 1,000 pounds milk received in cans.)	15.700
	Receiving--Bulk	
1	Receiving tank made ready, connection of lines	7.500
2	Receiving tank made ready for cleaning	7.500
		15.000
3	Receiving--A function of pump capacity 250 g.p.m. pump assumed used (minutes per 1,000 milk received)	.465

a/ Survey of Consolidated Dairies, Ronan, Montana.

line from the tank truck pump to the receiving tank. The amount of milk unloaded per hour then depends on the capacity of the truck pump. This can range from 50-100 gallons per minute. A truck pump will seldom exceed 100 g.p.m. because of farm wiring capacities. Most are in the range of 50-70 g.p.m.

Receiving can also be accomplished by the use of a pump at the plant site. The milk is pumped from the truck directly to the receiving tank, These pumps are generally of larger capacity because the plants' wiring systems can accept heavier loads without becoming overloaded.

For purposes of this analysis a 250 g.p.m. pump was assumed to be available at the plant site. If unloading time is a function of pump capacity then:

$$T_u = f(C_p)$$

where: T_u = unloading time

C_p = pump capacity

To unload 1,000 pounds of milk would require .465 minutes. Therefore,

$$T_u = .465(V_r)$$

where: T_u = time to unload in minutes

V_r = volume received in thousands

Time requirements for this stage are also included in Table 4.1. Part of this time has been charged to the transfer operation.

Equipment requirements are included in Appendix III, Table I. Sampling, weighing, and related functions are eliminated because this is accomplished at the farm site.

Processing

Several interrelated activities are lumped into a cycle called processing. The separation of any of these activities into a distinct category is strictly arbitrary because of the multi-stage use of some of the same equipment. These various machines can also cause bottlenecks in the processing operation due to the capacity of one particular machine or machines in the operation.

First of all, consider the storage tank. Several different capacities might be chosen depending on the aim of the plant. Size of the tank can range from 1,000-20,000 gallon capacity and can be custom made in larger or smaller capacities. If the processor desires to process only three days a week he must have storage capacity for the other four days production.

If he processes six days a week then only enough storage for the seventh day's production must be incorporated into the plant set up.

Total plant capacity is also affected by the next step in processing, the separation and pasteurization of milk. Separators and pasteurizers come in a variety of sizes, generally ranging from 11,000 to 20,000 pounds of milk per hour. Stage time requirements for these sizes of pasteurizers are included in Table 4.2. Since the milk is pumped directly

TABLE 4.2. PASTEURIZING--STAGE TIME REQUIREMENT PER 1,000 MILK BY STAGE. a/

Stage	Time Required to Process 1,000 Pounds Milk
	Minutes
Pasteurizing	
15,000 pounds per hour	4.000
20,000 pounds per hour	3.000
25,000 pounds per hour	2.400
35,000 pounds per hour	1.710
Filtering or Clarifying	
25,000 pounds per hour	2.400

a/ From specifications supplied with proposals submitted by Stoelting Brothers Company, Kiel, Wisconsin; Damrow Brothers Company, Fond du Lac, Wisconsin; and the DeLaval Separator Company, Chicago, Illinois.

from the pasteurizer to the cheese vat, the time necessary to fill the vat is determined by the capacity and number of pasteurizers in operation and also by the size of the cheese vat. While the vat is filling and the temperature standardized at 88° the starter is added. The starter is allowed to act in the tank for about one hour and the rennet is added. The curd then starts to form. After about 15 minutes the curd is "cut". This is done by moving stainless steel "harp-like" cutting instruments vertically and horizontally through the curd which accomplishes the cutting action. In about 20 minutes, the steam is turned up until the vat temperature finally reaches 102°F. After 40 minutes the steam is turned off and agitation continues for 20-30 minutes. The curd is now fully formed and the whey is ready for separation. A bottleneck can occur in the operation at this point. If the plant has a sufficient vdume of milk to justify whey separation, the whey must be pumped from the cheese vat to the whey tank. While the whey is being pumped out the cheese maker settles the curd and pushes it back from the tank opening. The pump necessary to accomplish the whey transfer can also vary; therefore, the time required to drain the tank and settle the curd can vary. In larger plants a two-story design can eliminate a pump by draining the tank into a whey vat located a floor below. Of course this is only one of many considerations in floor design of larger plants. After the curd is allowed to mat it is then cut with a cheese knife into slabs. The slabs are then turned at intervals for about one hour. This is generally done 7 to 14 times during the hour.

After this cheddaring process is completed the slabs of "green" cheese are put through a milling machine which cuts the slabs into small pieces. After this is accomplished salt is mixed into the cheese and the agitator turned on for about 20 minutes so that the salt is mixed thoroughly through the cheese. Time requirements for the processing cycle are included in Table 4.3. Equipment requirements are included in Appendix III, Table I.

The important point to note is that the processing stage is composed almost entirely of fixed times regardless of the amount of milk that is in the vat. Due to the bacteriological changes that must take place, the fixed time involved for the operation requires almost five hours. If a 20,000 pound capacity pasteurizer is used another hour is required to fill the vat and three-fourths of an hour required to drain the vat if a medium capacity pump is used to drain the vat. This means that approximately seven hours is required to process a vat of milk. To compensate for the time loss generally two cheesemakers work two vats. After the first is filled and processing started, the second is immediately started filling so that a second vat could be finished within an hour after the first. This assumes the above suppositions about filling times and pasteurization rates.

Hooping and Pressing

Although it could be argued that the hooping and pressing phase should be included in the above discussion, it is a labor and time consuming operation. Hence, it was analyzed separately.

TABLE 4.3. PROCESSING--TIME REQUIREMENTS PER VAT. a/

Stage	Time Minutes
1 Pre-wash vat	5
2 Filling (function of past. rate & vat size) b/	
3 Starter process	60
4 Rennet addition	20
5 Cutting	3
6 Curd forming	17
7 Heat on	40
8 Heat off	40
9 Draining (function of pump capacity and vat size) b/	
10 Cheddaring c/	60
11 Milling	25
12 Salting	20
13 Wash vat	8
Total hours b/	4.97

a/ Survey conducted at Consolidated Dairies, Ronan, Montana.

b/ Excluding filling and draining time. If 20,000 pound vats are used and a 20,000 pound per hour pasteurizer, about one hour is required for filling. If a 430 pound per minute pump is used to drain the vat then about three-fourths of an hour is required to drain the vat.

c/ This time can vary according to the acidity of the milk.

After salting is completed the cheese is ready for hooping. The clean hoops and bandages are placed on the press beside the vat while the processing operation is being carried out. The bandages are placed in the hoops and the hoops transferred into the vat. The cheese is scooped by means of a stainless steel scoop into the hoop. The hoop is then placed on a portable scale for weighing. It is then transferred to the press where the cover is placed on the hoop and the hoop is then made ready for pressing. After the cheese is hooped the press is tightened and the excess moisture is squeezed out. The press is retightened once or twice and the cheese is generally left in the continuous hydraulic press overnight to cool. Following the cooling interval the presses are loosened, the hoops and bandages are removed from the cheese and it is ready for packaging. Stage time requirements are included in Table 4.4. Equipment requirements are included in Appendix III, Table I.

Packaging--In Plant Transportation

Packaging materials also vary a great deal. Paracoat, foil, and seran are all used as packaging materials. Seran is gradually replacing other materials as a packaging agent due to cost.

When the hoops and bandages have been removed from the cheese a portable seran and liner carrier is placed on the press, a length of foil and paper liner are removed simultaneously from the carrier and cut. The block is placed on the foil, the foil wrapped around the block and the paper wrapped around the foil. The block is then placed

TABLE 4.4, HOOPING AND PRESSING--TIME REQUIREMENTS PER 40 POUND BLOCK. a/

Stage	Variable Time Per Block	Fixed Time
	Minutes	Minutes
1 Preparing hoops	.333	
2 Applying cheese cloth	.383	
3 Filling hoops	.555	
4 Placing scales on vat, placing lid	.500	
5 Weighing, placing cover on, placing hoop on scales	.670	
6 Placing hoop in press	.500	
7 Pressing (actual labor) b/		6.000
8 Loosening press		1.335
9 Removal from box	.500	
	3.440	7.335
Total Time Per 1,000 Milk = 3.44 x 2.50 =	8.60	

a/ Survey at Consolidated Dairies, Ronan, Montana.

b/ This entails squeezing excess water from hoops, attaching clamps to press and periodically tightening them. This has to be done whether there is 10 or 30 hoops in the press.

in a sealer which heats the seran inside the liner and seals the cheese. The block is then placed on a scale, weighed, placed in a box, and stamped with the correct weight on the box. The box is then placed on a cheese transport and placed in storage at least long enough to bring the temperature to 45°. Equipment and time requirements for this operation are recorded in Table 4.5. Equipment requirements are recorded in Appendix III, Table I.

TABLE 4.5. PACKAGING AND IN PLANT TRANSPORTATION TIME REQUIREMENTS PER 40 POUND BLOCK. a/

Stage	Variable Time Per Block Minutes
1 Cutting wrap	.233
2 Wrapping	.533
3 Sealing	1.000
4 Weighing--boxing	.908
5 Transporting	.114
6 Recording number and weight	.057
7 Unloading	.086
	2.930
Total Time Per 1,000 Milk = 2.93 x 2.50 =	7.33 minutes

a/ Survey at Consolidated Dairies, Ronan, Montana.

Butter and Whey Operation

This is an optional operation that becomes feasible as plant capacity increases. The size that a plant must be is somewhat subjective. This can depend on the price of the churn and whey vat. Generally speaking unless a factory processes 80,000 pounds per day it is uneconomical to consider a butter operation from whey cream since the content is only about..002 percent fat. Smaller plants generally sell the whey cream.

The operation goes through the following steps. The whey is pumped or drained from the the cheese vat into a whey vat. The whey is then pumped from the whey vat through the separator. The cream is either collected in a bulk refrigerated tank or stored in cans until enough is accumulated for churning. The cream is then pasteurized, cooled, and transferred to the churn. The churn is filled to about one-half the capacity of the churn and churning begins. After churning the butter is washed, salted, worked, and removed by hand. The butter is stored or packaged. If a printer is available for this operation, this is accomplished by machine. The time requirements for these two stages are included in Table 4.6. Equipment requirements are included in Appendix III, Table I.

Non-Operational Activities

Utilities, laboratory, equipment, requirements and office equipment requirements for various sizes of plants are a somewhat subjective matter. Equipment requirements are listed in Appendix III, Table I, for these activities. Boiler requirements were obtained by recommendation of a manufacturer for the various plant sizes. 8/

8/ Specifications and prices supplied with proposals submitted by Damrow Brothers and Stoelting Brothers were the basis for selection of this equipment.

TABLE 4.6. BUTTER AND WHEY--TIME REQUIREMENTS PER 1,000 MILK. a/

Stage	Variable Time	Fixed Time
	Hours	Hours
Whey Separating		
1 Filling whey vat 60,000 pound/hr. pump	.0166	
2 Separating--20,000 pound per hour separator	.0550	
Butter Making		
1 Pumping in pasteurizer and churn--60,000 pound per hour	.0166	
2 Churning		6.00
3 Removal from churn	.5000	
4 Packaging either automated or by hand (a printer assumed)	.0013	

a/ Survey at Consolidated Dairies, Ronan, Montana.

Storage Requirements

Storage requirements were determined by the use of dairy engineering techniques. The amount of storage for each type of plant was that deemed necessary to handle three days' production of cheese. Cooling requirements are not only determined by the type of structure but also outside temperature, type of insulation, temperature of the product upon entering and other factors. Storage facilities ranged from 289 square feet for the two-vat installation to about 510 square feet for the large installation. 9/ To establish refrigeration requirements for these two facilities, techniques outlined by Desrasier were utilized. 10/

Refrigeration Requirements to Cool Cheese

The first step in refrigerated storage of cheese is to bring the temperature of the product down to the temperature desired. This is expressed by means of the following equation:

$$H_1 = (S_L)(W)(T_i - T_f)$$

where: H_1 = B.T.U. required to lower temperature of the product from the initial temperature (T_i) to the temperature desired (T_f)

S_L = specific heat of the product above the freezing point of the product (in this case .64)

9/ Storage facilities were determined from floor plans supplied by Damrow Brothers and Stoelting Brothers.

10/ Norman W. Desrasier, The Technology of Food Preservation (Westport, Conn.: The Civic Publishing Co., 1963), pp. 99-102.

W = weight of the food mass in pounds. (3,200 pounds maximum for a 2-vat factory; 16,000 pounds maximum for a 4-6 vat factory)

T_1 = temperature of cheese upon entering (80°)

T_f = temperature of cheese to be maintained (45°)

$$R_f = \frac{H_1}{288{,}000}$$

We also must consider the refrigeration requirements to maintain an empty cold storage chamber at desired temperature levels. This is determined by the following equation:

$$H_c = \frac{(K)(24)(S_a)(T_1 - T_2)}{I}$$

where: H_c = B.T.U. losses per 24 hours in the storage chamber

K = the thermal conductivity of the insulation material

S_a = the surface area of the outer wall of the storage chamber

T_1, T_2 = the temperature outside and inside the chamber

I = thickness of the insulation material (4 inches of cork insulation with a K of .28)

In addition to the work required in B.T.U.'s for cooling the material and maintaining the temperature of the chamber we must consider heat loads generated by electric appliances in the chamber and people entering and leaving the chamber. The following values were used in establishing the miscellaneous heat loads. 11/

11/ Ibid., p. 101.

Electric lights = 3.42 B.T.U. per hour per watt

Electric motors = 3,000 B.T.U. per hour per h.p.

Working man = 750 B.T.U. per man hour

For electric equipment then:

H_e = 3.42 (total lighting watts)(hours burning) x [3,000 (total motor h.p.)(hours running)]

H_m = 750 (no. of man hours in the chamber)

The number of air changes per day under reasonable use then is determined by:

$$H_a = (R_v)(N)$$

where; R_v = cubic feet of storage capacity in the chamber

N = number of changes per 24 hours

H_a = B.T.U. load added by changing air under average conditions

The total refrigeration requirement for the operation of the chamber (R_c) without any consideration for food is then obtained by:

$$R_c = \frac{H_c + H_e + H_m + H_a}{288,000}$$

The total refrigeration requirement for cooling the cheese and maintaining the temperature can be calculated by:

$R = R_c + R_f$ = tons of refrigeration required.

In addition a safety factor of 25 percent must be added. 12/ By the use of this technique total tons of refrigeration were computed and compressor size was calculated for the two storage rooms. For the smaller room a 2 h.p. compressor was chosen and for the larger room two 3 h.p. compressors were selected. The selection of the two compressors adds standby capability to this type of operation.

The Model

1. Assumptions Concerning Receiving

    a. Two thousand pounds milk a day is received in cans. The remainder is received in bulk. This prescribes to approximate can volume at various plants.

    b. All plants equipped with 250 g.p.m. unloading pump.

    c. Used price quoted on all can receiving equipment.

    d. Non-refrigerated storage tanks in receiving stage.

    e. All receiving centers have in-place washing systems for bulk receiving units.

    f. Plants have sufficient storage to store one day's volume without processing.

    g. Receiving tanks are placed outside the building.

    h. Milk contains 3.5 percent butterfat,

2. Assumptions Concerning Processing

    a. The 8-hour shift will be considered a minimum shift.

    b. Starter manufactured in cans to the processing level of 8,000 pounds of milk per hour.

    c. Cheesemaker or workers have ability to start vat filling operation before rest of crew arrives.

12/ Ibid., p. 106.

3. Assumptions Concerning Hooping and Pressing

   a. Forty pound block only size cheese manufactured.

   b. Automatic hoop washer employed at processing levels of 12,000 pounds of milk per hour and higher.

4. Assumptions Concerning Packaging and In-Plant Transportation

   a. Seran and paper used as wrapper.

5. Assumptions Concerning Utilities

   a. Natural gas used as heating fuel.

   b. Access to city water supply.

6. Assumptions Concerning Storage

   a. Storage capacity designed for three days' storage.

7. Assumptions Concerning Butter and Whey

   a. Whey processing begins at volumes of 2,000 pounds per hour and higher. At lower volumes whey cream sold.

   b. Used prices on all equipment in butter center.

   c. Whey can be disposed of other than in city sewage system.

Determination of Processing Costs

Comparison of costs must be made at different levels of output in order to determine how costs vary with increases in volume. Stage costs can also be used to construct a total processing cost function. As in the case of a particular method of transporting milk from one area, a particular plant combination must take into account fixed costs, variable costs, and the capacity of that plant combination. Fixed costs considered were taxes, land, buildings, equipment, interest, insurance, and repairs and maintenance.

Variable costs consisted principally of labor, materials, electricity, steam, water, and natural gas.

In order to obtain cost estimates consistent with the volume of milk available for manufacturing in the study area, model plant cost estimates were constructed through the range of processing from 2,000 to 18,000 pounds of milk per hour. The lower figure represented a fairly low level of operation while the upper range was more than adequate to handle all the milk available for manufacturing in the study area.

Fixed Costs

Building Requirements and Costs.--Possible floor plans were studied from those made available by Damrow and Stoelting. The plant set up was basically the same through all levels of operation. Allowance had to be made in building requirements for increase in vat size, larger storage space, and the addition of a butter and whey center when the plant processed 8,000 pounds of milk or more. Substantial variance in the actual allocation of floor space to a particular center exists in the existing plants. The particular method employed in the study eliminates this variation and provides a consistent manner of allocating costs to a particular center as volume is increased. The plants were specified to be of concrete block structure and were to be one story high in the processing section. Office construction was limited to 8 feet in height.

A covered bulk receiving area 25 x 35 and 30 feet in height at the rear of each plant was also specified. Construction estimates vary from $9.00 to $14.00 per square foot for this type of construction. 13/ Ten dollars per square foot was used as the figure for this type of construction. 14/ The covered bulk receiving area was estimated to cost $6.00 per square foot. 15/ Building requirements and costs are included in Table 4.7.

Building requirements ranged from a factory of two vat size which would process at a rate of 2,000 to 4,000 pounds per hour, through 5,000 to 12,000 pounds per hour which would be of four vat size, to 13,000 to 18,000 pounds per hour which would be of six vat size.

Land Requirements and Costs.--Land requirements were to be such that the plant could have 60 feet of frontage, 30 feet on each side of the plant and 60 feet in the rear of the plant. Cost estimates for land vary from $2,500 an acre to $15,000 an acre. 16/ A cost figure of $5,000 per acre was selected. 17/ Land requirements and costs over the range are

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13/ Johnson, Clarke, and Forker, *op. cit.*, p. 32.

14/ Interview with Carl Lehrkind, III, Manager of local Coca-Cola bottling plant.

15/ Bucher's estimate was $7.50 per square foot for a storage area. Since this area would have one less wall an estimate of $6.00 per square foot was used. See Bucher, *Feasibility of a Milk Marketing Association*, *op. cit.*, p. 48.

16/ Interviews with Bud Lowe, Lowe Realty, Bozeman, Montana, and Ted Cooey, Eliott Realty, Bozeman, Montana.

17/ This is the author's own estimate based on the above interviews.

TABLE 4.7. BUILDING REQUIREMENTS AND COSTS MODEL PLANTS. a/

Volume Processed Per Hour Pounds	Required Area Sq. Ft.	Total Cost Dol.	Life Yrs.	Annual Depreciation Dol.
2,000	3,675	33,250	40	831
4,000	4,480	41,300	40	1,032
8,000	6,160	58,100	40	1,452
10,000	6,160	58,100	40	1,452
12,000	7,880	75,300	40	1,882
14,000	9,095	87,450	40	2,186
16,000	9,095	87,450	40	2,186
18,000	9,095	87,450	40	2,186

a/ From blueprints supplied by Damrow Brothers, Co., Kiel, Wisconsin, and Damrow Brothers Co., Fond du Lac, Wisconsin.

included in Table 4.8. The building was assumed to have a life for depreciation purposes of 40 years. This conforms to the Johnson, Forker estimate, 18/

TABLE 4.8. LAND REQUIREMENTS, COSTS, AND ANNUAL DEPRECIATION. a/

Volume Processed Per Hour	Required Area	Cost Per Acre	Life	Annual Depreciation b/
Pounds	Acres	Dol.	Yrs.	Dol.
2,000	1.0	5,000	40	125
4,000	1.0	5,000	40	125
8,000	1.0	5,000	40	125
10,000	1.0	5,000	40	125
14,000	1.5	5,000	40	187
16,000	1.5	5,000	40	187
18,000	2.0	5,000	40	250

a/ Based on the assumptions of at least 60 feet of frontage, 30 feet on each side of the plant and 60 feet in the rear of the plant.

b/ There is a question whether the land depreciates or not. In actuality land located in a desirable area may appreciate in value. However, some charge would have to be assessed for removal of the building and fixtures. This corresponds to the procedure used in other studies. See Johnson, Forker, and Clarke, op. cit., pp. 32-37.

Equipment Costs.--Equipment requirements and costs were summarized by stage in Appendix III, Table I. Selection of the appropriate price of equipment for the particular stage was accomplished by three methods. First, by reviewing the time requirements for a particular volume of processing--if the time requirement exceeded the capacity of the particular piece of equipment for that level of processing then the next larger piece of equipment was substituted.

18/ Johnson, Forker, and Clarke, op. cit., p. 32.

For example, assume the level of processing is 14,000 pounds per hour. This places us in an operation of six vats. A 15,000 pound per hour pasteurizer could cause a bottleneck in processing because the vat filling time is directly related to the capacity of the pasteurizer. Therefore, a 25,000 pound per hour pasteurizer was chosen and the costs computed for it. A second method of equipment selection was by actual physical capacity of the equipment. For example, two 12,000 pound cheese vats would be sufficient for a 2,000 pound per hour operation. However, substitution of two 20,000 pound vats would be necessary if it were necessary to process 4,000 pounds per hour. Finally, some equipment was chosen by engineers and manufacturers' recommendations. Boilers, refrigeration units would come under this category. A summary of total investment by stage is included in Table 4.9. The principal fixed expenses associated with the equipment are depreciation, insurance, taxes, and interest. Since the same principles apply to land and buildings the discussion of the derivation of these costs were lumped for the sake of brevity.

<u>Depreciation</u>.--Depreciation was calculated by the "straight line" method for each piece of equipment based on its expected life. The total cost of depreciation was obtained by summing the costs of all individual items in a stage. The depreciation costs for each processing level were summed to obtain total depreciation costs for that particular size of plant. Table 4.10 contains the schedule of depreciation costs for each processing level.

TABLE 4.9. SUMMARY OF TOTAL EQUIPMENT INVESTMENT FOR MODEL PLANT BY STAGE, 1967. a/

Volume Processed Per Hour	Receiving	Processing	Hooping	Packaging	Office and Lab	Utilities	Butter and Whey	Cleaning	Total b/ Investment
Pounds	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
2,000	13,662	22,601	2,690	2,285	4,000	8,653	--	--	53,891
4,000	15,704	26,955	4,540	2,285	4,000	11,600	--	--	65,084
8,000	19,642	42,488	9,080	2,285	7,000	11,600	9,392	--	101,487
10,000	19,642	42,488	10,040	4,570	7,000	11,600	9,392	--	104,732
12,000	22,940	53,041	12,180	4,570	8,000	17,000	15,292	7,200	140,223
14,000	24,261	60,018	12,990	6,855	8,000	17,000	15,292	7,200	151,616
16,000	25,983	62,543	17,070	7,040	8,000	25,000	15,292	7,200	168,128
18,000	26,782	73,946	18,330	7,040	8,000	25,000	15,292	7,200	181,590

a/ From Appendix III, Table I.

b/ Excludes land and building.

TABLE 4.10. SUMMARY OF DEPRECIATION COSTS FOR MODEL PLANT BY STAGE. a/

Volume Processed Per Hour	Receiving	Processing	Hooping	Packaging	Office and Lab	Utilities	Butter and Whey	Cleaning	Total Depreciation
Pounds	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
2,000	1,137	1,949	189	152	400	532	--	--	4,359
4,000	1,277	2,296	304	152	400	680	--	--	5,109
8,000	1,539	3,163	608	152	700	680	879	--	7,721
10,000	1,671	3,163	672	304	700	680	879	--	8,069
12,000	1,759	4,005	795	304	700	1,000	1,469	360	10,392
14,000	1,887	4,361	895	456	400	1,000	1,469	360	10,392
16,000	1,962	4,536	1,090	468	400	1,400	1,469	360	11,685
18,000	2,015	5,704	1,329	468	400	1,400	1,469	360	13,145

a/ From Appendix III, Table I.

Interest.--Selection of the proper interest rate was accomplished by charging 6 percent of the midlife value of the equipment, land, and buildings. This rate was assumed to represent the expected returns from similar economic activity involving the same element of risk, subject to the reservations expressed in Chapter I. Since it was assumed that the investment would decrease in value to zero at the end of the useful life of the asset this rate was applied to one-half the original amount of the investment, Table 4.11.

Taxes.--Taxes are levied on the appraised value of the property as determined by the local assessor or other tax authority and are computed on a specified tax rate per dollar valuation. In Montana the procedure for assessing this tax is fairly constant although the tax rate may vary considerably. The question of a proper rate to apply was settled by selecting four Montana cities that were representative of the type of town that the plant would be built. Table 4.12 indicates these cities and their tax rates.

The procedure in computing the tax has three steps. First, the determination of an appraised value. The appraiser appraises the value of the property. Second, 40 percent of the value is taken as the "true" value. Third, 30 percent of the value is assigned as the taxable value. An example would be a property that is appraised at $30,000. Forty percent of the value would be $12,000. Thirty percent of the value yields $3,600. Assuming a tax of 161.5 mills means that the tax would be 3.6 x 161.5 or $581.40. This is the procedure that was followed in the computation of the tax for the model plant. The results are included in Table 4.13.

TABLE 4.11. INTEREST CHARGES FOR MODEL PLANTS. a/

Volume Processed Per Hour	Total Investment b/	Interest
Pounds	Dollars	Dollars
2,000	92,141	2,764
4,000	111,384	3,341
8,000	164,587	4,938
10,000	167,832	5,035
12,000	220,523	6,616
14,000	246,566	7,397
16,000	263,078	7,892
18,000	279,040	8,371

a/ Six percent of average value.

b/ Includes all equipment, land, and buildings.

TABLE 4.12. TAX RATES--FOUR MONTANA CITIES, 1966. a/

City b/	Levy
	Mils
Belgrade	183.49
Amsterdam	114.00
Gallatin Gateway	160.77
Butte	188.00
Average	161.50

a/ Interview at Gallatin County Assessor's Office.

b/ An actual check of the four cities after the study was made indicated that this method of approximation was fairly accurate. However, it should be recognized that this was an approximation. Actual rates were: Whitehall 167.97 in, 134. out; Stevensville 219.46 in, 155.2 out; and Ronan 203.81 mils in, 159.81 out.

TABLE 4.13. PROPERTY TAXES--VARYING LEVELS OF OUTPUT, USING 1966 RATES. a/

Volume Processed Per Hour	Appraised Value b/	True Value	Taxable Value	Total Tax per Year
Pounds	Dollars	Dollars	Dollars	Dollars
2,000	92,141	36,856	11,056	1785.54
4,000	111,384	44,554	13,366	2158.61
8,000	164,587	65,834	19,750	3189.62
10,000	167,832	67,132	20,140	3253.61
12,000	220,523	88,209	26,463	4273.77
14,000	246,566	98,626	29,588	4778.46
16,000	263,078	105,231	31,569	5098.39
18,000	279,040	111,616	33,485	5407.83

a/ Computed from Table 4.10 and 4.11.

b/ Total investment in land, equipment, and buildings, Table 4.10.

Repairs and Maintenance.--Data on repairs and maintenance was not available in meaningful terms on existing plants. Therefore, the same technique employed by Johnson, Clarke, and Forker was used to determine this cost. 19/ This procedure was to equate annual repairs and maintenance costs with that allowance for depreciation. The corresponding cost schedule for varying levels of output is summarized in Table 4.14.

Insurance.--Insurance was considered for the physical plant, for the equipment inside and for the stock that might be on hand. Boiler insurance was also included. This was included in the event that a boiler might explode, injuring any occupants. Extended coverage was also included. This covered damage that might have been done by something other than fire, such as hail or lightning. A final clause was included to cover $50,000 of personal liability per worker in the plant. Rates vary considerably not only from city to city but from building to building. Rates given by Safeco Insurance Group as applying to industrial buildings in Belgrade were deemed appropriate. Coverage was assigned at 90 percent of actual value where appropriate. Some error is possibly introduced on the basis of the coverage and rates considered. This should not be a serious source of error on the basis of insurance share of total fixed costs. This was 5 percent of fixed costs at the low processing level and about 7 percent at the high processing level.

19/ Johnson, Forker, and Clarke, op. cit., p. 35.

TABLE 4.14. REPAIRS AND MAINTENANCE--VARYING LEVELS OF OUTPUT. a/

Volume Processed Per Hour	Total Depreciation Per Year	Repairs & Maintenance
Pounds	Dollars	Dollars
2,000	4,722	4,722
4,000	5,673	5,673
8,000	8,705	8,705
10,000	9,003	9,003
12,000	11,805	11,805
14,000	12,608	12,608
16,000	13,465	13,465
18,000	14,988	14,988

a/ Computed by the same method Johnson, Forker, and Clarke employed. See Johnson, Forker, and Clarke, op. cit., p. 35.

Using this as a basis for computation of costs, insurance costs were assigned to various plant capacities as indicated in Table 4.16.

In addition to those costs miscellaneous costs were attached to the plant sizes to include licensing, legal fees, bonding, and auditing. Those costs were estimated to be \$1,000, \$1,500, and \$2,000 for two, four, and six vat operations, respectively.

A summary of all fixed costs attributed to the plant as volume processed increases is included in Table 4.17.

The previous method is somewhat cumbersome in predicting costs for volumes processed per hour over then the specific ones. To predict costs as volume increases a cost prediction equation was fitted to the data as volume processed ranged from 2,000 to 18,000 pounds per hour. This relationship was obtained by fitting an equation of the form $TPC_F = a + b_1 V_P$ where TPC_F = total annual fixed processing costs and V_P = volume processed per hour in thousands. This yielded the following equation:

$$TPC_F = 11,856.8 + 2160.61\ V_P \qquad 4\text{-}1$$

where: TPC_F = total fixed processing cost per year

V_P = volume processed in 1,000 pounds per hour.

Figure 4.1 illustrates the graphical relationship of budgeted and estimated total fixed processing costs. The coefficient of determination was .9876 indicating a close relationship between budgeted and estimated fixed costs.

TABLE 4.15. INSURANCE RATES FOR COMMERCIAL BUILDINGS IN BELGRADE, 1967 RATES. a/

Coverage Item	Rate Per $1000 Coverage Dollars	Discount for 90 Percent Coverage Percent	Rate Per $1000 Coverage Dollars
Fire	.75	40	.45
Equipment	.95	25	.7125
Stock	2.00	--	2.00
Boiler (total charge)	75.00	--	
Extended Coverage	.15	25	
Liability (bodily injury & products--total charge)	200.00		.1125

a/ Interview with Safeco Insurance Representative, Bozeman, Montana.

TABLE 4.16. INSURANCE COSTS, USING 1967 RATES. a/

Volume Processed Per Hour Pounds	Building Dollars	Equipment Dollars	Maximum Product on Hand Dollars	Liability Dollars	Fixed Insurance Costs Dollars	Total Dollars
2,000	154.91	345.57	37.80	202.50	250.00	835.87
4,000	187.52	417.35	75.60	303.75	250.00	1,234.22
8,000	255.56	650.75	345.60	556.87	250.00	2,058.88
10,000	255.56	671.58	432.00	607.50	250.00	2,216.74
12,000	325.22	899.17	518.40	759.38	250.00	2,752.17
14,000	384.55	972.20	604.80	860.63	250.00	3,072.18
16,000	384.55	1,078.15	691.20	961.87	250.00	3,365.77
18,000	394.65	1,164.44	777.60	1,012.50	250.00	3,599.19

a/ Computed from schedule presented in Table 4.15.

TABLE 4.17. SUMMARY OF ANNUAL FIXED COSTS FOR CHEESE PLANT PROCESSING FROM 2,000-18,000 POUNDS OF MILK PER HOUR--BY STAGES. a/

Volume Processed Per Hour	Total Invest.	Ins.	Repairs and Maintenance	Taxes	Interest	Bldg. and Land	Receiv.	Proc.	Hooping	Packaging	Office and Lab	Utilities	Butter and Whey	Cleaning	Misc.	Total Annual Cost
Pounds	Dollars															
2,000	92,141	836	4,722	1785	2764	956	1137	1949	189	152	400	582	--	--	1000	16,422
4,000	111,384	1234	5,673	2159	3341	1157	1277	2296	304	152	400	680	--	--	1000	19,673
8,000	164,587	2059	8,705	3190		1577	1539	3163	608	152	700	680	879	--	1500	29,690
10,000	167,832	2217	9,003	3254	5035	1577	1621	3163	672	304	700	680	879	--	1500	30,605
12,000	220,523	2753	11,805	4274	6616	2007	1759	4005	794	304	700	1000	1469	360	1500	39,346
14,000	246,566	3072	12,608	4778	7397	2373	1887	4361	895	456	400	1000	1469	360	2000	43,056
16,000	263,078	3366	13,465	5098	7892	2373	1962	4536	1090	468	400	1400	1469	360	2000	45,879
18,000	279,040	3599	14,988	5407	8371	2436	2015	5704	1329	568	400	1400	1469	360	2000	49,946

a/ Summary of Tables 4.7-4.15.

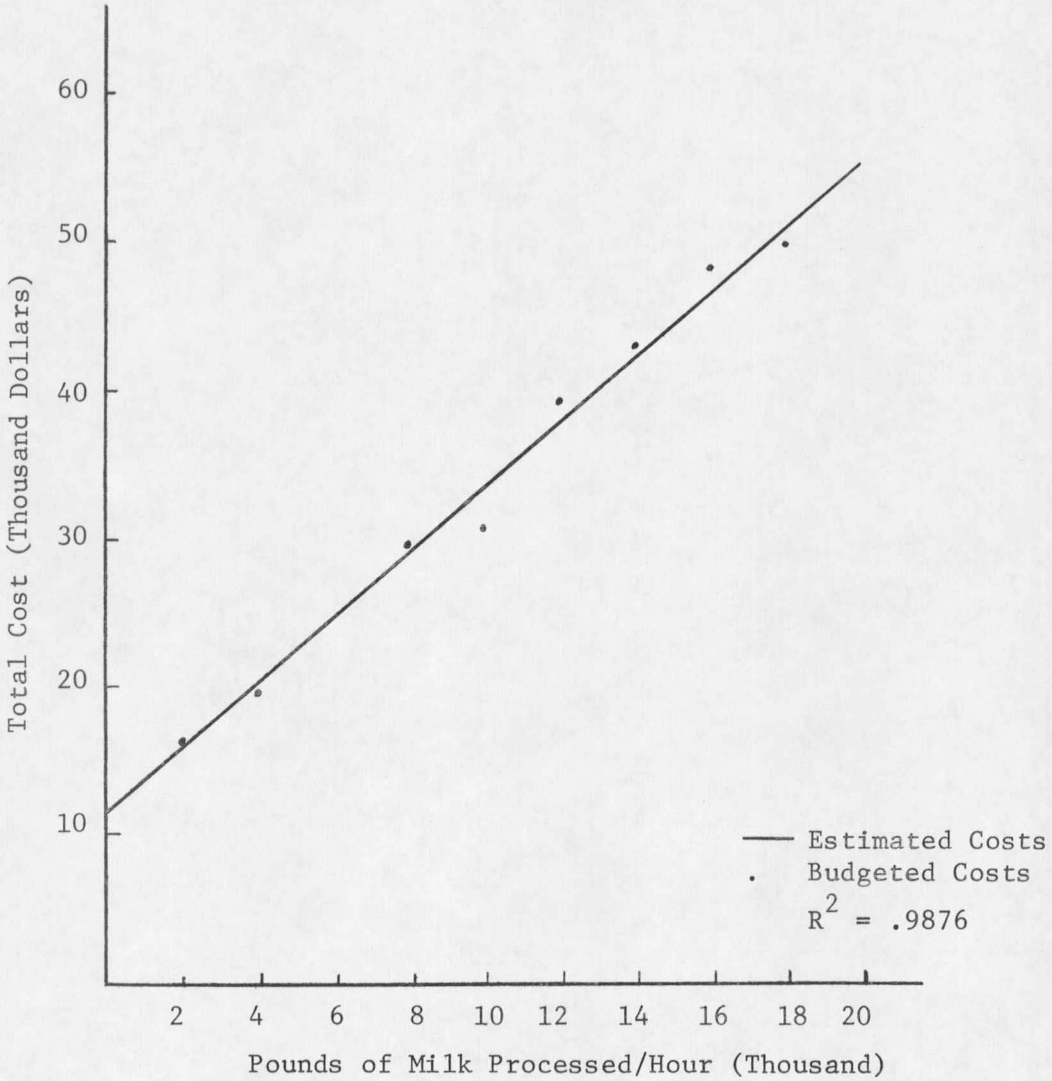

Figure 4.1. Estimated Fixed Costs and Budgeted Fixed Costs for Varying Processing Levels.

Variable Costs

In addition to the fixed costs discussed in the previous section requirements and costs directly associated with volume of milk had to be analyzed. These costs were labor, materials, electricity, steam, water, and natural gas.

Labor.--In interviews at plants 20/ and in reviewing related material 21/ it was found that the minimum force necessary to operate a two-vat factory was three to five people. This depended on whether the manager worked or not. If the manager was a working manager, the force could be cut to three people. For purposes of this study it was assumed that the manager was not actively engaged in the physical work in the plant. The minimum force necessary then would be four people. The force would consist of a manager, a cheesemaker foreman, one worker in the plant and a clerk in the office. A general rule of thumb followed is that it takes one man for each vat with a minimum force of two men. 22/ In other words, the cheesemaker foreman and one worker would be necessary for the operation of the two-vat factory in addition to the manager. As vats are added one worker would be added for each vat added. This was one rule for the addition of labor. A survey of plants indicated that the one worker at minimum levels would have time to handle the receiving

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20/ Interview with Joe and Shane Heap, Managers, Glacier Mountain Cheese Factory, Gallatin Gateway, Montana and Ned Davidson, Manager, United Irrigation District Cheese Factory, Glenwood, Alberta, Canada.

21/ Bob Bucher, Can a Cheese Factory--, op. cit., p. 26.

22/ Ibid.

station as well. Routine maintenance would be handled by the existing plant personnel. Field work at this level would be handled by the manager. As volume handled increased, packaging and in-plant transportation became quite labor demanding. It was noted that for a plant handling 8,000 pounds of milk per hour total time required to package the 40 pound blocks, weigh them, and transport to the truck or storage would require 7.8 hours daily. (7.323 min. x 64 = 468.67 min. This divided by 60 yields 7.8 hours) This would require two people for packaging, transporting, and to assist in cleaning the hoops and cheese cloths. Using this same method at the highest level of processing indicated that five workers would be needed at this station and to assist in cleaning the hoops. A stainless steel hoop washer of 5-stage conveyorized design would be used as a labor saving device at processing levels of 12,000 pounds and higher. This machine is often employed in plants of this scale.

One additional man was employed at processing levels of 8,000 pounds per hour and higher for the operation of the butter center. If necessary, additional part-time help would be utilized from the processing center. An additional worker was also placed in the utilities center at this volume and would assist the manager in field work.

The division of labor, between departments is strictly arbitrary. From a review of plants 23/ the total breakdown represents a minimum

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23/ Interviews at Cache Valley Dairy Association, Smithfield, Utah; Star Valley Swiss Cheese Factory, Thane, Wyoming; Gallatin Cheese Factory, Gallatin Gateway, Montana and at Foremost Dairies in Stevensville provide the basis for this statement. These plants processed from 25-400,000 pounds of milk daily. An observation of the number of workers at each of these stages in these plants indicate that this is a reasonable work force.

force obtainable under reasonably efficient operation to process and package the cheese into 40 pound blocks and for the part-time processing of butter. Total plant requirements for labor are included in Table 4.18.

Wages.--Bucher assigned a salary of $700 per month to the cheesemaker manager in his 1962 study. 24/ In a 1967 study he assigned $10,000 yearly as a minimum salary. 25/

Since this was essentially a long-run study it would be better to err on the upward side than for a lower wage. Therefore, a basis of a salary of $10,300 was assigned for a manager at levels to 14,000 pounds hourly. For the management of a six-vat operation, a salary of $12,400 was assigned.

It is customary in most studies to establish the management salary as a fixed cost. With present-day incentives on performance, salaries can vary from $6 to $14,000 yearly for basically the same job. This is due to bonuses, a share of cheese sales, a share of the whey operation, and other incentives. Ten thousand dollars yearly is a high salary for managership of a two-vat operation. Scaling the wage per hour on the hourly basis partially compensates for this cost effect.

24/ Bucher, Can A Cheese Plant Improve Income for Billings Milk Producers, op. cit., p. 23.

25/ Bucher, Feasibility of a Milk Marketing Association for the Billings Area, op. cit., p. 35.

TABLE 4.18. LABOR REQUIREMENTS FOR MODEL PLANTS BY PROCESSING STAGE. a/

Volume Processed Per Hour	Manager	Receiving	Processing and Hooping	Packaging & In-Plant Transportation	Cleaning	Office	Maintenance, Fieldmen and Utilities	Butter and Whey	Total
2,000	1	1	1	–	–	1	–	–	4
4,000	1	1	2	1	–	1	–	–	6
8,000	1	1	3	2	–	2	1	1	11
10,000	1	1	4	2	–	2	1	1	12
12,000	1	1	5	2	1	3	1	1	15
14,000	1	1	6	3	1	3	1	1	17
16,000	1	1	7	4	1	3	1	1	19
18,000	1	1	7	5	1	3	1	1	20

a/ Derivation of labor requirements are discussed on p. 116.

In interviews with plant managers in Idaho, Wyoming, and Utah, 26/ the point continually stressed was the importance of a good cheesemaker-foreman. Salaries ranged from $700 to $900 per month for this person. Therefore, a wage of $9,600 yearly was assigned to him. It was felt that a wage of $2.00 per hour assigned to workers in the plant and fieldmen would be representative of the wage paid. A wage of $1.32 per hour was assigned to clerical help.

In addition to wages paid, retirement plans, social security, health and welfare plans, and unemployment must be added to the plants labor costs. The total costs are included in Table 4.19.

Materials.--Table 4.20 includes a summary of prices and quantities used to determine material costs in the processing stage.

The cost of materials used in packaging consisted of a liner, seran, and a box. These costs are included in Table 4.21.

Johnson and Forker estimate variable costs for office supplies to be $.08 per 1,000 milk and $.045 for lab supplies. They also used a cost of $.05 per 1,000 for cleaning supplies. 27/ These costs were used here.

Electricity.--The horsepower specification which provide the basis for estimating the electricity requirements for each stage were estimated

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26/ The managers at Smithfield and Thane both indicated the cheesemaker was the most important man in their operation. The operation at Jerome was a diversified one but the manager still felt that the cheesemaker was very important.

27/ Johnson, Clarke, and Forker, Operations and Costs, op. cit., p. 51.

TABLE 4.19. WAGE COSTS FOR MODEL PLANT PERSONNEL. a/

Job	Wage	Pension	S.S. (4.4% of 6,600)	Health Welfare	Unemployment (2.9% of total)	Total Cost Per Hour
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
Mgr.-to 14,000#	3.44	.05	.097	.07	.098	3.75
Mgr.-greater than 14,000#	4.14	.05	.097	.095	.116	4.50
Cheesemaker-Foreman	3.21	.05	.097	.06	.094	3.51
Workers	2.00	.04	.092	.055	.061	2.25
Clerical help	1.32	.04	.055	.045	.036	1.49

a/ Survey at Smithfield, Thane, Gallatin Gateway, and Ronan.

TABLE 4.20. PROCESSING MATERIALS COST FOR MODEL PLANTS PER 1,000 MILK, 1967. a/

Material	Quantity Used Per 1,000	Cost Per Unit	Total Cost (1,000 milk)
		Dollars	Dollars
Rennet	16 oz.	36.00 gal.	.4500
Salt	2.5 lb.	2.75 cwt.	.0700
Marstar	1.0 lbs.	.346 lb.	.3460
Starter	.1 qt.	.50 qt.	.0500
Coloring	1.6 oz.	4.85 gal.	.0606
Total			.9766

a/ Interview at Glacier Mountain Cheese Factory, Gallatin Gateway.

TABLE 4.21. PACKAGING MATERIALS COST PER 1,000 MILK. a/

Material	Cost per 40 Pound Box	Cost per 1,000
	Dollars	Dollars
Liner	.0632	.1580
Seran	.12	.3000
Box	.0991	.2477
Total		.7057

a/ Interview at Glacier Mountain Cheese Factory, Gallatin Gateway.

with aid of engineering specifications for the equipment and from a review of existing plants, for all motors operating in each stage. The horsepower specifications were then converted to kilowatt hours by use of the ratio of 1 kilowatt hour of electrical energy consumed for each installed motor horsepower per hour of use. 28/ Kilowatt hours were then totaled to determine electricity requirements for each stage.

Electricity requirements for cooling were derived from engineering data. A ton of refrigeration is defined in terms of heat at the rate of 12,000 B.T.U.'s per hour. 29/ There is a great deal of variance in the requirements of mechanical refrigeration systems. However, a rule of thumb specification that one-ton of refrigeration capacity requires the equivalent of one motor horsepower which in turn is equivalent to 1 kilowatt hour of electrical energy. This is the rule of thumb used here. On this basis the cooling of one pound of milk through a temperature range of (t_1-t_2) degrees Fahrenheit utilizes electrical energy as determined by the formula:

$$KWH = \frac{(t_1 - t_2)}{12,000}$$

where: t_1 = starting temperature in degrees Fahrenheit

t_2 = cooled temperature

28/ Johnson, Forker, and Clarke, op. cit., p. 28.

29/ Ibid.

On this basis electrical requirements for each stage were computed. Additional allowances for electrical lights and miscellaneous requirements for each stage were also calculated. These requirements are included in Table 4.22.

Electricity Cost.--Electrical service is priced in terms of the total quantity of electricity used during the month and the maximum rate at which it is used. Charges for electricity then consist of two elements, the "energy" charge and the "maximum demand" charge. The energy charge is expressed as a cost per kilowatt hour. Montana Power schedules these cost rates in decreasing increments, the last elements being less costly than the first. The second element, the maximum demand charge is a monthly charge based on the maximum rate at which electricity is used (peak load). This is determined by the 15 minute period of maximum use during the month and is expressed as kilowatts. The power rate schedule is included in Table 4.23.

Total kilowatt hours per month used in the plant were calculated. The rates in the previous tables were then applied. An average charge per kilowatt hour was taken times the total number of kilowatt hours used in each stage. Thus, the total electrical charge per stage was computed. The total electrical costs per stage are included in Table 4.24.

Natural Gas.--Estimates of the amount of natural gas required for producing steam for pasteurizing and heating milk products were derived from secondary sources. 30/

30/ A.W. Farrall, Dairy Engineering (New York: John Wiley & Sons, Inc., 1953), 477 pp.

TABLE 4.22. ELECTRICITY REQUIREMENTS BY PROCESSING STAGE MEASURED IN KILOWATT HOURS. a/

Volume Processed Per Hour	Receiving Hours	Processing Hours	Packaging & In-Plant Transportation Hours	Butter and Whey Hours	Office and Lab Hours	Utilities Hours	Total KWH Hours
2,000	2.38	5.85	.57	--	2.06	12.78	23.64
4,000	2.92	9.32	1.17	--	3.03	15.59	32.03
8,000	3.77	13.19	2.34	7.41	3.34	26.41	56.46
10,000	4.34	15.07	2.94	8.97	4.13	29.69	65.14
12,000	4.77	17.18	3.53	9.84	5.41	34.69	75.42
14,000	5.13	18.79	4.16	11.00	6.18	36.25	81.51
16,000	5.48	21.55	4.76	13.08	7.00	50.81	102.68
18,000	5.83	23.28	5.37	13.99	7.47	53.94	109.88

a/ Computed on basis of procedure outlined on pp. 124-125.

TABLE 4.23. ELECTRICITY SERVICE, MONTANA POWER COMPANY, 1967 RATES. a/

80 ¢ per kwh for the first 20 kwh or less
3.7¢ per kwh for the next 80 kwh
2.9¢ per kwh for the next 1,700 kwh
1.7¢ per kwh for the next 3,200 kwh
1.0¢ per kwh for the next 15,000 kwh
.8¢ per kwh for the next 200 kwh per kilowatt
.55¢ per kwh for all additional kwh

PLUS

First 10 kilowatts -- no charge
Next 20 kilowatts -- $1.00 per kilowatt
All additional kilowatts -- $.90 per kilowatt

a/ Montana Power Rate Schedule, GS-64. Rates could vary slightly from location to location.

TSBLE 4.24. TOTAL ELECTRICITY COST PER STAGE USING 1967 RATES. a/

Volume Processed Per Hour	Receiving	Processing	Packaging & In-Plant Transportation	Butter and Whey	Office and Lab	Utilities	Total Cost Per Hour
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
2,000	.0463	.1139	.0110	--	.0401	.2488	.4601
4,000	.0501	.1599	.0192	--	.0520	.2677	.5489
8,000	.0520	.1869	.0331	.1049	.0474	.3742	.7985
10,000	.0586	.2034	.0397	.1211	.0557	.4008	.8793
12,000	.0616	.2216	.0455	.1270	.0697	.4475	.9729
14,000	.0641	.2350	.0520	.1376	.0773	.4535	1.0195
16,000	.0655	.2577	.0569	.1564	.0837	.6077	1.2279
18,000	.0666	.2659	.0613	.1597	.0853	.6160	1.2548

a/ Based on rates and wage outlined in Tables 6.21 and 6.22.

Natural gas is not available at all the locations. However, the selection of natural gas as a heating media was based on a ready availability of data on heat conversion from natural gas both from the manufacturer and from previous studies. This could result in a slight downward bias in cost at two of these locations.

Under normal conditions, approximately 1,000 B.T.U.'s of heat are available per pound of steam. 31/ This rule is used here. The relationship of 1/1000 pound of steam requirement for each change of 1 degree in temperature per pound of product was used to determine steam requirements for processing stages. The preceding was expressed in terms of the following formula: 32/

$$S = \frac{M(t_2 - t_1)}{1,000}$$

where: S = pounds of steam requirements

M = pounds of product

$(t_2 - t_1)$ = number of degrees by which the temperature is raised

Steam requirements for can cleaning, tank cleaning, vat cleaning, and hoop cleaning were obtained from manufacturers recommendations 33/

31/ Johnson, Forker, and Clarke, op. cit., p. 29.

32/ Ibid.

33/ Manufacturers specifications obtained from Damrow Brothers and Stoelting Brothers.

and interviews with plant personnel. 34/ A further specification used in computing natural gas requirements was that natural gas contains 1,100 B.T.U.'s per pound. Assuming the boiler operates at 70 percent of efficiency, this will involve the use of 1.558 cubic feet of natural gas per pound of steam. 35/ The natural gas requirements for the model plants are specified by stage in Table 4.25.

TABLE 4.25. NATURAL GAS REQUIREMENTS FOR MODEL PLANTS BY STAGE--THOUSAND CUBIC FEET. a/

Volume Processed Per Hour	Receiving	Processing	Butter, Whey and Office	Cleaning	Total Gas Required
Pounds	MCF	MCF	MCF	MCF	MCF
2,000	.3888	.4112	.0390	.6267	1.4657
4,000	.4868	.8350	.0487	.6455	2.0160
8,000	.6816	1.6076	.0584	1.0043	3.3519
10,000	.8763	2.0877	.0681	1.0472	4.0793
12,000	1.0711	2.5051	.0778	1.0527	4.7067
14,000	1.2533	2.9228	.0876	1.2373	5.5010
16,000	1.3632	3.3403	.0973	1.3125	6.1133
18,000	1.4606	3.7578	.1071	1.4000	6.7255

a/ Computed by means of procedures outlined on pp. 129-131.

34/ Survey conducted at Consolidated Dairies, Ronan, Montana.

35/ Johnson, Forker, and Clarke, op. cit., p. 29.

Natural Gas Costs.--Natural gas is also supplied by Montana Power. Its cost as in the case of electricity is based on useage. The following schedule indicates the cost of natural gas to commercial users, Table 4.26.

TABLE 4.26. NATURAL GAS COSTS PER THOUSAND CUBIC FEET--1967 RATES. a/

First 1 MCF or less per month -- $2.00
Next 99 MCF per month @ $0.65 per MCF
Next 200 MCF per month @ $0.47 per MCF
Next 700 MCF per month @ $0.36 per MCF
Next 4,000 MCF per month @ $0.32 per MCF

a/ Based on Montana Power Company Rate Schedule GS6-62.

To compute the cost of natural gas at each volume of processing an average total volume of natural gas used each month was first computed; the average cost per thousand cubic feet of natural gas was then calculated. This quantity times the hourly quantity of gas used for each volume of milk processed yielded the natural gas cost per hour. The cost for natural gas for each volume of gas processed are included in Table 4.27.

Water Requirements.--Water requirements and costs are quite difficult to obtain. At some plants water is pumped out of owned wells. The cost to a plant depends on the depth of the well and the size and efficiency of its pump. Other plants are on city water and their water costs depend on the city water rate. Since these factors vary greatly it was decided to use a constant cost for water. Johnson, Clarke, and Forker found that

TABLE 4.27. NATURAL GAS COSTS FOR MODEL PLANTS PER THOUSAND CUBIC FEET AT 1967 RATES. a/

Volume Processed Per Hour	Receiving	Processing	Butter, Whey, Office and Lab	Cleaning	Total Cost Per Hour
Pounds	Dollars	Dollars	Dollars	Dollars	Dollars
2,000	.1948	.2056	.0215	.3138	.7357
4,000	.2258	.3873	.0225	.2994	.9350
8,000	.2850	.6725	.0245	.4202	1.4022
10,000	.3550	.8457	.0276	.4242	1.6525
12,000	.4250	.9943	.0390	.4178	1.8761
14,000	.4837	1.1279	.0338	.4775	2.1229
16,000	.5186	1.2707	.0371	.4993	2.3257
18,000	.5475	1.4088	.0402	.5249	2.5214

a/ Using rates from Table 4.26 and requirements from Table 4.25.

for cottage cheese operations in California water costs averaged about $.025 per 1,000 pounds of milk. 36/ Rowe's estimates averaged from $.01 to $.03 per 1,000 pounds of milk. 37/ It was decided to use a water cost of $.025 per 1,000 pounds of milk processed. 38/ Using this factor the following results were recorded for water costs, Table 4.28.

TABLE 4.28. WATER COSTS FOR MODEL PLANTS. a/

Volume Processed Per Hour	Water Cost
Pounds	Dollars
2,000	.0500
4,000	.1000
8,000	.2000
10,000	.2500
12,000	.3000
14,000	.3500
16,000	.4000
18,000	.4500

a/ Computed from procedure outlined in above section.

Summary of Variable Costs

Table 4.29 presents a summary of all variable costs associated with processing at various alternative levels of output. A "cost prediction"

36/ Johnson, Clarke, and Forker, Operation and Costs, op. cit., p. 52.

37/ Gordon A. Rowe, Economics of Cheese Manufacturing in Tillamook County Oregon, Agr. Expt. Sta. Bulletin 529 (Corvallis, 1952), p. 11.

38/ Author's estimate based on above references.

TABLE 4.29. SUMMARY OF TOTAL VARIABLE COSTS FOR MODEL PLANTS BY STAGE. a/

Volume Processed Per Hour	Receiving		Processing	Hooping	Packaging & In-Plant Transportation	Office and Lab	Utilities	Butter and Whey	Cleaning	Water	Total Cost Per Hour
	Can	Bulk									
Pounds	Dollars										
2,000	.8167	1.7607	5.2554	1.5887	2.9422	2.3453	.7845	--	.3148	.0500	15.8583
4,000	.8167	1.7956	9.0484	2.2267	4.8777	3.5943	1.5543	--	.4494	.1000	24.5122
8,000	.7497	1.7897	14.0448	3.5648	10.6474	7.0246	1.5929	2.8236	.8202	.2000	43.2577
10,000	.7497	1.8663	17.8333	4.1792	12.0654	7.2862	1.6195	2.8398	.9242	.2500	49.6136
12,000	.7497	1.9393	20.3502	4.8064	13.4826	9.0533	3.9162	2.8457	1.0178	.3000	58.4612
14,000	.7497	2.0005	25.2831	5.4397	17.1505	9.3138	3.9222	2.8563	1.1775	.3500	68.2433
16,000	.8435	2.1306	29.1065	6.1725	20.9106	9.6673	4.1702	2.9689	1.2993	.4000	77.6694
18,000	.8435	2.1606	31.2060	6.1725	24.5764	9.9220	4.1785	2.9722	1.4249	.4500	83.9066

a/ Summary of Tables 4.17-4.27.

technique was again employed by fitting a least squares estimate of the following form:

$$TPC_V = 7.91 + 4.306V_P \qquad 4\text{-}2$$

where: TPC_V = total variable costs per hour

V_P = volume processed in 1,000 pounds per hour

Figure 4.2 illustrates the graphical relationship between budgeted and estimated total variable processing costs. The coefficient of determination was .9984 indicating a close relationship between budgeted and estimated variable costs.

Equations 4-1 and 4-2 can be used on a cost prediction basis to predict total costs for this type of plant given the volume of milk handled and hours of operation. This involves multiplying the variable cost equation by H, the number of hours operated per season and adding the two together to obtain the following:

$$TPC = 11{,}856.8 + 2160.61V_P + 7.91H + 4.306V_PH \qquad 4\text{-}3$$

where: TPC = total yearly processing cost

This equation will be used as the cost prediction equation for this type of plant. An application of this equation will be made in the next chapter with the use of the Stollsteimer model.

<u>Processing Cost Estimation</u>.--Equation 4-3 may be used to estimate processing costs under varying operating conditions.

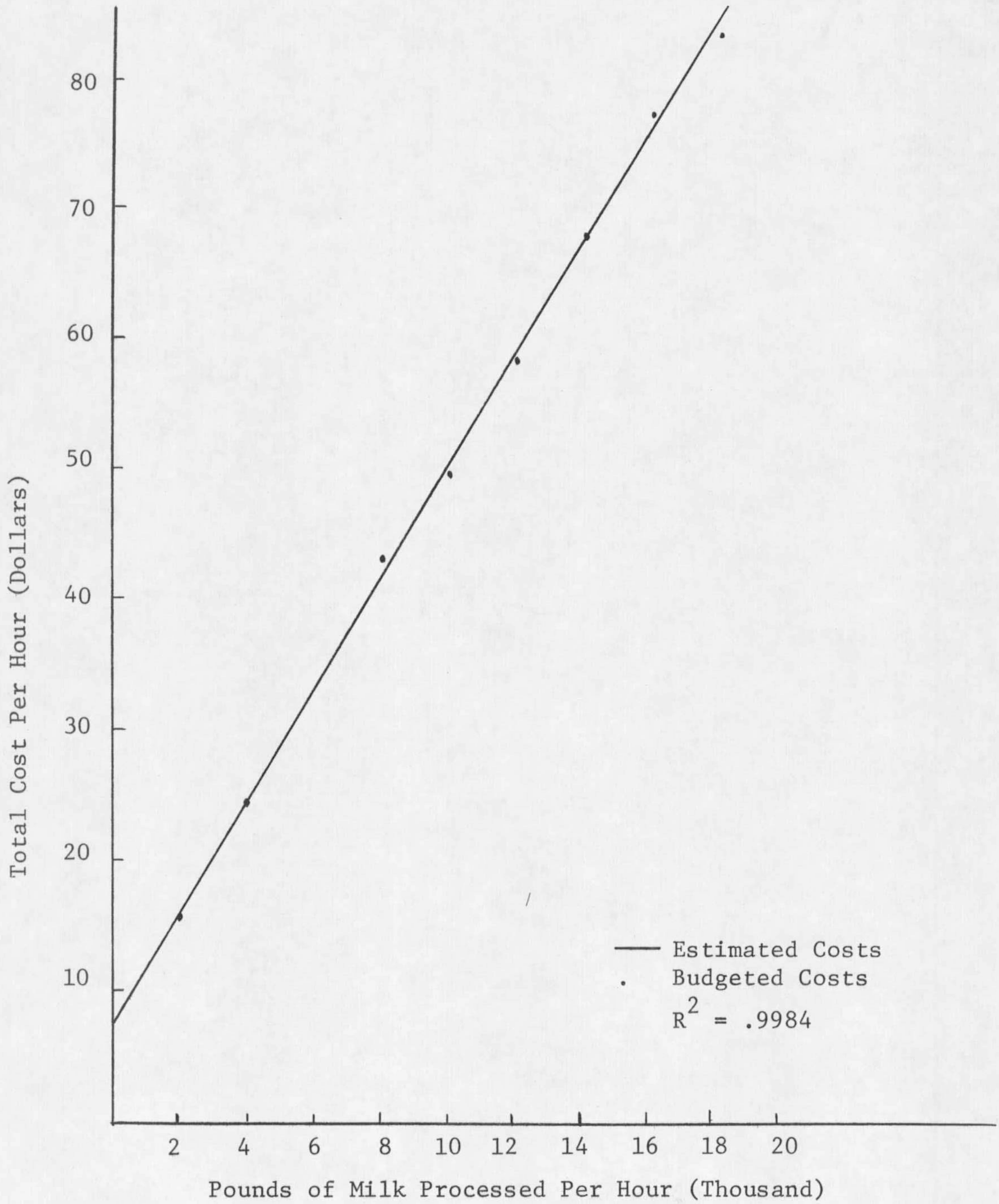

Figure 4.2. Estimated Variable Costs and Budgeted Variable Costs for Varying Processing Levels.

The cost curves plotted in Figure 4.3 provide an insight as to the effect of plant size on average costs. Figure 4.3 illustrates how average costs decrease as plant size increases. The major portion of these decrease in costs come about in the early stages--from 1,000-4,000 pounds per hour. This decrease in average costs comes about through the scattering of fixed costs such as buildings and equipment costs over the larger ranges of output. It also comes about due to the better utilization of high costs, high capacity equipment such as pasteurizers and separators which are underutilized in the lower capacity plants.

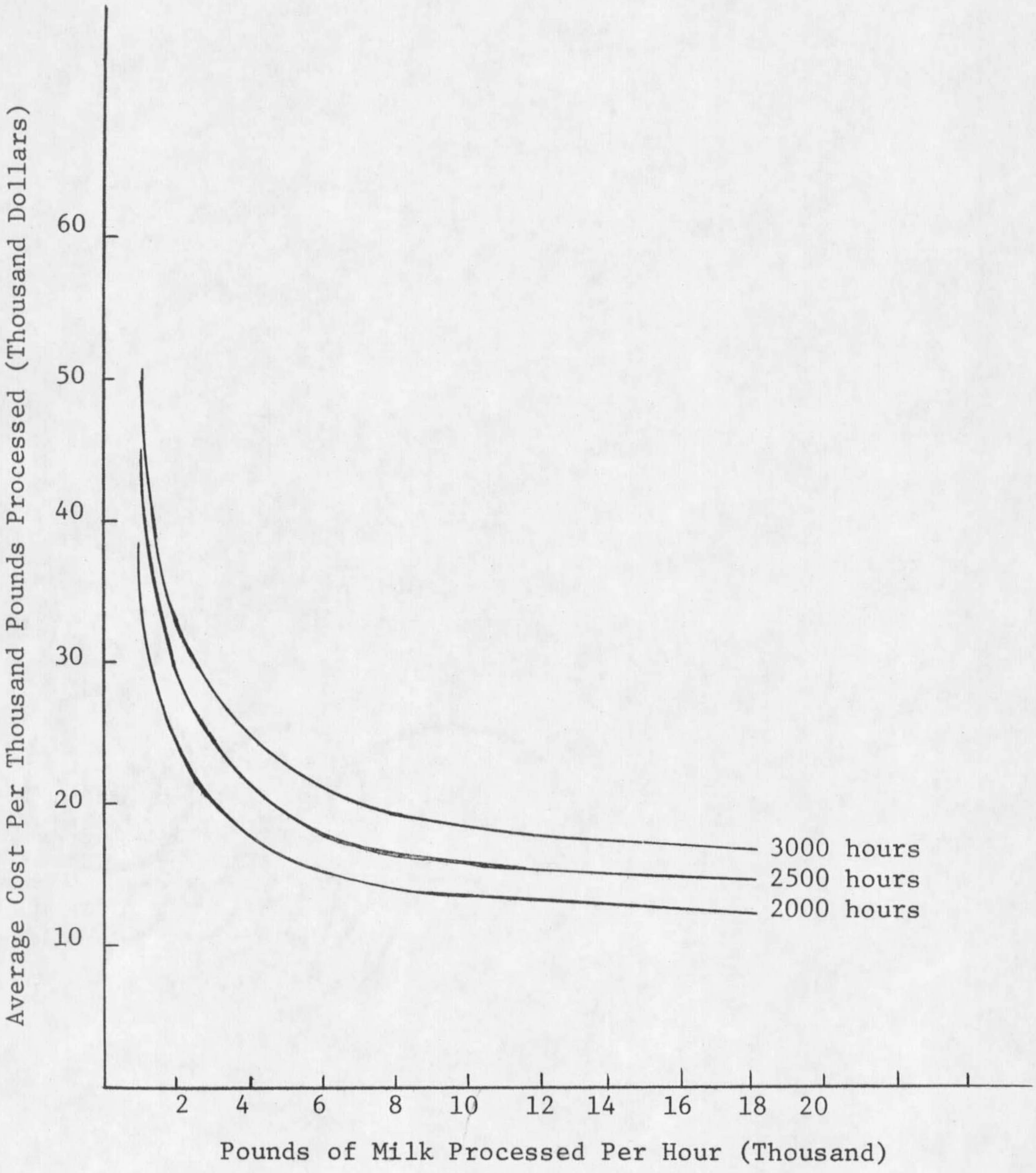

Figure 4.3. Average Total Processing Costs Associated with Varying Processing Levels.

CHAPTER V

APPLICATION OF THE MODEL

Introduction

Methods of cost prediction outlined in the previous two chapters combined with data on milk available for manufacturing purposes in Western Montana provide a basis for the analysis in this chapter. The purpose of this chapter was to apply this production data to the equations derived previously to determine the combined processing and transfer costs for this given number of plants and locations in this area. Cost data were combined with the production data to determine the number, size, and location of processing plants required to minimize the combined assembly and processing costs for an estimated amount of milk available in this region in 1970.

The Area Considered

The area considered as a basis for this study was scattered over a wide geographical region. Five cities and four towns were analyzed for purposes of the transfer and processing of milk. These cities were Billings, Bozeman, Great Falls, Missoula, and Kalispell. The four towns were Gallatin Gateway, Whitehall, Ronan, and Stevensville-Hamilton. Gallatin Gateway, Ronan, Stevensville, and Hamilton are sites of the present cheddar operations in the state. A plant is at Whitehall but has not been in operation for some time. A description of the climatology and farming patterns in these areas was given in Chapter I. According to data released by the Statistical Reporting Service, Helena, Montana, these four plants have processed from 82 percent of the total manufacturing milk produced in 1960 to 92.8 percent of the total manufacturing milk produced in 1964.

TABLE 5.1. TOTAL MANUFACTURING MILK SOLD IN STATE AND FOUR PLANT TOTALS, 1960-65. a/

Year	Total Manufacturing Milk Sold (1,000 Pounds)	Four Plant Total (1,000 Pounds)	As a Percent of Total
1960	37,120	30,458.5	82.1
1961	40,800	36,905.2	90.5
1962	40,800	33,923.0	83.1
1963	38,400	32,246.6	84.0
1964	34,300	31,831.4	92.8
1965	34,160	30,710.1	89.9

a/ Unpublished data released by the Montana Crop and Livestock Reporting Service, Helena, Montana.

The five cities analyzed are all cities where a large amount of the processing is of Grade A milk. No cheddar plants are in existence in these cities with the exception of Bozeman.

The five cities and three towns are all connected with all-weather, hard surface roads. Highway 10 is the principal link between Bozeman and Billings. Highway 191 connects Bozeman and Gallatin Gateway. Highway 10 North from Bozeman to Missoula and Highway 93 South from Missoula to Stevensville-Hamilton is the primary route from Bozeman to Stevensville. Highway 93 North to Ronan and Kalispell is the major route in this area. Highway 20 West to Ronan and Highway 15 South are the principal routes from Great Falls.

Problem Procedure

The model used in solving for the number, size, and location of processing plants that will minimize the combined transfer and processing costs of manufacturing and surplus milk in these areas in 1970 was the basic Stollsteimer model outlined in Chapter I.

Stollsteimer offers four different solution procedures for minimizing combined transfer and processing costs. The procedure used required that there were economies of scale in plant operations and that plant cost functions did not vary with plant site. The analysis was on a long run basis. In this case, the year 1970 was chosen. This particular year was far enough in the future to allow for plant changes but short enough so that the production estimates could be made by the method outlined in the following section.

The data necessary for this solution are:

1. Projected 1970 milk production at each point specified in the area previously.

2. A transportation cost matrix which contains the cost of transferring milk from each origin to each plant site.

3. A plant cost function which would allow the calculation of total cost of processing a fixed total volume of milk in various numbers of plants.

4. Specification of potential plant locations.

Milk Available--1970

Milk Production--Grade B.--Table 5.1 contains data on the volume of milk manufactured by the four cheddar plants in the years 1960-65. Data was also obtained from the Statistical Reporting Service on a plant basis for these years. Due to the confidential nature of this data, the actual amounts processed during those years by individual plants is not disclosed.

From an analysis of the data it became apparent that choice of a particular method for projecting 1970 milk production would be a difficult task. From the years 1961-64 low support levels caused by high national production probably was one of the reasons State production has shown a sharp decline. However, since 1966 support levels have been at the highest level since 1950, which should have some stabilizing effect on production. However, there has been a continual downward adjustment in the number of producers. If there is a leveling off in the decline, a linear trend would probably interject some downward bias into the estimate. For this short period it was felt that a linear estimator would not be unrealistic.

With these reservations in mind, a linear estimator was fitted to 1960-66 data. This resulted in the following equation:

$$Y = 35.35 - 1.03(T_2 - T_1) \qquad 5\text{-}1$$

where: Y = production in millions of pounds in year to be estimated

T_2 = year in which production is to be estimated; in this case 1970

T_1 = base year, 1963

This would result in an aggregate 1970 production of slightly over 28 million pounds of milk. This was adjusted on a plant basis to obtain area estimates for this period.

Milk Production--Grade A.--Surplus that could be made available for manufacturing was calculated for five cities. These cities were Billings, Great Falls, Bozeman, Missoula, and Kalispell.

First it was necessary to determine the meaning of the word surplus as used in this study. The Montana Milk Control Board until June 30, 1967 categorized milk in the following four ways: 1/

Class I: Raw whole milk, pasteurized and homogenized whole milk, low fat milk, buttermilk, chocolate milk and chocolate drink ultimately used in bottled or packaged form, shrinkage attributable to producer milk in excess of two percent of current producer receipts; and plant averages.

Class II: Whipping cream, coffee cream, half and half, skim milk and other commercial cream.

Class III: All butterfat and skim milk used in the manufacture of cottage cheese, cheese dressing, cultured sour cream, ice cream mix, egg nog, tom and jerry batter, and yogurt.

1/ State of Montana Milk Control Board, "General Official Order Regulating Transactions Involving the Purchase and Resale of Milk Within the State, Which is Intended to Accomplish the Declared Policy of the Act, as Set Forth in Title 27, Revised Codes of Montana, 1947", Official Order 641-B (Helena: May 25, 1966), p. 11.

Class IV: All butterfat and skim milk used in manufacture of cheddar or similar cheese, butter, livestock feed, plant loss or shrinkage attributable to producer milk or two percent or less of current producer receipts and plant inventories of fluid products.

As of June 30, 1967, the categories have been combined to three. Class I and II have been combined into Class I. Class III now is Class II and Class IV is now Class III.

With these definitions several attempts have been made at determining surplus in a particular area.

In two separate studies, Bucher derived surplus figures for the Billings area. 2/ At best the separation of milk in an area into milk for Class I usage and that that would be considered surplus is a nebulous thing. Some of the reasons for this are as follows:

1. A particular area may be in short supply of milk. Milk may be shipped in from another area. Due to transportation costs this may be utilized as Class I while some local milk would be surplus. Therefore some surplus could show up in and area that is actually short of milk.
2. There is debate on what size of inventory a plant should carry over from month to month. Jones considered 15 percent as a reasonable figure. 3/

2/ Bucher, Can A Cheese Plant Improve Income for Billings Milk Producers, op. cit., and Feasibility of a Milk Marketing Association for the Billings Area, op. cit., p. 10.

3/ Jones, Marketing Alternatives for Surplus Grade A Milk in Montana, op. cit., p. 13.

3. In order to carry a "full line" in the stores, some manufacture of butter and other Class IV products is necessary on a plant basis.
4. Surplus in an area may be shipped to another area and utilized as Class I. For example, although the Bozeman area may show a large surplus in plant usage, this may be shipped to another area as Class I and is paid for as Class I. Milk is shipped from the Bozeman area to Great Falls, Havre, and Helena during the summer months resulting in a high percentage of Class I utilization and resulting in a reduction of surplus for the Bozeman producers.

With these reservations in mind then a workable definition of surplus used here would be that amount of producers' milk available for manufacturing after Class I, II, and III have been deducted with an allowance for bulk sales. This amount could be already part of the volume that is being used for manufacturing purposes. The question is whether it could be more efficiently utilized by being transported elsewhere and consolidated into larger quantitites for manufacturing.

Surplus was determined in the following manner:

1. Monthly summaries supplied by the Milk Control Board consolidated from plant records were utilized.
2. Producer surplus from the Class IV category was used.
3. Producer surplus for each plant for each month was recorded.

4. Total monthly producer surplus for each plant in the respective city was totaled to give the surplus for the city.
5. Where a plant had out-of-area producers, this volume was added to that plants receipts. This only occurred in one plant.
6. Monthly totals were added to give a yearly total.

The volume of milk that could be available for manufacturing in 1970 if the present stability of the Grade A market continues is illustrated in Table 5.2.

The three high months were in the spring in all cases--April, May, and June. Low months were in the fall. In some cases a deficit situation appeared in the fall. Surplus dwindled in the Great Falls area to 797 pounds per day average in November. This could have been a "bookkeeping" surplus. However, using this method of analysis, quite a large volume of milk appeared to be available for manufacturing in the Missoula and Bozeman areas, particularly in the Missoula area. Billings and Kalispell also showed very small quantitites available in the fall months.

This is admittedly quite an imperfect method of predicting the amount of milk available for manufacturing in any long run situation. Using this method provides us with some concrete data to suggest what could be accomplished with that amount of surplus given the data available. A summary of total milk available at these eight locations in 1970 is listed in Table 5.3.

TABLE 5.2. COMPOSITE SURPLUS--FIVE MONTANA CITIES, 1965-66. a/

City	Total Surplus	High Month	Low Month	High Day	Low Day
	1,000 Pounds	1,000 Pounds	1,000 Pounds	1,000 Pounds	1,000 Pounds
Billings	2,669.9	485.4 b/	70.5 d/	16.2 b/	2.35 d/
Bozeman	6,816.9	1,478.9 b/	168.7 e/	49.3 b/	5.63 e/
Great Falls	1,986.8	374.3 c/	23.9 f/	12.4 c/	.797 f/
Kalispell	2,729.4	486.2 c/	79.3 g/	16.2 c/	2.64 g/
Missoula	10,467.5	1,993.4 b/	237.6 f/	66.4 b/	7.92 f/
Total	24,670.5				

a/ Montana Milk Control Board Data 1965-66.
b/ June.
c/ May.
d/ December.
e/ January.
f/ November.
g/ August.

TABLE 5.3. PROJECTED VOLUME OF MILK TO BE AVAILABLE FOR MANUFACTURING IN 1970 IN FIVE CITIES AND FOUR TOWNS.

Location	Projected Volume--1970 1,000 Pounds
Billings b/	2,669.6
Kalispell b/	2,729.4
Great Falls b/	1,986.8
Bozeman b/	6,816.9
Missoula b/	10,467.4
Ronan a/	9,978.0
Stevensville-Hamilton a/	11,700.0
Gallatin Gateway a/	6,469.2
Total	52,817.3

a/ Derived by Equation 5-1.
b/ Derived from Table 5.2.

Transfer Costs

A transfer cost matrix was computed in the following manner. Road mileages from all the origins to the prospective locations were included in a matrix. Because the transfer costs were a function of volume and distance, routes and pickup or trip intervals were a primary consideration. These routes and a consideration of alternatives in trip intervals together with the mileages and cost information developed in Chapter III were used to develop an element of the transfer cost matrix for each origin and location, that is a C_{ij}.

Locations.--Stollsteimer noted that in choosing potential plant sites that almost an indefinite number of sites could be chosen. 4/ Even if the number of sites is limited to points adjacent to improved road systems this number can be infinite. Clearly due to the factorial expansion of the model we cannot consider all plant sites. However, the type of analysis employed in considering the manufacturing locations eliminates many of these. Since plant-to-plant transportation costs are

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4/ John Stollsteimer, "The Effect of Technical Change and Output Expansion on the Optimum Number, Size, and Location of Pear Marketing Facilities in a California Pear Producing Region," (Unpublished Ph.D. dissertation, Department of Agricultural Economics, University of California, 1961), p. 165.

considered instead of farm-to-plant, the final solutions are going to be weighted towards plants that are currently processing milk. This study is pointed towards the effects of a consolidation of volume at existing plant sites. The sites for plants were Ronan, Gallatin Gateway, Stevensville-Hamilton, and Whitehall.

Processing facilities exist at the Whitehall location at the present time although they are not in use. Interest was expressed by individuals in determining transportation costs to this location. 5/ Therefore, it was included.

Due to the distances considered, the Stevensville-Hamilton sites were consolidated into one possible location. With one-way transportation distances of up to 400 miles, it was felt that it would be difficult to meaningfully distinguish between sites that would be only 20 miles apart.

Transfer Distances.--Assembly distances were calculated on improved hard surface highways over the routes outlined previously. These mileages are illustrated in Table 5.4.

Since very little milk exists in the Great Falls-Billings area, a route was selected from the potential origins so that the milk from the Great Falls-Billings area could be picked up in one trip. Therefore, the mileages represent the total distance from the origin to these two cities and back to the origin.

5/ Glacier Mountain Cheese Factory, Gallatin Gateway, Montana.

TABLE 5.4. ROUND-TRIP DISTANCES FROM EIGHT ORIGINS TO FOUR LOCATIONS. a/

Location	Ronan	Whitehall	Gallatin Gateway	Stevensville-Hamilton
			Miles	
Kalispell	130	530	666	286
Great Falls-Billings	833	615	570	771
Bozeman	536	130	24	434
Missoula	112	294	430	50
Gallatin Gateway	546	140	0	444
Ronan	0	408	546	188
Stevensville-Hamilton	188	292	444	0

a/ All distances calculated from state highway map, Montana Highway Commission.

The Transfer Cost Matrix

Transfer costs for 1,000 pounds of milk transported between each origin and potential plant location were computed under two possible types of operating conditions. These were:

Case 1: Daily pickup from Ronan and Stevensville-Hamilton. Every other day for Gallatin Gateway, Great Falls, and Billings. Daily for three months and every other day for nine months from Missoula and Bozeman. Every third day from Kalispell.

Case 2: The same model with Bozeman omitted.

There were several reasons for latitude in operating conditions. First of all one of the Bozeman plants has facilities to process Grade A surplus into cheddar. These facilities were large enough to handle its surplus plus what remains in the Bozeman area. To consider it as a definite source of milk could be misleading. However, the question remains that perhaps higher returns could be realized by processing it elsewhere as part of a larger volume. It could be argued that this source of milk should be considered as a potential source of supply. Therefore, costs under two sets of operating conditions were calculated.

An analysis of the seasonal pattern of delivery in the Billings, Great Falls, and Kalispell areas indicated a great deal of seasonal variation in production patterns. For three summer months very little milk would be available in this area. Daily, every other day, or even every other third day pickup would be quite expensive. Therefore, costs were computed for the area on the minimum of an every other day basis with the additional consideration of holding the milk three days before delivery. The capacity of the 5,700 or 6,000 gallon tanker in all cases would be adequate even during the high month for this type of delivery, Table 5.2. Milk could be held much longer than this during the low months but quality considerations were such that three days were considered to be the limit.

These costs were based on the hauling distances specified in Table 5.4, the quantities available specified in Table 5.3, and the transfer cost estimation method outlined in Chapter III.

The first step in determining the cost of transporting milk from these origins to the potential location was to select a combination of routes to be serviced by each unit. These routes are listed in Table 5.5 for one-plant locations. Similar routes were derived for two, three, and four plant locations.

It was assumed that milk would be picked up in Kalispell every third day; at Great Falls, Billings, and Gallatin Gateway every other day; at Ronan and Stevensville daily and at Bozeman and Missoula daily for three months and every other day for nine months. For example, this type of pickup would make it possible to service Kalispell one day and Gallatin Gateway the next. Four units at the maximum would be necessary to service these routes. In case of the Stevensville-Hamilton location only three units would be necessary.

TABLE 5.5. ROUTES TO TRANSPORT PROJECTED VOLUME OF MILK AVAILABLE IN 1970 FROM EIGHT CITIES TO FOUR LOCATIONS. a/

Location	Route 1	Route 2	Route 3	Route 4
Ronan	Kalispell Gallatin Gateway	Great Falls- Billings	Bozeman	Stevensville- Hamilton Missoula
Whitehall	Kalispell Bozeman	Great Falls- Billings Missoula	Stevensville Hamilton	Ronan Gallatin Gateway
Gallatin Gateway	Kalispell Missoula	Great Falls- Billings Bozeman	Stevensville- Hamilton	Ronan
Stevensville-Hamilton	Ronan Gallatin Gateway	Great Falls- Billings Kalispell	Missoula Bozeman	

a/ The routes selected represent the minimum number of units necessary to service each route and still have some safety in terms of working hours.

The total hours in service of these routes were computed for each of the transporting units in the manner described in Chapter III. Fixed costs were allocated to each of the locations by determining the percentage of total hours operated in service of that location and apportioning that percentage of total fixed costs to that location. Costs were then determined and the least cost unit selected. The least cost units for one-plant sites are specified in Table 5.6.

TABLE 5.6. LEAST COST UNITS TO TRANSPORT PROJECTED 1970 VOLUME FROM EIGHT ORIGINS TO FOUR LOCATIONS--FOR ONE-PLANT SITE. a/

Location	Route 1	Route 2	Route 3	Route 4
	------Transporting Unit--Gallons---------			
Ronan	5,700	6,000	5,700	6,000
Whitehall	5,700	6,000	6,000	6,000
Gallatin Gateway	6,000	6,000	6,000	6,000
Stevensville-Hamilton	6,000	6,000	6,000	

a/ Selected by budgeting costs for each route for each unit and then selecting the least cost unit by the method outlined in Chapter III.

The total hours operated by each of these units in servicing the routes are listed in Table 5.7.

Changes in the Input Mix

The elimination of Bozeman from the analysis or analyzing different combinations of sites causes a change in the input mix. Rather than using

TABLE 5.7. TOTAL HOURS OPERATED BY LEAST COST UNITS IN TRANSPORTING 1970 PRODUCTION FROM EIGHT ORIGINS TO FOUR LOCATIONS IN YEARLY OPERATION--FOR ONE-PLANT SITES. a/

Origin	Route 1	Route 2	Route 3	Route 4
	Hours			
Ronan	4,013	4,285	5,767	4,195
Whitehall	4,161	4,798	3,765	5,016
Gallatin Gateway	6,722	3,789	5,152	6,082
Stevensville-Hamilton	4,343	5,805	3,389	

a/ Represents total hours on each route determined by method outlined in Chapter III.

regression analysis, which would not give an accurate representation of the change in costs as the input mix changed, costs were budgeted for the input mix required to service each site combination from one to four sites. For example, the elimination of Bozeman from the analysis changes the input mix at two of the four origins. A 4,000 gallon unit would become the least cost unit when shipping from Kalispell to Whitehall and the Bozeman to Ronan route would be eliminated entirely. In some of the two plant combinations the input mix changed also. Therefore the C_{ij}'s changed as the number of potential locations considered changed.

In addition to the costs described in Chapter III, there was an unpredictable cost due to delay in a city, inter-city plant-to-plant transfer of milk and other items. Kerchner placed this cost at $.04 per hundredweight. 6/ For purposes of this analysis a cost of $.06 per hundredweight in the four cities and $.04 per hundredweight in the towns was assumed in addition to the transportation costs computed by the least cost prediction method. This cost would be $.60 per 1,000 and $.40 per 1,000, respectively. For our Ronan to Gallatin Gateway example, cost prediction yielded a cost of $5.03 per 1,000. The delay-transfer cost of $.40 per 1,000 added to this cost yielded a total transfer cost of

6/ Kerchner, Costs of Transporting Bulk and Packaged Milk by Truck, op. cit., p. 7. Since several plants might be visited in a city, the transfer cost would probably be higher than that for a small town such as Gallatin Gateway; therefore, costs were arbitrarily assumed to be $.02 higher.

\$5.43 per 1,000 on an every day pickup basis. The transportation cost matrices computed for the two cases outlined previously are shown in Tables 5.8 and 5.9.

Processing Costs

It can be recalled that cost prediction was used also in the plant cost analysis. The determination of the optimum number, size, and location of processing plants required the use of the cost prediction equation at this point. The equations calculated in Chapter IV and repeated here are:

$$TPC_F = 11{,}856.8 + 2{,}160.61V_P \qquad 4\text{-}1$$

$$TPC_V = 7.91 + 4.306V_P \qquad 4\text{-}2$$

where: TPC_F = total annual fixed processing costs

TPC_V = total variable costs per hour

V_P = volume processed per hour in 1,000 pounds

By multiplying the variable cost equation by H, the number of hours operated per season, and adding the two together we obtained the following:

$$TPC = 11{,}856.8 + 2{,}160.61V_P + 7.91H + 4.306V_PH \qquad 4\text{-}3$$

To obtain a single equation representing total processing costs for the season, it was assumed that the plant operates 3,000 hours per season. (25-8 hour days per month for nine months and 25-16 hour days per month for three months.)

TABLE 5.8. TRANSPORTATION COST MATRIX--FOR ONE-PLANT LOCATIONS, CASE 1.

From \ To	Ronan	Whitehall	Gallatin Gateway	Stevensville-Hamilton
	Dollars Per 1,000 Pounds			
Kalispell	3.28	7.78	7.85	5.15
Great Falls	8.80	4.96	6.93	7.68
Bozeman	5.97	2.43	1.77	4.36
Billings	9.02	5.47	7.11	7.87
Missoula	1.59	2.64	3.18	1.53
Gallatin Gateway	4.48	2.98	.40	4.01
Ronan	.40	3.62	5.44	1.99
Stevensville-Hamilton	2.59	3.43	4.19	.40

TABLE 5.9. TRANSPORTATION COST MATRIX--FOR ONE-PLANT LOCATIONS, CASE 2.

From \ To	Ronan	Whitehall	Gallatin Gateway	Stevensville-Hamilton
	Dollars Per 1,000 Pounds			
Kalispell	3.28	8.41	7.85	5.15
Great Falls	8.80	4.96	7.41	7.68
Billings	9.02	5.47	7.61	7.87
Missoula	1.59	2.64	3.18	2.31
Gallatin Gateway	4.48	2.98	.40	4.01
Ronan	.40	3.62	5.44	1.99
Stevensville-Hamilton	2.59	3.43	4.19	.40

Addition of these two equations on this basis resulted in the following equation:

$$TPC = 35{,}586 + 15{,}078V_P \qquad 5\text{-}2$$

As in the basic Stollsteimer model, this equation is linear with respect to V_P and means that given uniform factor prices at each of the plant sites total long run costs will increase with an increase in the number of locations by the amount of the intercept value for each location added.

The Stollsteimer Model

Given the analysis of the previous sections, the number, size, and location of plants that would minimize combined transfer and processing costs in handling the 1970 output for the area concerned was determined.

The Total Cost Function.--The total cost function to be minimized was:

$$TC = \sum_{j=1}^{J} P_j X_j | L_k + \sum_{i=1}^{I} \sum_{j=1}^{J} X_{ij} C_{ij} | L_k$$

where: TC = total transfer and processing costs

$\sum_{i=1}^{8} X_{ij} = X_j$ = volume of milk handled at plant j in 1,000 pounds

$\sum_{j=1}^{J} X_{ij} = X_i$ = volume of milk available in the i^{th} city or town; i=1 ... 8 in 1,000 pounds. These data are specified in Table 5.8.

$\sum_{i=1}^{8} \sum_{j=1}^{J} X_{ij} = X =$ 52,817.3 thousand pounds. Total projected volume available, Table 5.3.

P_j = unit processing cost in plant j, estimated by means of equation 5-2.

C_{ij} = cost of shipping 1,000 pounds of milk from origin i to plant j located at site L. Transfer costs are specified in Table 5.8 and 5.9.

L_j = one combination of locations for J plants among the $\binom{4}{j}$ possible combinations of locations. These locations and distances are specified in Table 5.4.

The cost minimization process was applied to these data.

Minimum Transfer Costs.--The 8 x 4 transfer cost matrices, C_{ij}, are shown in Table 5.8 and 5.9. An 8 x 1 vector, X_i whose entries X_i represent the volume of milk in 1,000 pound units available at each origin was formed from Table 5.3. Given these two sets of data, a transfer cost function, $\overline{TTC}|J$ minimized with respect to plant location was found by means of the procedure outlined by Stollsteimer. 7/ The possible number of plant locations could number anywhere from 1 to 4.

The numerical operations involved in determining the function were carried out on a IBM 1620 computer. For a matrix this small, the calculations could be done quite easily manually. However, due to the factorial expansion of the model it becomes quite cumbersome after five or six locations are considered. 8/

7/ Stollsteimer, A Working Model, op. cit., p. 634.

8/ If only six locations are considered there are still 63 possible locations of plants. (26-1) Stollesteimer states that with the use of the IBM 704 computer that a problem involving 100 origins and 50 locations could still be solved in one hour and 15 minutes. The new third generation computer such as the Scientific Data System Sigma 7 would probably be even faster.

The operations performed by the computer are as follows: 9/

1. With the 8 x 4 transportation cost matrix C_{ij}, the sub-matrices $*C_{ij}$ are formed by considering all possible combinations of columns in the matrix. This is to say that we form $\sum_{j=1}^{8}\binom{4}{j}$ sub-matrices. These sub-matrices contain the transportation costs from all origins to all locations. For example, for J=1 these sub-matrices will consist of four 8 x 1 matrices, for J=2, six 8 x 2 matrices, for J=3, four 8 x 3 matrices, and for J=4, one 8 x 4 matrice.

2. Each of these sub-matrices is scanned by row and the minimum element is picked out of each row. This is used to form $\binom{4}{j}$ (8 x 1) vectors for each value of J. These minimum raw elements indicate the minimum transfer cost for the volume available at a given origin and a particular set of locations for J plants.

3. Each of these vectors formed in the previous step is multiplied by the volume of milk available, a 1 x 8 vector formed from Table 5.3. These vector multiplications result in total transfer costs with these J plants in each of the $\sum_{J=1}^{H}\binom{4}{j}$ possible plant locations. The minimum of these values is selected for each J and the set of plant locations (columns of C_{ij}) associated with this minimum value are specified. The level of the minimized total transfer costs are also specified in this process.

Optimum Plant Locations.--Optimal plant locations when from one to four plants are considered are illustrated in Table 5.10 when every other day pickup is initiated at Great Falls, Billings, and Gallatin Gateway;

9/ This is approximately the method that Stollsteimer used in explaining the procedure. Rather than change the notation, Stollsteimer's explanation was essentially used.

daily pickup from Ronan and Stevensville-Hamilton; daily pickup from Bozeman and Missoula for three months and every other day for nine months.

TABLE 5.10. OPTIMUM PLANT LOCATIONS, SIZE, AND MINIMUM TRANSFER COSTS FOR FOUR PLANT LOCATIONS, CASE 1.

Number of Plants	Optimum Set of Locations	Total Receipts by Plants	Hourly Plant Capacity	Minimized Total Transfer Costs
		1,000 Pounds		Dollars
1	Stevensville	52,817.3	17.61	146,539
2	Gallatin Gateway	17,942.5	5.98	102,010
	Stevensville	34,874.8	11.63	
3	Ronan	12,707.4	4.24	
	Gallatin Gateway	17,942.4	5.98	90,193
	Stevensville-Hamilton	22,167.5	5.98	
4	Ronan	12,707.4	4.24	
	Whitehall	1,986.8	.66	
	Gallatin Gateway	17,942.5	5.98	92,013
	Stevensville-Hamilton	20,280.6	6.76	

If pickup is initiated on this basis, transfer costs are minimized for one plant sites at Stevensville with the Ronan location the second best at $171,132. There is a strong locational pull from the Missoula area. The Stevensville location is slightly closer to the Bozeman area and has a large volume in the area. These sites were followed by the Whitehall and Gallatin Gateway ones. For two-plant locations, the locations at Gallatin Gateway and Stevensville minimize transfer costs. The Gallatin Gateway location is closer to the Billings, Great Falls, and Bozeman areas and also has quite a large volume of its own.

The locational pattern is what one would expect for the three plant pattern. With the volume the existing plants have, all three come into the solution.

With the same pickup pattern but Bozeman omitted as a possible site a slightly different cost situation developed. This is illustrated in Table 5.11.

TABLE 5.11. OPTIMUM PLANT LOCATIONS, SIZE, AND MINIMUM TRANSFER COSTS FOR FOUR PLANT LOCATIONS, CASE 2.

Number of Plants	Optimum Set of Locations	Total Receipts by Plants	Hourly Plant Capacity	Minimized Total Transfer Costs
		1,000 Pounds		Dollars
1	Stevensville-Hamilton	46,000.4	15.33	124,982
2	Gallatin Gateway	11,125.6	3.70	100,530
	Stevensville-Hamilton	34,874.8	11.63	
3	Ronan	12,707.4	4.24	
	Gallatin Gateway	11,125.6	3.70	80,415
	Stevensville-Hamilton	22,167.4	7.39	
4	Ronan	12,707.4	4.24	
	Whitehall	1,986.8	.66	82,693
	Gallatin Gateway	9,138.8	3.04	
	Stevensville-Hamilton	22,167.4	7.39	

Transfer Cost Concavity.--Stollsteimer's classical transfer cost concavity is illustrated in Figure 5.1 for each of the cases. The increase in transfer costs from three to four locations due to the increase in fixed costs can be observed from these figures. This comes about because the

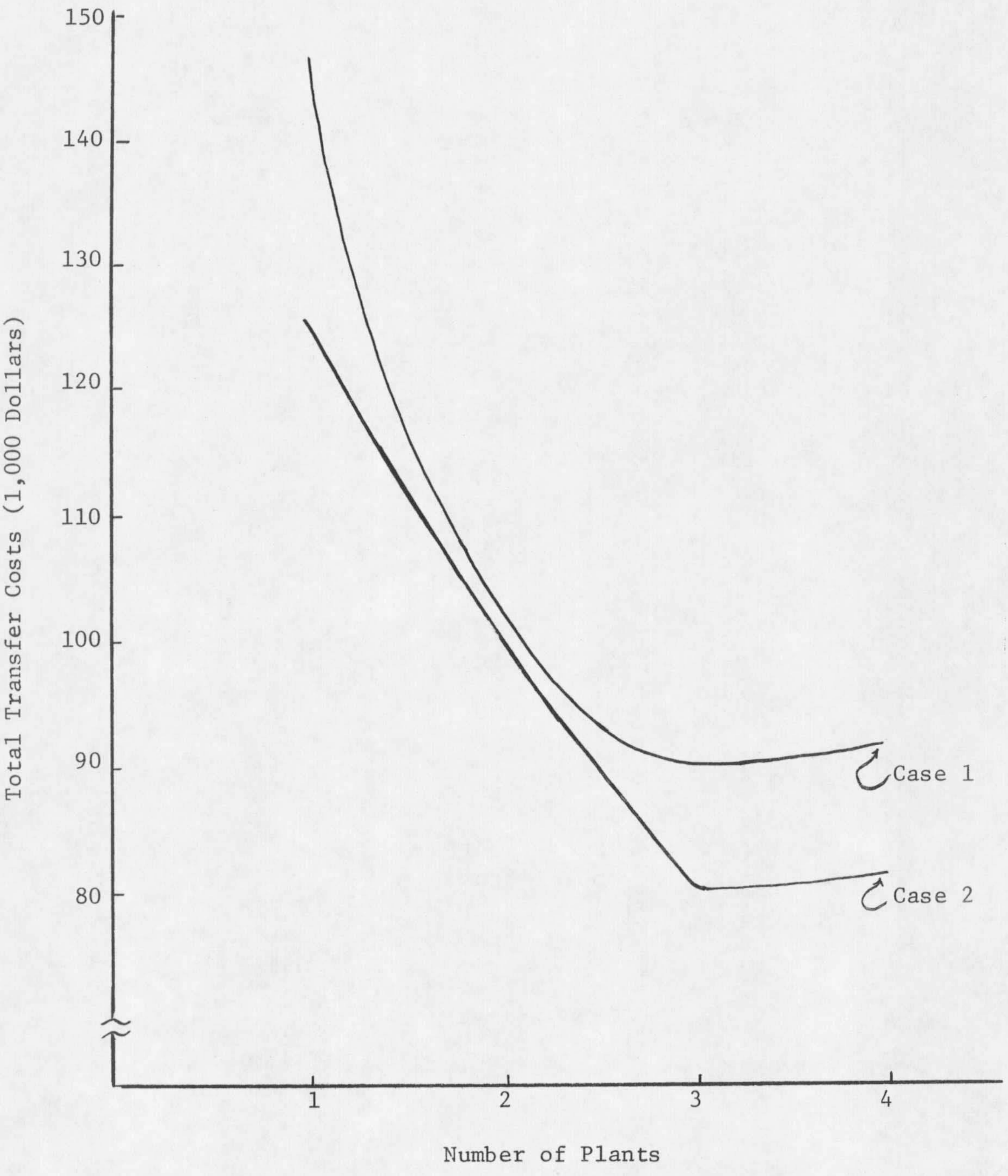

Figure 5.1. Case 1 and Case 2 Transfer Cost Concavity with the Stollsteimer Model, 1967.

increase in fixed costs associated with servicing four different locations more than offsets the decline in variable costs associated with fewer hours of operation.

Plant Size.--Plant size was also determined in each of the two cases from Tables 5.10 and 5.11. Volume was allocated to the various plants from the transfer cost matrix. Total receipts were estimated to be 46,000,000 and 52,817,000 pounds of milk depending on whether the Bozeman origin was considered. The minimum entries in each of the rows of the appropriate combination determined where the production will go. For example, assume that we are looking at the comparison of two-plant locations and that we have found the Gallatin Gateway-Stevensville locations minimize transfer costs. The minimum C_{ij} in this sub-matrix tells us that Bozeman, Billings, Great Falls, and Gallatin Gateway volume go to Gallatin Gateway while the Ronan, Stevensville, Missoula, and Kalispell volume all go to Stevensville.

With these receipts the appropriate capacity was obtained by dividing the total receipts by the number of hours operated during the season, in this case 3,000. Appropriate plant capacity under these conditions is also specified in Tables 5.10 and 5.11.

Plant Costs.--Total plant costs are shown in Table 5.12 for one through four locations. These costs were developed through the use of Equation 5-2.

An examination of Table 5.12 allows us to draw some conclusions about the optimum number, location, and size of plants that minimize

TABLE 5.12. TOTAL PLANT COSTS AND TRANSFER COSTS FOR ONE THROUGH FOUR PLANTS--INCLUDED ARE TWO SETS OF OPERATING CONDITIONS.

Number of Plants	Total Plant Costs		Transfer Costs		Plant Costs Plus Transfer Costs	
	Case 1	Case 2	Case 1	Case 2	Case 1	Case 2
	Dollars		Dollars		Dollars	
1	301,110	266,732	146,539	124,982	447,649	391,714
2	336,696	302,318	102,010	100,530	438,706	402,848
3	372,282	337,904	90,193	80,415	462,475	418,319
4	407,868	373,490	92,013	82,693	499,881	456,183

combined processing and transfer costs. In Case 1 two plants located at Gallatin Gateway and Stevensville processing 5.98 and 11.63 thousand pounds per hour were optimal. The high cost of transportation from the Billings and Great Falls area on even a two day basis plus the factor of the available volume in the Bozeman area caused this solution. The one remaining case, Case 2, was probably the most interesting. This was the case where Bozeman was not included in the solution. In this example one plant located at Stevensville processing 15.33 thousand pounds per hour was optimal. The removal of the Bozeman volume made this solution possible. With Bozeman's ability to process her own surplus this was probably the most realistic of all cases examined. The total processing and assembly cost curves are plotted in Figure 5.2. An analysis of cost differences between four plant locations and the optimum number also resulted in some interesting conclusions. Costs would be 12.3 and 14.2 percent less for the optimum number than for four plants in the two cases analyzed.

Stollsteimer outlined a procedure for determining the stability of those solutions 10/ over time. This required that the relative costs in plant and transfer operations remain within a range in which the reduction in transfer costs associated with adding one plant was less than the associated increase in plant costs. This would be the case

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10/ John F. Stollsteimer, The Effect of Technical Change, op. cit., p. 183.

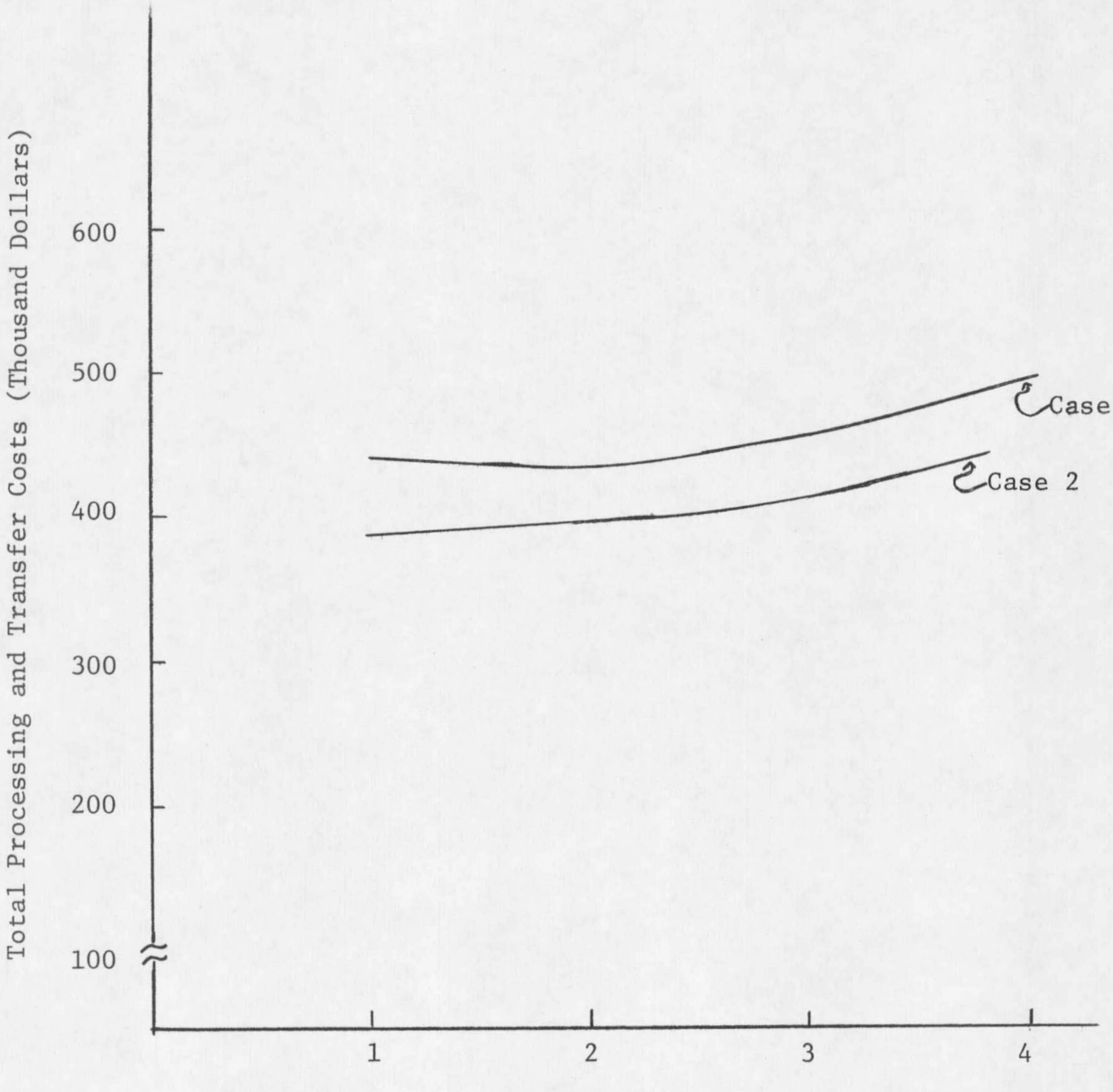

Figure 5.2. Estimated Total Transfer and Processing Costs with Varying Plant Numbers.

of the consideration of the addition of another plant. If one were to consider conditions necessary for the elimination of one plant, then the relative costs in plant and transfer operations would have to remain in the range in which the addition to transfer costs associated with the subtraction of one plant is greater than the associated decrease in plant costs. This may be shown as follows: 11/

"Recall that

$$\overline{TTC}|J = \overset{\min}{L_J} X_i C_{ij} | L_J$$

and

$$\frac{\Delta \overline{TTC}}{\Delta J} = \overline{TTC}|J + 1 - \overline{TTC}|J$$

If transfer costs are increased by a given percentage, P, each of the entries in C_{ij} including those in $\overline{C_{ij}}|L_J$ will in effect be multiplied by the scales (1+P). It can be shown that

$$\overset{\min}{L_J} X_i^1 (1+P)\overline{C_{ij}}|L_J = (1+P)\overline{TTC}|J$$

Therefore the effect of increasing assembly costs by P on $\frac{\Delta \overline{TTC}}{\Delta J}$ is equal to

$$(1+P)\frac{\Delta \overline{TTC}}{\Delta J} = (1+P)\text{TTC}|J + 1 - \text{TTC}|J \text{ "}$$

11/ Ibid.

In the example of Case 1,

$$\left|\frac{\Delta TTC}{\Delta J}\right| = 44{,}529 \qquad \frac{\Delta TPC}{\Delta C} = 35{,}586$$

$$\frac{\frac{\Delta TPC}{\Delta J} - \left|\frac{\Delta TTC}{\Delta J}\right|}{\left|\frac{\Delta TTC}{\Delta J}\right|} = \frac{35{,}586 - 44{,}529}{44{,}529} = .20$$

where: TPC = total plant costs and

$\left|\frac{\Delta TTC}{\Delta J}\right|$ = the absolute value of the change in transfer costs associated with a change in plant numbers

From this we conclude that in the model conditions considered under Case 1, transfer costs would have to decrease by an amount greater than 20 percent of plant costs in order for the optimal conditions to change from two plants to one plant.

Applying this same analysis in the example of Case 2, transfer costs would have to decrease by an amount greater than 45 percent of plant costs in order for the solution to go from one plant to two plants.

A Sub-Solution

A brief look was taken at a hypothetical reorganization of plants without the benefit of any Grade A surplus. Table 5.13 specifies minimized transfer costs and processing costs with only three sources and three plant sites.

Following the same optimizing procedure, the optimal location was again one plant located at Stevensville. Total costs would be

TABLE 5.13. OPTIMUM PLANT LOCATIONS, SIZE, AND MINIMUM TRANSFER AND PROCESSING COSTS FOR THREE PLANT LOCATIONS--EVERY OTHER DAY DELIVERY GALLATIN GATEWAY--DAILY RONAN, STEVENSVILLE-HAMILTON.

Number of Plants	Optimum Set of Locations	Total Receipts by Plants	Hourly Plant Capacity	Minimized Total Transfer Costs	Plant Costs	Plant Costs Plus Transfer Costs
		Thousands	Thousands	Dollars	Dollars	Dollars
1	Stevensville	28,147	9.39	61,739	177,168	238,907
2	Gallatin Gateway	6,469.2	2.16	39,097	212,754	251,851
	Stevensville	21,678	7.23			
3	Ronan	9,978	3.33			
	Gallatin Gateway	6,469.2	2.16	11,258.88	248.340	259,599
	Stevensville-Hamilton	11,700	3.90			

approximately 8 percent lower with a one plant location than with the three plant location.

Revenue-Cost Relationships

The relative stability of the relationship between market prices and support prices allows us to make some predictions about the nature of the cost-revenue relationships under these varying plant transfer conditions. Total volume of milk in the two cases was predicted to be 46,000,000 pounds and 52,817,000 pounds depending on whether Bozeman was considered as a source or not. If we consider the first case we know that 46,000,000 pounds of milk will yield about 4,600,000 pounds of cheese. If we assume this cheese can be sold for \$.44 per pound (about 90 percent of parity) revenue from this source would be \$2,024,000. If the whey yields about .002 butterfat and this can be sold for \$.66 per pound (the same parity relationship) then revenue from this source would be \$54,648. Thus total plant revenue would be \$2,078,648. If we look at the minimal total cost for Case 2, we find that it is \$391,714. Subtracting this from Total Revenue yields \$1,686,934. Dividing this figure by 460,000 we obtain a price per hundredweight of \$3.66. This figure does not consider profits or a desirable profit level. In the case of a co-operative where no profits accrue to the firm this could be considered as a producer payment.

Price per hundredweight for the other models computed in the same manner as previously illustrated are listed in Table 5.14.

TABLE 5.14. AVERAGE PRICE PER HUNDREDWEIGHT UNDER TWO SETS OF OPERATING CONDITIONS--WITH CHEESE AT $.44 PER POUND AND BUTTER AT $.66 PER POUND.

Number of Plants	Case 1	Case 2
	Dollars Per Hundredweight	
1	3.67	3.66
2	3.68	3.64
3	3.64	3.60
4	3.57	3.52

Given different revenue relationships other cost-revenue relationships can be obtained by computing total revenue at different support levels.

An idea of the sensitivity of the cheese operation to price is given by Table 5.15.

TABLE 5.15. AVERAGE PRICE PER HUNDREDWEIGHT UNDER TWO SETS OF OPERATING CONDITIONS--WITH CHEESE AT .393 PER POUND BUTTER AT .6175 PER POUND.

Number of Plants	Case 1	Case 2
	Dollars Per Hundredweight	
1	3.19	3.18
2	3.21	3.16
3	3.16	3.13
4	3.09	3.04

The support price for butter in this case would be about \$.6175 per pound and the price per pound of cheese would be about \$.393 per pound. Average price per hundredweight in Case 1 varies from \$3.09 to \$3.19 per hundredweight and from \$3.04 to \$3.18 in Case 2. This is about \$.50 per hundredweight drop in most cases.

CHAPTER VI

SUMMARY AND CONCLUSIONS

This dissertation has been concerned with some of the economic problems in both the production and processing of milk for manufacturing purposes in Montana. A decline in the volume of milk available for manufacturing coupled with the continuing adjustment problem at the producer level has brought about several problems. This thesis has attempted to provide some insight into some of these problems and some possible solutions.

For purposes of analysis, the thesis was divided into three sections.

The first section concerned economic optimization under various farm organizations with various production and price levels within the dairy enterprise. Throughout the thesis the economic criterion for optimization was defined to be cost minimization. The traditional farm management linear programming model was used in two types of representative farming operations. Cost data for these two particular types of farming operations was derived from secondary sources provided by the Cooperative Extension Service and the Economic Research Service as well as consultation with various experts.

The models were not derived with the thought in mind of suggesting supply response with the particular model or to suggest that this was an optimal operation that should exist in a particular area. The analysis was done with the expectation of determining at what production and price level the dairy enterprise would compete with other enterprise opportunities in a particular area.

The second and third parts of the study consisted of the marketing aspect of the dairy manufacturing industry in Western Montana. One of the possibilities of more efficient operation in Western Montana is the recombination of existing plants into larger operations to more efficiently utilize the existing volume of milk. In order to solve this problem, the problem of transporting the raw product from existing sites to other locations was considered. The other phase of this same problem was the consideration of processing costs involved once the product reached the particular site.

Costs were budgeted for three different types of units used to transport milk and least cost units were determined from these cost estimates. The problem of a changing input mix and its effect on fixed costs necessitated this type of approach rather than using regression analysis to determine the least cost units.

Cost prediction equations were used to be able to predict costs at various rates of output in the processing of milk. These equations were constructed by means of cost synthesis with total cost relationships constructed from estimates of costs at various stages. Industrial and dairy engineering techniques as well as other secondary sources were employed in estimating the various input-output relationships at the various stages.

These cost prediction equations developed for the processing of milk and the least cost estimates of transporting milk together with data on the potential source of supply of milk both from Grade A and B sources in Western Montana formed the basis for predicting the optimum size, number, and location of plants that minimize the combined transfer and processing costs for this volume of milk. Through the selection of a given number of locations and with the application of a derivation of the basic linear programming transportation model this was accomplished. This model, the Stollsteimer model, permits simultaneous variation in plant numbers and their location and a study of these effects on combined transfer and processing costs. Various modifications of transfer possibilities were considered including the possibility of storage of milk for three days until shipment to a processing site.

The Results

The linear programming model was considered as a basis for determining the relative competitiveness of the dairy enterprise under two types of farming operations in Western Montana. The first was what might be considered an intensive row crop operation that might be found in the Bitterroot Valley of Western Montana or the Yellowstone Valley near Billings. The second possibility was the consideration of the dairy enterprise in a less intensive farming area. The area that this might represent was the Gallatin Valley. The results of the first model indicated that for marginal herds milk must be at least $3.28 per hundredweight if dairying was to be included as an enterprise. For herds averaging 9,000-11,000 pounds, the price of milk could fall to $2.58 and dairying would still be included as an activity. For high producing herds this figure was $2.30. All optimization was done on a variable cost basis.

An analysis of the second model indicated that again the herd that averaged 6,000 pounds of milk would be included as an enterprise if the price was $3.27 per hundredweight or higher and could fall to as low as $2.30 if a very high production level was considered.

A conclusion of this phase of the study was that dairying can at least be as profitable as other enterprises available to a farmer in Western Montana. However, in order for it to be a profitable enterprise, one of two possibilities had to exist. Either the price of milk must exceed present levels for these marginal operations or management practices must be such that much higher production standards than are presently attained by Grade B producers must come about.

Although some improvement has come about in the Grade B producers herds, the bulk of the high producing herds are producing for the Grade A market. There has been quite a rapid attrition in number of herds producing for the Grade B market. Consequently, plant volumes have gradually been dwindling over the past several years. This places pressure on the plant operator to maintain plant efficiency with the excess capacity generated and to sustain the level of prices that he can pay his producers. Thus more attrition in the number of producers and processors can be expected.

As a possibility of increasing payment to producers as well as considering the possibility of more efficient operation of existing plants the long run possibility of plant recombination was considered.

This involved an analysis of the cost of transporting milk over rather long distances in Western Montana. Cost prediction techniques were developed for three types of tankers. These were a 4,000 gallon, a 5,700 and a 6,000 gallon tanker. There is some use of these types of tankers in Western Montana at this time although the largest unit which employs a "pup" trailer is not in use in the State. In most cases the 6,000 gallon tanker was found to be the least cost unit for transporting milk long distances. With the seasonal variation in production, this unit has distinct advantages. Fuel costs and tire costs are both less than the other units that must be employed on a complete unit basis at all times. The unit has a slightly higher initial cost than the 5,700 gallon unit but unless full capacity transfer rates are considered at all times the versatility of this unit compensates for this factor.

Cost prediction equations for plant costs were also developed. Long run plant costs per 1,000 pounds of milk handled were found to decrease very rapidly in the range of 2,000-4,000 pounds per hour. Minor reductions in costs were found to occur as volume exceeded 12,000 pounds per hour. These costs were developed by industrial and dairy engineering techniques. Stage costs were developed and costs were then aggregated over all stages. These costs were developed on the basis of a fixed volume of milk received in cans. This fixed amount was believed to be representative of the amount that plants receive in cans. The cost reductions that accrued to the firm as volume expands were due to a spreading of fixed costs over a broader range and the better use of high-capacity, high-cost items.

The number, size, and location of milk processing plants that would minimize combined transfer and processing costs were then estimated. This was done on the basis of these cost prediction equations and the projected volume of milk available for manufacturing in Western Montana in 1970. Both surplus Grade A and Grade B milk were considered. Four prospective sites were chosen. These were the existing plant sites and one site that is presently not in use but one that represented an intermediate site in terms of distance. These four sites were all on hard surface, well improved roads.

Routes were developed to deliver this milk and a least cost input mix was developed to service these routes. This was accomplished by computing the cost of transporting this milk for each of the units selected and selecting the least cost unit. Since it is virtually impossible for a unit to operate 8,760 (365 days) hours per year the input mix had to have a reserve or idle time incorporated. The input mix selected for each of the routes reflected this idle time by the number of units and their effect on fixed costs.

The production from these four plants as well as five cities were considered as sources for milk. These five cities were Billings. Bozeman, Great Falls, Kalispell, and Missoula. In each of these cities surplus occurs during certain times of the year. One of the purposes of this model was to examine the possibility of processing this volume of milk in these cities as part of a larger volume in order to realize higher returns for this milk. Data from the Milk Control Office in Helena as well as data from the Statistical Reporting Service was utilized as sources for determining production potential.

Two cases were considered. In the first case the Bozeman volume was considered as part of a larger volume to be processed. Since there are facilities in Bozeman to process cheddar cheese, a second case was considered without the Bozeman volume. With the delivery pattern considered in the model indicated that in the first case, two plants located at Stevensville and Gallatin Gateway minimized combined transfer and processing costs. Investigation of the stability of this solution indicated that transfer costs would have to decrease 20 percent relative to processing costs in order for the solution to go from a two plant solution to a one plant solution. In the second case a one plant solution located at Stevensville minimized combined transfer and processing costs.

One of the considerations was the consolidation of existing plants' volume into one or more plant sites. A one plant solution, located at Stevensville, was optimal.

Conclusions

Analysis of available data indicates that four plants will process over 90 percent of Grade B milk in 1970. This represents a volume that will be slightly over 28 million pounds of milk. This would be over 20 percent lower than the 1961 figures. Analysis of data made available by the Milk Control Board indicates that there could be 24 million pounds of surplus Grade A milk if the surplus picture continues in the same pattern as 1965-66.

Results of the application of the Stollsteimer location model indicates that some consolidation of plant operations is possible in all of the different transportation and supply possibilities considered. Costs would be from 12 to 15 percent lower depending on supply potential if this were to come about.

Under the assumption of this model, average price per hundredweight is quite visibly affected by Government support programs. Two illustrations were given. The first assumed the price of cheese to be at about 90 percent of parity. The average price per hundredweight in this case was nearly $.50 per hundredweight higher than in the case where cheese was supported at 78 percent of parity. A long range planning price for cheese of $.393 per pound for cheese drops the price per hundredweight for milk more closely to the price levels in the industry prior to the June, 1966 support raise. In the latter case it would appear that there would be no real incentive for a consolidation of activities. If producers were paid on the basis of $3.15 to $3.20 per hundredweight this would more than likely not be enough to encourage their continued production.

The practical difficulties surrounding such a consolidation are numerous. Three of the four plants are privately owned while the fourth is a cooperative. Institutional barriers surrounding such a consolidation then would be tremendous. The same could be said for surplus usage in the five cities concerned. In order for the surplus to be effectively utilized, it would be necessary for it to be controlled by a type of producers association outlined by Bucher. 1/ This analysis considers only the economic aspects of transporting and processing the milk. The model is in essence a single product model. It considers none of the aspects of local sales of this product as well as local sales of products such as ice cream or cottage cheese. It also only considers one type of technology involved and the costs associated with this type of processing operation. Very large cheddar plants frequently cheddar out of the vats. This process cuts processing time by about 25 percent. Sufficient cost and return data was not available so that an accurate assessment of this type of operation could be made. Cheddaring machines are also being developed so that hand cheddaring is eliminated and deeper vats can be installed. This type of operation was not analyzed either.

1/ Bucher, Feasibility of a Milk Marketing Association for the Billings Area, op. cit.

Recommendation.--In lieu of consolidation, other short run measures could be adapted that could have some effect on this declining volume. These are enumerated below.

1. Hundredweight versus Butterfat Pricing--three of the four plants pay on a butterfat basis. Volume could be encouraged by conversion to a hundredweight basis with an incentive payment for butterfat. The advantages of the hundredweight basis can be illustrated by this example. Assume first of all payment is made on a butterfat basis. In this case 8,000 pounds of milk testing 5 percent fat and 10,000 pounds of milk testing 4 percent fat both yield 400 pounds of butterfat and are equal in revenue yield. Now let us assume payment is now $3.50 per hundredweight with a $.06 premium per hundredweight for each tenth of a percent milk tests over 3.5 percent. In the previous example payment would be made on the following basis:

8,000 x $4.40 = $352

10,000 x $3.80 = $380

In this example the price in the first case would be $4.40 [3.50 + (15 x .06)]. In the second case the price would be $3.80 [3.50 + (5 x .06)]. This pricing procedure encourages the production of milk rather than of butterfat. Fat premiums can be adjusted so that the pricing plan can be the same as on a butterfat basis if desired merely by increasing the size of the fat premium.

2. Volume Incentives--Several plants in the Utah, Idaho area have adopted volume incentives with varying degrees of success. This program can best be illustrated by the following schedule:

Pounds/Shipment	Cents/Hundredweight Premium
500	3
1,000	10
1,000	17.5
2,000	20
3,000	25
4,000	30

This bonus is paid on the basis of each daily shipment that falls in a particular volume category. If producers have 15 shipments per month over 8,000 pounds per shipment then he would receive 30 cents per hundredweight in addition to the base payment. This plan can also be coupled with the standard hundredweight payment plan.

3. Educational Programs--Institutional barriers to dairying were encountered in some communities. Financing dairy enterprises is generally on a two-year basis at the maximum. More liberal plans exist in Idaho and Utah. Some sound programs are financed on a five-year basis and many on a 36-39 month plan. This entails education of the financial institutions and lending agencies on the merits of a dairy enterprise and its advantage over a straight row crop operation.

4. Surplus Usage--Interest has been expressed in some of the Grade A producing areas in better utilization of surplus. Analysis of available

data indicates that there is a possibility of better utilization of surplus through centralized processing. This probably would entail the establishment of producers associations in the appropriate areas so that available milk could be better apportioned and utilized.

The dairy industry in Western Montana will continue to face great pressure in the next few years. Cost pressures and alternative opportunities have been the cause of a great number of producers leaving the industry. Recent Government support operations could have some stabilizing effect on production but production over the next few years will probably continue downward.

This thesis has attempted to propose some alternatives to this rather pessimistic picture. Some of these alternatives are immediately applicable. The major alternative, that of consolidation of plant operations will probably not come about until considered absolutely necessary by plant owners. Dairying is a long range program. It takes time to acquire cattle of the caliber necessary to compete in today's competitive situation. By the same token, sufficient capital and management are difficult to acquire. On the other hand, it takes only a short time to liquidate these holdings. Once the producer has liquidated his herd, it is much more difficult to entice him to produce again.

This study has examined some of the alternatives available to the Western Montana producer and manufacturer. It is hoped that some of these possibilities, if applied, can help alleviate this decline in the industry.

APPENDICES

APPENDIX I

TABLE I. SUMMARY OF COSTS FOR REPRESENTATIVE 150 ACRE IRRIGATED FARM--BASIC MODEL 1. a/

Item	Cost Per Acre	Total Cost Per Acre
	Dollars	Dollars
Sugar Beets		
Variable Costs		
Cultural costs b/	96.42	
Harvest costs	21.00	
Miscellaneous costs	5.58	
Total		123.00
Fixed Costs c/		54.00
Hay d/		
Variable Costs		
Cultural costs	21.51	
Harvest costs	9.51	
Miscellaneous costs	1,17	
Total		32.19
Fixed Costs c/ e/		56.00
Wheat		
Variable Costs b/		
Cultural costs	16.49	
Harvest costs	10.26	
Miscellaneous costs	1.34	
Total		28.09
Fixed Costs c/		54.00
Corn Silage		
Variable Costs		
Cultural costs	37.33	
Harvest costs	17.79	
Miscellaneous costs	2.76	
Total		57.88
Fixed Costs c/		54.00

(table continued)

TABLE I. (continued) SUMMARY OF COSTS FOR REPRESENTATIVE 150 ACRE IRRIGATED FARM--BASIC MODEL 1. a/

Item	Cost Per Acre	Total Cost Per Acre
	Dollars	Dollars
Pasture		
Variable Costs		
Cultural costs	10.05	
Miscellaneous costs	.95	
Total		11.00
Fixed Costs c/		54.00
Beans		
Variable Costs		
Cultural costs	36.90	
Harvest costs	12.40	
Miscellaneous costs	2.48	
Total		51.78
Fixed Costs c/		54.00
Barley		
Variable Costs		
Cultural costs	16.49	
Harvest costs	10.26	
Miscellaneous costs	1.34	
Total		28.09
Fixed Costs c/		54.00

a/ Budget data taken from Sample Costs: Irrigated Crops Yellowstone County Montana, Cooperative Extension Circular (Bozeman, 1964).

b/ Cultural cost of sugar beets increased $4.11 per acre for chemical application.

c/ Value per acre set at $300 rather than $400.

d/ Hay budget corrected to cover cost of twine and adjustment in mowing, raking, and baling.

e/ Includes $2 per acre for cost of stand establishment.

TABLE II. SUMMARY OF COSTS FOR REPRESENTATIVE 440 ACRE IRRIGATED FARM--BASIC MODEL 2. a/

Item	Cost Per Acre	Total Cost Per Acre
	Dollars	Dollars
Hay b/		
Variable Costs		
Cultural costs	7.49	
Harvest costs	17.84	
Miscellaneous costs	1.17	
Total		26.50
Fixed Costs c/		56.00
Barley		
Variable Costs		
Cultural costs	16.49	
Harvest costs	10.26	
Miscellaneous costs	1.34	
Total		28.09
Fixed Costs c/		54.00
Wheat		
Variable Costs		
Cultural costs	16.49	
Harvest costs	10.26	
Miscellaneous costs	1.34	
Total		28.09
Fixed Costs c/		54.00
Irrigated Pasture		
Variable Costs d/		
Cultural costs e/	10.05	
Miscellaneous costs	.95	
Total		11.00
Fixed Costs c/		55.00

a/ Budget data taken from Sample Costs: Irrigated Crops, Yellowstone County Montana, Extension Circular (Bozeman, 1964).

b/ Cultural and harvest costs adjusted for yield assumed for Gallatin Valley.

c/ Includes $2 for stand establishment. $330 per acre assumed to be value of land.

d/ Estimate of irrigating time required was revised downward as well as cost of fertilizer.

e/ Includes $1 per acre for stand establishment.

APPENDIX I-A

The specifications and requirements for the dairy enterprise are outlined in the following Appendix. Each of these tables contain somewhat controversial data. Attempting to pinpoint the value of dairy equipment and animals is a difficult task.

For purposes of this model, it was assumed that a marginal animal was just that--a marginal animal. Therefore, an animal of this caliber could be purchased for something above the beef price, which in this case was assumed to be $130. By the same token, an animal from a high producing herd would have a much higher value, would probably have a longer life and would command more at salvage time due to the improved management practices. Table I lists these specifications with this in mind.

Used prices were used for all dairy equipment. There is a ready availability of used dairy equipment. This is particularly true of smaller bulk tanks. As a thumb rule, a tank of less than 500 gallons in capacity sells for about $1 per gallon. Demand for larger tanks is quite good. The tendency towards larger herds has caused the demand for larger tanks to remain high, particulary for 600 to 1,000 gallon tanks. By the same token, since the used equipment is quite close to salvage value, its salvage value is quite close to acquisition.

It was also assumed that existing facilities on the farm could be remodeled sufficiently for milking for Grade B purposes. This entails sealing off an area in the barn for a milk room, pouring a concrete floor, improving the electrical wiring due to the demands placed on it by the two compressors and improving drain facilities. This would be a major improvement but would be a permanent one. Many other items can be added to a dairy operation to include completely mechanized feeding and other improvements but it is the author's own experience that this is not completely necessary. Good forage quality and management practices make up for a multiplicity of mechanization.

Determining labor requirements is also a difficult thing. A successful dairyman is going to spend a lot of time with his cows--how much is arbitrary. A poor dairyman will probably not spend 1.67 hours feeding his cows. He may not even spend 16 minutes. However, some consideration must be given for effort and the fact that low production may after all be an inherited characteristic. Consequently, four feedings a day were assumed to be required for the first three production levels. Each of these feedings consumed 25 minutes of working time. For the high producing herd, this time requirement was assumed to be 30 minutes.

Most three-unit milking systems will milk approximately 30 cows per hour. This is a thumb rule that generally assumes the cows are in a holding pen or some type of enclosure. Such claims also do not count the time in driving these cows into the enclosure or the initial preparation time in the barn. Milking time also varies with the operator's ability to properly prepare the cow and the cow's inherited ability to let down her milk rapidly. The actual milking time for a high producing cow is actually quite short if she has been prepared properly and is a rapid milker. Total milking and clean-up time for the highest producing herd in this model would be about 2.2 hours twice daily, (5 x 40 + 68 per 60).

The budgets contained in this Appendix and the preceding one form the basis for the two matrices at the end of this Appendix. The analysis of Chapter IV also stems from the budgets and the accompanying matrices.

TABLE I. LIVESTOCK REQUIREMENTS AT VARYING PRODUCTION LEVELS. a/

Production Level	Life	Acquisition Price	Salvage Value	Annual Depreciation	Interest b/
6,000	5	180	130	10	9.00
9,000	5	195	130	13	9.72
11,000	6	280	135	24	12.42
15,000	7	370	135	33.57	15.15

a/ Taken from Western Dairy Journal and author's experience.

b/ Six percent of average value.

TABLE II. EQUIPMENT REQUIREMENTS AT VARYING PRODUCTION LEVELS.

Item a/	Life	Acquisition Price	Salvage Value	Annual Depreciation Per Cow (÷ by 40)	Interest b/
Pipeline milker	10	1,100	500	1.50	1.20
Bulk tank c/					
250 Gal-6,000# Ave	10	350	250	.25	.45
350 Gal-9,000# Ave	10	450	350	.25	.60
450 Gal-11,000# Ave	10	550	450	.25	.75
600 Gal-15,000# Ave	10	1,000	800	.50	1.35
Remodel facilities	40	3,000	0	1.87	2.25

a/ Used prices, interviews with Floyd Olson, Joe Heap, and Lyons Smith, all plant managers.
b/ Six percent of average value.
c/ Tank large enough to hold one extra day's milking.

TABLE III. TIME REQUIREMENTS FOR FOUR PRODUCTION LEVELS. a/

Item	Production Per Cow Pounds 6,000	9,000	11,000	15,000
	------Daily Time in Minutes-------			
Fixed Time				
Feeding	100	100	100	120
Clean-up	68	68	68	68
Care	15	15	20	35
	183	183	188	223
Divided by number in herd (40)	4.58	4.58	4.70	5.57
Multiplied by days in year-365	1,670	1,670	1,715.5	2,033
Variable Time				
Milking	3.5	4.04	4.25	5.0
Multiplied by days in lactation-305	1,067.5	1,231	1,296.25	1,525
Total time min.	2,737.5	2,901	3,011.25	3,558
Total time--annual hours	46	48.75	50.19	59.3

a/ Surveys at author's farm.

TABLE IV. SUMMARY OF COSTS FOR DAIRY ENTERPRISE. a/

Item	Milk Level Per Cow Per Yearly Lactation			
	6,000#	9,000#	11,000#	15,000#
	Dollars			
Variable Costs				
Transportation @ $.25/Cwt b/	15.00	22.50	27.50	37.50
Breeding	8.00	8.00	8.00	8.00
Vet Fees	6.00	6.00	6.00	6.00
Labor @ $1.50/hr	69.00	71.52	75.15	87.96
Less Calf	40.00	40.00	40.00	40.00
Total Variable Costs	58.00	68.02	75.65	99.46
Fixed Costs				
Equipment & building depreciation	3.62	3.62	3.62	3.77
Taxes & insurance	1.20	1.20	1.20	1.20
Livestock depreciation	10.00	13.00	24.00	33.57
Interest-equipment	3.90	4.05	4.20	4.80
Interest-livestock	9.00	9.72	12.42	15.15
Total Fixed Costs	31.34	35.21	49.06	62.26

a/ Twin Falls County DHIA data.

b/ Transportation is not generally a constant from farm to farm. However from interviews at Ronan, Stevensville, and Gallatin Gateway, it was felt that this was a representative charge.

TABLE V. COW-CALF ENTERPRISE. a/

Item	Cost Per Animal	Total Cost
	Dollars	Dollars
Variable Costs		
Vet fees	.58	
Insurance	.60	
Salt	.60	
Breeding	1.50	
Supplemental feed b/	6.93	
Taxes per animal unit	1.80	
Motor vehicles	5.22	
Labor--2.5 hours @ $1.50/hr	3.75	
Total Cost		1.00
Less Sale @ 450# @ $22		
Cow-Calf 1	99.00	78.00
Less Sale @ 450# @ $25		
Cow-Calf 2	112.00	90.00
Less Sale @ 450# @ $28	126.00	105.00
Fixed Costs		
Machinery and equipment	5.34	
Buildings	1.23	
Livestock	13.04	
Total Cost		19.61

a/ Budget taken from Resource Situations: Non-Irrigated, 1370 Acre Grain-Livestock Farm, Economic Research Service Mimeo Circular, 1970 (Bozeman, 1964).

b/ Since this would entail slightly more than 2 AU's per acre (about 95 cows) irrigated pasture would have to be supplemented. This cost estimated to be about $5.52 per animal higher than in above study.

TABLE VI. FEEDING REQUIREMENTS AT VARYING PRODUCTION LEVELS. a/

Item	Units	Production Level 6,000	9,000	11,000	15,000
Barley b/	Bu.	40.0	60.0	80.0	100.0
Hay c/	Ton	3.0	3.5	4.0	4.5
Silage d/	Ton	4.5	5.0	6.0	7.0
Hay e/	Ton				
Protein Supplement f/	Cwt.	.4	.6	.8	1.0

a/ Taken from Twin Falls County DHIA data.

b/ One pound of grain per three pounds of milk produced.

c/ Cows were fed at rate of 16.5, 19.2, 21.9, and 24.6 pounds daily.

d/ Cows were fed at rate of 24.6, 27.4, 32.9, and 38.4 pounds daily.

e/ Cows were fed at rate of 24.6, 28.5, 32.9, and 37.4 pounds daily due to absence of silage in second model.

f/ Assuming a 14 percent grain ration.

TABLE VII. MATRIX FOR FIRST BASIC MODEL.

		Sgbt.	Hay	Wheat	Silcrp.	Barley	Beans	*Milk 1	*Milk 2	*Milk 3	*Milk 4	HaySel	BenSel	WhtSel	BlySel	SgbtSel	SilSel	BlyBuy	HayBuy	SilBuy	Past	MSel 1	MSel 2	MSel 3	MSel 4	PsBuy	LbrUse	CapUse		Farm
Obj. Fu.	Profit(cost)	-123	-64	-28	-58	-28	-52	-58	-68	-75.6	-99.4	22	6.50	1.50	.80	15	6	-.90	-.23	-6.52	-11	3.00	3.50	4.00	4.50	-4.20				
Constraints	Land 1 (A)	1	2	1	1	1	1																						=	126
	Alt 1 (A)	3	-2				-1																						=	0
	Alt 2 (A)	1		-1		-1																							=	0
	Alt 3 (A)	1			-1																								=	0
	Alt 4 (A)	1	-1																										≥	0
	Land 4 (A)																				1								=	24
	Labor (Hrs)	22	9	3.5	9.0	3.5	13.5	46	48.3	50.1	59.3																		=	0
	SgbAlt (A)	1																											≤	27
	Hay (T)			-8				3	3.5	4	4.5	1							-1										=	0
	HayAlt (A)		1																										≤	26
	Beans (Cwt)						-15						1																=	0
	Wht (Bu)			-50										1															=	0
	Barley (Bu)		-65			-65		40	60	80	100				1			-1											=	0
	Sgbt	16.5														1													=	0
	GrzUse (AU)							1	1	1	1										-2								=	0
	WhtAlt (A)			1																									≤	16
	Captl ($)	5.4	112	54	54	54	54	31	35	49	62							.90	23	6.50	55					4.20		-1	=	0
	Silage (T)				-20			4.5	5.0	6.0	7.0						1			-1									=	0
	Milk L1 (Cwt)							-60	-90	-110	-150											1	1	1	1				=	0
	CowAlt (No)							1	1	1	1																		≤	40
	Prots (Cwt)							.4	.6	.8	1															-4.20	-1		=	0

Structural Variables

TABLE VIII. MATRIX FOR SECOND BASIC MODEL.

	Structural Variables																								Farm
Obj. Fu.	Hay	Wheat	Barley	*Milk 1	*Milk 2	*Milk 3	*Milk 4	WhtSel	BlySel	HaySel	BlyBuy	HayBuy	Past	MSel 1	MSel 2	MSel 3	MSel 4	CowCa1	CowCa2	CowCa3	PsBuy	LbrUse	CapUse			
Profit(cost)	-26.50	-28	-28	-58	-68	-75.6	-99.5	1.50	.80	22	-.90	-23	-11	3.00	3.50	4.00	4.50	78	91	105	-4.20					
Constraints																										
Land 1 (A)	1	1	1																						=	360
Land 4 (A)													1												=	40
Labor (Hrs)	4.5	3.5	3.5	46	48.4	50.1	59.3											2.5	2.5	2.5		-1			=	0
Hay (T)	-3			4.5	5.2	6	6.83			1		-1						1	1	1					=	0
Wht		-45						1																	=	0
Barley (Bu)			-60	40	60	80	100		1		-1							3	3	3					=	0
GrzUse (AU)				1	1	1	1						-2					1	1	1					=	0
WhtAlt (A)		1																							≤	80
Captl ($)	56	54	54	31	35	49	62						54					19.6	19.6	19.6			-1		=	0
MilkL1(Cwt)				-60	-90	-110	-150							1	1	1	1								=	0
CowAlt (No)				1	1	1	1																		≤	40
Prots				.4	.6	.8	1														-1				=	0
CafAlt (no)																		1	1	1					≤	80

APPENDIX II

TABLE I. TRACTOR-TRAILER SPECIFICATIONS--THREE TRUCKS, 1967. a/

Item	Cost	Unit 4,000	Unit 5,700	Unit 6,000
	Dollars			
Tractor Specification				
Engines				
Cummins NHC-220	131 extra			
Cummins NHC-265	432 extra	432	432	--
International DVT-573	Standard			
Detroiter 8V71-M	1,267 extra			1,267
Wheelbase				
Standard to 152"	20,508			
Heavy Duty to 152"	20,705			
Standard 153"-184"	20,705	20,705	20,705	20,705
Standard 185" up	20,903			
Fuel Tanks				
Saddle side mount, 100 gal. both sides	470.21	470.21	470.21	470.21
Real Axle--34,000 pound capacity				
Transmission				
10-speed Road Ranger	866.18	866.18		
16-speed Spicer	1,127.65		1,127.65	1,127.65
Wheels				
Standard with 10 x 20				
Budd, high tensile 11 x 20	533.16	533.16	533.16	533.16
Cab				
Non-sleeper, 73"	350			
Sleeper, 83"	504	504	504	504
		23,510	23,772	24,607
Tank-Trailer Specifications				
Tanks-Trailerized				
Tank w/farm pick up features		11,800	14,900	10,000
Rewind reel		100	100	100
Pump, Viking, 90 g.p.m.		240	240	240
		12,140	15,240	10,340
Tank, 4-wheel, trailerized 3,000 gallon w/converter gear, 8-10 x 20 tires		--	--	11,500
Total Tractor-Trailer Cost		35,650	39,012	46,447

a/ Interview at Owenhouse Hardware, Summer, 1967.

APPENDIX III

TABLE I. EQUIPMENT REQUIREMENTS FOR VARIABLE PLANT SIZE, 1967. a/

Item	Estimated Life	Purchase Price	Annual Depreciation	Volume Per Hour 2,000	4,000	8,000	10,000	12,000	14,000	16,000	18,000
	Years	Dollars	Dollars								
Receiving--Can--(used prices)											
Can Conveyor, Complete w/drives and turns	15	2,000	133								
Weighing Tank, two compartments, 750-pound stainless steel	15	1,000	67								
Drop Tank, 2,000 pound, two conductor spout openings	15	800	53								
Scale, 1,000 pound	15	800	53								
Milk Pump, 5-h.p. centrifugal 60,000 pounds per hour at 40 ft. head	10	542	54								
Can washer, 6 c.p.m., rust-proofed	15	1,500	100								
Sample Cooler, 240 bottle capacity 1/4 h.p. compressor	15	500	33								
Total		7,142	593	Requirements assumed constant through range of volume handled							
Receiving--Bulk											
Storage Tank, stainless steel agitators, insulated, horizontal type--2,000 gallon	15	3,120	208	208							
Storage Tank, stainless steel agitators, insulated, horizontal type--4,000 gallon	15	4,500	303			606					
Storage Tank, stainless steel agitators, insulated, horizontal type--5,000 gallon	15	5,162	344		344		688				
Storage Tank, stainless steel agitators, insulated, horizontal type--6,000 gallon	15	6,199	413					826	413		
Storage Tank, same as above--7,000 gallon	15	7,321	488								
Storage Tank--8,000 gallon	15	8,120	541						541	541	1,082
Tank washer, in place, for cleaning bulk delivery units	10	2,800	280	280	280	280	280	280	280	280	280
Milk Pump, 9 h.p., centrifugal, 250 g.p.m.	10	600	60	60	60	60	60	60	60	60	60
Total				544	684	946	1,028	1,166	1,294	1,369	1,422
Total Depreciation for Receiving Stage				1,137	1,277	1,539	1,621	1,759	1,887	1,962	2,015

(table continued)

TABLE I. (continued) EQUIPMENT REQUIREMENTS FOR VARIABLE PLANT SIZE, 1967.

Item	Estimated Life	Purchase Price	Annual Depreciation	Volume Per Hour 2,000	4,000	8,000	10,000	12,000	14,000	16,000	18,000
	Years	Dollars	Dollars								
Processing											
Pasteurizer, 15,000 pounds per hour, plate pasteurizer complete w/pump, motor, and hot water set	10	6,943	694	694	694						
Separator, 15,000 pounds per hour, grey enamel finish, accessories	10	5,500	550	550	550						
Separator, 20,000 pounds per hour, grey enamel finish, accessories	10	5,900	590			590	590	590	590	590	590
Cabinet, starter 74" x 27.5" x 35", 10 can	10	700	70	70	70						
Can, starter, 86 pound S.S.	15	30	2	6	8						
Vat, pasteurizer, for starter manufacture 200 gallon	15	2,500	150			150	150	300	300	300	300
Vat, cheese, 12,000 pound capacity, fully insulated, exterior painted, stainless steel heating system, 19'6" x 58" x 24"	15	2,760	184	368							
Agitator, single carriage, 20' length, for 12,000 pound vat	15	1,061	70	140							
Vat, cheese, 20,000 pound capacity, fully insulated, exterior painted, stainless steel heating system, 31'6" x 5' x 2'	15	4,100	273		546	1,092	1,092		1,638	1,638	
Agitator, double carriage, 32' length, for 20,000 pound vat	15	1,843	153		306	612	612		918	918	
Vat, cheese, 25,300 pound capacity, fully insulated, exterior painted, stainless steel heating system, 38' x 5' x 2'	15	5,500	366					1,464			2,196
Agitator, double carriage, 37' length, for 25,300 pound vat	15	3,800	253					912			1,518

(table continued)

TABLE I. (continued) EQUIPMENT REQUIREMENTS FOR VARIABLE PLANT SIZE, 1967.

Item	Estimated Life Years	Purchase Price Dollars	Annual Depreciation Dollars	Volume Per Hour 2,000	4,000	8,000	10,000	12,000	14,000	16,000	18,000
Pasteurizer, 20,000 pound per hour stainless steel finish, plate pasteurizer complete w/pump, motor, and hot water set	15	7,643	509			509	509	509			
Pasteurizer, same as above--25,000 pound/hour	15	8,495	566						566		
Pasteurizer, same as above--35,000 pound/hour	15	11,120	741							741	741
Knives, curd, for 58" vat	20	275	14	14	14	28	28	28	42	42	42
Mill curd, 12" with motor	15	541	36	36	36	36	36	36	72	72	72
Pump, milk, 5 h.p. centrifugal 60,000 pounds per hour	10	542	54			54	54	54	108	108	108
Curd fork, strainers, curd rake, scoop, curd pail, cheese knives and miscellaneous	20	160	8	8	8	16	16	16	24	24	24
Scale, Fairbanks, cheese, and butter, portable	15	120	8	8	8	8	8	16	16	24	24
Sink, wash	15	150	10	10	10	10	10	15	15	15	15
Piping, 2", stainless steel complete w/ferrules-per foot	15	3.50	--	15	16	28	28	35	42	44	44
Filter, cold milk, 20-35,000 pounds per hour	10	300	30	30	30	30	30	30	30	30	30
Total for Processing Stage				1,949	2,296	3,163	3,163	4,005	4,361	4,536	5,704
Hooping and Pressing											
Hoops, block, 40 pound, stainless steel	15	24	1.60	40	128	256	320	384	448	512	576
Press, cheese, 20', double row for large type cheese	20	1,990	99								
Press, cheese, 30', double row for large type cheese	20	2,520	126		126	252	252				
Press, cheese, 30', triple row for large type cheese	20	3,110	155					310			
Press, cheese, 32', double row for large type cheese	20	3,030	151							302	453
Bandage, cheese, nylon, per M	2	100	50	50	50	100	100	100	150	150	300
Total Depreciation				189	304	608	672	794	895	1,090	1,329

(table continued)

TABLE I. (continued) EQUIPMENT REQUIREMENTS FOR VARIABLE PLANT SIZE, 1967.

Item	Estimated Life	Purchase Price	Annual Depreciation	Volume Per Hour							
				2,000	4,000	8,000	10,000	12,000	14,000	16,000	18,000
	Years	Dollars	Dollars								
Packaging and In-Plant Transportation											
Sealer, block, cheese, 40 pound	15	1,950	130	130	130	130	260	260	390	390	390
Scale, Fairbanks, cheese	15	150	10	10	10	10	20	20	30	30	30
Truck, cheddar cheese, three deck, w/rubber tires, roller bearing wheels	15	185	12	12	12	12	24	24	36	48	48
Butter Center (used prices) b/											
Tank, whey, 1,800 gallon, stainless steel w/painted exterior	15	1,800	120			120	120	120	120	120	120
Pump, milk centrifugal, 5 h.p., 60,000 pounds per hour	10	542	54			54	54	54	54	54	54
Churn, butter, 2,000 pound capacity, aluminum w/7 1/2 h.p. motor, 12' x 5 1/2'	10	3,000	300			300	300	300	300	300	300
Vat, pasteurizer, 10,320 pounds	10	2,000	200			200	200	200	200	200	200
Printer, butter	10	2,000	200			200	200	200	200	200	200
Pump, milk, centrifugal, 1/4 h.p.	10	50	5			5	5	5	5	5	5
Separator, 20,000 pound per hour, grey enamel finish, complete w/accessories	10	5,900	590					590	590	590	590
Total Depreciation						879	879	1,469	1,469	1,469	1,469
Utilities											
Boiler, 50 h.p., gas fired, complete w/feed pump, condensate tank, 20' stack and auxiliaries 3-phase operation	20	5,253	262	262							
Boiler, 80 h.p., gas fired, etc.	20	8,200	410		410	410	410				
Boiler, 100 h.p., gas fired, etc.	20	10,000	500					500	500		
Boiler, 200 h.p., gas fired, etc.	20	18,000	900							900	900
Compressor, cold room, 2 h.p., complete w/coil, sight glass, heat exhanger, tubing, and 2 fans	20	1,400	70	70	70	70	70				
Compressor, cold room, 3 h.p., etc.	20	2,000	100					200	200	200	200

(table continued)

TABLE I. (continued) EQUIPMENT REQUIREMENTS FOR VARIABLE PLANT SIZE, 1967.

Item	Estimated Life Years	Purchase Price Dollars	Annual Depreciation Dollars	Volume Per Hour 2,000	4,000	8,000	10,000	12,000	14,000	16,000	18,000
Shop and spare equipment	10	2,000	200	200	200	200	200				
Shop and spare equipment	10	3,000	300					300	300	300	300
Total Depreciation				532	680	680	680	1,000	1,000	1,400	1,400
Office and Lab											
Bottles, testing	10										
Centrifuges, 36 bottles	10										
Sediment testing discs	10										
Marshall acid test	10										
Rennett test	10										
Balance Scales	10										
Titration set	10										
Acid dispenser	10										
Sink, double	10										
Sterilizer	10										
Incubator	10										
Refrigerator	10										
Desk and chairs	10										
Calculators	10										
Adding machine	10										
Billing machine	10										
Typewriters	10										
Safe	10										
Miscellaneous	10										
2-vat total		4,000	400	400	400						
4-vat total		7,000	700			700	700	700			
6-vat total		8,000	800						800	800	800

a/ Taken from specifications and proposals submitted by Damrow, Stoelting, and DeLaval.

b/ Used prices determined from interviews with plant managers.

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