OPTIMUM MARKET ORGANIZATIONS OF THE OKLAHOMA FLUID MILK INDUSTRY, 1965 AND 1975

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PREFACE

This study was concerned with an evaluation of the resources required in the marketing of fluid milk in Oklahoma under alternative market organizations. The overall objective of the study was to determine the number, size, and location of fluid milk processing plants that would minimize the total assembly, processing, and distribution costs under alternative assumptions concerning market organization. Analyses were made using a spatial equilibrium model (developed in this study) that includes economies of scale in processing together with assembly and distribution costs.

The author expresses thanks to his major adviser, Dr. Leo V. Blakley, for his guidance and assistance throughout this study. Special thanks are due to Dr. James E. Martin for his help in the formulation of the model used in the study. The author was also assisted by other members of his advisory committee, Dr. D. D. Badger and Dr. Julian H. Bradsher.

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CHAPTER I

INTRODUCTION

Significant changes in the production, processing, and consumption patterns in the Oklahoma fluid milk industry have occurred during the past 25 years. Total milk production in Oklahoma in 1940 was approximately 2.4 billion pounds. By 1965, production had declined 45 percent to total only 1.3 billion pounds. During the same period, however, the quantity of milk sold to plants as whole milk increased from 306 million pounds to more than 1.1 billion pounds. The increase in whole milk deliveries has reflected changes in both demand and supply conditions for dairy products within the State. Population growth and a continuing increase in the concentration of the population in urban areas probably will result in a further increase in the volume of whole milk deliveries to processing plants in Oklahoma.

While the quantity of whole milk delivered to processing plants has increased, the number of processing plants has decreased. Data on plant numbers within the State were not available for 1940. However, the number was 84 in 1950. In 1955, 50 Oklahoma processors processed approximately 531 million pounds of milk. By 1965, only 23 plants processed approximately 665 million pounds of milk. The decrease in plant numbers has occurred primarily for plants processing less than 10 million pounds annually.

Forces Affecting the Marketing of Fluid Milk

Past spatial equilibrium studies indicate that the costs of producing milk in Oklahoma and the location of Oklahoma with respect to other dairy producing areas are such that Oklahoma would fulfill its own fluid milk requirements under an optimum interregional flow of milk. Surplus production in Oklahoma would be sold in Texas markets.[1] Currently, Class I receipts from producers in Oklahoma are greater than consumption requirements and most of the surplus is being sold either as fluid milk in Texas markets or as manufacturing milk products.

The past changes in the organization of the Oklahoma fluid milk industry have resulted from the interaction of technological, institutional, and economic developments in the dairy industry. These developments have occurred in all sectors of the dairy industry from farm production to consumption.

At the producer level, technological developments in the form of selective breeding, improved feeds, and better feeding practices have resulted in substantial increases in production per cow. Technological developments also have provided for increased mechanization. This trend, aided by rising costs of labor and shortage of labor, has resulted in the substitution of capital for labor. The large amount of capital required for technological improvements has resulted in the exit of some marginal producers. At the producer level, the trend is to a smaller number of

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[1] M. M. Snodgrass and C. E. French, Linear Programming Approach in the Study of Interregional Competition in Dairying, Purdue Agricultural Experiment Station Bulletin 637 (Lafayette, 1958); R. E. Freeman and E. M. Babb, Marketing Area and Related Issues in Federal Milk Orders, Purdue Agricultural Experiment Station Bulletin 782 (Lafayette, 1964).

dairy farms and a smaller total number of cows with producers having more cows per herd and attaining greater average production per cow.

Bulk handling and improvements in roads and trucks have been the major technological developments affecting the assembly of milk. The improvements in the transportation facilities have resulted in wider procurement areas and a decline in the number of country receiving stations. The bulk tank system was more efficient than the old can system, and in some cases, assembly of milk in cans was discontinued. In other cases, the dairy operations were not large enough to justify the use of the bulk tank and the smaller producers could not remain competitive using the old can system. In addition, the initial capital requirements of the bulk tank and of the required improvements for roads and facilities were too great for some of the smaller producers.

The most significant product developments in the dairy industry that have had an impact on market organization occurred in the late 1800's and the early 1900's.[2] Many of these early developments contributed to some extent to a decrease in the number and an increase in the average size of firms.[3] In processing and manufacturing dairy products, the important developments that have had a pronounced effect on the optimum size of business have occurred since the 1930's. Many of the technological developments in processing and manufacturing have added to capital requirements and increased the optimum volume per plant. This has made entry

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[2]North Central Regional Committee on Dairy Marketing Research, Changing Organization of the Dairy Marketing Industries of the North Central Region (preliminary), (Urbana, 1965), p. 50.

[3]Ibid., p. 5.

more difficult and, as a result, there has been a decline in the number of processing firms.

The most significant development in the packaging of dairy products has been the design and use of the paper container for milk. The paper container greatly increased distribution areas, and it was strategic in forcing more complete adaptation of other innovations such as homogenization and pasturization. It increased the profit opportunity for those with the capital to invest and accelerated the egress rate for those who did not invest in the equipment because of the added operating expenses and increased competition in formerly local markets. The paper container also has facilitated increased attempts to establish product differentiation.

Technological changes in merchandising have come about in association with changes in places and habits of living and of shopping. A decline in the number of wholesale outlets has been associated with the increase in the number and size of supermarkets. An increased emphasis upon product differentiation, private brands, and substantial increases in vertical integration also have been associated with the development of supermarkets and chain stores.

One of the most significant institutional factors in the dairy industry was the imposition of sanitary regulations which came into existence during the latter half of the nineteenth century. They can be and have been used to restrict the free movement of milk. By requiring different sanitary requirements and by refusing to perform the inspection service for milk in distant areas, the local area could protect the producers in the area by eliminating the potential competition from outside milk. Health requirements also have added to capital requirements and to the cost of producing milk for fluid use.[4] The health and sanitary requirements have had the effect of increasing the optimum size of plants in the fluid milk industry, thereby influencing the number and size of plants.

Federal milk marketing orders have been one of the major governmental activities affecting the marketing of fluid milk in Oklahoma. The first Federal order in Oklahoma was established in 1950. One objective of Federal milk marketing orders is to provide for the orderly marketing of milk. Federal milk marketing orders apply only to prices paid to producers by handlers of milk. They do not apply to the retail price of milk, nor do they guarantee a fixed level of price to producers. They attempt, however, to establish minimum milk prices that are consistent with local and general economic conditions affecting the supply of and demand for milk. Prices are established for classes of milk defined according to the fluid use of milk. The highest minimum price is paid for the highest class-Grade A milk for consumption as fluid milk. The primary standard for establishing fluid milk prices has been the concept of equating supply and demand within certain limits. Several pricing plans, or modifications thereof, have been used to establish fluid milk prices in an attempt to equate the demand and supply of fluid milk throughout the year.[5]

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[4]Ibid., p. 18.

[5]Ibid, pp. 23-29.

Product specification, grading, market reporting, and price supports are other governmental activities that have affected the market environment of the dairy industry. Product specification, if applied uniformly over market areas, could add to the competitiveness of the market. Uniform product specification would make it more difficult for firms to differentiate their products. If, however, standards of product specification varied among market areas, this variation could provide a barrier to the free flow of dairy products. Government grading might make it more difficult for firms to differentiate their products since smaller firms could market government graded products on the basis of grade alone. The market information provided by the Federal government probably improves the competitive position of producers and smaller processors and manufacturers and, as such, likely influences market organization. Governmental price supports for dairy products have provided a floor for prices of lower class products under Federal orders. As administered, the distribution of manufactured products to government versus private markets has influenced the market organization within states.

In addition to Federal laws regulating the marketing of fluid milk, individual states may have laws which govern the marketing of milk within the state. These laws vary among states and in some cases can restrict the flow of milk among states. Some of the regulations affecting the marketing of fluid milk in Oklahoma are discussed in Chapter II.

Problem

The continuous interaction of changes in the technological, institutional, and economic environment in the dairy industry has given rise to changes in the size and composition of the dairy industry. These changes have altered the market organization and there is a need to establish the market organization which could achieve the maximum efficienty in marketing. In addition, as changes in the requirements of the marketing system arise in the future, firms will need guidelines as to the type of adjustments needed to meet efficiently the demands placed on the marketing system. The failure of firms to make the proper adjustments would result in unnecessary inefficiencies in the marketing system. Policy makers also have been involved in formulating programs and policies which affect the marketing of dairy products and need guidelines that could be used in the formation of new, and in altering existing, marketing policies.

Objectives of the Study

This study was concerned with an evaluation of the changes in the Oklahoma fluid milk industry and the resource requirements in the marketing of fluid milk in Oklahoma. The overall objective of the study was to determine the number, size, and location of fluid milk processing plants that would minimize the total assembly, processing, and distribution costs under alternative assumptions concerning market organization. Involved in fulfilling this objective were (1) an evaluation of changes in the demand requirements of the fluid milk industry, (2) an evaluation of changes in the supply of Class I milk, and (3) an integration of the results from (1) and (2) into a spatial equilibrium model to determine adjustments in the market organization of the Oklahoma fluid milk industry that would result in a minimum cost for the assembly, processing, and distribution of fluid milk.

The remainder of this study is divided into five chapters. Chapter II includes a description of the Oklahoma fluid milk industry and an evaluation of past changes in the production, processing, and consumption of milk. In addition, institutional factors affecting the marketing of fluid milk in Oklahoma are discussed.

Chapter III includes a discussion of the analytical framework and the development of the cost estimates used in the study. Early developments in the theory of location are reviewed, then some of the principles of location theory used in the study are discussed. Following the discussion of the principles, empirical estimates of the assembly and distribution cost functions are made. Next, theoretical plant cost curves are considered and the estimated processing cost function used in the study is developed.

In Chapter IV, some of the mathematical programming models that have been used in spatial equilibrium studies are discussed. Particular emphasis is given to the limitations of these models in solving spatial equilibrium problems where economies of scale exist in processing. A spatial equilibrium model which can consider economies of scale in processing is developed in Chapter IV and forms the basis for most of the analyses included in the study.

Chapter V contains a description of the geographical area of the study and the results of the analyses. Cost functions developed in Chapter III and the spatial equilibrium model developed in Chapter IV are used to determined the minimum cost organization of the Oklahoma fluid milk industry under various assumptions and restrictions. Market organizations for 1965 and projected 1975 market requirements are determined.

Finally, Chapter VI contains a summary and a discussion of the implications and conclusions from the analyses. A discussion of the limitations of the study and suggestions for future research is also included.

CHAPTER II

OKLAHOMA FLUID MILK INDUSTRY

An industry could be described in part by its physical dimensions such as the number, size, and location of the economic elements that comprise the industry. In addition to its physical dimensions, an industry has an institutional dimension which includes those factors that affect directly or indirectly the manner in which the economic activity of an industry is conducted. The physical and institutional organization of the Oklahoma fluid milk industry along with recent changes in the organization will be discussed in this chapter.

Production

The production of dairy products has been an important sector in Oklahoma agriculture during the past 25 years. Sales of dairy products have usually ranked third or fourth among the commodity groups. During the past five years, cash receipts from the sale of dairy products have accounted for around eight percent of the cash receipts from farm marketings in Oklahoma (Table I). This percentage was down from approximately 11 percent during the previous 20-year period. Although the relative importance of dairy products as a percentage of total cash receipts has declined, actual cash receipts from the sale of dairy products have doubled since 1940. In constant dollar terms the value of cash receipts was up more than eight percent from 1940, but was down approximately 36 percent from 1945.

TABLE I

CASH RECEIPTS FROM THE SALE OF DAIRY PRODUCTS IN OKLAHOMA: ACTUAL, DEFLATED, PERCENT OF TOTAL, AND RELATIVE IMPORTANCE AMONG FARM PRODUCTS, SELECTED YEARS, 1940-1965

Year	Actual Receipts	Deflated[a] Receipts	Percent of Total Receipts	Rank Among Farm Products
	(1,000 dollars)	(1,000 dollars)		
1940	23,076	47,286	12.2	4
1945	50,519	80,572	11.0	4
1950	52,292	62,401	9.3	4
1955	52,522	56,294	11.1	4
1960	53,311	51,708	7.9	4
1961	57,752	51,162	8.4	4
1962	54,938	52,123	8.4	3
1963	52,988	49,661	7.9	4
1964	55,039	50,915	8.8	3
1965	56,404	51,323	7.6	3

[a]Deflated by Consumer Price Index.

Source: U. S. Department of Agriculture, _Agricultural Statistics_ (Washington), selected issues; and _Farm Income State State Estimates_, _Supplement to July Farm Income Situation 1951-1965_ (Washington).

The doubling of cash receipts from the sale of dairy products since 1940 was not, however, an indication of what had happened to production during the same period. Total milk production declined approximately 45 percent from 1940 to 1965 (Table II).

TABLE II

MILK PRODUCTION AND DISPOSITION, OKLAHOMA,
SELECTED YEARS, 1940-1965

Year	Total Production	Utilized on Farms	Sold to Plants As Whole Milk	Sold to Plants As Farm Skimmed Cream	Retailed By Farmers
	(mil. lb.)	(mil. lb.)	(mil. lb.)	(mil. lb.)	(mil. lb.)
1940	2,380	807	306	1,119	148
1945	2,562	710	630	1,092	130
1950	1,991	531	760	620	80
1955	1,710	353	842	460	55
1960	1,421	190	1,030	180	21
1961	1,488	157	1,150	160	21
1962	1,431	131	1,160	120	20
1963	1,342	112	1,120	90	20
1964	1,303	98	1,115	70	20
1965	1,312	86	1,150	56	20

Source: U. S. Department of Agriculture, ERS, Dairy Statistics Through 1960, Statistical Bulletin No. 303 (Washington, 1962); and Supplement for 1963-1964.

TABLE III

TOTAL FARMS, FARMS REPORTING MILK COWS, AND NUMBER OF
MILK COWS ON FARMS, OKLAHOMA, CENSUS YEARS,
1940-1959

Year	Total Farms	Farms Reporting Milk Cows	Number of Milk Cows on Farms
			(1,000)
1940	179,687	155,020	704
1950	142,246	107,233	541
1954	118,979	78,014	442
1959	94,676	41,061	274

Source: U. S. Department of Agriculture, ERS, Dairy Statistics Through 1960, Statistical Bulletin No. 303 (Washington, 1962).

Important changes occurred in the utilization of milk produced by farmers. The percentage of milk produced that was utilized on the farm declined from approximately 34 in 1940 to about seven in 1965. The decline in the share of milk utilized on farms was associated with a decline in the number of farms reporting milk cows. The number of milk cows on farms declined more than 60 percent from 1940 to 1959 (Table III). During the same period, the quantity of milk delivered as whole milk to dealers increased from 13 to more than 87 percent.

Data on Class I producer receipts were obtained from market administrators for Federal marketing order areas into which Oklahoma producers commonly sold Grade A milk. Producer receipts and the number of producers were obtained from the Ozarks, Southwest Kansas, Wichita, Neosha Valley, Memphis, Red River Valley, Oklahoma Metropolitan, North Texas, and Texas Panhandle orders. According to reports from market administrators, Oklahoma producers sold milk in the Texas Panhandle, Neosha Valley, Wichita, Red River Valley, Oklahoma Metropolitan, North Texas, Ozarks, and Memphis order areas in 1965.

Total Class I producer receipts from Oklahoma farmers and the number of producers are included in Table IV for the period 1961 through 1965. Since 1961, Class I receipts from producers have increased approximately six percent. During the same period the number of producers making deliveries declined approximately 24 percent. Consequently, receipts per individual producer have increased.

One of the factors contributing to the increase in receipts per producer has been the introduction of the bulk tank. The first commercial assembly of milk from farm bulk milk tanks in Oklahoma was initiated in

TABLE IV

OKLAHOMA PRODUCERS AND PRODUCER RECEIPTS ASSOCIATED WITH FEDERAL ORDER MARKETS, 1961-1965

Year	Number of Producers	Producer Receipts
		(mil. lb.)
1961	3,092[a]	891.4
1962	2,798[a]	876.3
1963	2,567[a]	860.5
1964	2,424[b]	895.6
1965	2,351[b]	947.0

[a]Producers in November.

[b]Producers in December.

Source: Data Furnished by the Market Administrators (CMS, USDA) for Federal Milk Marketing Order numbers 67, 71, 73, 74, 97, 104, 106, 126, 132, and 138.

1954 in Chickasha. Since that time bulk milk pick-up systems in Oklahoma have expanded rapidly. By 1959, approximately 50 percent of the Grade A milk in the Oklahoma Metropolitan marketing area was assembled under the bulk milk system. The adaptation of the bulk tank expanded throughout the State and by 1964 over 99 percent of the Grade A milk assembled in Oklahoma was assembled under the bulk tank system. As the use of the bulk tank expanded, smaller producers tended to either expand and adapt the bulk tank or go out of business.[1] Also there has been a general

[1]Fred A. Mangum, "Costs and Returns of Bulk Tanks on Dairy Farms in the Oklahoma City Milkshed," (unpub. Ph.D. dissertation, Oklahoma State University, 1959) p. 100.

decline in the number of producers as a result of better alternatives for the use of resources, including off-farm work for the labor resource.

Producer receipts for the State have increased since 1961, but producer receipts in some counties have declined (Figure 1). Several counties in the eastern third of the State had lower producer receipts in 1965 than in 1961. Changes also occurred in the concentration of producer receipts within the State. Figure 2 shows the counties in which producer receipts as a percentage of total producer receipts changed from 1961 to 1965. Data on producer receipts by county for 1961 and 1965 are included in Appendix B, Tables VIII and IX respectively. The concentration of production has increased in counties surrounding Oklahoma City and in the northwestern part of the State. The concentration of producer receipts in the eastern third of the State and in the southwest has, in general, decreased.

Most of the increase in production in the western part of the State has not been delivered to Oklahoma dealers. According to reports from market administrators, more than 90 percent of the milk delivered to dealers from Texas, Harper, Ellis, Roger Mills, Beckham, and Washita counties was delivered to the Texas Panhandle Marketing Order in 1965. More than 70 percent of the milk delivered from Custer County and more than 50 percent of the milk delivered from Woodward County went to the Texas Panhandle order in 1965.

Consumption

Estimates of the per capita consumption of milk for the United States and for the Oklahoma Metropolitan and Red River Valley marketing

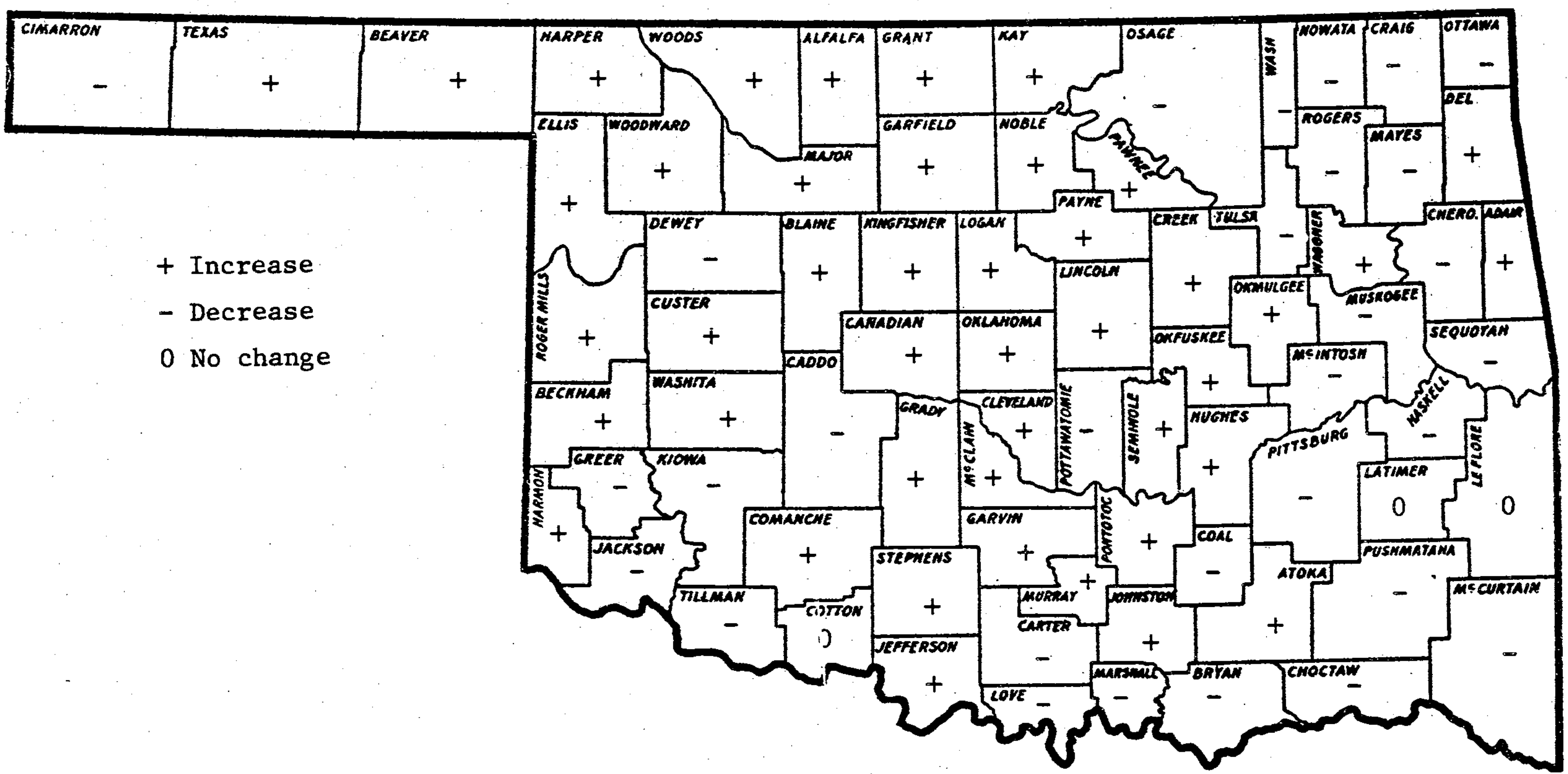

Figure 1. Direction of Change in Total Producer Receipts, by County, Oklahoma, 1961 to 1965

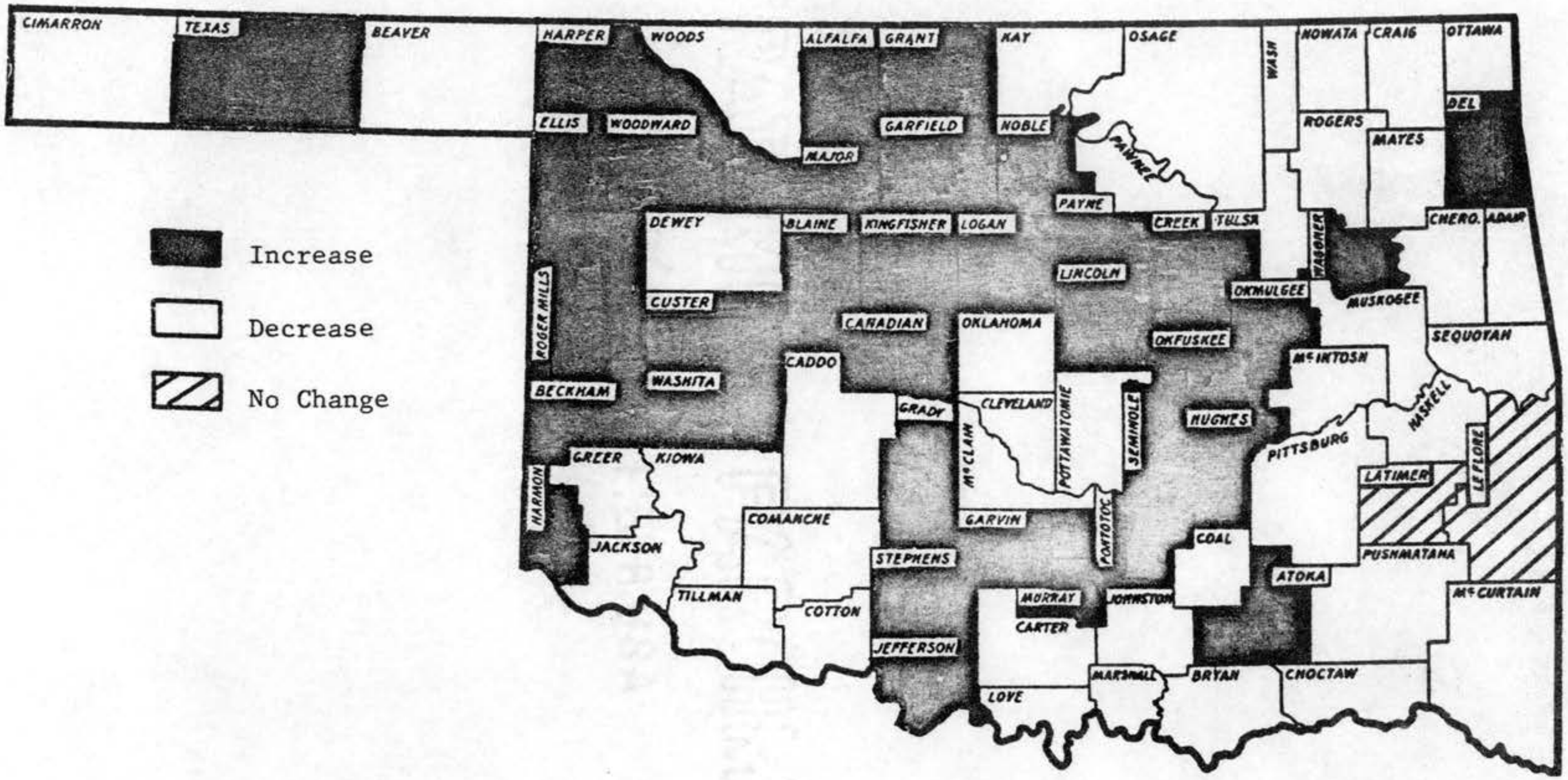

Figure 2. Changes in the Percentage of Producer Receipts, by County, Oklahoma, 1961 to 1965

order areas for selected years are presented in Table V. The per capita consumption of fluid milk in the United States declined continually from 1955 through 1964. Although no regular pattern existed, the per capita

TABLE V

PER CAPITA CONSUMPTION OF WHOLE AND SKIM MILK AND TOTAL MILK-EQUIVALENT FOR ALL FLUID ITEMS, OKLAHOMA METROPOLITAN MARKETING AREA, RED RIVER VALLEY MARKETING AREA, AND UNITED STATES, 1955-1965

	Oklahoma Metropolitan		Red River Valley		United States
Year	Whole and Skim Milk	All Fluid Items	Whole and Skim Milk	All Fluid Items	All Fluid Items (Fluid Milk-Equivalent)
			POUNDS		
1955	287	286	na	na	348
1956	294	296	na	na	348
1957	293	300	na	na	343
1958	308	310	na	na	335
1959	306	311	297	277	328
1960	305	313	297	281	322
1961	293	302	305	296	310
1962	297	308	297	290	308
1963	304	315	297	292	307
1964	302	309	291	284	305
1965	309	314	290	273	na

na Not available.

Source: U. S. Department of Agriculture, SRS, _Fluid Milk and Cream Consumption in Selected Marketing Areas 1950-1959_, Statistical Bulletin No. 312 (Washington, 1962); and _Fluid Milk and Cream Report_ (Washington), selected issures; U. S. Department of Agriculture, ERS, _U. S. Food Consumption_, Statistical Bulletin No. 364 (Washington, 1965); and _Supplement for 1964_.

consumption of whole and skim milk has increased in the Oklahoma Metropolitan area since 1955. Per capita consumption of milk in the Red River Valley marketing area tended to decrease from the 1959 level, the year it was first reported.

No data were available on per capita consumption of milk by county within the State. Therefore, population, per capita consumption, and per capita income estimates were used to obtain estimates of fluid milk consumption by county. Estimates of the 1965 population per county were obtained from Dr. James D. Tarver of the Department of Sociology and Rural Life at Oklahoma State University. These estimates are included in Table VI of Appendix B. Per capita incomes by counties were obtained from estimates made by the Oklahoma Bureau of Business Research.[2] The average of the per capita income estimates for 1959 and 1961 was used. The reason for using these years rather than later years was that discrepancies appeared to exist in some of the estimates for the later years. The increases in incomes reported for some counties appeared to be very large after 1961. The average per capita consumption of fluid milk in Oklahoma was obtained from a weighted average (by population) of the per capita consumption reported for the Oklahoma Metropolitan and Red River Valley marketing areas.[3] The estimated average per capita consumption of fluid milk and cream used in the study was 300 pounds.

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[2] Bureau of Business Research, Per Capita Income Estimates for Oklahoma by County, University of Oklahoma (Norman, 1962).

[3] U. S. Department of Agriculture, SRS, Fluid Milk and Cream Report (Washington, 1966), p. 50.

TABLE VI

PERCENTAGE OF SALES CLASSIFIED BY TYPE OF CONTAINER AND BY MARKET OUTLET, OKLAHOMA METROPOLITAN AND RED RIVER VALLEY MILK MARKETING AREAS, NOVEMBER AND MAY 1960-1965

Month and Year	Oklahoma Metropolitan				Red River Valley			
	Glass	Paper	Whole-sale	Retail	Glass	Paper	Whole-sale	Retail
				Percent				
May 1960	30.96	69.05	78.69	21.31	na	na	na	na
Nov 1960	23.86	76.14	81.06	18.94	10.37	89.63	91.02	8.98
May 1961	38.00	62.00	67.95	32.05	11.71	88.29	91.69	8.31
Nov 1961	36.05	63.95	69.94	30.06	12.35	87.65	92.20	7.80
May 1962	36.83	63.17	68.35	31.35	12.42	87.57	92.65	7.35
Nov 1962	35.92	64.08	70.11	29.88	13.10	86.90	93.26	6.74
May 1963	35.60	64.40	69.52	30.48	11.38	88.62	93.18	6.82
Nov 1963	26.66	73.34	71.32	28.68	8.62	91.38	93.20	6.80
May 1964	23.20	76.80	72.18	27.82	6.50	93.50	92.88	7.12
Nov 1964	20.45	79.55	74.69	25.31	na	na	na	na
May 1965	15.85	84.15	72.43	27.57	na	na	na	na

na Not available.

Source: _Market Administrator's Bulletin_ for the Oklahoma Metropolitan marketing area, May and October issues. _Market Administrator's Bulletin_ for the Red River Valley marketing area, August 1961, November 1961, April 1962, October 1962, March 1963, September 1963, July 1964, March 1965; _Market Administrator's Bulletin_ for the Oklahoma Metropolitan and Red River Valley marketing areas, October 1965.

The per capita consumption for each county was estimated from the following equation:

$$(2.1)\quad C_i = 300 + (300)\ (\Delta I_i)\ (0.16)$$

where

C_i = per capita consumption in county i,

300 = average per capita consumption in the state,

ΔI = the percentage difference in per capita income in county i from the state average per capita income,

0.16 = the estimated income elasticity of demand for fluid milk.[4]

Estimates of per capita consumption and of total consumption for each county for 1961 and for 1965 are given in Appendix B, Table VI.

The changing concentration of consumption in various areas of the State is an important factor affecting market requirements. The concentration of consumption around the major population centers has increased since 1961 (Figure 3). County consumption figures for 1961 and 1965 obtained from equation (2.1) indicate changes in the concentration of consumption by county. Figure 3 shows there were seven counties for which consumption as a percent of total consumption in the State increased from 1961 to 1965. These seven counties contained the major population centers of the State. One county (Washita) had no change, and all other counties had lower shares in 1965 than in 1961. 1

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[4]This estimate of the income elasticity of demand for fluid milk was obtained from George E. Brandow, Interrelations Among Demands for Farm Products and Implications for Control of Market Supply, Pennsylvania Agricultural Experiment Station Bulletin 680 (University Park, 1961), p. 17.

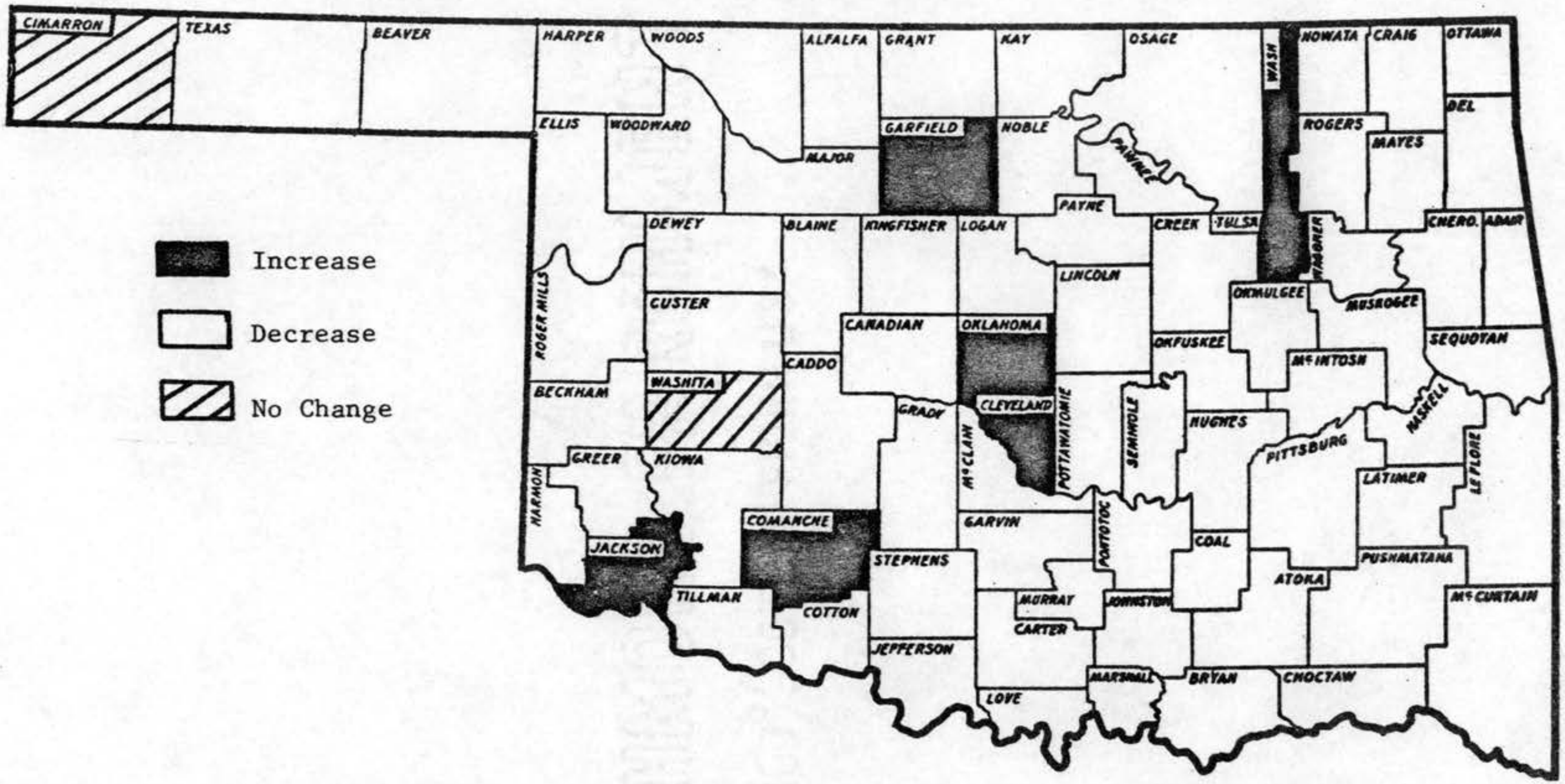

Figure 3. Changes in the Percentage of Fluid Milk Consumption, by County, Oklahoma, 1961 to 1965

Changes in consumption patterns have been reflected in changes in the percentage of sales in glass and paper containers and in changes in the percentage of sales through wholesale and retail outlets. The percentage of sales in glass containers decreased from 1961 to 1965 in the Oklahoma Metropolitan marketing area after an increase in the percentage of sales in glass containers from 1960 to 1961 (Table VI). The reason for the large increase from 1960 to 1961 was not apparent unless it was a result of changes in the market area included under the order. A similar decline from 1961 to 1965 occurred in the Red River Valley marketing area, though the percentage for glass was at a much lower level. The percentage for paper increased as the percentage for glass decreased. Associated with the increase in the percent of sales in paper containers from 1961 to 1965 was an increase in the percentage of wholesale sales. This reflected an increase in the importance of supermarkets as sales outlets and a decrease in importance of home delivery as a sales outlet for fluid milk.

Changes in consumers' buying habits were also reflected in the percentage of sales in various container sizes. The percentage of milk sold in gallon containers has increased at the expense of the milk sold in half-gallon and quart containers (Table VII). Apparently, larger containers have been replacing the smaller containers for the home consumption market outlet. The percentage of milk sold in pints and half-pints has remained almost constant since 1961. These smaller containers have been purchased mainly by institutions such as schools and by resturants and cafeterias, and the growth in demand for milk in these container sizes has paralleled the growth in demand for fluid milk.

TABLE VII

PERCENTAGE OF REGULAR AND HOMOGENIZED MILK SALES IN VARIOUS CONTAINER SIZES, OKLAHOMA METROPOLITAN MARKETING AREA, 1960-1965

Year	Gallons	Half-Gallons	Quarts	Pints and One-Third Quarts	Half-Pints
			Percent		
1960	17.7	64.4	10.7	0.9	6.3
1961	20.1	62.9	9.9	0.8	6.3
1962	22.7	61.3	8.8	0.8	6.4
1963	25.0	59.9	7.8	0.8	6.5
1964	29.9	55.7	6.9	0.8	6.7
1965	32.4	53.9	6.3	0.7	6.7

Source: Market Administrator's Bulletins, Oklahoma Metropolitan, Marketing Area, December, 1960-1965.

Processing Plants

Data available on the number and size of fluid milk processing plants in Oklahoma indicate that a continual decline occurred in the number of processing plants since 1950. There were 84 fluid milk processing plants in the State in 1950 and only 50 plants in 1955. The number of fluid milk processing plants in Oklahoma has decreased 50 percent since 1955 and totaled only 23 in 1965. The large decrease since 1955 has been in the number of plants processing less than 15 million pounds of milk annually (Table VIII). There was a small decrease in the number of plants

TABLE VIII

ANNUAL SIZE DISTRIBUTION OF FLUID MILK PROCESSING FIRMS, OKLAHOMA, 1955-1965

Size (Mil. Pounds)	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965
under 5	25	26	26	20	11	6	6	6	6	5	5
5-14	12	9	9	8	9	7	7	5	3	2	3
15-29	8	9	7	5	6	3	2	3	4	6	5
30-49	4	3	4	7	6	7	8	6	6	6	6
50 and over	1	2	2	2	2	4	4	5	5	5	6
Total	50	49	48	42	34	27	27	25	24	23	23

Source: Dairy Division, Oklahoma Department of Agriculture, (Oklahoma City).

processing between 10 million and 40 million pounds annually, but there has been an increase in the number of plants processing 30 million or more pounds per year. The locations of fluid milk processing plants by counties in Oklahoma in 1965 are given in Figure 4. The 50 plants in 1955 represented 48 firms. In 1965, the 23 plants were operated by 21 firms.

Marketing Orders[5]

Federal milk marketing orders constitute one of the major institutional factors affecting the marketing of fluid milk in Oklahoma. The first Federal milk marketing orders in Oklahoma became effective on May 1, 1950 with the establishment of one order in the Oklahoma City milkshed and another in the Tulsa milkshed. The next order in Oklahoma became

[5]Dates of formation and merging of marketing orders were obtained from the U. S. Department of Agriculture, Federal Milk Order Statistics, Annual Summary for 1963, Statistical Bulletin 345 (Washington, 1964), p. 7.

Each dot represents one plant,

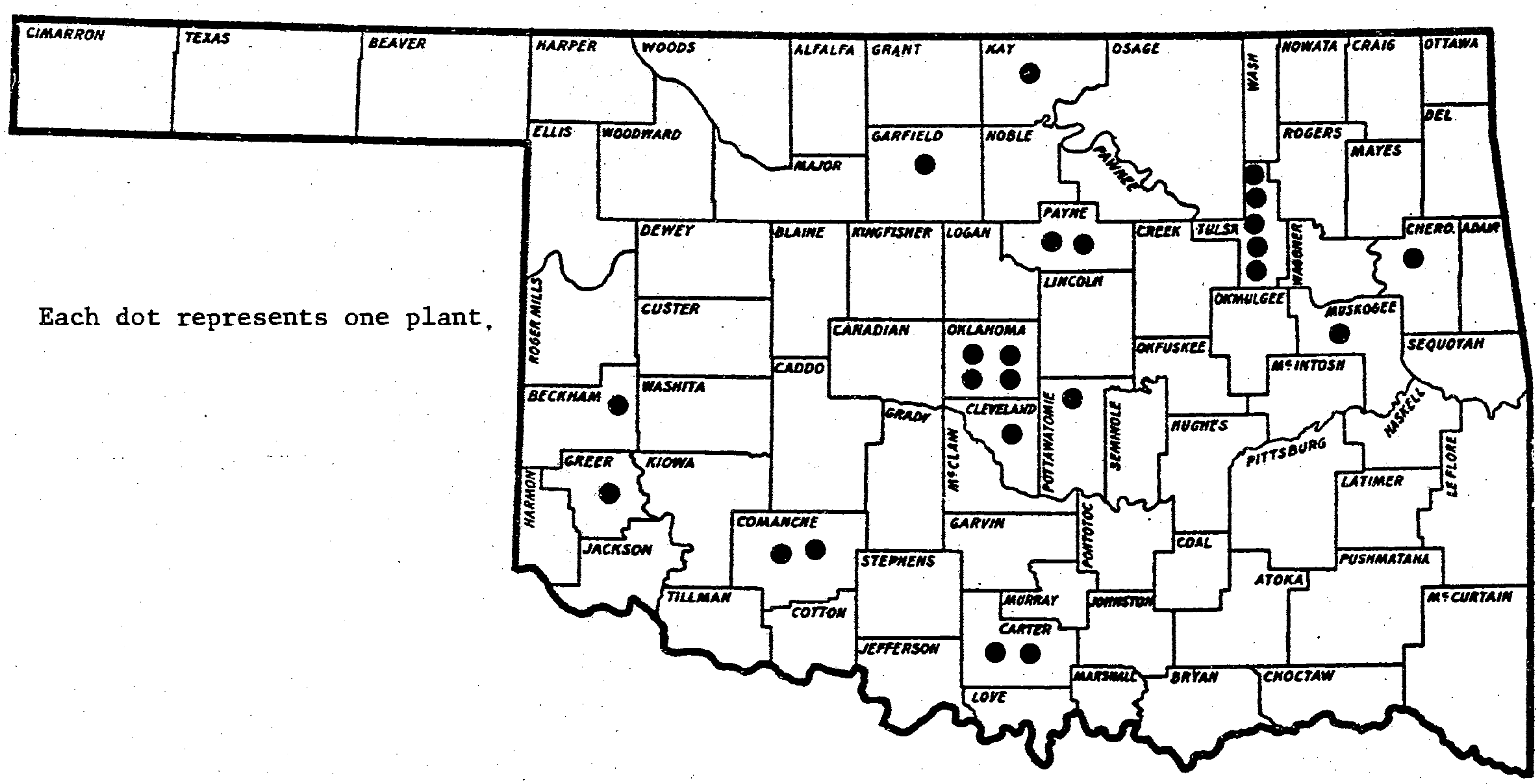

Figure 4. Locations of Fluid Milk Processing Plants, Oklahoma, 1965

effective in the Muskogee milkshed on July 1, 1951. The Tulsa and Muskogee orders were merged on August 1, 1953. On May 1, 1957, the Oklahoma City and the Tulsa-Muskogee orders were merged into the Oklahoma Metropolitan Marketing Order.

Other orders established that included part of Oklahoma or affected milk sold by Oklahoma farmers were the Texas Panhandle order and the Red River Valley order. The Texas Panhandle order became effective February 1, 1956, and the Red River Valley order became effective November 1, 1958. The present organization under Federal milk marketing orders in Oklahoma has existed since May, 1960, when handlers in the Enid milkshed came under the Oklahoma Metropolitan order. The milk marketing areas in Oklahoma as of January 1, 1966 are shown in Figure 5.[6]

One basic structural change brought about by the establishment of Federal marketing orders was the change in the relationship between producers and handlers. Often before the installation of marketing orders, an oligopsony-oligopoly group of handlers was buying milk from a competitive group of producers and selling processed milk to a competitive group of consumers. The institution of a marketing order made it possible for producers to emerge as a more cohesive group with an increased bargaining position relative to handlers and consumers. For producers, the essence of the change in structure brought about by a Federal marketing order was essentially to substitute industry

[6]The Oklahoma Metropolitan Marketing area is defined in terms of cities and townships and all of the area outlined in the Oklahoma Metropolitan area in Figure 5 is not necessarily part of the Oklahoma Metropolitan area.

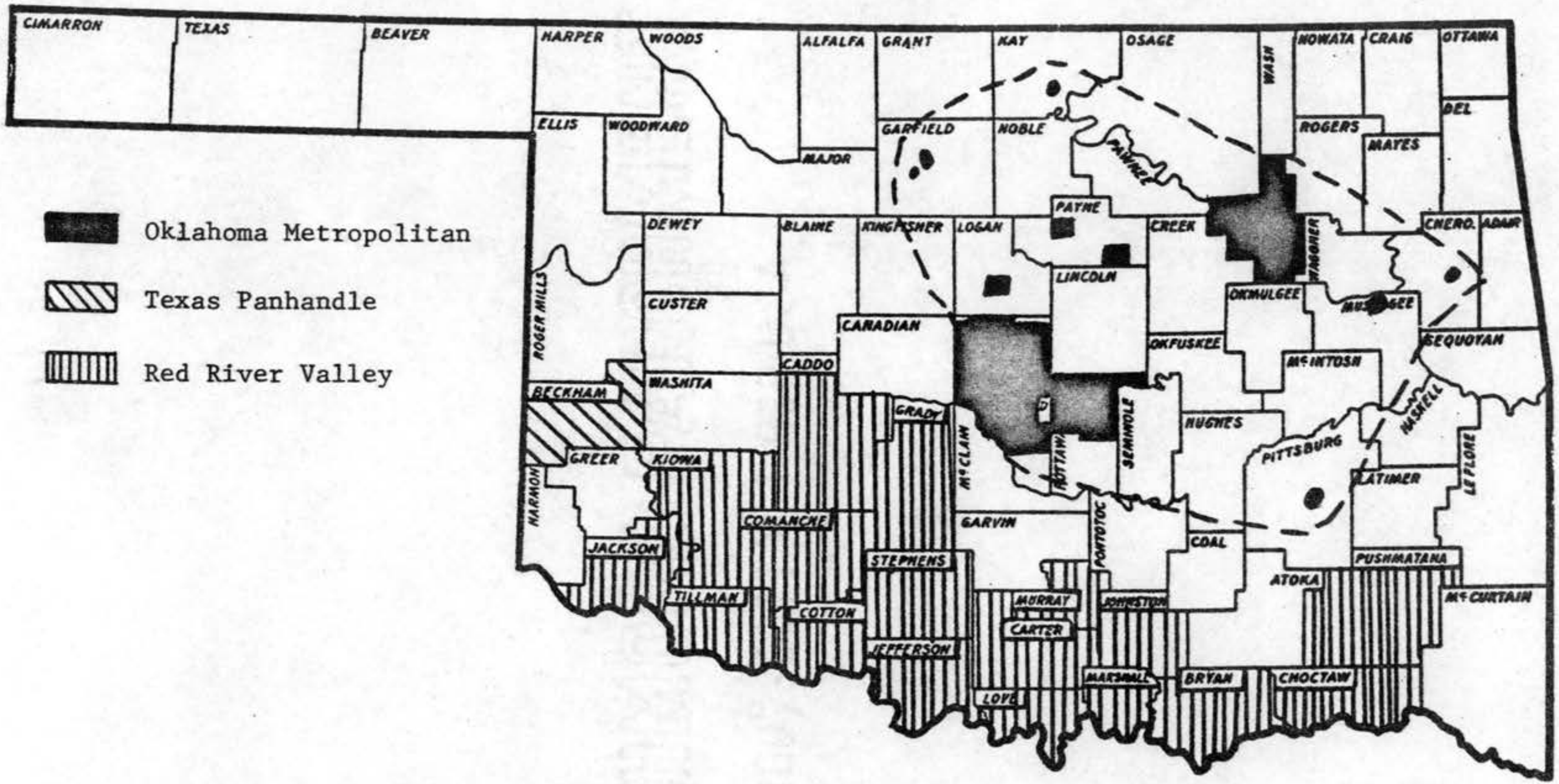

Figure 5. Areas of Oklahoma Included in the Oklahoma Metropolitan, Red River Valley, and Texas Panhandle Federal Order Marketing Areas, January 1, 1966

agreement, with full compliance enforced, for uncertain performance under imperfect market conditions.

Another structural change brought about by Federal orders was the establishment of uniform classified pricing of milk for all producers in each milkshed. Under Federal orders, pricing plans have been used whereby the prices paid for the milk will reflect a differential value of milk according to whether it is used for fluid milk and cream or in manufactured production. Classified pricing will enable all producers in each milkshed to obtain a higher price for that portion of milk going into the higher value Class I use (individual handler pools have not been used in Oklahoma). The effect is to establish discriminatory pricing of milk, though returns from the discrimination process have not been maximized.

The collection and dissemination of economic data necessary to operate a Federal order has increased the degree of knowledge within the industry. The availability of economic information provided under a marketing order can result in an improved communication process between groups with conflicting interests in the industry. Another change following the institution of a Federal order that could result is the establishment of conditions favorable for increased vertical and horizontal relationships among marketing firms.

State Laws

Like Federal marketing orders, state laws are an institutional force affecting the marketing of fluid milk. Among the laws in some states is a law governing the retail price of milk. Oklahoma does not have such a law, but there are other laws in Oklahoma affecting price competition.

One law requires each fluid milk distributor to file with the State Department of Agriculture a schedule of wholesale prices for each county in which he offers dairy products for sale. Another law prohibits a dairy products processor from furnishing equipment to retailers. Also, a general law prohibits the sale of any product below cost, though enforcement has not been uniform or consistent since proceedings must be initiated by trade associations. Such laws tend to limit the alternatives available to larger firms for pressuring smaller firms out of the market.

In addition to laws affecting price competition directly, there are laws in Oklahoma administered by city-county health departments which set forth minimum sanitary regulations for milk to be sold in the respective areas. Regulations are set forth specifying minimum sanitary standards for buildings, equipment, sewer disposal, and bulk tanks used for cooling and storing milk. These laws influence the structure of the Oklahoma fluid milk industry to the extent that the additional requirements imposed by the regulations affect the economic scale of the enterprise at the producer and/or processor level. In general, health and sanitary requirements have had the effect of increasing the scale of plant in the fluid milk industry.

Oklahoma law also defines product specifications for dairy products manufactured and/or sold in Oklahoma. Such a law may make it more difficult for larger firms to differentiate their products since products marketed by all firms must meet the same minimum product specifications.

CHAPTER III

ANALYTICAL FRAMEWORK AND COST ESTIMATES

The problem considered in this study is embodied in location theory and the cost concepts of marginal analysis. Location theory includes considerations of transportation costs in both the assembly and the distribution of products. In this chapter the general nature of the location problem is reviewed and a limited discussion of the development of location theory is presented. Although many contributions to location theory were considered, the discussion of the development of location theory in this chapter is limited to the contributions of three persons: Von Thunen, Weber, and Losch. The purpose of the review is to give the general nature of the location problem and to provide a basis for analysis of the spatial dimension of the problem considered in this study. A detailed discussion of the writings of location theory can be found in Been.[1] The development of the assembly and distribution costs for this study will follow the discussion of location theory.

The principles of marginal analysis will provide the basis for examining firm processing costs. Traditional hypotheses concerning the economic and technical relationships within a firm will be reviewed, and cost curves for an alternative hypothesis will be considered. The

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[1]Richard O. Been, "A Reconstruction of the Classical Theory of Location," (unpub. Ph.D. dissertation, University of California, 1965).

empirical cost function of the study will follow the theoretical discussion of firm costs.

Location

Location Theory

Location theory is concerned with the spatial dimension of the economic problem. According to Been, there are two categories of location problems.[2] In the first category, location itself is variable and the optimum location of an economic enterprise is desired. The major factors which influence the decision of choice of location include relative prices or costs of materials, relative and prospective prices of and demand for the product at markets, and the structure of transfer costs for materials and products. In the second category, the economic unit is fixed. In this situation, economic decisions with respect to location involve the consideration of the relative location positions of other economic units with which trading activities must be carried on, and the selection of certain of those locations and units from which materials and products are to be bought and sold. Often these problems cannot be seperated in decision making because they are interdependent.

Von Thunen developed the first principles of location theory.[3] Von Thunen was concerned with the location of agricultural enterprises around a central city. His analysis, based on experience and observation in agricultural production and marketing, indicated that agricultural products.

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[2]Ibid., p. 3.

[3]J. H. Von Thunen, The Isolated State (Chicago, 1960).

would be produced in different intervals surrounding a central city according to the relative bulkiness of the products. Those products that were bulky and had low value per unit of weight, along with perishables, would be produced closest to the central city.

Alfred Weber was the first writer after Von Thunen to receive early recognition in the development of the principles of location theory.[4] Weber's analysis was confined to the consideration of the choice of location for a plant or enterprise relative to fixed point locations or markets and of material supplies. Weber assumed fixed sites for raw materials, fixed market locations, and an inelastic demand, and sought to determine the enterprise location where total transfer cost of materials and of finished product was minimized.

In 1939, August Losch published his book entitled, Die raumliche Ordnumg der Wirtschaft.[5] Losch relaxed Weber's assumption of an inelastic demand and considered the problem of locating processing plants from the standpoint of transport cost and demand. Losch's position was that the correct location of an individual enterprise should be determined in terms of net profit and not in terms of minimum costs. According to Losch, Weber's solution for the problem of location would break down if the possibility of a change in sales were permitted.[6] Losch determined economic regions shaped as hexogons to be the optimum-shaped economic areas.[7]

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[4]Alfred Weber, Uben den Standort der Industrien, I Teil, Reine Theorie das Standorts (Tubingen, 1909).

[5]Translated by William H. Woglom and Wolfgang F. Stolpher as, The Economics of Location (New Haven, 1954).

[6]Ibid., p. 28.

[7]Ibid., p. 110.

In general there are two spatial relationships in economic activity. One is the separation of the raw material sites from processing plants. The other is the separation of processing plants from consumption sites. Following Hoover, the locational relation of processing plants to raw material sites will be referred to as supply areas, and the locational relation between processing plants and consumption sites will be called market areas.[8] The formation of supply areas is analogous to the formation of market areas. Where only one is discussed in this section, what is said about the one will be applicable to the other with only a modification of terms.

The complexity of the problem concerning the location of economic activity will depend on the assumptions made with respect to products, the nature of competition, relevant cost structures, and the stages of production considered. The more restrictive the assumptions, generally the simpler will be the analytical nature of the problem and the greater the abstraction from reality. However, valuable insights as to the nature of a theory and its applications to problems may be gained by analyses based on restrictive assumptions and the effects of relaxing some of those assumptions.

In the most restrictive case, consider the geographic structure of prices paid to producers for a homogenous product sold under competitive conditions in a single consuming center with discrete transportation costs proportional to distances. In such a case the geographic structure of

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[8] Edgar M. Hoover, The Location of Economic Activity (New York, 1948), p. 49.

prices paid to producers would be the familiar Von Thunen circles.[9] Assuming no discrimination among producers, the concentric circles would still exist in the absence of pure competition.

The delineation of supply areas where there are multiple consuming centers, not sufficiently isolated to be independent, will depend on the relative sizes of the consuming centers and the nature of transportation costs.[10] If two consuming centers were the same size and transportation costs were uniform, then a straight line equidistant from the two consuming centers would be the boundary of their respective supply areas. If the consuming centers were of different sizes, then the dividing line between the two supply areas would be a hyperbola rather than a straight line.[11] The effect of long-haul economies in transportation would be to increase the curvature of the boundary between two areas.[12] The existence of consuming centers of different sizes and transportation economies will lead to the existence of irregularly shaped supply areas.

The above situations involved the delineation of market and supply areas for single and multiple centers of assembly and distribution. Processing costs were ignored or assumed constant. If economies of scale exist, such economies will affect the delineation of the markets. Assume,

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[9]Leo V. Blakley, Theoretical Considerations of Intermarket Price Alignment for Milk, Oklahoma Agricultural Experiment Station, Agricultural Economics Paper No. 6514 (Stillwater, 1965), p. 2.

[10]At this point no consideration is being given to processing costs. The same conclusions would hold, however, if one considered processing costs and assumed that they were independent of volume.

[11]Blakley, p. 10.

[12]Hoover, p. 53.

for example, that raw material sites and consumption sites are given, assembly and distribution costs are proportional to distance, economies of scale exist, and existing plants are unequal in size.

In Figure 6, market areas for three plant sizes are illustrated. Plant A is assumed to be the largest plant and plant C is the smallest. Plant B is intermediate in size. Demand and supply areas for the plants will not have the conventional hexagonal shape, but will have irregular shapes. The shape will depend on the extent of the economies of scale and supply and demand concentration. The boundary lines of the territory which might be served by each plant in Figure 6, for example, will be located closest to plant C, the smallest plant operating without benefit

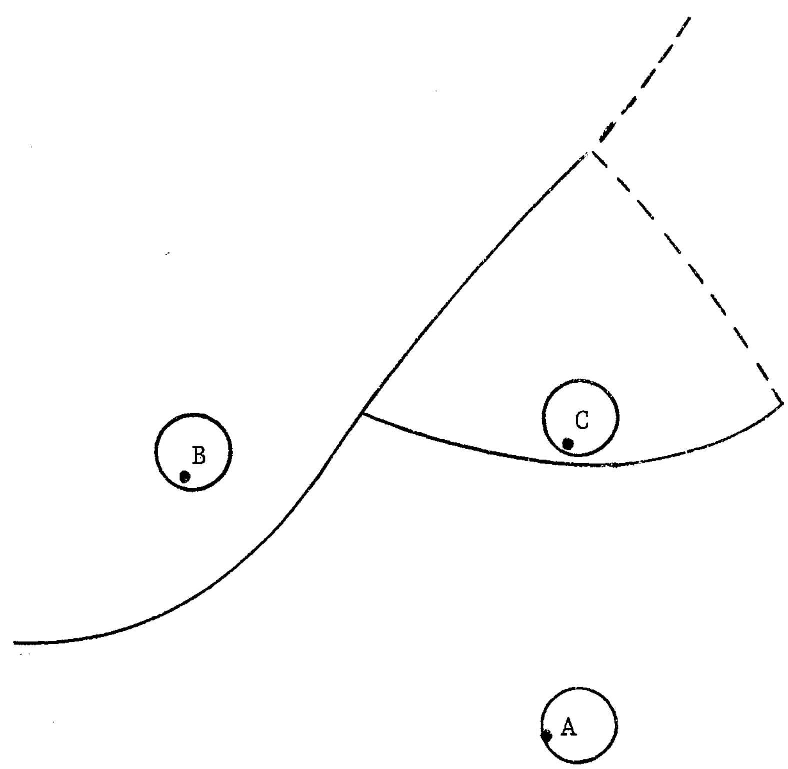

Figure 6. Market Areas of Three Processing Plants with Unequal Processing Costs

of economies of scale. The boundary between plant A and B will be located closest to plant B. The ultimate effects of economies of scale in processing where transportation costs are proportional to distances will be the same as long-haul economies in transportation.

If the quantity processed at one processing plant (Plant A) were sufficiently greater than the quantity processed at another processing plant (Plant C), then as distance increased, the distribution cost differential could be offset by scale economies in processing and the larger processing plant would have the entire market area to itself. The broken lines in Figure 6 illustrate the outer boundary for Plant C under this situation.

The size and location of processing plants that would minimize total market cost is a function of assembly and distribution costs, scale economies in processing, supply density, and demand density. The assembly and distribution cost functions to be used in the study will be developed first.

Assembly Costs

Assembly costs were defined as those costs involved in moving the milk from the farm to the processing plant. In Oklahoma, assembly costs are based on zone rates per 100 pounds of milk. In the Oklahoma City milkshed, the distance intervals of the zones increase as distance increases and costs per 100 pounds of milk assembled increases with distance. In the Tulsa milkshed assembly costs are based on five mile zones beyond 20 miles. Assembly costs per 100 pounds are constant for the first 20 miles but increase with distance for zones beyond 20 miles from Tulsa.

Recent studies of hauling charges of fluid milk shipped in bulk tank trucks have reported transportation charges ranging from 14 to 20 cents per 100 pounds of milk per 100 miles for long distance hauling fluid milk.[13] The cost per 100 pounds in each case was influenced by the size of load hauled and the distance hauled. The cost of shipments over shorter distances were higher because of the expenses associated with hauling that were independent of the distance shipped. The results of one study indicated that assembly costs per 100 pounds per 100 miles were lower for larger loads.[14]

To determine an assembly cost function for use in this study, assembly cost functions obtained in previous studies were compared with the existing assembly cost structure in Oklahoma. The function obtained by West and Brandow was selected for use in this study and is as follows:

$$(3.1) \quad C^A_{ij} = 0.12 + .0013X_{ij} \qquad X_{ij} \leq 400$$

$$= .0016X_{ij} \qquad X_{ij} > 400$$

where

C^A_{ij} = assembly cost, dollars per 100 pounds

X_{ij} = shortest highway distance between i and j, miles.

The relationship between the function in (3.1) and the 1965 assembly cost structure in Oklahoma is illustrated in Figure 7. The West and

[13] D. A. West and G. E. Brandow, Equilibrium Prices, Production, and Shipments of Milk in Dairy Regions of the United States, 1960, Pennsylvania, Agricultural Experiment Station A.E. and R.S. 49 (University Park, 1964), pp. 67-68.

[14] Ibid., p. 69.

Brandow function gives lower assembly cost per 100 pounds than was charged in Oklahoma in 1965. The 1965 charges for assembly of fluid milk in Oklahoma were based upon relatively short assembly distances as indicated by the constancy of the charge for assembly beyond 50 miles. It is doubtful that increasing quantities of milk could be assembled for a constant charge per 100 pounds for the area beyond 50 miles from the market. Since this study will include the possibility of long-distance assembly, the function relating rate to distance was used rather than the actual rates.

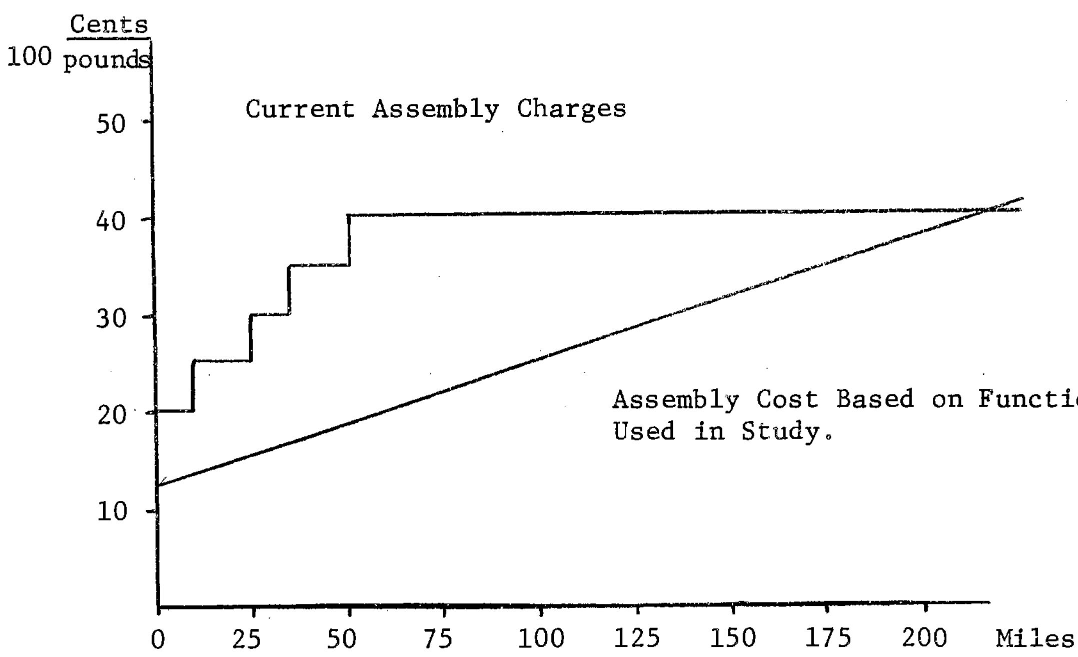

Figure 7. Hauling Charges for One Oklahoma Firm in 1965 and the Assembly Costs Assumed for This Study

Distribution Costs

Distribution costs were defined as those costs involved in moving the packaged milk from the processing plants to market centers away from the plant. No consideration was given to distribution costs within the market since these costs would have depended upon the particular methods of distribution employed in the various markets and would have existed independent of plant location within the State.

Defined in this way, labor costs and truck costs were the only costs involved in distribution costs. Truck costs included fixed costs that were independent of the miles driven and of variable costs which were a function of the number of miles driven. Labor costs had both fixed and variable components and were defined as a function of the number of miles driven and the volume of milk hauled.

The computation of a distribution cost function required the specification of the type of delivery truck, labor time for handling the milk, driving time, wage rates, length of delivery day, and the composition of the load of milk with respect to container type. The physical and cost elements used to compute the distribution cost function in this study are given in Table IX. Distribution costs, C^D, were estimated as

$$C^D = \text{average fixed cost per day} + (\text{variable truck cost per mile})(\text{miles driven}) + (\text{variable labor cost per mile})(\text{miles driven}) + (\text{labor cost per pound})(\text{pounds delivered}).$$

Fixed truck costs consisted of depreciation, interest, insurance, taxes, and licenses. Fixed costs for a gasoline tractor-trailer truck with a net load of 40,000 pounds had been estimated by Cobia and Babb.[15] Since these estimates were consistent with Oklahoma costs (based on discussions with processors in Oklahoma), they were used in this study. Annual fixed costs for trucks, as estimated by Cobia and Babb, totaled \$4,201.15.[16] To obtain fixed truck cost per day, total fixed truck costs were divided by the number of delivery days. The number of delivery days used was 5 days per week, or 260 days per year.[17] The fixed truck cost per day was \$16.16. To obtain total daily fixed cost for the distribution cost equation, \$1.40 was added to the daily fixed truck cost to allow for a fixed labor charge associated with the driver check-in time of one-half hour. Fixed cost per day totaled \$17.56.

Variable truck costs per mile included fuel, oil, repairs, and tires. In interviews with Oklahoma processors, variable cost estimates made by Cobia and Babb appeared applicable for Oklahoma conditions. Variable truck costs per mile of 9.735 cents were used in the study.

Labor costs of distribution included the costs of loading and unloading the milk, the cost of unloading empty cases, and the cost associated with driving time. Estimates of the time for loading and unloading milk and unloading empty cases were obtained from three Oklahoma processors. On an 800-case load-equivalent, the estimates ranged from one and one-half manhours to three and one-half manhours for loading, three

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[15] D. W. Cobia and E. M. Babb, Determining the Optimum Size Fluid Milk Processing Plant and Sales Area, Purdue University Agricultural Experiment Station Research Bulletin 778 (Lafayette, 1964), p. 12.

[16] Ibid.

[17] Processors interviewed were delivering 5 days per week and stated that they expected to continue this practice.

to five manhours for unloading, and three-fourths to two manhours for unloading empty cases. The estimates used in the study, and listed in Table IX, were intermediate within these ranges. The unloading time involved one stop per load. Driver time was a function of the estimated average driving speed. An average driving speed of 40 miles per hour was estimated by Oklahoma processors for average road conditions in the State in 1965.

TABLE IX

PHYSICAL CHARACTERISTICS, HOURS, AND WAGE RATES USED TO COMPUTE DISTRIBUTION COST

Item	Magnitude or Description
Delivery Days Per Week	5
Type Tractor	Gas
Maximum Net Weight of Load (pounds)	40,000
Average Driving Speed (MPH)	40
Hourly Wage Rate for Truck Driver (dollars)	2.80
Average Load (16-quart cases)	800
Maximum Length of Delivery Day (hours)	10
Average Load Time (hours)	2
Average Unload Time (hours)	4
Average Time for Unloading Empty Cases (hours)	1
Hourly Wage Rate for Loading (dollars)	2.00
Hourly Wage Rate for Unloading (dollars)	2.40
Hourly Wage Rate for Unloading Empty Cases (dollars)	2.00
Driver Check-in Time (hours)	0.50

It was also necessary to estimate wage rates in order to estimate costs. The wage rate for loading the milk and unloading empty cases was assumed to be \$2.00 per hour, approximately the same as the average hourly wage rate for the food industry in Oklahoma.[18] The truck driver's wage was assumed to be \$2.80 per hour and was based on data obtained in interviews with Oklahoma processors. The hourly wage rate for unloading the milk was assumed to be an average of the rate for the driver and the rate for one man at the distribution point who was paid the average hourly wage for the food industry.

Once the hour requirements had been estimated, labor costs were determined by applying wage rates to the time requirements. Fixed labor costs for handling the milk and empty cases were equal to \$15.60 per 800-case equivalent-load. Variable labor cost was \$0.07 per mile for the driver labor.

The total cost of distributing the 800-case load (40,000 pounds) was obtained from the following equation:

$$(3.2) \quad C_{ij}^{D} = \$17.56 + \$0.09735M_{ij} + \$0.700M_{ij} + \$0.00057\ Q$$

where

$\$17.56$ = daily fixed cost,

$\$0.09735$ = variable truck cost per mile,

$\$0.0700$ = variable labor cost per mile,

$\$0.00057$ = labor cost per pound shipped,

M_{ij} = twice the distance in miles between i and j,

Q = pounds shipped.

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[18] Oklahoma Employment and Security Commission, Oklahoma Labor Market, December, 1965 (Oklahoma City, 1965), p. 23.

Given a maximum length of the delivery day of 10 hours, a limit was imposed on the distance that a single driver could deliver milk in one day. It was assumed that the driver's time was not employed in loading the milk or unloading the empty cases. However, two hours of the driver's time were employed in unloading the milk at distribution points. Considering the driver's check in time of one-half hour and two hours unloading, seven and one-half hours of driver's time remained for driving. At an average speed of 40 miles, one driver could drive 300 miles or deliver milk to a distribution point 150 miles from the processing point.

It was assumed that if the distribution point were greater than 150 miles from the processing point an extra driver would be placed on the truck. This would permit delivery to points up to 350 miles from the processing point in a single day. In the distribution cost function, the variable labor cost per mile would be doubled. Delivery points greater than 350 miles from the processing point would require two days for delivery, and for these points fixed costs for delivery would be doubled. For various mileages, the distribution cost per pound obtained from equation (3.2) and based on a 40,000 pound load (27,520 pounds of milk excluding cases and containers) was as follows:

$$\text{(3.3)} \quad C^D_{ij} = \$0.0012 + \$0.000006M_{ij} \qquad M_{ij} \leq 150$$

$$= \$0.0012 + \$0.000007M_{ij} \qquad 150 < M_{ij} \leq 350$$

$$= \$0.0024 + \$0.000007M_{ij} \qquad M_{ij} > 350$$

where M_{ij} represents the distance in miles from the processing point i to the distribution point j.

Plant Costs

Short Run

The basic technical relationships of a firm are expressed in the production function. The production function assumes technical efficiency and expresses the maximum output (Y) that can be obtained from a given level of inputs (X_1, X_2, . . . ,X_n). Equation (3.4) represents a firm's short-run production function in which k inputs are variable and n-k inputs are fixed.

$$(3.4) \quad Y = f(X_1, \ldots, X_k/X_{k+1}, \ldots, X_n)$$

The short run is defined as a period of time in which the firm is unable to vary the quantity of some of the resources employed by the firm. It is assumed that equation (3.4) possesses continuous first and second order derivatives.

Cost functions express cost as a function of output. While production functions express the maximum output from a given quantity of inputs, cost functions express the minimum cost of producing a specific output, given the technical conditions of the production function and the input prices.

If W_i is the cost of the i^{th} variable input, the total cost outlay of a firm is given by

$$(3.5) \quad TCO = A + \sum_{i=1}^{k} W_i X_i$$

The cost of the fixed inputs that cannot be varied in the short-run is represented by A. Since a cost function expresses the minimum cost of producing a given output, minimization of the following function gives the firm's cost function based on a given production function and given input prices:

$$(3.6)\quad Z = A + \sum_{i=1}^{n} W_i X_i - \lambda \{Y_o - f(X_1, \ldots, X_k/X_{k+1}, \ldots, X_n)\}$$

Y_o represents an arbitrary level of output and λ is a Lagrangian multiplier.

First order conditions for the minimization of Z require that the partial derivatives of Z with respect to X_i and λ equal zero.[19]

$$(3.7)\quad \begin{aligned} \frac{\partial Z}{\partial X_1} &= W_1 - \lambda \frac{\partial f}{\partial X_1} = 0 \\ &\vdots \\ \frac{\partial Z}{\partial X_n} &= W_n - \lambda \frac{\partial f}{\partial X_n} = 0 \\ \frac{\partial Z}{\partial \lambda} &= Y_o - f(X_1, \ldots, X_k/X_{k+1}, \ldots, X_n) = 0 \end{aligned}$$

The equalities in (3.7) constitute a system of n + 1 equations in n + 1 unknowns, $(X_1, \ldots, X_n, \lambda)$. This system of equations can be solved for the optimal values of the n variable inputs and the Lagrangian variable, λ. The system (3.7) specifies that when the cost of producing Y_o is a minimum, the marginal physical product per dollar's worth of each of the X_i is equal. Since λ equals the ratio of each factor price to its marginal physical product, λ is equal to the marginal cost of production.

The conditions for minimizing the cost of producing an arbitrary level of Y are obtained from equation (3.6). To determine the firm's

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[19] See, James M. Henderson and Richard E. Quandt, Microeconomic Theory (New York, 1958), pp. 272-274, and R.G.D. Allen, Mathematical Analysis for Economists (New York, 1962), pp. 495-508 for second order conditions.

cost function, the firm's expansion path is needed. An expansion path is a function of the variable production inputs for which the first- and second-order conditions for the constrained maxima and minima are fulfilled. Equation (3.8) gives the expansion path.

$$H(X_1, X_2, \ldots, X_k) = 0 \tag{3.8}$$

Equations (3.4), (3.5), and (3.8) can be reduced to a single equation, (3.9), in which cost is stated as a function of output plus the costs of the fixed inputs, A.

$$C = C(Y) + A \tag{3.9}$$

This function specifies the minimum total cost of producing any level of output given the constraints of the fixed factors, the implied production function, and the input prices.

The cost functions that are important in decisions with respect to pricing and output can be obtained from equation (3.9). These cost functions are total variable cost (TVC), total fixed costs (TFC), average variable costs (AVC), average fixed cost (AFC), and marginal cost (MC). Respectively, these cost functions are given by:

$$TVC = C(Y) \tag{3.10a}$$

$$TFC = A \tag{3.10b}$$

$$AVC = \frac{C(Y)}{Y} \tag{3.10c}$$

$$AFC = \frac{A}{Y} \tag{3.10d}$$

$$MC = \frac{d\,C(Y)}{dY} \tag{3.10e}$$

If after certain input levels the law of diminishing returns holds for each of the variable inputs, then the cost curves of the equations in (3.10) will have the shapes given in Figure 8 and Figure 9. The law of diminishing returns states:

> "If the input of one resource is increased by equal increments per unit of time while the inputs or other resources are held constant, total product output increase will become smaller and smaller.[20]"

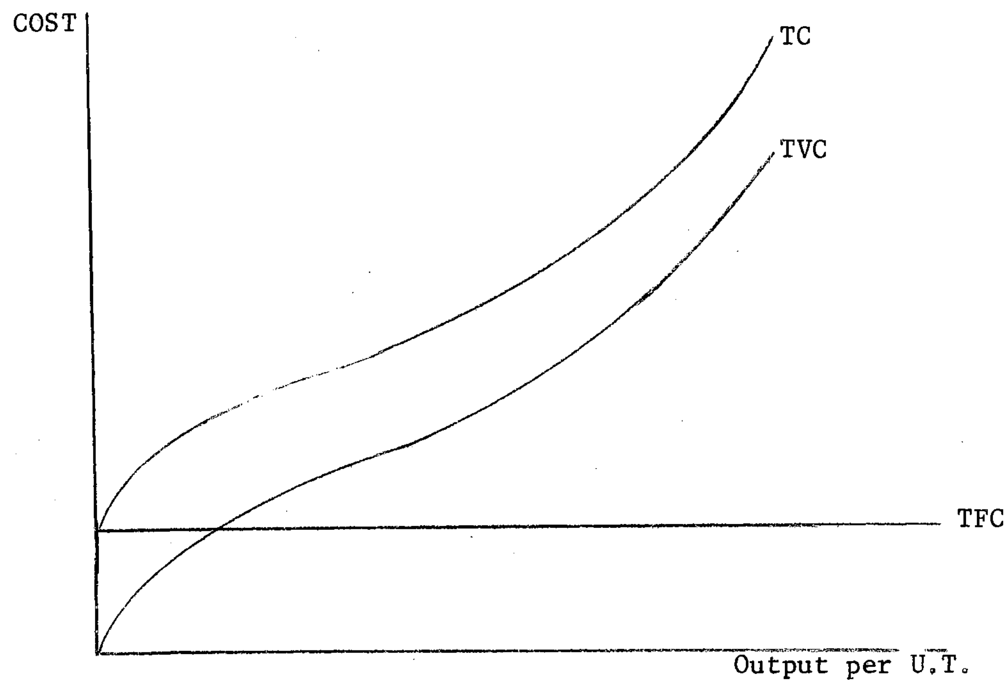

Figure 8. Theoretical Total Cost Curves

The U-shape of the short-run average and marginal cost curves can be explained in terms of the law of diminishing returns and the two

[20] Richard H. Leftwich, The Price System and Resource Allocation (New York, 1960), p. 109.

relationships $AVC = \frac{W}{APP}$ and $MC = \frac{W}{MPP}$ where APP and MPP denote average physical product and marginal physical product, respectively. Initial increases in the employment of a variable factor may result in increasing marginal and average physical products. When this occurs, marginal and average costs decline because of the inverse relationships existing between marginal physical product and marginal cost, and between average physical product and average cost. According to the law of diminishing returns, as successive units of an input are added, other factors of production constant, the marginal physical product of that factor will decline. When marginal physical product declines, marginal cost will

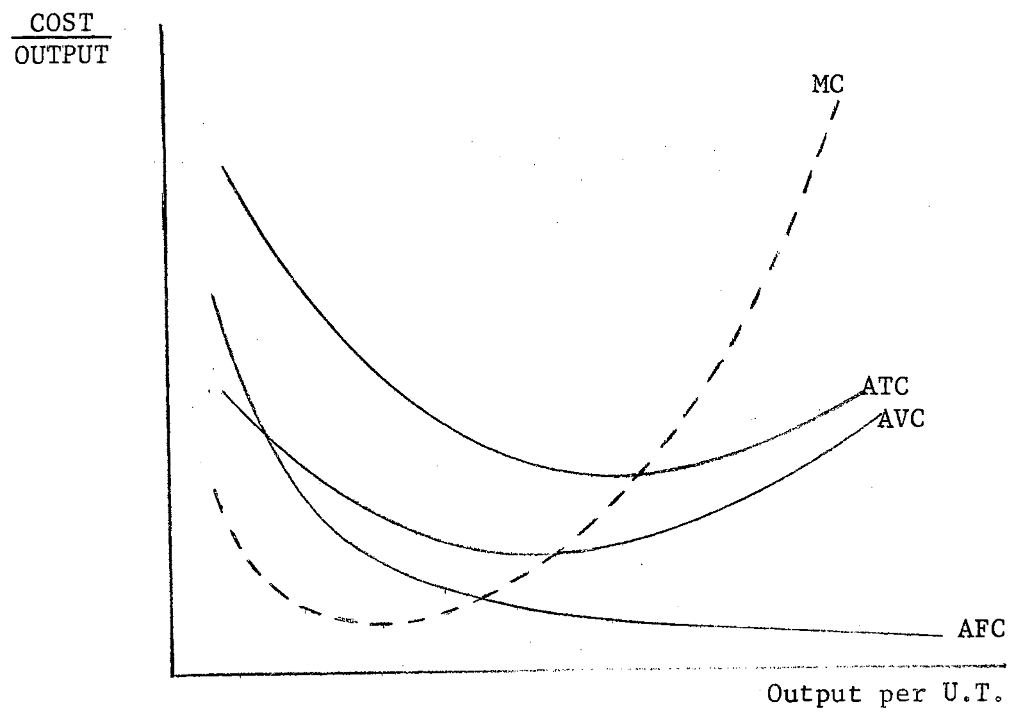

Figure 9. Theoretical Short-Run Cost Curves

increase. The average cost curve will decline until increasing marginal costs equal the declining average costs. Subsequent increases in output will result in marginal costs that are greater than average variable costs, and consequently, average variable costs will rise. The average fixed cost curve is a rectangular hyperbola. As output is increased, fixed costs are spread over a larger number of units and the average fixed cost curve declines monotonically.

Long Run

The long-run is a period of time long enough for the firm to vary the quantities of all resources used. In the long-run, there are no fixed factors and the production technique is variable. Associated with each plant size are certain fixed inputs, A. However, A will increase with plant size. In the short-run the problem is optimum utilization of a fixed plant. The long-run problem is that of determining the optimum size of plant.

The long-run cost function gives the minimum cost of producing a given output when the firm is free to vary the scale of plant. This function can be obtained from the firm's long-run production function, total cost equation, and expansion path. These are given respectively in (3.11), (3.12), and (3.13).

$$(3.11) \qquad Y = f(X_1, \ldots, X_k, A)$$

$$(3.12) \qquad TC = \sum_{i=1}^{n} W_i X_i + Y(A)$$

$$(3.13) \qquad 0 = H(X_1, \ldots, X_k, A)$$

Equation (3.14) expresses total cost as a function of output level and plant size.

$$(3.14) \qquad TC = P(Y,A) + (A)$$

Since it is assumed that A is continuously variable and since the long-run total cost curve gives the minimum cost of producing a given output when it can vary the scale of plant, the long-run total cost curve is the envelope of the short-run total cost curves. Similarly, the long-run average cost curve is the envelope to the short-run average cost curves. Kells states:[21]

> If f(X,Y,C) = 0 represents a one-parameter family of curves and E is a curve which contacts tangentially (has a common tangent with) every curve of the family f = 0, and contacts tangentially one or more curves of f = 0 at each of its points, then E is an envelope of f.

The function expressing long-run total cost as a function of output is obtained by eliminating A from

$$(3.15) \qquad F\,(Y,\ X,\ A) = 0$$

where

Y = output,

X = a vector of inputs,

A = scale parameter.

A is eliminated from (3.15) by first setting the partial derivative of (3.15) with respect to A equal zero.

$$(3.16) \qquad F_A(Y,\ X,\ A) = 0$$

Solve (3.16) for A and substitute the expression for A into (3.12) to obtain the long-run cost equation

$$(3.17) \qquad C = C(Y).$$

Long-run average and marginal costs can be obtained from equation (3.17).

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[21] Lyman M. Kells, Elementary Differential Equations (New York, 1965), p. 107.

Like the short-run average cost curve, the long-run average cost curve is usually thought to be U-shaped. The reason for the U-shape of the long-run average cost curve is not the same as for the short-run average cost curve. In the short-run, the U-shape of the average cost curve was explained in terms of the law of diminishing returns. The law of diminishing returns is not applicable to long-run cost curves, because there are no fixed factors of production in the long-run. A decrease in long-run average costs as output increases implies that larger scales of plant are more efficient than the smaller plants. A rising long-run average cost curve as output increases implies that larger scales of plant beyond a certain output level are less efficient than a scale of plant that is smaller.

The forces giving rise to decreasing long-run average cost are referred to as economies of scale and include such factors as increasing possibilities of division and specialization of labor, and increasing possibilities of using advanced technological developments, and/or larger machines.[22] The long-run average cost curve increases as output increases when diseconomies of scale more than offset the economies of scale. Diseconomies of scale are considered as limitations to the efficiency of management in controlling and coordinating a single firm.[23]

It is emphasized at this point that the above descriptions of long-run and short-run cost curves are strictly theoretical and may not agree with empirically determined cost curves. In fact, it has been suggested that cost curves of the types depicted in Figure 10 are most plausible

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[22]Leftwich, p. 156.

[23]Ibid., p. 157.

according to empirical evidence.[24] In Figure 10, average variable costs and marginal costs are constant. Hence, the average total cost curve approaches equality with average variable and marginal costs as output increases. In this study, processing costs were developed under the assumption of essentially constant marginal costs per unit of product which is closer to the relationships specified in Figure 10 than to those in Figure 9.

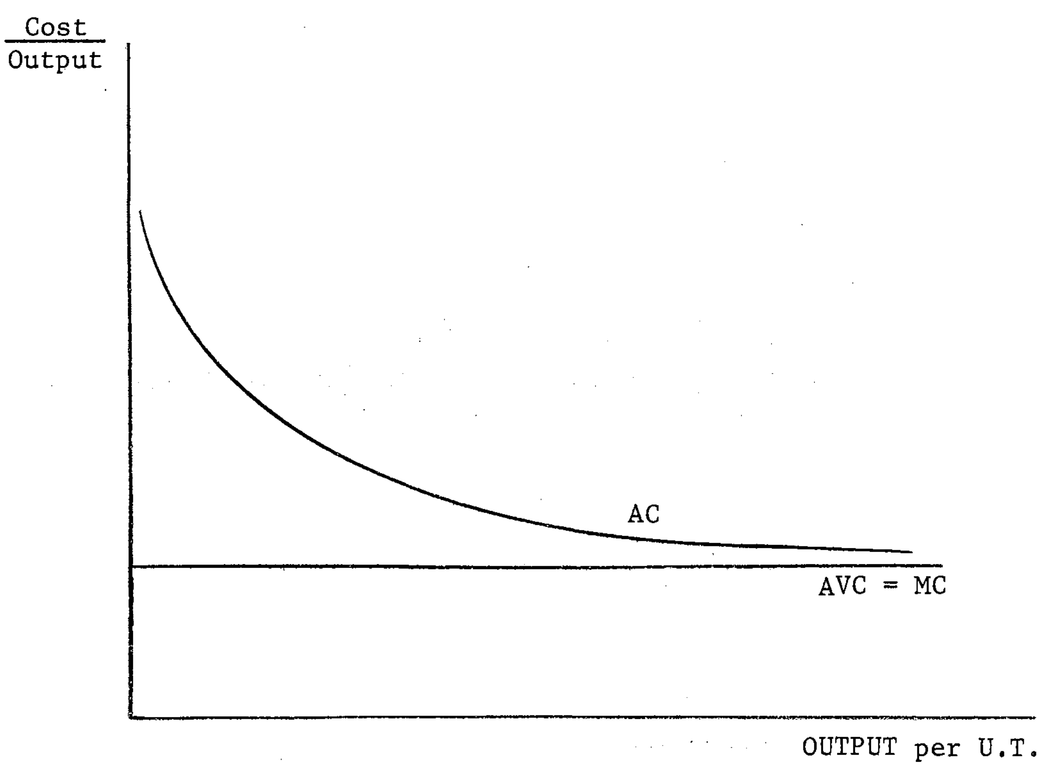

Figure 10. Theoretical Average and Marginal Cost Curves

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[24] John Johnston, Statistical Cost Analysis (New York, 1960), p. 13.

Processing Costs

Processing costs were defined as costs incurred in transforming the raw milk into the final packaged product ready for delivery. Several studies of the costs of processing fluid milk have been reported in recent years, and Cobia and Babb standardized the findings of a number of the studies.[25] One additional recent study not included in the results of Cobia and Babb was reported by Webster et al.[26] In most of the studies, the average processing cost curve was similar to the type illustrated in Figure 10 in which average processing cost per quart processed decreased as volume increased. In none of the studies did the processing cost actually reach a minimum point for the scale of plant budgeted.

The results of these previous cost studies appeared to be applicable to Oklahoma conditions, but interviews with managers of three of the larger processing plants in Oklahoma were conducted in order to verify the applicability. Detailed breakdowns of the costs were made for various volume levels in order that each manager could compare his costs with those reported in the studies. Each processor interviewed stated that, except for product mix and types of containers, the results of the study by Webster et al. were consistent with costs for his volume level under Oklahoma conditions. In May, 1965, for example, approximately 16 percent of the milk processed in the Oklahoma Metropolitan marketing area was packaged in glass, as compared with 45 percent of the milk packaged in glass in the study by Webster et al. (Table VI).

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[25] Cobia and Babb, pp. 5-9.

[26] Fred Webster et al., Economies of Size in Fluid Milk-Processing Plants, University of Vermont Agricultural Experiment Station Bulletin 636 (Burlington, 1963).

Because of the importance of cost of containers in the processing cost, container costs for the plant sizes in the Webster etal. study were recomputed based on the distribution of container sizes and type reported for the Oklahoma Metropolitan marketing area in 1965. The volume processed in containers of various sizes was determined from the percent of milk processed in various container sizes as reported earlier in Table VII. The volume processed by container types was determined from the percent of milk packaged in glass and in paper for each size of container as reported in Table X. Container costs were computed from the volume data and the estimated prices per unit for each container type. The prices of paper containers were obtained from the price list furnished by Dairy Pak, Cleveland, Ohio. The prices of glass containers were obtained from Liberty Glass Company, Sapulpa, Oklahoma, and it was assumed that each glass container would make an average of 12 trips.

The recomputations resulted in container costs for plants in Oklahome which were higher than for the plants in the Webster et al. study. The higher costs reflected the higher percentages of volume packaged in paper in Oklahoma than in the Northeast.

The container costs also provided a lower limit for estimates of minimum processing costs for extremely large scale plants. In previous studies, processing costs per unit declined as quantity processed increased over the range of volumes investigated. However, a lower limit would be reached when average processing cost per unit approached the minimum container cost per unit. Under the 1966 price structure for containers, the minimum processing cost for a plant processing 27 million quarts per year, would be 1.31 cents per quart for the distribution of container sizes and types in the Oklahoma Metropolitan marketing area in

TABLE X

PERCENTAGES OF GLASS AND PAPER CONTAINERS, OKLAHOMA CITY METROPOLITAN MILK MARKETING AREA, AVERAGE MAY 1965 AND NOVEMBER 1965

Container Size	Glass	Paper
	Percent	
Gallon	25.785	74.215
Half Gallon	13.065	86.935
Quart	19.98	80.02
Pint and One-third Quart	.335	99.665
Half Pint	2.155	97.845

Source: Market Administrator's Bulletin, Oklahoma Metropolitan and Red River Valley Marketing Areas, October 1965 and May 1966.

1965, Appendix B, Table I. The lowest minimum cost per quart for paper containers would be 1.27 cents per quart with all milk packaged in gallon containers. Minimum cost per quart for one-half gallon containers would be 1.3 cents per quart.

In estimating the cost function in this study, it was assumed that the processing cost per quart could not fall below 1.8 cents. This estimate was based on an equivalent minimum container cost of 1.3 cents per quart and on the assumption that the total of the remaining costs of processing would not fall below 0.5 cents per quart equivalent. With the restriction imposed by this minimum of 1.8 cents, an equation of the form $C^P = aQ^b + K$ was fitted to the data in the Webster et al. study. The resulting equation was as follows:

$$(3.18) \qquad C^P = 2.979\ Q^{-0.4144} + .837 \qquad R^2 = .988$$

where

C^P = processing cost per pound (cents),

Q = million pounds processed annually.

The results in equation (3.18) differed from the results obtained by Cobia and Babb when no restrictions on the minimum level of processing costs were imposed. Costs given by equation (3.18) declined more rapidly with increasing output than for any of the functions obtained by Cobia and Babb.[27] However, the equations represented different time periods and product-mixes. The studies standardized by Cobia and Babb involved the adjustment of each cost element to a 1961 price level by an appropriate price index. Also processing costs were not adjusted for differences in product mix. In this study, the 1965 time period and product mix have been utilized.

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[27]The equation obtained for all observations used by Cobia and Babb was $C^P = 12.505\ Q^{-0.11142}$, Cobia and Babb, p. 8.

CHAPTER IV

SPATIAL EQUILIBRIUM MODELS

In recent years mathematical programming models such as linear programming, transportation models, reactive programming, and others have been used to solve transhipment problems. In this chapter, some of the models and their limitations will be discussed. Particular emphasis will be given to the limitations of these models in relation to the type of problem under consideration, namely, minimizing assembly, processing, and distribution costs when economies of scale exist in processing. Finally, a model for solving the problem under consideration will be presented.

Linear programming is concerned with the optimization of a linear function subject to linear constraints. The general linear programming problem can be stated as:

$$\begin{aligned} &\text{optimize} \quad Z = C'X \\ (4.1) \quad &\text{subject to } AX \leq B \\ &\qquad\qquad X \geq 0 \end{aligned}$$

where X is a (Nxl) vector of activities, A is a (MxN) matrix of known constants, B is a (Mxl) vector of known constants, C is a (Nxl) vector of known constants, and Z is the value to be optimized.

There may be several solutions to the system (4.1). The only solutions that are meaningful, however, are the feasible solutions. A feasible solution is a solution that does not violate any of the constraints, $AX \leq B$. If there exists one or more feasible solutions and the objective function and the constraints are linear, an optimum solution can always be found for (4.1) using linear programming procedures. If, however, the constraints are nonlinear, linear programming methods will not insure optimum solutions to programming problems.

When the objective function is nonlinear, there are two cases to be considered. If the objective function is concave, linear programming procedures can be used to solve maximization problems. Minimization problems can be solved if the objective function is convex. Solutions to maximization and minimization problems are based on the assumption of a convex feasible region. In economic terms, these conditions imply that problems can be solved when the feasible region is convex and there are constant or decreasing returns. Therefore, problems with increasing-returns cost functions cannot be handled satisfactorily with linear programming procedures.

Credit for the formulation of the transportation model is generally given to Koopmans and Hitchcock.[1] Koopmans and Hitchcock were concerned with the following problem: to determine the shipping pattern that would minimize total shipping costs when a specified number of ships is to be sent from a number of ports to a specified number of receiving ports where the unit costs of shipping and the total volume shipped to each port is specified.

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[1]Tjalling C. Koopmans, "Optimum Utilization of the Transportation System," Proceedings of the International Statistical Conferences (Washington, 1947), Frank L. Hitchcock, "The Distribution of a Product from Several Sources to Numerous Localities," Journal of Mathematics and Physics, XX (1941), pp. 224-230.

Algebraically, the transportation problem can be stated as finding a set of $X_{ij} \geq 0$ such that

$$(4.2a) \quad Z = \sum_{j=1}^{m} \sum_{i=1}^{n} C_{ij}X_{ij} = \text{minimum}$$

subject to

$$(4.2b) \quad \sum_{j=1}^{m} X_{ij} = a_i \qquad (i = 1, \ldots, n)$$

$$(4.2c) \quad \sum_{i=1}^{n} X_{ij} = b_j \qquad (j = 1, \ldots, m)$$

$$(4.2d) \quad \sum_{i=1}^{n} a_i = \sum_{j=1}^{m} b_j$$

where X_{ij} represents the amount of the products shipped from the i^{th} supply area to the j^{th} demand area; a_i is the amount of the product available for shipment from the i^{th} supply area, b_j is quantity demanded in the j^{th} location; and C_{ij} represents the per unit cost of shipping from region i to region j.

The transportation problem is a special case of the general linear programming problem. Expressed as a linear programming problem, the transportation model, equations (4.2), would be expressed as

$$(4.3a) \quad \text{minimize } Z = \sum_{j=1}^{m} \sum_{i=1}^{n} C_{ij}X_{ij}$$

subject to

$$(4.3b) \quad \sum_{j=1}^{n} X_{ij} \leq a_i$$

$$(4.3c) \quad \sum_{i=1}^{n} X_{ij} \geq b_j$$

$$(4.3d) \quad X_{ij} \geq 0$$

The advantage of using the transportation model rather than linear programming to solve the Koppmans-Hitchcock problem is that the transportation model is computationally more efficient.

The transportation model is limited in the scope of problems that it can handle. The formal characteristics which a problem must have if it is to be solved by the transportation procedure include:

> "1. One unit of any input can be used to produce one unit of any output.
> 2. The cost or margin which will result from conversion of one unit of a particular input into a particular output can be expressed by a single figure regardless of the number of units converted.
> 3. The quantity of each individual input and output is fixed in advance and the total number of inputs equals the total number of outputs."[2]

Leath and Martin have considered formulations of the transportation model which permit the introduction of time, storage, segmented production functions, and stepped supply functions.[3] Hurt and Tramel have developed formulations of the transportation model involving multiple products and multiple stages of processing.[4]

Samuelson has shown that the Koopmans-Hitchcock problem is a special case of a more general spatial equilibrium problem.[5] In the more general spatial equilibrium problem, the demand and supply curves for each of two or more localities are given. In addition, constant transport costs

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[2]Alexander Henderson and Robert Schlaifer, "Mathematical Programming - Better Information for Better Decision Making," Harvard Business Review (May-June, 1954), pp. 94-100.

[3]Mack N. Leath and James E. Martin, Formulations of the Transhipment Problem Involving Inequality Restraints, Oklahoma Agricultural Experiment Station Journal Paper (forthcoming).

[4]Verner G. Hurt and Thomas E. Tramel, "Alternative Formulations of the Transhipment Problem," Journal of Farm Economics, XLVII (1965), pp. 763-773.

[5]Paul A. Sameulson, "Spatial Price Equilibrium and Linear Programming," American Economic Review, XLII (1952), pp. 283-303.

for moving one unit of a product between any two of the specified localities are given. The problem is to determine the final competitive equilibrium of prices in all markets, the amounts supplied and demanded at each place, and the exports and imports. This more general problem can be solved by solving the dual of the linear programming formulation of the transportation problem in equations (4.3a) - (4.3d). The development of this dual is given in Dorfman, Samuelson, and Solow.[6] Since the solution is obtained using linear programming procedures, the model has the same restrictions with respect to increasing and decreasing returns as the linear programming model.

Studies by Henry and Bishop,[7] and Snodgrass and French[8] provide examples of the application and use of the transportation model. The application and use of the more general spatial model are demonstrated in studies by Fox,[9] and Judge and Wallace.[10]

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[6]Robert Dorfman, Paul A. Samuelson, and Robert M. Solow, Linear Programming and Economic Analysis (New York, 1958), pp. 122-127.

[7]W. R. Henry and C. E. Bishop, North Carolina Broilers in Interregional Competition, A. E. Series Number 56, North Carolina State College, Department of Agricultural Economics (Raleigh, 1957).

[8]Snodgrass and French.

[9]K. A. Fox, "A Spatial Equilibrium Model of the Livestock-Feed Economy of the United States," Econometrica, XXI (1953), pp. 547-566.

[10]G. G. Judge, and T. D. Wallace, Spatial Price Equilibrium Analyses of the Livestock Economy.

1. Methodological Development and Annual Spatial Analysis of the Beef Marketing Sector, Oklahoma Agricultural Experiment Station Technical Bulletin TB-78 (Stillwater, 1959).
2. Application of Spatial Analysis to Quarterly Models and Particular Problems within the Beef Marketing System, Oklahoma Agricultural Experiment Station Technical Bulletin TB-79 (Stillwater, 1959).
3. Spatial Price Equilibrium Models of the Pork Marketing System, Oklahoma Agricultural Experiment Station Technical Bulletin TB-80 (Stillwater, 1960).

Reactive programming is another model used to solve spatial equilibrium problems. This model was developed by Tramel and Seale, and is defined as "a means of obtaining the equilibrium flows of a commodity between areas with given transportation cost functions, given demand schedules in each of several areas of consumption, and given supply schedules in each of several areas of production."[11] The reactive programming model, like the spatial equilibrium model, permits the determination at one and the same time of the equilibrium quantities in each consuming area and the least cost route of providing these quantities from each of the producing areas. Reactive programming does not consider processing enroute. Reactive programming models, however, will determine the optimum market organization and resource allocations where supply and demand functions are linear or linear in logarithms.

In the above models, the number and location of supply and demand areas are taken as given. If the supply areas are sources of raw materials and if the demand areas are processing plants, the models assume that the number of processing plants and their locations are given. The location of raw material supply is also assumed to be fixed.

Stollsteimer developed a model where plant numbers and locations can be included as variables and economies of scale in plant costs can be considered.[12] Since plant numbers and locations can be considered

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[11]Thomas E. Tramel and A. D. Seale, Jr., "Reactive Programming of Supply and Demand Relations - Applications to Fresh Vegetables," Journal of Farm Economics, XLI (1959), p. 1012.

[12]John F. Stollsteimer, "A Working Model for Plant Numbers and Locations," Journal of Farm Economics, XLV (1963), pp. 631-645.

as variables, the Stollsteimer model is amenable to the analysis of long-run problems. The Stollsteimer model determines simultaneously the number, size, and location of processing plants that minimize the combined transportation and processing cost involved in assembling and processing any given quantity of raw material from a number of scattered points. Likewise, the model will determine the optimum number and location of processing plants when processing and distribution costs are considered. It will not, however, determine the system that minimizes assembly, processing, and distribution costs. Polopolus has extended Stollsteimer's model to encompass the multiproduct case.[13] The Stollsteimer model has been used in empirical studies by Stollsteimer,[14] Mathia and King,[15] and Peeler.[16]

The logical extension from the Stollsteimer model is a model that will determine simultaneously the optimum number, size, and location of processing plants that will minimize assembly, processing, and

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[13]Leo Polopolus, "Optimum Plant Numbers and Locations for Multiple Product Processing," _Journal of Farm Economics_, XLVII (1965), pp. 287-295.

[14]John F. 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," (unpub. Ph.D. dissertation, University of California, 1961).

[15]G. A. Mathia and R. A. King, _Planning Data for the Sweet Potato Industry: Selection of the Optimum Number, Size, and Location of Processing Plants in Eastern North Carolina_, A. E. Series Number 97, North Carolina State College, Department of Agricultural Economics (Raleigh, 1963).

[16]R. J. Peeler, "Effects of Assembly and In-Plant Cost on the Optimum Number, Size, and Location of Egg Grading and Packing Plants in North Carolina," (unpub. Ph.D. dissertation, North Carolina State College, 1963).

distribution costs. Martin has formulated a "production-distribution" model that can be used for such a problem.[17]

The problem to be solved is the following: given n production regions, L potential plant locations and m demand or market areas, what should be the number, size, and location of processing plants to minimize assembly, processing, and distribution costs. It is permissible to have producing and consuming areas which are identical geographically. This is true for all combinations of factor supply, processing, and demand areas. If any of these areas are the same geographical area, the transfer cost between the areas is zero.

The production-distribution model will determine the optimum number, size, and location of processing plants to minimize assembly, processing, and distribution costs, given the following assumptions:

1. The supply of the raw material and demand for the final product are known.
2. The processing capacity in each processing area is known.
3. Per unit assembly, processing, and distribution costs are independent of volume.

Three basic types of restrictions in the model are: (1) market restrictions, (2) production restrictions, and (3) factor supply restrictions. These restrictions will be discussed in that order.

Market Restrictions: In each of the m demand areas there is assumed to be a known quantity demanded for the final product of X_{di} ($i = 1, \ldots, m$). The market restriction for each market is that the

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[17] James E. Martin, <u>The Effects of Changes in Transportation Rates on the Delmarva Poultry Industry</u>, Miscellaneous Publication No. 515, Maryland Agricultural Experiment Station (College Park, 1964).

sum of the quantity of product shipped from the producing areas to demand area i must equal the demand in area i.

In equation form, the restriction is:

$$(1) \quad X_{di} = \sum_{k=1}^{L} X_{ik} \qquad (i = 1, \ldots, m)$$

where

X_{di} = the total amount of product required in demand area i.

X_{ki} = amount of product shipped from producing area k to demand area i.

L = the number of producing areas.

Production Restrictions: Restrictions in the producing or processing sector are affected by four factors: (1) the processing capacity in each area, (2) the production function in each area, (3) the quantity of the factors of production (raw milk in this study) received in each area, and (4) the amount of product shipped from the producing area. Basically the production restrictions state:

1. The output in producing area k cannot exceed the processing capacity in area k.
2. The output in producing area k cannot be greater than that limited by the production function and amount of factor(s) available in area k.
3. The amount of product shipped from producing area k to the m demand areas cannot exceed the amount of product produced in area k.

In equation form, these restrictions are:

$$(2) \quad X_k^m \geq X_k \qquad (k = 1, \ldots, L)$$

$$(3) \quad X_k = \text{Min}\ (A_{fk}\ S_{fk}) \qquad (f = 1, \ldots, L)$$

(4) $X_k \geq \sum_{i=1}^{m} X_{ik}$ $\quad (k = 1, \ldots, L)$

(5) $S_{fk} = \sum_{j=1}^{n} S_{fkj}$ $\quad (f = 1, \ldots, L)$ $(k = 1, \ldots, L)$ $(j = 1, \ldots, n)$

where

X_k^m = maximum processing capacity in area k.

X_k = total amount processed in area k.

A_{fk} = input-output coefficient for factor f in producing area k.

S_{fk} = total amount of factor f available in area k.

S_{fjk} = amount of factor f shipped from factor supply area j to producing area k.

Factor Supply Restrictions: Basically, factor supply restrictions specify that the amount of a factor shipped out of a factor supply area cannot exceed the amount of factor available in that area.

In equation form, the restriction is:

(6) $S_{fj}^m \geq S_{fj}$ $\quad (f = 1, \ldots, h)$ $(j = 1, \ldots, n)$

(7) $S_{fj} = \sum_{k=1}^{L} S_{fkj}$ $\quad (f = 1, \ldots, h)$ $(j = 1, \ldots, n)$

where

S_{fj}^m = maximum amount of factor f available in factor supply area j.

S_{fj} = total amount of factor f shipped out of factor supply area j.

The objective of the model is to minimize assembly, processing, and distribution costs, i.e., the total cost of moving the factor from the factor supply area to the processing area, processing the final product, and moving the final product to the demand areas.

In equation form, the objective of the model is:

$$(8) \quad \text{Minimum } Z = \sum_{i=1}^{m} \sum_{k=1}^{L} C_{ik} X_{ik} + \sum_{k=1}^{L} P_k X_k + \sum_{f=1}^{h} \sum_{k=1}^{L} \sum_{j=1}^{n} T_{fkj} S_{fkj}$$

where

C_{ik} = per unit cost of shipping the final product from processing area k to market area i.

P_k = per unit processing cost in producing area k.

T_{fkj} = per unit cost of shipping factor f from factor supply area j to producing area k.

Other factors have been defined previously. The matrix format of the production-distribution model is given by Martin.[18]

The problem considered in this study is the determination of the optimum number, size, and location of processing plants to minimize assembly, processing, and distribution costs when economies of scale exist in the processing operation. The solution to this problem requires an extension of the production-distribution model. This extension can be accomplished with a technique known as separable programming.[19]

Consider the problem of minimizing assembly, processing, and distribution cost when the average processing costs (AC) can be represented by the function

$$(4.4) \quad AC = aQ^{-b} + K$$

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[18] Ibid., p. 46.

[19] Clair E. Miller, "The Simplex Method for Local Separable Programming," Recent Advances in Mathematical Programming, ed. R. L. Graves and P. E. Wolfe (New York, 1963), pp. 89-100.

where

K is a constant that average cost (AC) approaches asymtotically as Q approaches infinity,

Q is the quantity processed.

The graph of an average cost curve of the nature given in equation (4.4) is presented in Figure 10. The total cost curve for the average cost curve in equation (4.4) is presented in Figure 11.

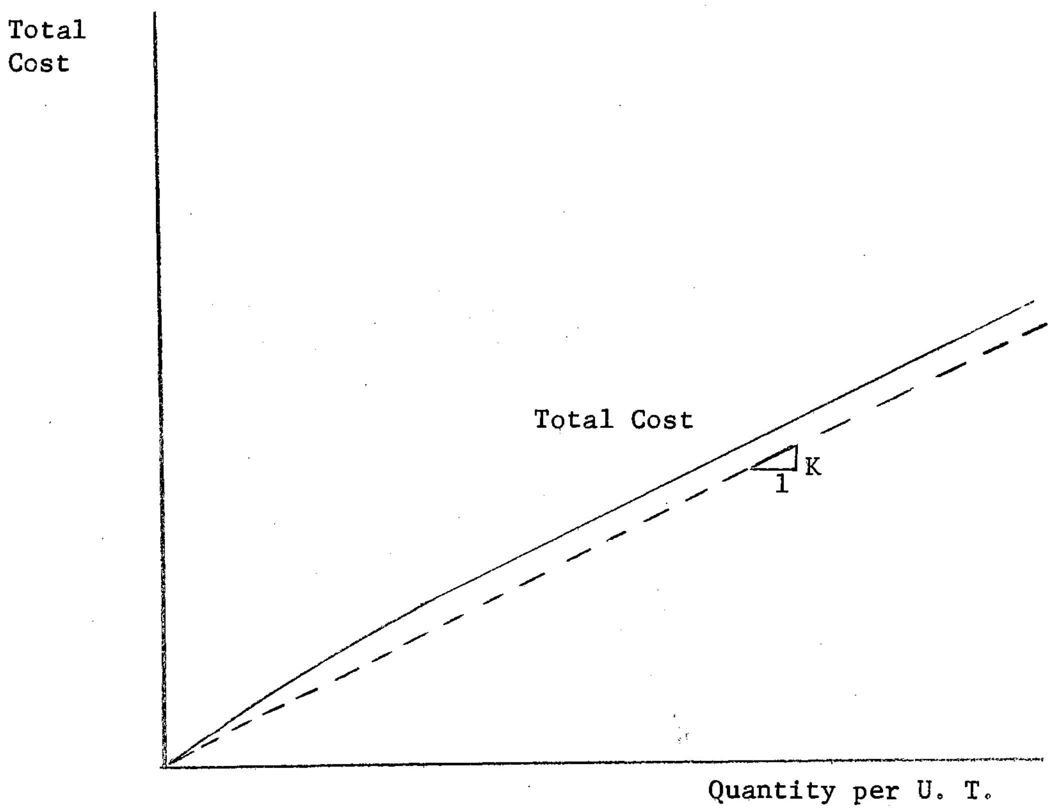

Figure 11. Total Cost Curve Representative of the Cost Function Used in This Study.

In the discussion of linear programming, it was stated that for linear programming procedures to provide solutions to minimization problems, the objective function must be convex. The total cost curve in Figure 11 is concave, i.e., a line segment connecting any two points on the function lies below the connecting arc. Although this curve represents only processing cost, the total of assembly, processing, and distribution costs probably is concave within some range of the function for an average processing cost as given in equation (4.4). Normal linear programming procedures, therefore, can not be used to solve the production-distribution model which includes economies of scale in processing.

Separable programming is a technique which can be used to solve the non-linear problem if the non-linear function is a function of a single variable. The non-linear function under consideration in this study is a function of only one variable. Therefore, an integration of the separable programming algorithm with the production-distribution model can give an extended production-distribution model which permits consideration of economies of scale in processing in the process of minimizing assembly, processing, and distribution costs. Assumptions of the extended production-distribution model are:

1. Demand in each of the market areas is known.
2. The quantity of resources in factor supply areas is known.
3. Per unit assembly and distribution costs are known and are independent of volume shipped.
4. The processing capacity in each producing area is known.

The market, production, and resource restrictions are the same for the extended production-distribution model as for the regular production-distribution model. The difference between the extended form of the production-distribution model and the regular production-distribution model is in the objective function. The objective of the extended production-distribution model is to minimize assembly, processing, and distribution costs when processing cost in each producing area is a function of the quantity processed in the area. In equation form, the objective is:

$$(4.8) \quad \text{Minimum } Z = \sum_{i=1}^{m} \sum_{k=1}^{L} C_{ki} X_{ki} + \sum_{k=1}^{L} \beta(X_k) X_k + \sum_{f=1}^{h} \sum_{k=1}^{L} \sum_{j=1}^{n} T_{fjk} S_{fjk}$$

where

X_{ki} = amount of product shipped from producing area k to demand area i.

C_{ki} = per unit cost of shipping the product from producing area k to demand area i.

X_k = total amount of product processed in producing area k.

$\beta(X_k)$ = function expressing the per unit cost of processing quantity, X_k, in area k.

S_{fjk} = amount of factor f shipped from factor supply area j to producing area k.

The extended production-distribution model is solved using the modified simplex procedure discussed in Appendix A.

CHAPTER V

ANALYSIS AND RESULTS

The Area

The area included in the analysis of this study was the state of Oklahoma with the exception of three counties (Figure 12). Excluded from the analysis were Cimarron, Texas, and Beaver counties located in the panhandle. The reason for excluding the three counties from the analysis was that almost 100 percent of the milk produced in the three county area has been sold in marketing orders outside Oklahoma. Also, the processed milk sold in the three counties has been processed primarily in either Kansas or Texas.

The magnitude of the spatial dimension involved in this study was measured in miles between counties. To determine assembly and distribution distances between counties, a base point was selected within each county. The city selected as the base point in each county was selected on the basis of population and geographic location within the county. An attempt was made to select as base points the cities with large populations, relative to other cities in the county, which were located in the center of the county. In some cases, however, cities with up to as much as 50 percent of the population were not located near the geographic center of the county. In such cases, the base point was chosen on the basis of population alone. The base point for each county is given in Appendix B, Table XI. Distances between base points were obtained

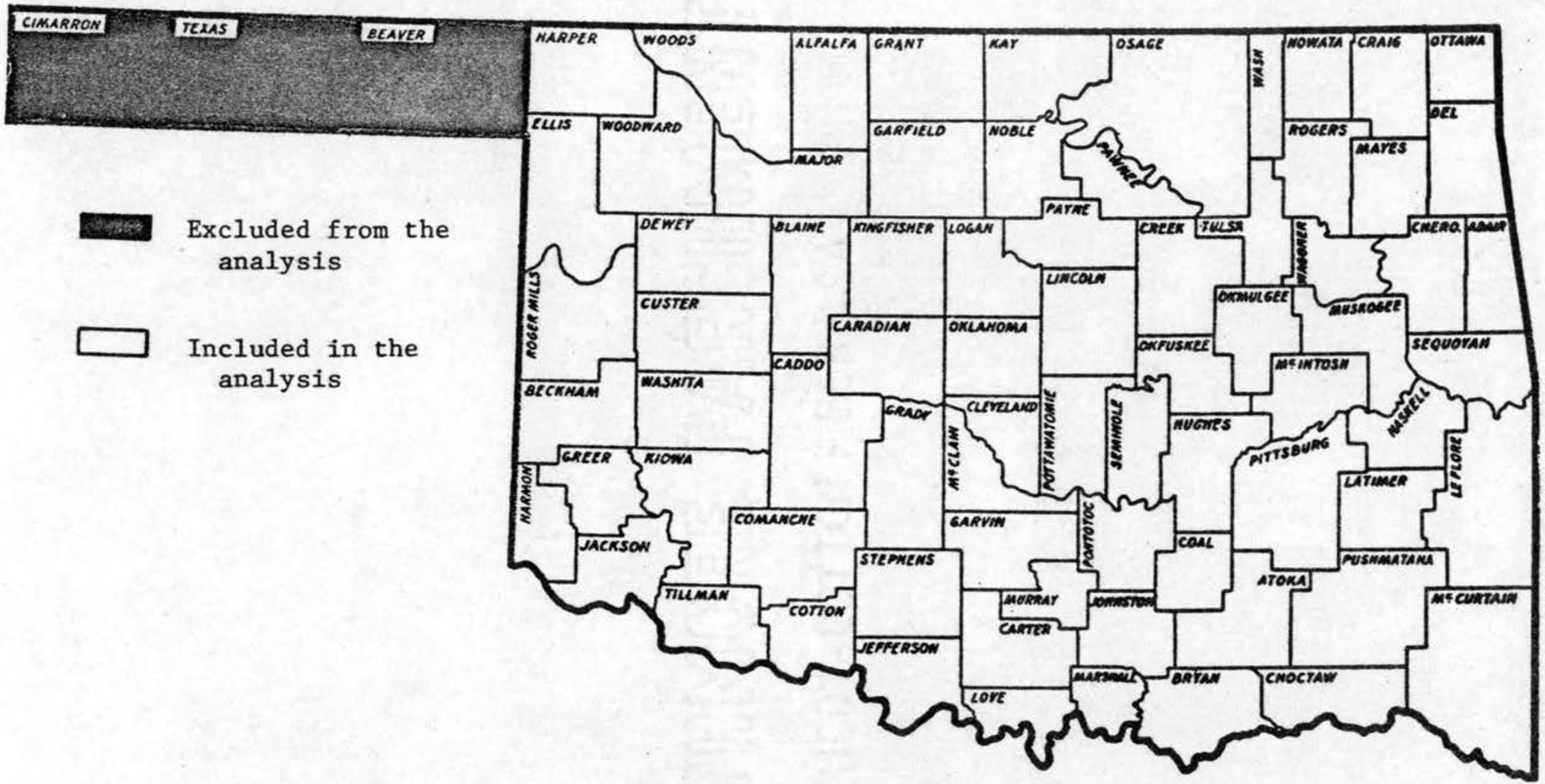

Figure 12. Area of Oklahoma Included in the Analysis

from the mileage chart in the legend of the official state highway map of Oklahoma published by the Oklahoma State Highway Commission.

Model I - Minimum Cost for Existing 1965 Market Organization

Model I was formulated to determine the minimum cost flow of fluid milk from producers to processors to consumers that would satisfy the quantity demanded in each county included in the analysis. It was assumed that all milk was produced within the 74 county area included in the study and that all milk was processed by processors located within the same 74 county area.

Fluid milk consumption in Oklahoma in 1965 was estimated in Chapter II to be approximately 747 million pounds. Consumption in the 74 counties in the analysis totaled 739 million pounds in 1965. Class I producer receipts from Oklahoma producers totaled 947 million pounds. Fluid milk was processed in 23 different processing plants located in 13 of the 74 counties included in the study (Figure 4). These plants processed 665 million pounds of fluid milk, 74 million pounds less than the estimated consumption in the study area in 1965. Since the analysis was based on the assumption that the total quantity demanded would be produced and processed in the area of analysis, the quantity of milk processed by each firm was adjusted upward such that the total quantity demanded could be processed by plants located in the area of analysis.

Given the 1965 conditions and assumptions, the production-distribution model discussed in Chapter IV was used to determine the minimum cost of assembling, processing, and distributing fluid milk in Oklahoma. For the number, size, and location of the processing plants as they existed in

1965, the production-distribution model essentially determined the optimum flow of milk that would minimize assembly and distribution costs. Although the model determined only the optimum flow of milk, total processing costs were computed in the model. Comparison of the optimum flows with actual flows could not be made since the actual assembly and distribution patterns were not known. However, the optimum flows could provide a bench mark for subsequent comparisons with costs determined for other organizations of the fluid milk industry.

In order not to disclose the volume of any existing firm, it was necessary to group processing firms by areas and to discuss the movement of milk into and out of processing areas rather than into and out of individual plant locations. As a result, supply and demand areas for processing areas rather than for individual plants were delineated. The processing firms were grouped into five areas as follows: Area I - firms in Garfield, Kay, and Payne counties; Area II - firms in Tulsa, Cherokee, and Muskogee counties; Area III - firms in Oklahoma, Cleveland, and Pottawatomie counties; Area IV - firms in Greer and Beckham counties; and Area V - firms in Comanche and Carter counties.

The supply areas based on the least cost flow pattern for the assembly of the raw milk are illustrated in Figure 13. The quantities of milk shipped from each county to the processing areas, the unused production in each county, and the value of additional production for each county are given in Table XI. Counties from which no milk was assembled in the optimum flow pattern were not included in Table XI.

In the optimum assembly pattern, milk was assembled from 55 of the 74 counties included in the analysis. Of the 19 counties from which no milk was assembled, there were five with no reported supplies (Appendix B,

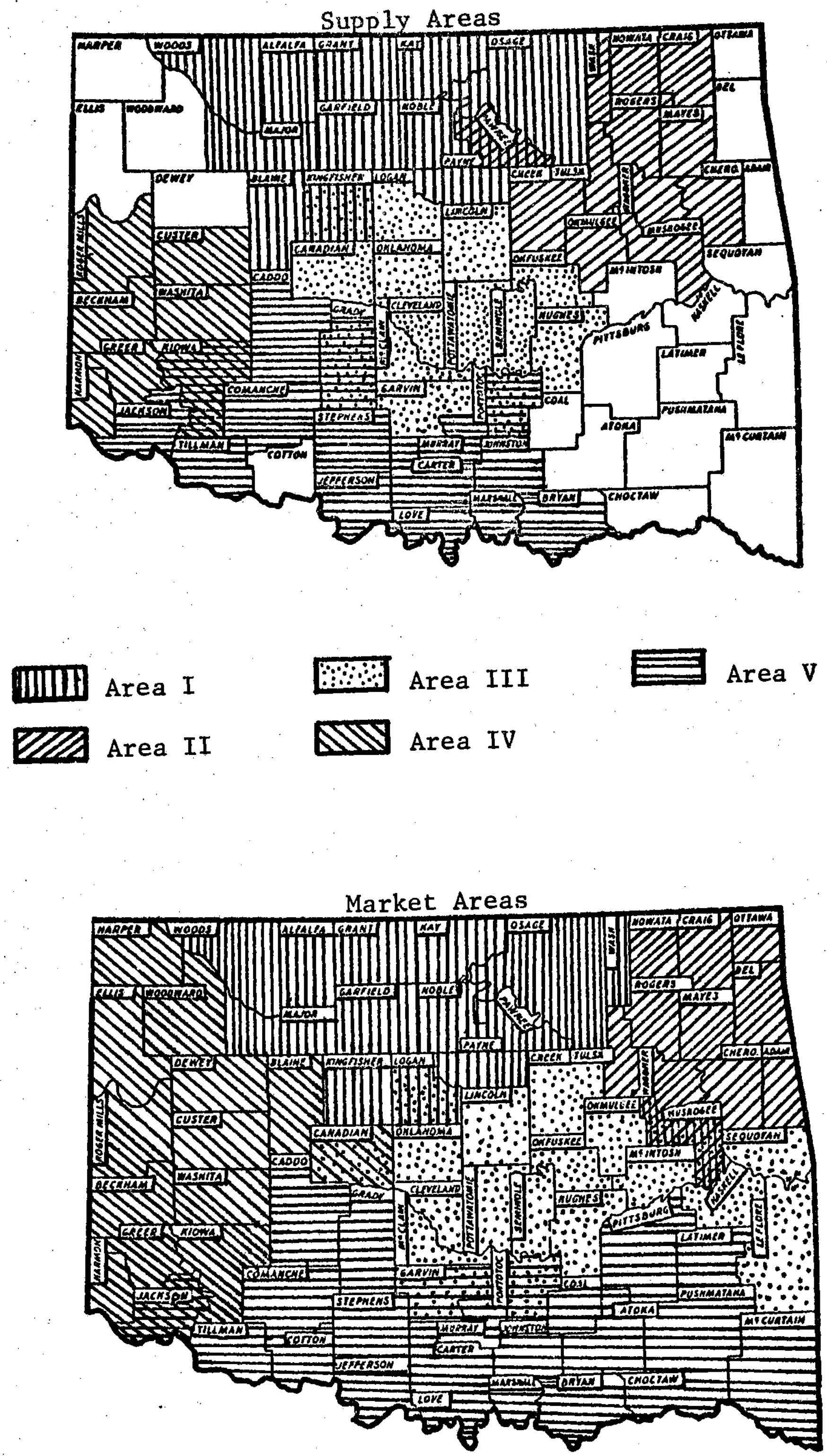

Figure 13. Supply and Market Areas for Model I, Minimum Cost for Existing 1965 Market Organization

TABLE XI

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PRODUCERS TO PROCESSORS AND VALUE OF ADDITIONAL PRODUCTION, BASED ON EXISTING PROCESSING PLANT LOCATIONS, 1965

From County	To Processing Area	Quantity Shipped	Unused Production	Value of Additional Production
		(1,000 lbs.)	(1,000 lbs.)	($ per 1,000 lbs.)
Alfalfa	1	7,439	0	0.286
Beckham	4	15,620	0	1.564
Blaine	1	10,068	0	0.104
Bryan	5	10,601	0	0.156
Caddo	5	10,849	0	0.559
Canadian	3	34,156	0	0.650
Carter	5	5,091	0	2.032
Cherokee	2	255	10,595	0
Cleveland	3	19,933	0	2.032
Comanche	5	23,649	0	2.318
Craig	2	2,865	11,800	0
Creek	2	6,279	0	0.377
Custer	4	13,580	0	0.026
Garfield	1	6,286	0	2.162
Garvin	3	12,558	0	0.312
Grady	3	25,952	0	0.429
	5	25,825		
Grant	1	1,781	0	0.520
Greer	4	1,837	0	1.889
Harmon	4	1,218	0	0.208
Hughes	3	510	562	0
Jackson	5	2,277	0	0.364
Jefferson	5	2,147	0	0.377
Johnston	5	10,276	0	0.429
Kay	1	19,676	0	0.091
Kingfisher	1	3,258	0	0.455
	3	28,569		
Kiowa	4	3,975	0	0.286
Lincoln	3	32,974	0	0.403
Logan	3	9,529	0	0.533
Love	5	1,128	0	0.598
McClain	3	32,981	0	0.598
Major	1	13,151	0	0.442
Marshall	5	2,090	0	0.507
Mayes	2	25,430	0	0.260
Murray	5	22,429	0	0.390

TABLE XI (continued)

From County	To Processing Area	Quantity Shipped	Unused Production	Value of Additional Production
		(1,000 lbs.)	(1,000 lbs.)	($ per 1,000 lbs.)
Muskogee	2	19,225	0	0.091
Noble	1	6,245	0	0.442
Nowata	2	10,365	0	0.182
Okfuskee	3	5,278	0	0.039
Oklahoma	3	27,061	0	2.227
Okmulgee	2	4,225	0	0.325
Osage	1	3,642	0	0.182
Pawnee	1	1,799	0	0.169
	2	4,893		
Payne	1	23,866	0	1.733
Pontotoc	3	4,983	5,905	0
	5	8,952		
Pottawatomie	3	32,538	0	0.533
Roger Mills	4	17,787	28,030	0
Rogers	2	25,480	0	0.481
Seminole	3	11,628	0	0.299
Stephens	5	8,436	0	0.702
Tillman	5	3,470	0	0.520
Tulsa	2	45,803	0	2.032
Wagoner	2	12,441	0	0.234
Washington	2	8,915	0	0.195
Washita	4	2,154	12,721	0
Woods	1	3,381	0	0.026

Table IX). The net result was that milk would be assembled from 55 of 69 counties with available milk supplies. With the exception of Cotton County, the value of additional production in counties from which no milk was assembled was zero. There was no reported supply in Cotton County, but the analysis indicates that had milk been available in Cotton County, total market costs would have been reduced by $0.83 per 1,000 pounds.[1] Also, there was a zero value for additional production in Cherokee, Craig, Hughes, Pontotoc, Washita, and Roger Mills counties. This resulted because not all of the milk available in these counties entered the optimum solution.

The existence of a zero value for additional milk production in some counties did not imply that the production of Class I milk should cease or be reduced in these counties. The analysis considered only the quantity of Class I milk demanded in Oklahoma. No consideration was given to quantities demanded outside the State. The fact that more than 90 percent of the Class I producer receipts from the western tier of counties in Oklahoma have been delivered to dealers in the Texas Panhandle order indicates the existence of an outside demand for milk produced in Oklahoma. In addition to the Texas Panhandle deliveries, producer receipts from counties along the southern border of Oklahoma have been sold in the North Texas Marketing Order.

The value of additional production given in Table XI represented the reduction in total marketing costs that would occur if an additional 1,000 pounds of milk were made available in the county. In general, the

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[1]Market cost is defined as the total of assembly, processing, and distribution costs where assembly, processing, and distribution costs are defined in Chapter III.

value of additional milk was greatest in counties where processing plants were located. The value of additional production was influenced by the location of production relative to the location of processing plants and by the capacity of the processing plant. It should be noted that a high value of additional production in a county would not necessarily imply that there should be an increase in production in that county. The analysis was a partial equilibrium analysis and did not consider other production alternatives which might provide greater returns to productive resources.

The market areas, given optimum patterns of movement of milk from processing areas to individual counties, are illustrated in Figure 13. The quantity shipped and the cost per additional 1,000 pounds, along with the source of milk for each county, are given in Table XII. The cost of additional demand for each county represented the increase in market costs that would occur with an increase in demand of 1,000 pounds of milk in that county. The increase in cost included the combined increase in assembly, processing, and distribution costs as demand might be increased. The increase in cost was greater for counties that were located away from processing plants.

The minimum cost for the existing 1965 market organization was 12.5 million dollars. Processing cost was 10.9 million dollars or 87 percent of the total market cost. The average processing cost per quart was 3.17 cents. Assembly cost totaled 0.9 million dollars and distribution cost totaled 0.7 million dollars. These costs represented the least possible costs of meeting market requirements in 1965, given the cost functions used in the study and the 1965 estimate of quantities supplied and demanded in counties within Oklahoma.

TABLE XII

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PROCESSOR TO DEMAND AREAS AND COST FOR ADDITIONAL QUANTITIES DEMANDED, BASED ON EXISTING PROCESSING PLANT LOCATIONS, 1965

Demand Area	Source of milk	Quantity	Cost Per Additional 1,000 Pounds
	(area)	(1,000 lbs.)	(dollars)
Adair	2	3,727	51.978
Alfalfa	1	2,505	50.010
Atoka	5	2,836	50.514
Beckham	4	5,069	47.814
Blaine	4	3,371	49.878
Bryan	5	6,837	50.286
Caddo	5	8,231	49.686
Canadian	3,4	7,457	50.022
Carter	5	12,282	48.462
Cherokee	2	5,282	51.690
Choctaw	5	4,222	50.922
Cleveland	3	15,741	48.462
Coal	5	1,508	50.550
Comanche	5	30,709	47.970
Cotton	5	2,346	49.434
Craig	2	4,634	51.594
Creek	3	11,899	50.622
Custer	4	6,493	49.326
Delaware	2	3,888	51.642
Dewey	4	1,707	49.770
Ellis	4	1,514	49.806
Garfield	1	16,314	48.186
Garvin	3,5	8,384	50.142
Grady	5	8,518	49.806
Grant	1	2,526	49.794
Greer	4	2,561	48.234
Harmon	4	1,742	49.878
Harper	4	1,971	50.358
Haskell	3	2,532	50.718
Hughes	3	4,199	50.514
Jackson	4,5	10,926	49.734
Jefferson	5	2,383	49.854
Johnston	5	2,439	50.034
Kay	1	16,558	50.190
Kingfisher	1	3,271	49.854
Kiowa	4	4,212	49.590
Latimer	5	2,213	57.330
LeFlore	3	7,971	51.210

TABLE XII (continued)

Demand Area	Source of milk	Quantity	Cost Per Additional 1,000 Pounds
	(area)	(1,000 lbs.)	(dollars)
Lincoln	3	5,394	50.250
Logan	1,3	5,432	50.130
Love	5	1,612	49.878
McClain	3	3,773	49.878
McCurtain	5	7,141	51.438
McIntosh	3	3,421	51.126
Major	1	2,257	49.866
Marshall	5	2,251	49.962
Mayes	2	5,950	51.354
Murray	5	3,151	50.070
Muskogee	1,2,3	18,833	51.426
Noble	1	3,195	49.866
Nowata	2	3,161	51.426
Okfuskee	3	3,166	50.586
Oklahoma	3	160,385	48.474
Okmulgee	3	10,927	50.994
Osage	1	9,563	50.346
Ottawa	2	8,626	51.966
Pawnee	1	3,221	50.202
Payne	1	13,552	48.822
Pittsburg	5	9,948	51.030
Pontotoc	3,5	8,480	50.430
Pottawatomie	3	12,492	50.106
Pushmataha	5	2,602	50.898
Roger Mills	4	1,418	49.350
Rogers	2	6,205	51.150
Seminole	3	7,907	50.238
Sequoyah	3	5,373	52.068
Stephens	5	12,363	49.554
Tillman	5	4,326	49.722
Tulsa	2	118,250	49.626
Wagoner	2	4,692	51.378
Washington	1	15,245	50.982
Washita	4	5,777	49.410
Woods	1	3,497	50.250
Woodward	4	4,247	49.962

Model II - Optimum 1965 Market Organization

The extended production-distribution model discussed in Chapter IV was used to determine the number, size, and location of processing plants that would minimize assembly, processing, and distribution costs for 1965 supply and demand conditions. It was assumed that there were five potential plant locations. These locations were Enid, Tulsa, Oklahoma City, Lawton, and McAlester. The reason for selecting these locations was that they represented population centers in the northwestern, northeastern, central, southwestern, and southeastern parts of the State.

The minimum cost organization for the 1965 supply and demand conditions included only three processing plants. The plants were located at Lawton, Oklahoma City, and Tulsa. The total cost of assembling, processing, and distributing milk to meet the 1965 quantity demanded with three processing plants was 10.4 million dollars. The potential decrease in costs with three plants rather than 23 plants was, therefore, 2.1 million dollars or about 17 percent.

The average processing cost per quart in Model II was 2.39 cents. Total processing cost amounted to 8.2 million dollars or approximately 79 percent of the total marketing cost. Processing was highly concentrated in the central part of the State. The quantity processed in the Oklahoma City plant was 452 million pounds or 61 percent of the total. About 256 million pounds were processed in Tulsa and 31 million pounds were processed in Lawton. The quantities represented 34 percent and five percent of the total, respectively. The processing costs per quart were 2.31 cents in Oklahoma City, 2.44 cents in Tulsa, and 3.31 cents in Lawton. The differences in processing costs per quart reflected the economies of size in the processing cost function.

With increased concentration in milk processing and lower processing costs, assembly and distribution costs increased. Assembly and distribution costs totaled 2.2 million dollars in Model II, an increase of 0.6 million dollars over the same costs for Model I. The increase was about the same for assembly cost as for distribution cost (0.3 million dollars). However, in percentage terms, assembly cost increased approximately 43 percent while distribution cost increased 33 percent. In Model II, assembly and distribution costs amounted to 11 percent and 10 percent, respectively, of total market cost. This compared with seven and six percent of the total market cost for the respective costs in Model I.

The supply areas for the three plants are represented in Figure 14. The results for counties in the southeastern part of the State were similar to those for Model I. Milk produced in the southeastern part of the State did not enter the optimum flow in either analysis. There were, however, differences in the assembly patterns with respect to the southwestern, northwestern, and northeastern parts of the State. With a larger quantity processed in Tulsa in Model II than in Model I, milk from Ottawa, Delaware, and Adair counties entered the optimum assembly flow. In the absence of plants in Greer, Beckham, and Garfield counties, milk produced in Harmon, Greer, Beckham, Roger Mills, Woods, Alfalfa, and Grant counties did not enter the optimum assembly pattern.

The quantities shipped, the unused production, and the value of additional production by county for Model II are given in Appendix B, Table XII. The value of additional production represented the reduction in marketing cost for each additional 1,000 pounds of milk made available in the given county. Counties from which no milk was assembled or from

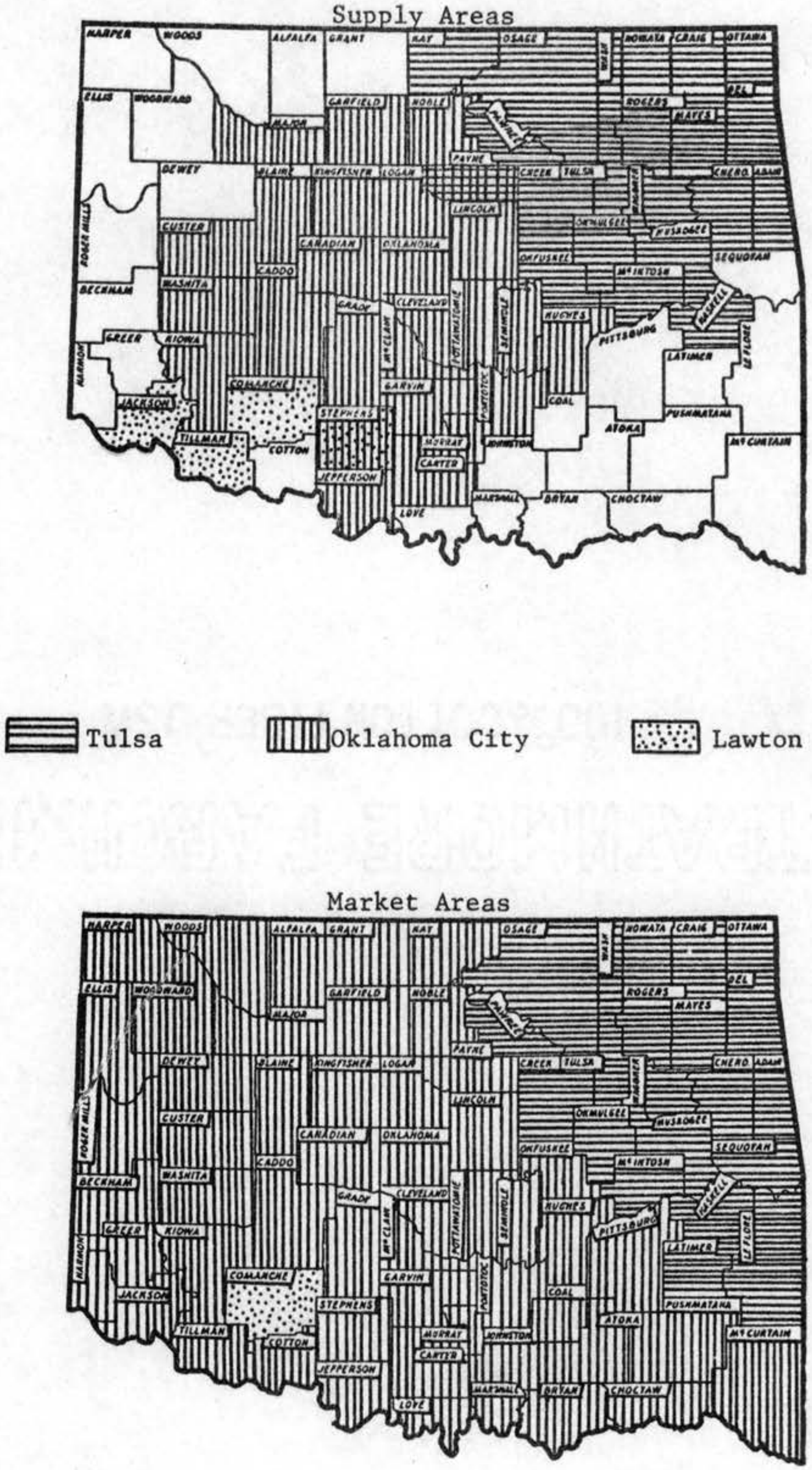

Figure 14. Supply and Market Areas for Model II, Optimum 1965 Market Organization

which no milk was available were not included in Table XII of Appendix B. The value of additional production in counties from which milk was available and not assembled was zero since demand outside Oklahoma was not considered. Also, the value of additional production was zero in counties from which not all of the milk available entered the optimum assembly pattern. The value of additional production was greatest in counties that were closest to the processing plants.

The optimum distribution patterns for Model II are depicted as market areas in Figure 14. Except for Comanche County, there were only two marketing areas, Oklahoma City and Tulsa. The Oklahoma City market area was larger in volume and in geographic area. The Tulsa market included 21 counties concentrated primarily in the northeastern part of the State. The Oklahoma City market included the rest of the State except for Comanche County. Milk for Comanche County was processed in Lawton.

The source of milk for each county, the quantity demanded, and the cost of additional demand in each county are given in Table XIII of Appendix B. The cost of additional demand in each county represented the increase in assembly, processing, and distribution costs that would occur with an increase in the quantity demanded in the respective counties. The increased cost of additional demand increased as the distance from the processing plants increased.

The resulting market areas and supply areas for the three plants supported the theoretical results from location theory developed in Chapter III. Economies of scale in processing and irregular concentrations of production and consumption resulted in irregularly shaped market and supply areas. The supply area for the larger Oklahoma City plant extended outward from the plant in all directions but primarily in the direction of "least resistance" from other markets. The supply area for the Oklahoma City plant extended further toward the smaller Lawton plant than toward the Tulsa Plant. Also, economies of larger scale production in the Oklahoma City plant were such that the market area for Oklahoma City surrounded the market area for Lawton.

Model III - Optimum 1975 Market Organization

In order to provide insights as to the type of adjustments that might be desirable in the fluid milk marketing system in Oklahoma, production and consumption projections were made for 1975. The extended production-distribution model was then used to determine the optimum movement of milk based on 1975 projections.

1975 Consumption

Estimates of the annual fluid milk consumption by county for 1975 were made using the same per capita consumption estimates as were used for 1965 consumption. The use of this procedure was based on three assumptions. First, the relationships of per capita income among counties were assumed to be about the same in 1975 as in 1965. Second, the income elasticity of demand for fluid milk used in determining county consumption relative to the average consumption in the State would have about the same effect in 1975 as in 1965, although the actual elasticity probably would decrease as income increased. Third, changes in consumer preferences over time would be neutral for fluid milk. That is no upward or downward trends in fluid milk consumption were postulated. Given these assumptions, only county population estimates for 1975 were needed to compute estimates of fluid milk consumption by county in 1975.

Population projections for 1975 were made on the assumption that the annual percentage change in population for each county for the ten-year period 1966-1975 would be the same as the average percentage change for the period 1960-1965. The projections were made using the compound interest formula. This procedure of estimating population gave estimates that were within the range of projections obtained by Tarver for Oklahoma and for selected economic areas within Oklahoma for the year 1970.[2] County population and consumption projections are given in Appendix B, Table VII. Projected consumption in 1975 was 853 million pounds compared with an estimated 739 million pounds in 1965, an increase of 15 percent.

One important change in the projected population and consumption estimates was the indicated increase in the concentration in the large metropolitan areas. Projections for 1975 indicated that 42 percent of the fluid milk consumption would be concentrated in Oklahoma and Tulsa counties alone. This increased concentration of consumption in metropolitan areas, along with an increase in the absolute quantity consumed, would increase the market requirements for the Oklahoma fluid milk industry.

1975 Production

Data on producer receipts from producers in Oklahoma were obtained from market administrators for the period 1958-1965. The trend in producer receipts was sharply upward between 1958 and 1965. The trend was biased upward partially because of the change in the area included in the

[2] James D. Traver, Projections of the Population of Oklahoma to 1970, Oklahoma Agricultural Experiment Station Bulletin 545 (Stillwater, 1960) p. 33.

Oklahoma Metropolitan Marketing Order. In 1960, handlers in Enid came under the order. After the change in the area included under the order, the upward trend in producer receipts was reversed. Producer receipts declined during the 1961-1963 period, a period when coverage of the marketing orders was the same. This decline in producer receipts appeared to be the result of pasture conditions and other exogenous variables affecting production. From 1963 to 1965 producer receipts increased. The rate of increase from 1963 to 1965 was extremely high, partially because of the low levels in 1962 and 1963.

Trends in producer receipts from 1961 to 1965 were used to project production for 1975. Because of the nature of the changes in producer receipts between 1961 and 1965, the average annual increase between 1961 and 1965 (1.56 percent) and the average annual increase between 1962 and 1965 (2.58 percent) were computed, and the average of the two (2.12 percent) was used to project production to 1975. Projected producer receipts for Oklahoma in 1975 was 1.15 billion pounds. With a projected consumption in 1975 of 853 million pounds, the estimated surplus production in 1975 was 300 million pounds as compared with a surplus production of 200 million pounds in 1965.

Estimates of the share (percent of state total) of producer receipts that would be produced in each county were computed on the basis of the assumption that the change in the share of producer receipts for each county between 1965 and 1975 would be the same as that which occurred between 1961 and 1965. The average annual change in the share of producer receipts between 1961 and 1965 was computed and this average change was multiplied by 10 and added to the share in 1965 to project the share of producer receipts for each county in 1975. Estimated production in each county was obtained by multiplying the projected share of production for each county by the projected production for the State in 1975. The estimated producer receipts for each county are given in Table X of Appendix B.

The extended production-distribution model was used to determine the optimum flow of milk from producers to processing plants to demand areas for projected 1975 supply and demand conditions. The results were similar to those for the 1965 optimum market organizations. Three processing plants entered the optimum solution and, as in the 1965 model, these plants were located in Oklahoma City, Tulsa, and Lawton.

The estimated minimum total cost of assembly, processing, and distribution in 1975 was 11.8 million dollars. This was 13 percent higher than the estimated cost in 1965, though the increase was smaller than a 15 percent increase in demand requirements. The smaller increase in marketing costs than in demand requirements resulted from decreasing processing costs per unit for the larger volumes. The average processing cost per quart for the 1975 organization was 2.36 cents per quart. This compared with a cost of 2.39 cents per quart for 1965 conditions. Assembly costs were 1.4 million dollars for 1975 as compared with 1.2 million dollars for 1965. Distribution costs were 1.0 million dollars in both Model II and Model III. The absence of an increase in distribution costs in Model III over Model II is the result of an increase in the concentration of consumption in Oklahoma, Tulsa, and Comanche counties. There was no distribution cost (as used in this study) for milk consumed in these counties since processing plants were located in these counties.

Supply areas for the three processing plants are shown in Figure 15. The quantities shipped, the unused production, and the value of additional

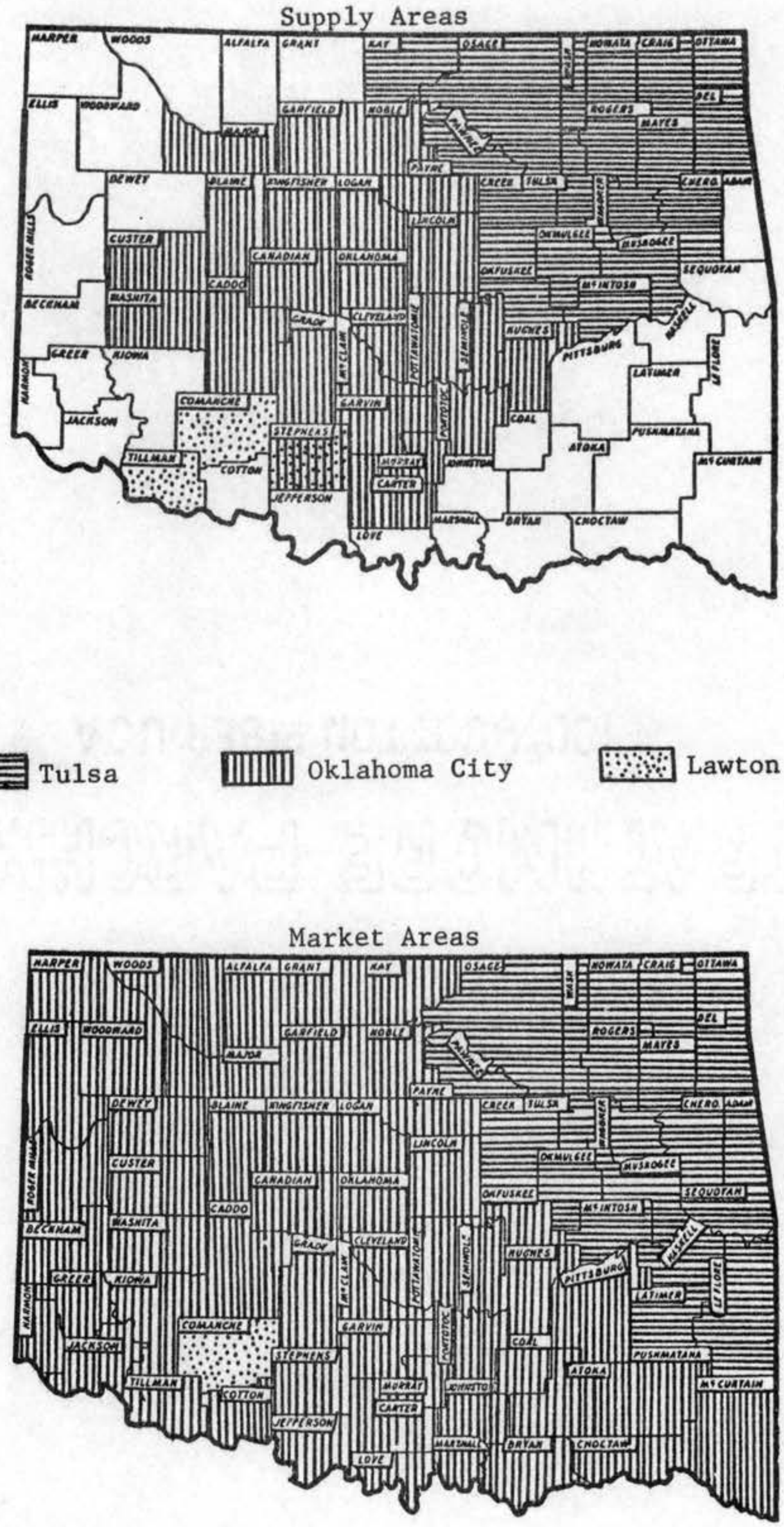

Figure 15. Supply and Market Areas for Model III, Optimum 1975 Market Organization

production for 1975 conditions are given in Appendix B, Table XIV. Some changes in supply areas resulted from the projected increases in production for 1975. The Tulsa plant would receive milk from only 18 counties in the 1975 solution as compared with 21 in 1965. The three counties that would be eliminated were Adair, Haskell, and Payne. In the 1975 organization, milk from Payne County would move to the Oklahoma City plant and milk would not be assembled from Adair and Haskell counties. The value of additional production in selected counties also differed between the organization for 1965 and the organization for projected 1975 conditions because of the differences in the supply areas. The market areas for the 1975 organization are shown in Figure 15. These areas were the same as for the 1965 market organization. Table XV of Appendix B gives the optimum shipments of milk from processing plants to demand areas and the cost of additional demand in each demand area. The cost of additional demand in each county was, in general, lower for the 1975 than for the 1965 organization. This reflected the decreasing per unit processing costs, an increase in production in counties surrounding large consuming centers, and an increase in the concentration of consumption.

Insights into the competitive position of processing plants at different locations were given in the results of the extended production-distribution model. Figure 16 indicates the competitive position for the plant in Tulsa for 1975 conditions.[3] The lines in Figure 16 delineate amounts by which market cost would be increased if the milk demanded

[3]The results for the plants in Oklahoma City and Lawton for each time period were similar and are ommitted.

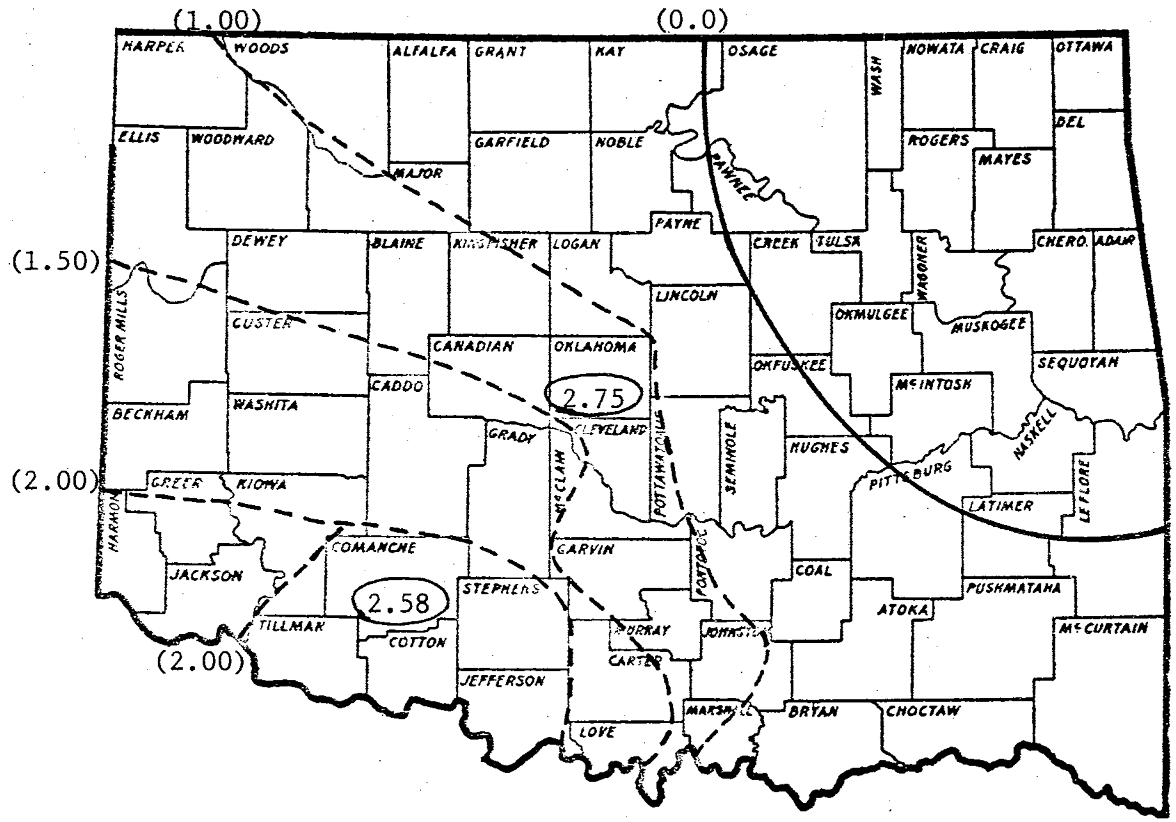

Figure 16. Equal-Cost Lines (Costs in Dollars Per Thousand) for Fulfilling Additional Demand from the Tulsa Processing Plant, Model III

in the area were processed in the Tulsa plant. Stated another way, the cost lines indicate the amount by which cost must be reduced in Tulsa for Tulsa to furnish milk in an area without increasing market costs.

If the cost lines in Figure 16 were considered as contour lines on a map, then Figure 16 would depict a series of hills and valleys. In general, the elevation of the surface would tend to increase as the distance from Tulsa increased. There were, however, sharp rises in the surface at locations where other processing plants were located. For example, the cost lines were much higher in Oklahoma and Comanche counties than in surrounding counties (Figure 16). The results indicated that the competitive disadvantage for Tulsa relative to other processing plants is less the further a given area is away from other processing plants.

Consideration of assembly cost along with processing and distribution costs resulted in plants of markedly different sizes than the "least-cost" solution obtained by Cobia and Babb.[4] Their results indicate that a minimum total average cost of processing and distribution occurs at a volume of 1,736,000 quarts per day for selected cost conditions. Results in this study included three plants ranging in size from 55,000 to 809,000 quarts per day in the 1965 solution. The difference suggests that assembly and distribution costs may offset the economies of scale in processing at a much lower scale of plant than distribution cost alone.

Cobia and Babb state,

> ". . .as the producer typically pays for delivery of his milk to the plant, these costs (assembly costs) would not be a consideration by the processing plant when expanding its operation. This would be true except in the case of a

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[4]Cobia and Babb, p. 14.

> producer-processing cooperative or shortage of milk in the market, a rather rare occurence today."[5]

It seems appropriate, however, to consider assembly costs when the time period considered is long enough for producers and processors to make adjustments in their operations. The assembly cost paid by the producer is a cost to the producer, and he must consider the cost in evaluating alternative employment for the resources at his command. As a processing plant increases in size, its supply area must expand, assuming no change in the density of production, and producers at the greater distances pay more for assembly cost. As the assembly cost for the individual producer increases other employment opportunities for the producers' resources become more attractive, other things equal. In addition, a firm may encounter competition from firms at other locations as it attempts to increase its supply area.

Assembly cost is part of the cost of getting milk from the farm to the consumer, and regardless of where the cost is incurred, it seems appropriate to consider it when considering firm size and market and supply areas for efficient industry organization. If, however, as Cobia and Babb suggest, firms do not consider assembly costs in planning plant operation, pressures from industry adjustment may lead to inefficient use of resources. Plant scales would tend to be larger than that required for maximum efficiency of resources in the marketing system. The actual scale of plant may not be as large as the scale indicated by analyses which consider only processing and distribution costs because of the increased cost to producers and the possibility of competition from other

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[5]Ibid., p. 3.

plants. The resulting scale of plant might be one between that indicated when considering only processing and distribution cost and that indicated when assembly cost is also included.

Model IV - Restricted 1975 Market Organization

The extended production-distribution model has been used thus far without any restrictions on the number of processing plants which would result in minimum assembly, processing, and distribution costs for 1965 and projected 1975 supply and demand conditions. The solutions for both time periods included one plant each in the cities of Tulsa, Oklahoma City, and Lawton.

It is unlikely that antitrust regulations, consumer preferences, or other institutional restrictions would permit such a concentrated organization of the Oklahoma fluid milk industry. Therefore, the optimum flow of milk was determined under the restriction that milk distribution would involve at least three plants in Tulsa and three plants in Oklahoma City. It was further stipulated that each plant would process a minimum of 30 million pounds of milk annually and that no plant could process more than two-thirds of the quantity demanded in the respective market areas of Oklahoma City and Tulsa. The size of the market for Oklahoma City and Tulsa were taken from the quantities processed in each city under the unrestricted 1975 solution. The milk processed in Lawton in the unrestricted 1975 solution was added to the Oklahoma City market.

Under the restricted model, one of the plants in Oklahoma City and one in Tulsa entered the solution at the maximum level equal to two-thirds of their respective markets. Also, one plant in each city entered at the minimum level of 30 million pounds. The third firm in each city processed the remaining share of the market required for that city.

Restricting the size of the firms resulted in an increase of almost eight percent in total marketing cost. The total cost in the restricted model was 12.7 million dollars compared with 11.8 million dollars in the unrestricted model. Processing cost per quart in the restricted model was 2.54 cents per quart as compared with 2.36 cents per quart under the unrestricted organization. Assembly and distribution costs also increased in the restricted model. Assembly cost increased from 1.4 to 1.5 million dollars while distribution cost increased from 1.0 to 1.1 million dollars.

Restricting plant locations to Oklahoma City and Tulsa altered the supply areas and resulted in changes in the value of additional production in some counties. In the unrestricted model, Tillman, Comanche, and Stephens counties constituted the supply area for the Lawton plant. In the restricted model Comanche and Stephens counties were part of the Oklahoma City supply area and no milk was assembled from Tillman County.

Adding the quantity processed in Lawton to the Oklahoma City plants in the restricted model also affected the supply area for the Tulsa market (Figure 17). With the additional requirements in the Oklahoma City plants, milk from Okfuskee County entered the Oklahoma City plants rather than the Tulsa plants. Milk from Adair County, unused in the unrestricted model, became part of the Tulsa supply area. In addition, the value of additional production in counties in the Tulsa supply area increased (Appendix B, Table XVI).

Market areas for Tulsa and Oklahoma City were the same in the restricted model as in the unrestricted model (Figure 17). However, the cost of additional quantities demanded in each county increased in the restricted model as compared with the unrestricted model (Appendix B,

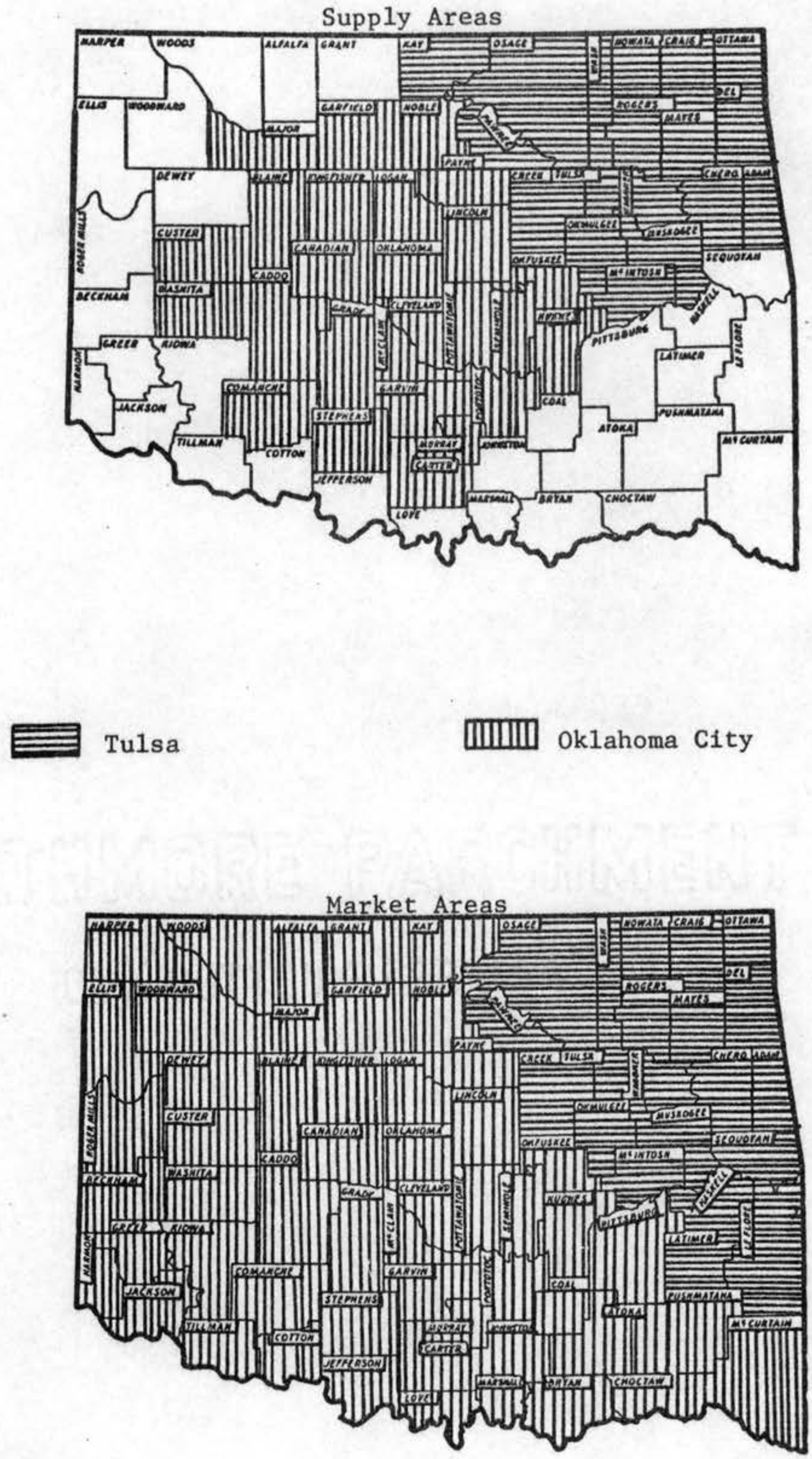

Figure 17. Supply and Market Areas for Model IV, Restricted 1975 Market Organization

Table XVII). This was primarily the result of an increase in processing cost per unit, through a small increase in assembly and distribution costs also occurred. Processing costs increased 0.7 million dollars in the restricted model over costs in the unrestricted model. Assembly and distribution costs amounted to 2.6 million dollars in the restricted model as compared with 2.4 million dollars in the unrestricted model, an increase of 0.2 million dollars. Although the size of the increase in processing costs was greater than for assembly and distribution costs, processing costs were about 80 percent of total marketing costs in each model.

Model V-Optimum Market Organization with Different Costs in Each Processing Area

Models I through IV have ignored one of the major features in the pricing of milk under Federal orders, intermarket price alignment. Historically, price alignment has involved, among other things, increasing Class I prices as the distance from the Minnesota-Wisconsin area increased. The reflection of these price differences could result in significantly different supply areas and distribution areas for each market. Model V was designed to determine the effect of differences in costs among processing areas on the market and supply areas obtained in Model III. The results could give insights into the competitive position of firms in different processing areas if some or all costs were different.

The 1965 institutional structure in Oklahoma was such that the price the producers received for milk delivered for processing in Enid (Garfield County) and in Tulsa was ten cents per 100 pounds less than the price the producer received for milk delivered for processing in Oklahoma City. Producers received 22 cents per 100 pounds more for milk delivered for processing in Lawton than in Oklahoma City. The producers paid the transportation cost from the farm to the processing plant. These price differences were incorporated into the processing cost function for each area in order to determine the effect of different costs in each area on the market and supply areas obtained in Model III.

An indication of what might be expected from the lowering of costs by ten cents per 100 pounds in Tulsa can be obtained from Figure 16. According to the cost lines in Figure 16, a reduction of ten cents per 100 pounds would enable the Tulsa market to expand to the one dollar per 1,000 line, assuming other costs would remain the same.

The market area for the Tulsa market with the 1965 Federal order price alignment in each area is depicted in Figure 18. The results were similar to those expected based on the information in Figure 16, but there were some differences. Other factors were not held constant. The reduction in the cost for processing in the Enid area, as a result of lower milk prices, permitted milk processing in Enid. The consequence of this was that competition from the Enid plant limited the expansion of the Tulsa market as far to the northwest as was indicated in Figure 16. Another change was that the reduction in the quantity processed in Oklahoma City increased the per unit processing cost in Oklahoma City. The expansion of the Tulsa market area to the southwest was almost identical with the expansion indicated by the cost lines in Figure 16 for Model III results. The quantity of milk processed in Lawton decreased. The supply areas estimated for the Federal order price alignment are also given in Figure 18.

The impact of cost differentials among processing areas in market areas can be further illustrated by a comparison of the quantities processed in each area for Model III and Model V (Table XIII). With equal processing costs in each area the quantity processed in Oklahoma City

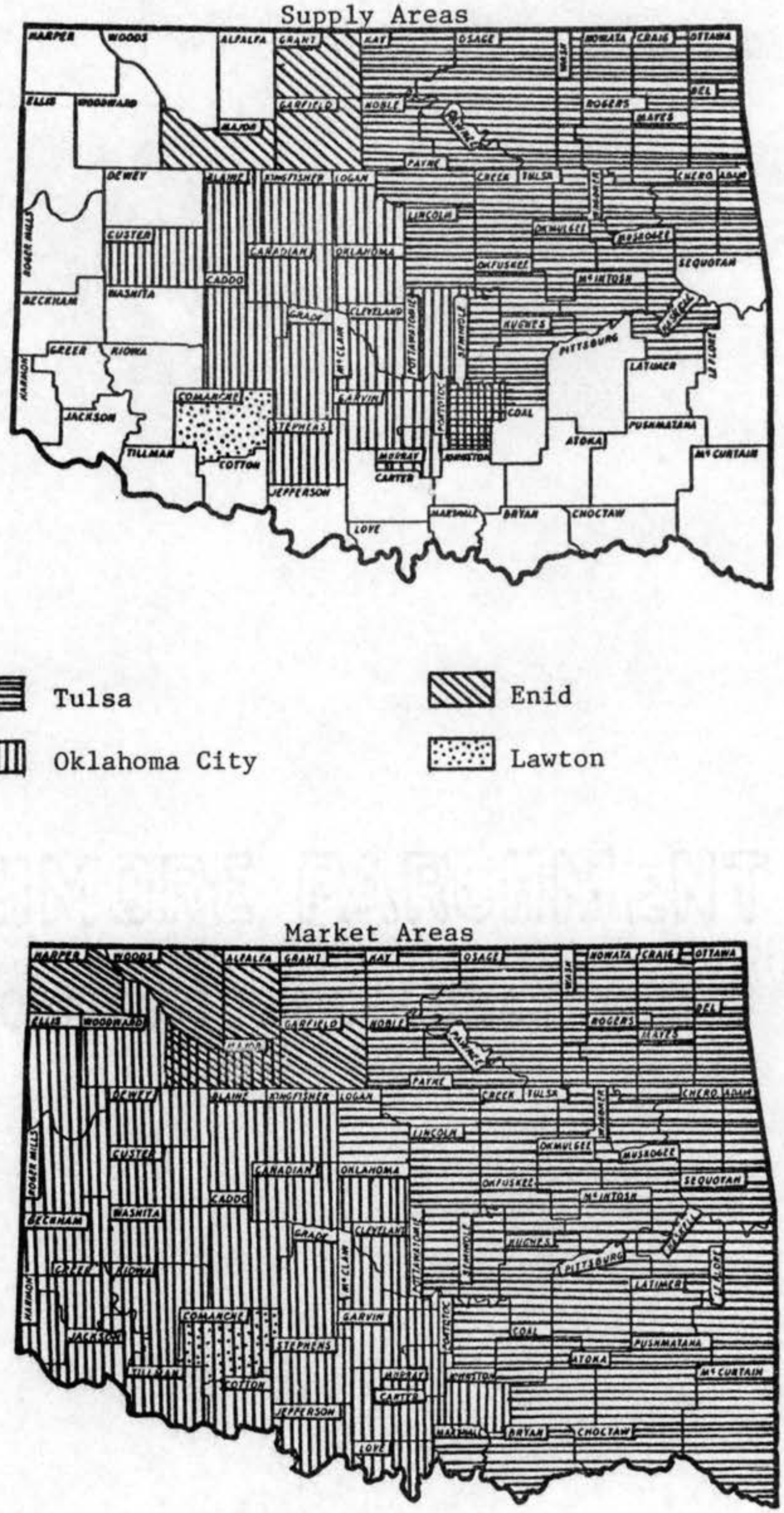

Figure 18. Supply and Market Areas for Model V, Optimum Market Organization with Different Processing Costs in the Processing Areas

exceeded the quantity processed in Tulsa by more than 255 million pounds. The quantities processed in Tulsa and Oklahoma City differed by only 2.7 million pounds when a ten cents per 100 pounds cost advantage existed in Tulsa. The ten cents per 100 pounds cost advantage in Enid over Oklahoma City resulted in milk processing of approximatley 26 million pounds in Enid. A decrease of more than 11 million pounds in the quantity processed in Lawton was associated with the 22 cents per 100 pounds disadvantage in the Lawton area.

TABLE XIII

QUANTITY OF MILK PROCESSED AT DIFFERENT PROCESSING LOCATIONS, MODEL III AND MODEL V

Processing Location	Model III	Model V[a]
	(Mil. Pounds)	(Mil. Pounds)
Enid	0	25.9
Tulsa	278.7	400.7
Oklahoma City	534.3	398.0
Lawton	40.2	28.6
McAlester	0	0

[a]The cost differentials for Model V are differences from the Oklahoma City cost and are as follows:
Enid - minus ten cents per hundredweight
Tulsa - minus ten cents per hundredweight
Lawton - plus 22 cents per hundredweight
McAlester - no differential

The market organization for Model V had a higher market cost than Model III. Total market cost for Model V is 11.96 million dollars as compared with 11.8 million dollars for Model III. This indicates to some extent the possible effect of built-in cost advantages for some areas on total market cost. Also, with a ten cents per hundred pound lower price paid to producers in the Tulsa and Enid markets, there is a reduction in the amount paid to producers in Model V as compared with Model III. Producer receipts for Model V would be approximately 173 thousand dollars less than for Model III.

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

Changes in the production and consumption patterns in the Oklahoma fluid milk industry suggest that changes in the market structure of the industry affect the efficiency with which the functions of the marketing system are performed. The major objective of this study was to evaluate changes in the production and consumption patterns in the Oklahoma fluid milk industry and to determine possible changes in the market structure which might increase the efficiency in the marketing system.

Total milk production in Oklahoma declined approximately 45 percent from 1940 to 1964. Recent data indicated, however, that Class I producer receipts from Oklahoma producers were increasing. Class I producer receipts increased six percent during the period 1961 to 1964. The concentration of production has increased in counties surrounding Oklahoma City and in the western part of the State. At the producer level, the number of producers and the total numbers of cows have decreased while the average size of herd and the production per cow have increased.

The total quantity of fluid milk demanded in Oklahoma has increased in recent years. This increase has been brought about mainly by an increase in population; no irregular pattern of changes in per capita consumption of fluid milk was evident. In addition to changes in total quantity demanded, changes in demand requirements have been exhibited in changes in the sales of milk through various sales outlets and in changes in the percentage of sales made in various container sizes and types. Sales in glass containers have decreased while sales in paper and plastic containers have increased. This reflected an increase in retail store outlets and a decrease in retail route outlets for milk. The percentage of milk sold in gallon containers has increased at the expense of sales in half-gallon and quart containers.

In processing plants, the trend has been toward a smaller number of plants processing larger volumes of milk. There was a decline of more than 30 percent in the number of processing firms in Oklahoma between 1950 and 1955 and an additional 50 percent decline between 1955 and 1965.

In order to compute assembly, processing, and distribution costs for current Oklahoma fluid milk market organization, functions for each cost were estimated. All functions were determined from estimates made in previous studies with adjustments made, where necessary, to adapt the functions to fit to Oklahoma conditions.

The production-distribution model was used to compute the flow of milk from producer to processor to consumer that would minimize assembly, processing, and distribution costs for 1965 quantities demanded and supplied and the location and size of processing plants in 1965. These results provide a bench mark from which to compare costs for the existing organization with alternative organizations. The minimum assembly, processing, and distribution cost for the 1965 organization was 12.5 million dollars. Processing cost made up 87 percent of this cost.

Although assembly, processing, and distribution costs have been included in spatial equilibrium models such as the production-distribution model, economies of scale in processing have not been included in the models. Other spatial equilibrium models have included economies of scale in processing but have not included either assembly or distribution cost. An extended production-distribution model has been developed in this study whereby assembly, processing (where economies of scale exist in processing), and distribution costs can be considered simultaneously in determining the optimum number, size, and location of processing plants.

The extended production-distribution model was used to determine the minimum cost for which the 1965 demand requirements could be met, given the 1965 supply and demand conditions. The extended production-distribution model considered simultaneously the demand requirements, supply conditions, assembly and distribution cost functions, and processing costs (where economies of scale exist in processing) in determining the number of processing plants that would minimize assembly, processing, and distribution costs. The result was that one processing plant would be located in each of the cities of Tulsa, Oklahoma City, and Lawton.

Total marketing cost under the organization involving only three plants was 10.4 million dollars. This represented a 17 percent reduction in costs from the minimum estimated for the existing 1965 organization. Processing costs were significantly lower. Average processing cost per quart for the three plant organization was 2.39 cents per quart as compared with 3.17 cents per quart for the existing organization. However, assembly and distribution costs were higher. Assembly and distribution costs for the three plant organization totaled 2.7 million dollars as compared with 1.6 million dollars for the existing 1965 organization.

Past changes in production and consumption patterns were used to project quantities demanded and supplied in Oklahoma for 1975. The extended production-distribution model was then used to determine the market organization that would require the least cost to meet the 1975 demand requirements. The results were analogous to the results for 1965.

Institutional restrictions are such that it is unlikely that a market organization with one plant in Tulsa, Oklahoma City and Lawton could exist. For this reason, market costs for an alternative market organization with three plants each in Tulsa and Oklahoma City were determined. There were some changes in the supply areas for the plants in Tulsa and Oklahoma City as compared with the unrestricted organization. The market area for the Tulsa plants in the restricted model was the same as in the unrestricted model. However, in the restricted analyses, Comanche County became part of the Oklahoma City market area.

There was an increase of 0.9 million dollars or approximately eight percent in total marketing cost in the restricted model as compared with the unrestricted model. Processing costs increased by 0.7 million dollars and assembly and distribution costs increased by 0.2 million dollars.

Conclusions

Implications

Results obtained from the models employed in Chapter V indicate that economies of scale in processing have notbeen fully exploited by the Oklahoma fluid milk industry. A reduction in plant numbers from 23 to three would results in a savings of 2.1 million dollars exclusive of savings resulting in distribution within the population center. When the number of plants was reduced, assembly and distribution costs increased from 1.6 to 2.2 million dollars for 1965 quantities demanded and supplied, but processing costs decreased by 2.7 million dollars. Although the number of processing plants in Oklahoma has been declining, it does not appear that the reduction in plant numbers has been fast enough to keep pace with the developments in the assembly, processing, and distribution of fluid milk.

If institutional restrictions or other restrictions prohibited the transition to a marketing system with single plants in Tulsa, Oklahoma City, and Lawton, as indicated in Chapter V, the model with the restricted organization indicated the increase in cost that would occur. Such an increase in cost would have to justified on the basis of such factors as providing consumers with alternative brands, modifying pure monopoly situations in selling processed milk, and possibly modifying a monopsony situation in the purchase of milk from producers.

The results of the study provided no information about how the savings would be shared. Since producers have paid the cost of assembly in the past, a reduction in the number of processing plants would increase costs for producers located at greater distances from the remaining processing plants. A reduction in the number of processing plants would benefit such producers only if some of the reductions in processing cost were passed on in the form of lower assembly costs, higher milk prices, or greater sales of Class I milk at existing Class I prices.

A reduction in the number of plants could result in a monopoly or oligopoly situation in the sale of processed milk. Such a situation could result in some of the reduction in cost not being passed on to the consumer. In fact, the firms might equate marginal revenues with marginal costs at volumes which would command significantly higher prices of milk at the consumer level.

The results of the study provided some information to producers as to the value of the additional production of fluid milk as one of their production alternatives. The value of additional production in each county determined by the various models indicated how much market costs would be reduced if additional milk were available in the given counties. These values were based strictly on the costs used in this study. The values did not consider the demand outside the state for Oklahoma milk or the demand for milk brought into Oklahoma from other states. For example, the results provided no information about the value of additional production in counties which sold milk primarily in other states. Nevertheless, an indication was given of the counties in which production would be the most valuable, based upon current and projected demand conditions in Oklahoma.

Information useful to processors was obtained on the cost of entering a particular county with milk distribution. It should be pointed out, however, that this analysis considered only cost, and not revenue, from the sale of milk. The cost of additional demand in an area represented the cost for the next unit of milk sold in the area, and the cost of additional units might not be the same as for the first unit. Also, no consideration was given to competition that might exist.

The market areas and supply areas in the results can be considered only with respect to cost conditions and quantities demanded and supplied within Oklahoma. The results indicated that supply areas and market areas as determined in a least cost model depend on assembly, processing, and distribution costs. Market areas defined without consideration of any one of these three could result in unnecessary inefficiencies in the market system.

Limitations

Although the models employed and the results have provided insights into adjustments that could reduce the fluid milk marketing bill in Oklahoma, there were several limitations of the analysis. The most obvious limitation was that the study was limited geographically by state boundaries. Two aspects of the geographic limitation were apparent. First, market areas and supply areas for plants were defined as being located only within Oklahoma. The state boundary area might not be the same as actual market areas and supply areas. Secondly, interstate movement of milk was not considered. Since Oklahoma was a surplus producing state, limiting the demand to Oklahoma conditions resulted in no information on the value of additional production in counties that were located such that they now or might in the future sell milk in other states. Also, the model did not consider the possibility of milk entering Oklahoma. No consideration was given to cost of production advantages from other states. The overall cost of milk to consumers could be less if it could be produced more cheaply and brought into Oklahoma, either in processed or unprocessed form.

Other limiting factors in the analysis were (1) quantities supplied and demanded were projected on the basis of past changes alone, (2) the same cost functions were used in computing 1975 costs as were used in computing 1965 costs, (3) technological innovations in such things as new containers could have the effect of changing the cost function and hence, the results obtained in this analysis, and (4) the analysis was a partial equilibrium analysis with no consideration given to other production alternatives.

Need for Further Study

An expansion of the study to a regional or larger level is needed. An expanded study could provide valuable information for defining market areas, supply areas, and the prices consistent with intermarket price alignment. Differences in production costs could be considered in the assembly cost function in order to provide a more meaningful delineation of supply areas. If processing costs differed among areas, different processing cost functions could be included in the model for each area. Technological advances in assembly, processing, and distribution along with the improvement in highways and an increase in the concentration of population in large urban areas suggest that adjustments in the direction of several large plants in a region rather than a state may occur in the not too distant future.

A study that included consideration of multiple product processing could provide valuable information to the dairy industry. Such a study could consider the impact of the seasonal nature of milk production and provide information on the number, size, and location of Class I milk and Class II milk processing facilities.

Additional studies on the nature of the supply of fluid milk are needed. Information on cost of production and supply responses in various areas could be valuable to both producers and processors. Knowledge of the impact of shocks, such as weather, on milk production is also needed.

It is believed that the extended production-distribution model has applicability to industries other than the fluid milk industry. However, since the model considers only market costs, the possibility of using a technique such as reactive programming with the extended production-distribution model to consider the nature of supply and/or demand functions simultaneously with market costs should be investigated.

Finally, valuable information could be provided (at a relatively low cost) to the Oklahoma fluid milk industry on a continuing basis by keeping the solutions obtained in this study updated as costs or other factors change over time.

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THE SEPARABLE PROGRAMMING ALGORITHM[1]

The separable programming algorithm is a modified simplex procedure capable of solving nonlinear programming problems where the non-linear functions are functions of a single variable. The nonlinear function(s) are replaced by a piecewise linear approximation with restraints and the modified simplex procedure is used to enforce the restraints.

Consider a nonlinear function f(x) that is replaced by a piecewise linear approximation. Let the finite number of points, P_i, on the approximation be represented by (a_i, b_i). To describe the relation between x and f(x), the variables $(\bar{X}_0, \bar{X}_1, \ldots, \bar{X}_k)$ with $\bar{X}_i \geq 0$ are introduced with the restraints

$$\sum_{i=0}^{k} \bar{X}_i = 1$$

$$\sum_{i=0}^{k} a_i\bar{X}_i = X$$

$$\sum_{i=0}^{k} b_i\bar{X}_i = f(X_i)$$

It is also required that no more than two $\bar{X}_i$ can be nonzero and these must be consecutive. This last condition is enforced by the modified simplex algorithm.

In the modified simplex algorithm the set of variables, $S(\bar{X}_0, \bar{X}_1, \ldots, \bar{X}_k)$ are designated as "special." In the separable programming algorithm, the normal simplex algorithm is modified to inhibit pricing of the special variables within each set as follows:[2]

---

[1]This discussion is based on Clair E. Miller, pp. 89-92.

[2]Ibid., p. 90.

"1. If no element of S is in the basis, then all of S will be allowed for pricing. (This can occur only when artificial variables are in the basis.)

2. If precisely one element of S is in the basis, then only the variable (if any) immediately preceding it and the variable immediately following it within S are allowed for pricing.

3. If two variables from S are in the basis, then no others from S shall be allowed for pricing."

Data, other than the special variables, are given as in a strictly linear problem.

The matrix format for the model employed in this study is given in Table I. The matrix is for a problem with two demand areas, two potential plant locations, and two supply areas. There are two sets of special variables, Sij, one for the nonlinear cost function at each potential plant location. In Table I

D_{ij} = the quantity shipped from plant i to demand area j.

C_{ij} = the cost of shipping one unit from plant i to demand area j.

Plt i = processing at plant i.

Cost i = cost of processing at plant i.

Sij = special variable j for plant i

T_{ij} = quantity of the factor shipped from supply area i to processing plant j.

R_{ij} = cost of shipping one unit from supply area i to processing plant j.

The solution to the model depicted in Table I is obtained by use of Program SC-M3, Linear and Separable Programming System, available from the SHARE library.

APPENDIX A, TABLE I

MATRIX FOR EXTENDED PRODUCTION-DISTRIBUTION MODEL: TWO DEMAND AREAS, TWO POTENTIAL PROCESSING LOCATIONS, AND TWO SUPPLY AREAS

Right Hand Side	Type Restriction	Objective Name	D_{11}	D_{21}	D_{12}	D_{22}	Plt 1	Cost 1	S11	S12	S13	S14	Plt 2	Cost 2	S21	S22	S23	S24	T_{11}	T_{21}	T_{12}	T_{22}
0	=	-1	C_{11}	C_{21}	C_{12}	C_{22}		1						1					R_{11}	R_{21}	R_{12}	R_{22}
Demand 1	=		1	1																		
Demand 2	=				1	1																
0	=		1		1		-1															
0	=			1		1							-1									
0	=						1												-1	-1		
0	=						-1		a_{11}	a_{12}	a_{13}	a_{14}										
0	=							-1	b_{11}	b_{12}	b_{13}	b_{14}										
1	=								1	1	1	1										
0	=												1								-1	-1
0	=												-1		a_{21}	a_{22}	a_{23}	a_{24}				
0	=													-1	b_{21}	b_{22}	b_{23}	b_{24}				
1	=														1	1	1	1				
Supply 1	$\geq$																		1		1	
Supply 2	$\geq$																			1		1

APPENDIX B

APPENDIX B, TABLE I

TOTAL AND PER UNIT FLUID MILK PROCESSING COSTS, BY COST COMPONENT, FOUR PLANT SIZES

	Size of Plant (Quarts Annually)											
	1,600,000			5,400,000			13,500,000			27,000,000		
Item	Total	Per Quart	Percent of Total	Total	Per Quart	Percent of Total	Total	Per Quart	Percent of Total	Total	Per Quart	Percent of Total
Labor	$28,782	$0.0180	31.0	$71,251	$0.0132	32.9	$143,941	$0.0107	32.3	$243,734	$0.0090	29.5
Containers	21,658	0.0135	23.4	71,324	0.0132	33.0	177,108	0.0131	39.7	353,986	0.0131	42.9
Operating Supplies	3,214	0.0020	3.5	10,680	0.0020	4.9	26,700	0.0020	6.0	53,400	0.0020	6.5
Equipment Rental	12,016	0.0075	13.0	17,527	0.0032	8.1	22.089	0.0016	4.9	47,865	0.0018	5.8
Depreciation & Repairs												
Building	2,825	0.0018	3.0	3,728	0.0007	1.7	7,577	0.0006	1.7	12,737	0.0005	1.5
Equipment	8,944	0.0056	9.6	15,512	0.0029	7.2	29,081	0.0022	6.5	50,326	0.0019	6.1
Taxes	2,471	0.0015	2.7	3,262	0.0006	1.5	6,630	0.0005	1.5	11,145	0.0004	1.4
Insurance	1,673	0.0010	1.8	2,570	0.0005	1.2	4,791	0.0004	1.1	8,265	0.0003	1.0
Utilities	5,800	0.0036	6.3	14,300	0.0026	6.6	20,800	0.0015	4.7	30,680	0.0011	3.7
Other[a]	1,100	0.0007	1.2	1,690	0.0003	.8	2,750	0.0002	.6	5,500	0.0002	.7
Manager's Salary	4,235	0.0026	4.6	4,537	0.0008	2.1	4,840	0.0004	1.1	7,260	0.0003	.9
TOTAL	92,718	0.0579	100.1	216,381	0.0401	100.0	446,307	0.0331	100.1	824,898	0.0306	100.0

[a]Travel, legal, auditing, and advertising expenses.

APPENDIX B, TABLE II

QUANTITIES, PRICES, AND COSTS OF FLUID MILK CONTAINERS FOR A PLANT PROCESSING 1,600,000 QUARTS ANNUALLY

Container Size	Total Volume of Milk[a]	Glass Containers					Paper Containers				Total Cost of Containers
		Volume of Milk	Number of Containers	Number Purchased[b]	Cost Per Unit	Total Cost	Volume of Milk	Number of Containers	Cost Per Unit[c]	Total Cost	
Gallon	518,400	133,669	33,417	2,785	$0.1944	$ 541	384,731	96,183	$54.67	$ 5,258	$ 5,799
Half Gallon	862,400	112,673	56,337	4,695	0.1278	600	749,727	374,864	26.48	9,926	10,526
Quart	100,800	20,140	20,140	1,678	0.0649	109	80,660	80,660	15.79	1,274	1,383
Pint	11,200	38	76	6	0.0576	e	11,162	22,324	11.03[d]	266	266
Half Pint	107,200	2,310	9,240	770	0.0448	34	104,890	419,560	8.70	3,650	3,684
TOTAL	1,600,000	268,830				1,284	1,331,170			20,374	21,658

[a]All volumes are expressed as quart equivalents.

[b]Based on the assumption that each glass container makes 12 trips.

[c]Cost per thousand.

[d]Average cost per thousand for pint and one-third quart containers.

[e]Less than one dollar.

APPENDIX B, TABLE III

QUANTITIES, PRICES, AND COSTS OF FLUID MILK CONTAINERS FOR A PLANT PROCESSING 5,400,000 QUARTS ANNUALLY

		Glass Containers					Paper Containers				
Container Size	Total Volume of Milk[a]	Volume of Milk	Number of Containers	Number Purchased[b]	Cost Per Unit	Total Cost	Volume of Milk	Number of Containers	Cost Per Unit[c]	Total Cost	Total Cost of Containers
Gallon	1,749,600	451,134	112,784	9,399	$0.1944	$1,827	1,298,466	324,617	$51.22	$16,627	$18,454
Half Gallon	2,910,600	380,270	190,135	15,845	0.1278	2,025	2,530,330	1,265,165	26.21	33,160	35,185
Quart	340,200	67,972	67,972	5,664	0.0649	368	272,228	272,228	15.38	4,187	4,555
Pint	37,800	127	254	21	0.0516	1	37,673	75,346	10.52[d]	793	794
Half Pint	361,800	7,797	31,188	2,599	0.0448	116	354,003	1,416,012	8.63	12,220	12,336
TOTAL	5,400,000	907,300				4,337	4,492,700			66,987	71,324

[a] All volumes are expressed as quart equivalents.

[b] Based on the assumption that each glass container makes 12 trips.

[c] Cost per thousand.

[d] Average cost per thousand for pint and one-third quart containers.

APPENDIX B, TABLE IV

QUANTITIES, PRICES, AND COSTS OF FLUID MILK CONTAINERS FOR A PLANT PROCESSING 13,500,000 QUARTS ANNUALLY

Container Size	Total Volume of Milk[a]	Glass Containers: Volume of Milk	Number of Containers	Number Purchased[b]	Cost Per Unit	Total Cost	Paper Containers: Volume of Milk	Number of Containers	Cost Per Unit[c]	Total Cost	Total Cost of Containers
Gallon	4,274,000	1,127,836	281,959	23,497	$0.1944	$ 4,564	3,246,164	811,541	$51.02	$ 41,405	$ 45,969
Half Gallon	7,276,500	950,675	475,338	30,612	0.1278	5,062	6,325,825	3,162,013	26.00	82,236	87,298
Quart	580,500	169,930	169,930	14,161	0.0649	919	680,570	680,570	15.26	10,385	11,304
Pint	94,500	317	634	53	0.0516	3	94,183	188,366	10.30[d]	1,940	1,943
Half Pint	904,500	19,492	77,968	6,497	0.0448	291	885,008	3,540,032	8.56	30,303	30,594
TOTAL	13,500,000	2,268,500				10,839	11,231,500			166,269	177,108

[a]All volumes are expressed as quart equivalents.

[b]Based on the assumption that each glass container makes 12 trips.

[c]Cost per thousand.

[d]Average cost per thousand for pint and one-third quart containers.

APPENDIX B, TABLE V

QUANTITIES, PRICES, AND COSTS OF FLUID MILK CONTAINERS FOR A PLANT PROCESSING 27,000,000 QUARTS ANNUALLY

		Glass Containers					Paper Containers				
Container Size	Total Volume of Milk[a]	Volume of Milk	Number of Containers	Number Purchased[b]	Cost Per Unit	Total Cost	Volume of Milk	Number of Containers	Cost Per Unit[c]	Total Cost	Total Cost of Containers
Gallon	8,748,000	2,255,672	563,918	46,993	$0.1944	$ 9,135	6,492,328	1,623,082	$50.93	$ 82,634	$ 91,769
Half Gallon	14,553,000	1,901,349	950,675	79,223	0.1278	10,125	12,651,651	6,325,826	26.00	164,471	174,596
Quart	1,701,000	339,860	339,860	28,322	0.0649	1,838	1,361,140	1,361,140	15.24	20,744	22,582
Pint	189,000	633	1,266	106	0.0516	6	188,367	376,734	10.21[d]	3,846	3,852
Half Pint	1,809,000	38,984	155,936	12,995	0.0448	582	1,770,016	7,080,064	8.56	60,605	61,187
TOTAL	27,000,000	4,536,498				21,686	22,463,502			323,300	353,986

[a]All volumes are expressed as quart equivalents.

[b]Based on the assumption that each glass container makes 12 trips.

[c]Cost per thousand.

[d]Average cost per thousand for pint and one-third quart containers.

APPENDIX B, TABLE VI

ESTIMATES OF POPULATION, PER CAPITA CONSUMPTION, AND TOTAL CONSUMPTION OF FLUID MILK, BY COUNTY, OKLAHOMA, 1965

County	Per Capita Consumption (pounds)	Population	Total Consumption (pounds)
Adair	280	13,312	3,727,360
Alfalfa	302	8,294	2,504,788
Atoka	287	9,880	2,835,560
Beaver	315	7,117	2,241,855
Beckham	287	17,662	5,068,994
Blaine	286	11,785	3,370,510
Bryan	283	24,158	6,836,714
Caddo	285	28,879	8,230,515
Canadian	288	25,892	7,457,896
Carter	305	40,269	12,282,045
Cherokee	287	18,405	5,282,235
Choctaw	278	15,186	4,221,708
Cimarron	312	4,750	1,482,000
Cleveland	288	54,656	15,740,928
Coal	291	5,182	1,507,962
Comanche	294	105,451	30,708,594
Cotton	300	7,819	2,345,700
Craig	281	16,490	4,633,690
Creek	287	41,460	11,899,020
Custer	291	22,314	6,493,374
Delaware	289	13,452	3,887,628
Dewey	297	5,749	1,707,453
Ellis	298	5,082	1,514,436
Garfield	300	54,381	16,314,300
Garvin	289	29,010	8,383,890
Grady	287	29,681	8,518,447
Grant	313	8,069	2,525,597
Greer	295	8,683	2,561,485
Harmon	309	5,639	1,742,451
Harper	310	6,357	1,970,670
Haskell	291	8,701	2,531,991
Hughes	299	14,044	4,199,156
Jackson	301	36,302	10,926,902
Jefferson	304	7,839	2,383,056
Johnston	290	8,411	2,439,190
Kay	313	52,902	16,558,326
Kingfisher	305	10,726	3,271,430
Kiowa	287	14,675	4,211,725
Latimer	289	7,658	2,213,162
LeFlore	274	29,090	7,970,660
Lincoln	287	18,795	5,394,165
Logan	291	18,665	5,431,515

APPENDIX B, TABLE VI (continued)

County	Per Capita Consumption	Population	Total Consumption (pounds)
Love	295	5,463	1,611,585
McClain	295	12,791	3,773,345
McCurtain	276	25,872	7,140,672
McIntosh	288	11,879	3,421,152
Major	297	7,598	2,256,606
Marshall	307	7,333	2,251,231
Mayes	284	20,952	5,950,368
Murray	290	10,866	3,151,140
Muskogee	296	63,624	18,832,704
Noble	304	10,510	3,195,040
Nowata	288	10,976	3,161,088
Okfuskee	280	11,307	3,165,960
Oklahoma	309	519,047	160,385,523
Okmulgee	298	36,668	10,927,064
Osage	283	33,791	9,562,853
Ottawa	301	28,659	8,626,359
Pawnee	300	10,736	3,220,800
Payne	295	45,940	13,552,300
Pittsburg	290	34,302	9,947,580
Pontotoc	296	28,649	8,480,104
Pottawatomie	292	42,783	12,492,636
Pushmataha	292	8,911	2,602,012
Roger Mills	288	4,922	1,417,536
Rogers	282	22,003	6,204,846
Seminole	288	27,456	7,907,328
Sequoyah	289	18,590	5,372,510
Stephens	306	40,402	12,363,012
Texas	311	14,904	4,635,144
Tillman	293	14,765	4,326,145
Tulsa	319	370,691	118,250,429
Wagoner	292	16,069	4,692,148
Washington	327	46,622	15,245,394
Washita	296	19,517	5,777,032
Woods	293	11,934	3,496,662
Woodward	291	14,595	4,247,145

APPENDIX B, TABLE VII

PROJECTIONS OF POPULATION AND TOTAL FLUID MILK CONSUMPTION, BY COUNTY, OKLAHOMA, 1975

County	Population	Total Consumption (pounds)
Adair	13,744	3,848,367
Alfalfa	8,064	2,435,531
Atoka	9,108	2,614,073
Beaver	7,428	2,339,676
Beckham	17,497	5,016,523
Blaine	11,283	3,227,054
Bryan	24,076	6,813,505
Caddo	29,474	8,399,967
Canadian	28,364	8,168,801
Carter	42,683	13,018,462
Cherokee	19,473	5,666,109
Choctaw	14,455	4,018,538
Cimarron	5,286	1,649,084
Cleveland	72,236	20,803,873
Coal	4,593	1,336,472
Comanche	136,790	40,216,278
Cotton	7,473	2,241,805
Craig	16,900	4,748,949
Creek	43,450	12,470,251
Custer	35,022	7,281,404
Delaware	13,978	4,039,519
Dewey	5,241	1,556,714
Ellis	4,464	1,330,302
Garfield	51,139	17,141,790
Garvin	30,475	8,807,383
Grady	29,961	8,598,859
Grant	7,977	2,496,952
Greer	8,379	2,471,743
Harmon	5,282	1,632,119
Harper	7,216	2,237,068
Haskell	8,021	2,334,216
Hughes	12,254	3,664,011
Jackson	54,694	16,462,936
Jefferson	7,259	2,206,679
Johnston	8,253	2,393,240
Kay	56,533	17,694,754
Kingfisher	10,949	3,339,449
Kiowa	14,459	4,149,805
Latimer	7,454	2,154,134
LeFlore	29,177	7,994,604
Lincoln	18,882	5,419,029
Logan	18,755	5,457,642

APPENDIX B, TABLE VII (continued)

County	Population	Total Consumption (pounds)
Love	4,799	1,415,639
McClain	12,927	3,813,533
McCurtain	26,017	7,180,761
McIntosh	11,084	3,192,289
Major	7,248	2,152,761
Marshall	7,479	2,296,205
Mayes	22,771	6,466,956
Murray	11,388	3,302,416
Muskogee	67,211	19,894,518
Noble	10,795	3,281,707
Nowata	11,269	3,245,539
Okfuskee	10,681	2,990,066
Oklahoma	725,264	224,106,550
Okmulgee	36,267	10,807,458
Osage	36,615	10,362,182
Ottawa	29,436	8,860,354
Pawnee	10,517	3,155,063
Payne	49,475	14,595,026
Pittsburg	34,378	9,969,486
Pontotoc	29,857	8,837,793
Pottawatomie	45,475	13,278,587
Pushmataha	8,626	2,518,925
Roger Mills	4,655	1,340,664
Rogers	24,963	7,039,456
Seminole	26,569	7,651,762
Sequoyah	19,834	5,732,117
Stephens	45,485	13,918,297
Texas	16,457	5,118,055
Tillman	15,045	4,408,168
Tulsa	418,398	133,468,940
Wagoner	16,901	4,935,050
Washington	55,991	18,308,961
Washita	22,646	6,703,160
Woods	11,977	3,509,270
Woodward	16,052	4,671,092

APPENDIX B, TABLE VIII

TOTAL CLASS I PRODUCER RECEIPTS AND PERCENT OF TOTAL CLASS I PRODUCER RECEIPTS, BY COUNTY, OKLAHOMA, 1961

County	Total Receipts (1,000 lbs.)	Percent of Total Receipts
Adair	13,255	1.49
Alfalfa	5,894	0.66
Atoka	000	0.00
Beaver	17,856	2.00
Beckham	9,123	1.03
Blaine	7,235	0.81
Bryan	11,865	1.33
Caddo	12,615	1.42
Canadian	28,098	3.15
Carter	7,679	0.86
Cherokee	12,681	1.42
Choctaw	8,488	0.95
Cimarron	1,897	0.21
Cleveland	19,726	2.21
Coal	361	0.04
Comanche	23,498	2.64
Cotton	000	0.00
Craig	18,104	2.03
Creek	5,396	0.61
Custer	10,340	1.16
Delaware	6,394	0.72
Dewey	5,624	0.63
Ellis	37,517	4.21
Garfield	5,509	0.62
Garvin	11,563	1.30
Grady	47,572	5.34
Grant	1,024	0.11
Greer	2,339	0.26
Harmon	873	0.10
Harper	6,615	0.74
Haskell	3,026	0.34
Hughes	000	0.00
Jackson	2,923	0.33
Jefferson	1,585	0.18
Johnston	7,156	0.80
Kay	18,254	2.09
Kingfisher	27,439	3.08
Kiowa	4,898	0.55
Latimer	000	0.00
LeFlore	000	0.00
Lincoln	23,104	2.59
Logan	8,020	0.90

APPENDIX B, TABLE VIII (continued)

County	Total Receipts (1,000 lbs.)	Percent of Total Receipts
Love	2,343	0.26
McClain	32,443	3.64
McCurtain	9,885	1.11
McIntosh	3,069	0.34
Major	8,932	1.00
Marshall	3,134	0.34
Mayes	24,817	3.30
Murray	19,087	2.14
Muskogee	24,727	2.77
Noble	3,884	0.44
Nowata	10,860	1.22
Okfuskee	3,571	0.41
Oklahoma	26,344	2.96
Okmulgee	000	0.00
Osage	6,602	0.74
Ottawa	6,576	0.74
Pawnee	6,447	0.72
Payne	19,425	2.18
Pittsburg	794	0.09
Pontotoc	15,824	1.78
Pottawatomie	32,665	3.66
Pushmataha	1,600	0.18
Roger Mills	30,303	3.40
Rogers	29,918	3.36
Seminole	8,469	0.95
Sequoyah	000	0.00
Stephens	6,342	0.71
Texas	5,490	0.62
Tillman	4,055	0.45
Tulsa	61,107	6.85
Wagoner	11,620	1.30
Washington	10,464	1.17
Washita	10,922	1.23
Woods	3,740	0.42
Woodward	5,543	0.66

APPENDIX B, TABLE IX

TOTAL CLASS I PRODUCER RECEIPTS AND PERCENT OF TOTAL CLASS I PRODUCER RECEIPTS, BY COUNTY, OKLAHOMA, 1965

County	Total Receipts (1,000 lbs.)	Percent of Total Receipts
Adair	13,354	1.41
Alfalfa	7,439	0.79
Atoka	1,151	0.12
Beaver	18,404	1.94
Beckham	15,620	1.65
Blaine	10,068	1.06
Bryan	10,601	1.12
Caddo	10,849	1.15
Canadian	34,156	3.61
Carter	5,091	0.54
Cherokee	10,851	1.15
Choctaw	5,200	0.55
Cimarron	380	0.04
Cleveland	19,933	2.10
Coal	274	0.03
Comanche	23,649	2.50
Cotton	000	0.00
Craig	14,665	1.55
Creek	6,279	0.66
Custer	13,580	1.43
Delaware	9,535	1.01
Dewey	2,054	0.22
Ellis	46,632	4.92
Garfield	6,286	0.66
Garvin	12,558	1.33
Grady	51,777	5.47
Grant	1,781	0.19
Greer	1,837	0.19
Harmon	1,218	0.13
Harper	10,837	1.14
Haskell	2,717	0.29
Hughes	1,072	0.11
Jackson	2,277	0.24
Jefferson	2,147	0.23
Johnston	10,276	1.09
Kay	19,675	2.08
Kingfisher	31,828	3.36
Kiowa	3,975	0.42
Latimer	000	0.00
LeFlore	000	0.00
Lincoln	32,974	3.48
Logan	9,529	1.01

APPENDIX B, TABLE IX (continued)

County	Total Receipts (1,000 lbs.)	Percent of Total Receipts
Love	1,128	0.12
McClain	32,981	3.48
McCurtain	6,030	0.64
McIntosh	2,156	0.23
Major	13,151	1.39
Marshall	2,090	0.22
Mayes	25,430	2.69
Murray	22,429	2.37
Muskogee	19,255	2.03
Noble	6,245	0.66
Nowata	10,364	1.09
Okfuskee	5,278	0.56
Oklahoma	27,061	2.86
Okmulgee	4,225	0.45
Osage	3,643	0.38
Ottawa	5,006	0.53
Pawnee	6,692	0.71
Payne	23,866	2.52
Pittsburg	000	0.00
Pontotoc	19,840	2.10
Pottawatomie	32,539	3.44
Pushmataha	298	0.03
Roger Mills	45,819	4.84
Rogers	25,480	2.69
Seminole	11,628	1.23
Sequoyah	000	0.00
Stephens	8,436	0.89
Texas	6,683	0.71
Tillman	3,470	0.37
Tulsa	45,803	4.84
Wagoner	12,441	1.31
Washington	8,915	0.94
Washita	14,875	1.57
Woods	3,381	0.36
Woodward	7,828	0.83

APPENDIX B, TABLE X

PROJECTED TOTAL CLASS I PRODUCER RECEIPTS AND PERCENT OF TOTAL CLASS I PRODUCER RECEIPTS, BY COUNTY, OKLAHOMA, 1975

County	Total Receipts (1,000 lbs.)	Percent of Total Receipts
Adair	16,155	1.41
Alfalfa	9,099	0.79
Atoka	1,382	0.12
Beaver	22,238	1.94
Beckham	19,236	1.68
Blaine	12,245	1.07
Bryan	12,791	1.11
Caddo	13,120	1.14
Canadian	41,921	3.65
Carter	6,150	0.54
Cherokee	13,113	1.14
Choctaw	6,251	0.54
Cimarron	475	0.04
Cleveland	24,043	2.09
Coal	344	0.03
Comanche	28,601	2.49
Cotton	000	0.00
Craig	17,581	1.53
Creek	7,587	0.66
Custer	16,528	1.44
Delaware	11,679	1.02
Dewey	2,500	0.22
Ellis	57,486	5.01
Garfield	7,579	0.66
Garvin	15,280	1.33
Grady	63,002	5.49
Grant	2,186	0.19
Greer	2,177	0.19
Harmon	1,494	0.13
Harper	13,219	1.15
Haskell	3,325	0.29
Hughes	1,266	0.11
Jackson	2,749	0.24
Jefferson	2,644	0.23
Johnston	12,604	1.10
Kay	23,873	2.08
Kingfisher	38,844	3.38
Kiowa	4,806	0.42
Latimer	000	0.00
LeFlore	000	0.00
Lincoln	40,841	3.56
Logan	11,627	1.01

APPENDIX B, TABLE X (continued)

County	Total Receipts (1,000 lbs.)	Percent of Total Receipts
Love	1,373	0.12
McClain	39,792	3.47
McCurtain	7,261	0.63
McIntosh	2,633	0.23
Major	16,113	1.40
Marshall	2,517	0.22
Mayes	30,411	2.65
Murray	27,365	2.38
Muskogee	22,874	1.99
Noble	7,619	0.66
Nowata	12,473	1.09
Okfuskee	6,455	0.56
Oklahoma	32,752	2.85
Okmulgee	5,224	0.46
Osage	4,323	0.38
Ottawa	6,058	0.53
Pawnee	8,149	0.71
Payne	29,177	2.54
Pittsburg	000	0.00
Pontotoc	24,302	2.13
Pottawatomie	39,275	3.42
Pushmataha	343	0.03
Roger Mills	57,566	5.01
Rogers	30,365	2.64
Seminole	14,220	1.24
Sequoyah	000	0.00
Stephens	10,264	0.89
Texas	8,169	0.71
Tillman	4,239	0.37
Tulsa	52,773	4.60
Wagoner	15,043	1.31
Washington	10,730	0.93
Washita	18,177	1.58
Woods	4,127	0.36
Woodward	9,579	0.83

APPENDIX B, TABLE XI

ASSEMBLY AND DISTRIBUTION POINTS USED FOR EACH COUNTY IN OKLAHOMA

County	Assembly and Distribution Point
Adair	Stillwell
Alfalfa	Cherokee
Atoka	Atoka
Beaver	Beaver
Beckham	Elk City
Blaine	Watonga
Bryan	Durant
Caddo	Anadarko
Canadian	El Reno
Carter	Ardmore
Cherokee	Tahlequah
Choctaw	Hugo
Cimarron	Boise City
Cleveland	Norman
Coal	Coalgate
Comanche	Lawton
Cotton	Walters
Craig	Vinita
Creek	Bristow
Custer	Clinton
Delaware	Jay
Dewey	Taloga
Ellis	Arnett
Garfield	Enid
Garvin	Pauls Valley
Grady	Chickasha
Grant	Medford
Greer	Mangum
Harmon	Hollis
Harper	Buffalo
Haskell	Stigler
Hughes	Holdenville
Jackson	Altus
Jefferson	Waurika
Johnston	Tishimingo
Kay	Ponca City
Kingfisher	Kingfisher
Kiowa	Hobart
Latimer	Wilburton
LeFlore	Poteau
Lincoln	Chandler
Logan	Guthrie

APPENDIX B, TABLE XI (continued)

County	Assembly and Distribution Point
Love	Marietta
McClain	Purcell
McIntosh	Checotah
Major	Fairview
Marshall	Madill
Mayes	Pryor Creek
Murray	Sulphur
Muskogee	Muskogee
Noble	Perry
Nowata	Nowata
Okfuskee	Okemah
Oklahoma	Oklahoma City
Okmulgee	Okmulgee
Osage	Pawhuska
Ottawa	Miami
Pawnee	Pawnee
Payne	Stillwater
Pittsburg	McAlester
Pontotoc	Ada
Pottawatomie	Shawnee
Pushmataha	Antlers
Roger Mills	Cheyenne
Rogers	Claremore
Seminole	Seminole
Sequoyah	Sallisaw
Stephens	Duncan
Texas	Guymon
Tillman	Frederick
Tulsa	Tulsa
Wagoner	Wagoner
Washington	Bartlesville
Washita	Cordell
Woods	Alva
Woodward	Woodward

APPENDIX B, TABLE XII

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PRODUCERS TO PROCESSORS AND VALUE OF ADDITIONAL PRODUCTION, BASED ON FIVE POTENTIAL PLANT LOCATIONS, 1965

From County	To City	Quantity Shipped	Unused Production	Value of Additional Production
		(1,000 lbs.)	(1,000 lbs.)	($ per 1,000 lbs.)
Adair	Tulsa	13,354	0	0.234
Blaine	Oklahoma City	10,068	0	0.553
Caddo	Oklahoma City	10,849	0	0.611
Canadian	Oklahoma City	34,156	0	1.092
Carter	Oklahoma City	5,091	0	0.130
Cherokee	Tulsa	10,851	0	0.546
Cleveland	Oklahoma City	10,933	0	1.235
Comanche	Lawton	23,649	0	1.967
Craig	Tulsa	14,665	0	0.650
Creek	Tulsa	6,279	0	1.027
Custer	Oklahoma City	13,580	0	0.325
Delaware	Tulsa	9,535	0	0.598
Garfield	Oklahoma City	6,286	0	0.390
Garvin	Oklahoma City	12,558	0	0.702
Grady	Oklahoma City	51,777	0	0.871
Haskell	Tulsa	2,717	0	0.169
Hughes	Oklahoma City	1,072	0	0.442
Jackson	Lawton	2,277	0	0.013
Jefferson	Oklahoma City	2,147	0	0.026
Kay	Tulsa	19,675	0	0.273
Kingfisher	Oklahoma City	31,828	0	0.897
Kiowa	Oklahoma City	2,781	1,194	0.000
Lincoln	Oklahoma City	32,974	0	0.845
Logan	Oklahoma City	9,529	0	0.975
McClain	Oklahoma City	32,981	0	0.988
McIntosh	Tulsa	2,156	0	0.481
Major	Oklahoma City	13,151	0	0.078
Mayes	Tulsa	25,430	0	0.910
Murray	Oklahoma City	22,429	0	0.338
Muskogee	Tulsa	19,225	0	0.741
Noble	Oklahoma City	6,245	0	0.611
Nowata	Tulsa	10,365	0	0.832
Okfuskee	Tulsa	5,278	0	0.624
Oklahoma	Oklahoma City	27,061	0	2.669
Okmulgee	Tulsa	4,225	0	0.975
Osage	Tulsa	3,643	0	0.780
Ottawa	Tulsa	5,006	0	0.247
Pawnee	Tulsa	6,692	0	0.819
Payne	Tulsa	3,879	0	0.598
	Oklahoma City	19,986		

APPENDIX B, TABLE XII (Continued)

From County	To City	Quantity Shipped (1,000 lbs.)	Unused Production (1,000 lbs.)	Value of Additional Production ($ per 1,000 lbs.)
Pontotoc	Oklahoma City	19,840	0	0.390
Pottawatomie	Oklahoma City	35,539	0	0.975
Rogers	Tulsa	25,480	0	1.131
Seminole	Oklahoma City	11,628	0	0.741
Stephens	Oklahoma City	7,123	0	0.351
	Lawton	1,313		
Tillman	Lawton	3,470	0	0.169
Tulsa	Tulsa	45,803	0	2.682
Wagoner	Tulsa	12,441	0	0.884
Washington	Tulsa	8,915	0	0.845
Washita	Oklahoma City	14,875	0	0.273

APPENDIX B, TABLE XIII

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PROCESSORS TO DEMAND AREAS AND COST FOR ADDITIONAL QUANTITIES DEMANDED, BASED ON FIVE POTENTIAL PLANT LOCATIONS, 1965

Demand Area	Source of Milk	Quantity	Cost per Additional 1,000 pounds
		(1,000 lbs.)	(dollars)
Adair	Tulsa	3,727	15.06
Alfalfa	Oklahoma City	2,505	15.19
Atoka	Oklahoma City	2,836	15.11
Beckham	Oklahoma City	5,069	14.93
Blaine	Oklahoma City	3,370	14.43
Bryan	Oklahoma City	6,837	15.35
Caddo	Oklahoma City	8,231	14.36
Canadian	Oklahoma City	7,457	13.92
Carter	Oklahoma City	12,282	14.81
Cherokee	Tulsa	5,282	14.78
Choctaw	Oklahoma City	4,222	16.12
Cleveland	Oklahoma City	15,741	13.79
Coal	Oklahoma City	1,508	14.96
Comanche	Lawton	30,708	14.41
Cotton	Oklahoma City	2,346	14.95
Craig	Tulsa	4,634	14.68
Creek	Tulsa	11,899	14.33
Custer	Oklahoma City	6,493	14.63
Delaware	Tulsa	3,888	14.73
Dewey	Oklahoma City	1,707	15.00
Ellis	Oklahoma City	1,514	15.77
Garfield	Oklahoma City	16,314	14.57
Garvin	Oklahoma City	8,384	14.28
Grady	Oklahoma City	8,518	14.12
Grant	Oklahoma City	2,526	14.96
Greer	Oklahoma City	2,561	15.31
Harmon	Oklahoma City	1,742	16.19
Harper	Oklahoma City	1,971	16.06
Haskell	Tulsa	5,373	15.12
Hughes	Oklahoma City	4,199	14.52
Jackson	Oklahoma City	10,927	15.77
Jefferson	Oklahoma City	2,383	14.90
Johnston	Oklahoma City	2,439	14.97
Kay	Oklahoma City	16,558	14.87
Kingfisher	Oklahoma City	3,271	14.10
Kiowa	Oklahoma City	4,212	14.93
Latimer	Tulsa	2,213	15.47
LeFlore	Tulsa	7,971	15.60
Lincoln	Oklahoma City	5,394	14.15
Logan	Oklahoma City	5,432	14.03

APPENDIX B, TABLE XIII (Continued)

Demand Area	Source of Milk	Quantity	Cost per Additional 1,000 pounds
		(1,000 lbs.)	(dollars)
Love	Oklahoma City	1,612	15.02
McClain	Oklahoma City	3,773	14.01
McCurtain	Oklahoma City	7,141	16.72
McIntosh	Tulsa	3,421	14.84
Major	Oklahoma City	2,257	14.85
Marshall	Oklahoma City	2,251	15.31
Mayes	Tulsa	5,950	14.44
Murray	Oklahoma City	3,151	14.61
Muskogee	Tulsa	18,832	14.60
Noble	Oklahoma City	3,195	14.36
Nowata	Tulsa	3,161	14.51
Okfuskee	Oklahoma City	3,166	14.48
Oklahoma	Oklahoma City	160,386	12.37
Okmulgee	Tulsa	10,927	14.38
Osage	Tulsa	9,563	14.56
Ottawa	Tulsa	8,626	15.05
Pawnee	Tulsa	3,221	14.52
Payne	Oklahoma City	13,552	14.37
Pittsburg	Oklahoma City	9,948	15.07
Pontotoc	Oklahoma City	8,480	14.57
Pottawatomie	Oklahoma City	12,493	14.03
Pushmataha	Oklahoma City	2,602	15.84
Roger Mills	Oklahoma City	1,418	15.29
Rogers	Tulsa	6,205	14.24
Seminole	Oklahoma City	7,907	14.24
Sequoyah	Tulsa	5,373	15.21
Stephens	Oklahoma City	12,363	14.60
Tillman	Oklahoma City	4,326	15.31
Wagoner	Tulsa	4,692	14.46
Washington	Tulsa	15,245	14.50
Washita	Oklahoma City	5,777	14.67
Woods	Oklahoma City	3,497	15.74
Woodward	Oklahoma City	4,247	15.30

APPENDIX B, TABLE XIV

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PRODUCERS TO PROCESSORS AND VALUE OF ADDITIONAL PRODUCTION, BASED ON FIVE POTENTIAL PLANT LOCATIONS, 1975

From County	To City	Quantity Shipped	Unused Production	Value of Additional Production
		(1,000 lbs.)	(1,000 lbs.)	($ per 1,000 lbs.)
Blaine	Oklahoma City	12,245	0	0.455
Caddo	Oklahoma City	13,120	0	0.533
Canadian	Oklahoma City	41,921	0	1.014
Carter	Oklahoma City	6,150	0	0.052
Cherokee	Tulsa	13,113	0	0.299
Cleveland	Oklahoma City	24,043	0	1.157
Comanche	Lawton	28,601	0	1.889
Craig	Tulsa	17,581	0	0.403
Creek	Tulsa	7,587	0	0.780
Custer	Oklahoma City	16,528	0	0.247
Delaware	Tulsa	11,679	0	0.351
Garfield	Oklahoma City	7,579	0	0.312
Garvin	Oklahoma City	15,280	0	0.624
Grady	Oklahoma City	63,002	0	0.793
Hughes	Oklahoma City	1,266	0	0.364
Kay	Tulsa	23,873	0	0.026
Kingfisher	Oklahoma City	38,844	0	0.819
Lincoln	Oklahoma City	40,841	0	0.767
Logan	Oklahoma City	11,627	0	0.897
McClain	Oklahoma City	39,792	0	0.910
McIntosh	Tulsa	2,633	0	0.234
Major	Oklahoma City	6,276	9,837	0
Mayes	Tulsa	30,411	0	0.663
Murray	Oklahoma City	27,365	0	0.260
Muskogee	Tulsa	22,874	0	0.494
Noble	Oklahoma City	7,619	0	0.533
Nowata	Tulsa	12,473	0	0.585
Okfuskee	Tulsa	6,455	0	0.377
Oklahoma	Oklahoma City	32,752	0	2.591
Okmulgee	Tulsa	5,224	0	0.728
Osage	Tulsa	4,323	0	0.533
Ottawa	Tulsa	3,439	2,614	0
Pawnee	Tulsa	8,149	0	0.572
Payne	Oklahoma City	29,177	0	0.520
Pontotoc	Oklahoma City	24,302	0	0.312
Pottawatomie	Oklahoma City	39,275	0	0.897
Rogers	Tulsa	30,365	0	0.884
Seminole	Oklahoma City	14,220	0	0.663
Stephens	Oklahoma City	2,888	0	0.273
	Lawton	7,376		

APPENDIX B, TABLE XIV (continued)

From County	To City	Quantity Shipped (1,000 lbs.)	Unused Production (1,000 lbs.)	Value of Additional Production ($ per 1,000 lbs.)
Tillman	Lawton	4,239	0	0.091
Tulsa	Tulsa	52,773	0	2.435
Wagoner	Tulsa	15,043	0	0.637
Washington	Tulsa	10,730	0	0.598
Washita	Oklahoma City	18,177	0	0.195

APPENDIX B, TABLE XV

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PROCESSORS TO DEMAND AREAS AND COST FOR ADDITIONAL QUANTITIES DEMANDED, BASED ON FIVE POTENTIAL PLANT LOCATIONS, 1975

Demand Area	Source of Milk	Quantity	Cost per Additional 1,000 pounds
		(1,000 lbs.)	(dollars)
Adair	Tulsa	3,848	14.82
Alfalfa	Oklahoma City	2,436	15.10
Atoka	Oklahoma City	2,614	15.04
Beckham	Oklahoma City	5,017	14.85
Blaine	Oklahoma City	3,227	14.36
Bryan	Oklahoma City	6,813	15.27
Caddo	Oklahoma City	8,400	14.28
Canadian	Oklahoma City	8,169	13.84
Carter	Oklahoma City	13,018	14.73
Cherokee	Tulsa	5,666	14.53
Choctaw	Oklahoma City	4,019	16.04
Cleveland	Oklahoma City	20,804	13.71
Coal	Oklahoma City	1,336	14.88
Comanche	Lawton	40,216	14.33
Cotton	Oklahoma City	2,242	14.87
Craig	Tulsa	4,749	14.43
Creek	Tulsa	12,470	14.08
Custer	Oklahoma City	7,281	14.55
Delaware	Tulsa	4,040	14.48
Dewey	Oklahoma City	1,557	14.92
Ellis	Oklahoma City	1,330	15.69
Garfield	Oklahoma City	17,142	14.49
Garvin	Oklahoma City	8,807	14.20
Grady	Oklahoma City	8,559	14.04
Grant	Oklahoma City	2,497	14.88
Greer	Oklahoma City	2,472	15.23
Harmon	Oklahoma City	1,632	16.11
Harper	Oklahoma City	2,237	15.98
Haskell	Tulsa	2,334	14.88
Hughes	Oklahoma City	3,664	14.44
Jackson	Oklahoma City	16,463	15.69
Jefferson	Oklahoma City	2,207	14.82
Johnston	Oklahoma City	2,393	14.90
Kay	Oklahoma City	17,695	14.79
Kingfisher	Oklahoma City	3,339	14.02
Kiowa	Oklahoma City	4,150	14.85
Latimer	Tulsa	2,154	15.22
LeFlore	Tulsa	7,995	15.36
Lincoln	Oklahoma City	5,419	14.07
Logan	Oklahoma City	5,458	13.95

APPENDIX B, TABLE XV (continued)

Demand Area	Source of Milk	Quantity	Cost per Additional 1,000 pounds
		(1,000 lbs.)	(dollars)
Love	Oklahoma City	1,416	14.94
McClain	Oklahoma City	3,814	13.94
McCurtain	Oklahoma City	7,181	16.64
McIntosh	Tulsa	3,192	14.59
Major	Oklahoma City	2,153	14.78
Marshall	Oklahoma City	2,296	15.23
Mayes	Tulsa	6,467	14.19
Murray	Oklahoma City	3,302	14.54
Muskogee	Tulsa	19,895	14.35
Noble	Oklahoma City	3,282	14.28
Nowata	Tulsa	3,246	14.26
Okfuskee	Oklahoma City	2,990	14.40
Oklahoma	Oklahoma City	224,107	12.29
Okmulgee	Tulsa	10,807	14.13
Osage	Tulsa	10,362	14.31
Ottawa	Tulsa	8,860	14.80
Pawnee	Tulsa	3,155	14.28
Payne	Oklahoma City	14,595	14.30
Pittsburg	Oklahoma City	9,969	14.99
Pontotoc	Oklahoma City	8,838	14.49
Pottawatomie	Oklahoma City	13,279	13.95
Pushmataha	Oklahoma City	2,519	15.76
Roger Mills	Oklahoma City	1,341	15.21
Rogers	Tulsa	7,039	13.99
Seminole	Oklahoma City	7,652	14.16
Sequoyah	Tulsa	5,732	14.96
Stephens	Oklahoma City	13,918	14.52
Tillman	Oklahoma City	4,408	15.23
Tulsa	Tulsa	133,469	12.46
Wagoner	Tulsa	4,935	14.22
Washington	Tulsa	18,309	14.25
Washita	Oklahoma City	6,703	14.60
Woods	Oklahoma City	3,509	15.66
Woodward	Oklahoma City	4,671	15.22

APPENDIX B, TABLE XVI

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PRODUCERS TO PROCESSORS AND VALUE OF ADDITIONAL PRODUCTION, BASED ON THREE PLANTS EACH IN TULSA AND OKLAHOMA CITY, 1975

From County	To City	Quantity Shipped (1,000 lbs.)	Unused Production (1,000 lbs.)	Value of Additional Production ($ per 1,000 lbs.)
Adair	Tulsa	3,841	12,314	0
Blaine	Oklahoma City	12,245	0	0.455
Caddo	Oklahoma	13,120	0	0.533
Canadian	Oklahoma City	41,921	0	1.014
Carter	Oklahoma City	6,150	0	0.052
Cherokee	Tulsa	13,113	0	0.312
Cleveland	Oklahoma City	24,043	0	1.157
Comanche	Oklahoma City	28,601	0	0.104
Craig	Tulsa	17,581	0	0.416
Creek	Tulsa	7,587	0	0.793
Custer	Oklahoma City	16,528	0	0.247
Delaware	Tulsa	11,679	0	0.364
Garfield	Oklahoma City	7,579	0	0.312
Garvin	Oklahoma City	15,280	0	0.624
Grady	Oklahoma City	63,002	0	0.793
Hughes	Oklahoma City	1,266	0	0.364
Kay	Tulsa	23,873	0	0.039
Kingfisher	Oklahoma City	38,844	0	0.819
Lincoln	Oklahoma City	40,841	0	0.767
Logan	Oklahoma City	11,627	0	0.897
McClain	Oklahoma City	39,792	0	0.910
McIntosh	Tulsa	2,633	0	0.247
Major	Oklahoma City	4,059	12,054	0
Mayes	Tulsa	30,411	0	0.676
Murray	Oklahoma City	27,365	0	0.260
Muskogee	Tulsa	22,874	0	0.507
Noble	Oklahoma City	7,619	0	0.533
Nowata	Tulsa	12,473	0	0.598
Okfuskee	Oklahoma City	6,455	0	0.403
Oklahoma	Oklahoma City	32,752	0	2,591
Okmulgee	Tulsa	5,224	0	0.741
Osage	Tulsa	4,323	0	0.546
Ottawa	Tulsa	6,053	0	0.013
Pawnee	Tulsa	8,149	0	0.585
Payne	Oklahoma City	29,177	0	0.520
Pontotoc	Oklahoma City	24,302	0	0.312
Pottawatomie	Oklahoma City	39,275	0	0.897
Rogers	Tulsa	30,365	0	0.897
Seminole	Oklahoma City	14,220	0	0.663
Stephens	Oklahoma City	10,264	0	0.273
Tulsa	Tulsa	52,773	0	2,448

APPENDIX B, TABLE XVI (continued)

From County	To City	Quantity Shipped (1,000 lbs.)	Unused Production (1,000 lbs.)	Value of Additional Production ($ per 1,000 lbs.)
Wagoner	Tulsa	15,043	0	0.650
Washington	Tulsa	10,730	0	0.611
Washita	Oklahoma City	18,117	0	0.195

APPENDIX B, TABLE XVII

OPTIMUM SHIPMENTS OF CLASS I MILK FROM PROCESSORS TO DEMAND AREAS AND COST FOR ADDITIONAL QUANTITIES DEMANDED, BASED ON THREE PLANTS EACH IN TULSA AND OKLAHOMA CITY, 1975

Demand Area	Source of Milk	Quantity	Cost per Additional 1,000 pounds
		(1,000 lbs.)	(dollars)
Adair	Tulsa	3,848	16.12
Alfalfa	Oklahoma City	2,436	15.98
Atoka	Oklahoma City	2,614	15.92
Beckham	Oklahoma City	5,017	15.73
Blaine	Oklahoma City	3,227	15.24
Bryan	Oklahoma City	6,813	16.15
Caddo	Oklahoma City	8,400	15.17
Canadian	Oklahoma City	8,169	14.72
Carter	Oklahoma City	13,018	15.61
Cherokee	Tulsa	5,666	15.83
Choctaw	Oklahoma City	4,019	16.92
Cleveland	Oklahoma City	20,804	14.59
Coal	Oklahoma City	1,336	15.77
Comanche	Oklahoma City	40,216	15.56
Cotton	Oklahoma City	2,242	15.75
Craig	Tulsa	4,749	15.73
Creek	Tulsa	12,470	15.39
Custer	Oklahoma City	7,281	15.43
Delaware	Tulsa	4,040	15.78
Dewey	Oklahoma City	1,557	15.80
Ellis	Oklahoma City	1,330	16.57
Garfield	Oklahoma City	17,142	15.37
Garvin	Oklahoma City	8,807	15.08
Grady	Oklahoma City	8,559	14.93
Grant	Oklahoma City	2,497	15.77
Greer	Oklahoma City	2,472	16.11
Harmon	Oklahoma City	1,632	16.99
Harper	Oklahoma City	2,237	16.87
Haskell	Tulsa	2,334	16.18
Hughes	Oklahoma City	3,664	15.32
Jackson	Oklahoma City	16,463	16.57
Jefferson	Oklahoma City	2,207	15.71
Johnston	Oklahoma City	2,393	15.78
Kay	Oklahoma City	17,695	15.67
Kingfisher	Oklahoma City	3,339	14.90
Kiowa	Oklahoma City	4,150	15.73
Latimer	Tulsa	2,154	16.53
LeFlore	Tulsa	7,995	16.66
Lincoln	Oklahoma City	5,419	14.95
Logan	Oklahoma City	5,458	14.83

APPENDIX B, TABLE XVII (continued)

Demand Area	Source of Milk	Quantity	Cost per Additional 1,000 pounds
		(1,000 lbs.)	(dollars)
Love	Oklahoma City	1,416	15.83
McClain	Oklahoma City	3,814	14.82
McCurtain	Oklahoma City	7,181	17.52
McIntosh	Tulsa	3,192	15.89
Major	Oklahoma City	2,153	15.66
Marshall	Oklahoma City	2,296	16.11
Mayes	Tulsa	6,467	15.49
Murray	Oklahoma City	3,302	15.42
Muskogee	Tulsa	19,895	15.65
Noble	Oklahoma City	3,282	15.17
Nowata	Tulsa	3,246	15.57
Okfuskee	Oklahoma City	2,990	15.29
Oklahoma	Oklahoma City	224,107	13.17
Okmulgee	Tulsa	10,807	15.43
Osage	Tulsa	10,362	15.61
Ottawa	Tulsa	8,860	16.10
Pawnee	Tulsa	3,155	15.58
Payne	Oklahoma City	14,595	15.18
Pittsburg	Oklahoma City	9,969	15.83
Pontotoc	Oklahoma City	8,838	15.37
Pottawatomie	Oklahoma City	13,279	14.83
Pushmataha	Oklahoma City	2,519	16.64
Roger Mills	Oklahoma City	1,341	16.09
Rogers	Tulsa	7,039	15.29
Seminole	Oklahoma City	7,652	15.05
Sequoyah	Tulsa	5,732	16.26
Stephens	Oklahoma City	13,918	15.41
Tillman	Oklahoma City	4,408	16.11
Tulsa	Tulsa	133,469	13.77
Wagoner	Tulsa	4,935	15.52
Washington	Tulsa	18,309	15.55
Washita	Oklahoma City	6,703	15.48
Woods	Oklahoma City	3,509	16.54
Woodward	Oklahoma City	4,671	16.10

VITA

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Doctor of Philosophy

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