VERTICAL INTEGRATION BY REGIONAL MILK COOPERATIVES IN THE SOUTHWEST: POTENTIALS AND PROBLEMS

By

CARY WILLIAM HERNDON, JR.

Bachelor of Science
Texas A & M University
College Station, Texas
1975

Master of Agriculture
Texas A & M University
College Station, Texas
1977

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1984

VERTICAL INTEGRATION BY REGIONAL MILK COOPERATIVES IN THE SOUTHWEST: POTENTIALS AND PROBLEMS

Thesis Approved:

Leo V. Blakley
Thesis Adviser

John E. Ikerd

John R. Franzmann

James N. Trapp

P. Larry Claypool

Dean of the Graduate College

ACKNOWLEDGMENTS

I would like to express my sincere thanks to all the people who have contributed directly and indirectly to the completion of this research project and to the attainment of my lifelong goal. Many colleagues, friends and family members have given me the confidence and support needed to reach my professional and personal objectives.

My deepest appreciation goes to Dr. Leo V. Blakley, my major adviser and respected teacher, whose patience and gentle urging provided the guidance and wisdom necessary to accomplish this research. I will miss the times we spent trying to learn computer programming and the closeness I felt toward him during our many conversations over the past four years. Dr. Blakley has provided me an academic education and a personal guidepost that will serve me throughout my career. When asked to describe Dr. Blakley, I say that if we were just a little more like him our world would be a much better place in which to live. Thank you, Dr. Blakley.

I would also like to thank the other members of my advisory committee, Dr. John Ikerd, Dr. John Franzmann, Dr. James Trapp and Dr. Larry Claypool for their comments, suggestions and indulgence in the preparation of the final manuscript. Special thanks go to the Department of Agricultural Economics at Oklahoma State University and Dr. James Osborn for the financial support given me through a research assistantship and computer funds.

A sincere note of thanks is given to Mr. James Alexander for his computer programming skills which made this research project a reality. I also appreciate the assistance given me by Mr. Terry Kinzie and his staff throughout the project and, especially for the daily soda water. Let me not forget to express my thanks for the work of Cade Wilcoxson for typing my rough draft and for the understanding and effort of Marsha Speer in transforming the manuscript into the finished thesis.

The individuals who encouraged me and understood my true feelings of frustration during this ordeal were my fellow graduate students and dearest friends. To Jerry Warmann, my clone and officemate; Lisa Miller, my children's godmother; and H. L. Goodwin, my partner in crime, I owe my sanity and thanks. These friends have made this experience truly rewarding and one that I would not have wanted to miss.

I am also deeply indebted to my family for their constant assistance throughout my graduate program. My long-suffering parents, Cary and Joyce Herndon, have provided financial and moral support and have made many sacrifices in their lives in helping me complete my goal. Thanks also go to my incredible in-laws, Curt and Emma Ross, for urging me on toward my objective when I needed it the most. My two sisters, Karen Logan and Alice Potts, gave me encouragement and improved my outlook on life, especially during the final months of this project.

Last of all, to my best friend and lovely wife, Gwen Herndon, I owe everything I am and have been able to attain. Our wonderful children, Trey and Katie (with another on the way), a beautiful home and wonderful life to look forward to would not have been possible if not for her. It is to Gwen and my 81-year-old grandmother, Josephine Olle, whose love for life and contagious enthusiasm affects everyone who meets her, that I dedicate this dissertation.

TABLE OF CONTENTS

Chapter Page

I. INTRODUCTION 1

  Regional Milk Cooperatives and Industry Structure . . . 2
  The Problem 5
  Objectives of the Study 6
  Organization 8

II. VERTICAL INTEGRATION AND STRUCTURE OF THE FLUID MILK INDUSTRY 11

  Fluid Milk Marketing Channel 12
  Historical Background and Market Development 14
    Self-Sufficiency Era 15
    Early Market Development Era 16
      Federal Milk Marketing Orders 17
    Horizontal Integration Era 18
    Vertical Integration Era 20
  Vertical Integration Theory 22
    Definitions 23
    Motivational Factors 27
    Economic Efficiencies 28

III. SPATIAL EQUILIBRIUM MODELS 34

  Theory of Spatial Models 35
  Selected Spatial Equilibrium Models 38
    Exact Methods Procedures 39
      Complete Enumeration 39
      Implicit Enumeration 42
    Approximate Methods Procedures 43
      One-Point Moves 44
      Combination Improvement 45

IV. THE MODEL 46

  Formulation of the Model 47
  Divisions of the Model 48
    Production Distribution Analysis 49
      Demand Allocation 49
      Supply Allocation 51
      Summary 52

Chapter Page

Elimination Routine 53
Minimization of Total Cost 53
Combination Improvement 56
Optimization Procedure 57
Presentation of Results 59
Summary 60
Flexibilities of the Model. 60
Limitations of the Model. 61

V. MARKET DELINEATION, BASIC DATA, AND COST ESTIMATES 63

Market Delineation 63
Fluid Milk Demand Estimates 65
Demand Function 67
Independent Variables 68
Population Estimates 72
Raw Milk Supply Estimates 72
Cost Estimates 73
Transportation Costs 73
Assembly Cost 74
Distribution Cost 75
Plant Costs 76
Raw Milk Costs 76
Processing Costs 77
Plant Capacity 79
Plant Size Categories and Conversion 82

VI. ANALYSIS AND RESULTS 84

Model I - Least Costs Product Distribution for the Existing 1982 Plant Locations 85
Model II - Optimum 1982 Minimum Total Cost Market Organization 89
Model III - Optimum 1982 Minimum Processor Cost Market Organization 93
Model IV - Optimum 1982 Maximum Producer Returns Market Organization 96
Model V - Optimum 1990 Minimum Total Cost Market Organization 101
Comparison of the Market Organizations 102
Regional Cooperative Vertical Integration Strategies . 106
Operating Statement Data 107
Acquisition Costs 108
Interest Expense 109
The Strategies 110
Strategy I 110
Strategy II 111
Strategy III 111
Strategy IV 112

Chapter Page

Evaluation of Vertical Integration Strategies . . 113
Underestimation of Distribution Costs . . . 116
Potential Problem Areas 116
Conflict With Customers-Competitors 117
Risk of Litigation 119

VII. SUMMARY AND CONCLUSIONS 120

Summary 120
Conclusions 122
Efficiencies of Industry Structure 122
Potential of Fluid Milk Processing 124
Problems of Cooperative Processors 125
Limitations 125
Need for Further Research 126

SELECTED BIBLIOGRAPHY 129

APPENDIX 135

LIST OF TABLES

Table Page

I. Size Distribution of Fluid Milk Processing Plants in the U.S., 1965, 1970 and 1979 21

II. Fluid Milk Demand Regression Equation Parameter Coefficients 69

III. Percentage Increases in Fluid Milk Processing Costs to Represent Multiple Plant Locations 81

IV. Plant Size Categories and Various Size Unit Designations. 83

V. Comparisons of Cost Structures of the Existing and Optimum Plant Systems 105

VI. Statements of Operations for the Four Selected Cooperative Market Penetration Strategies 114

VII. County Milk Production and Population, Fluid Milk Demand and Fluid Milk Sales Revenue, 1982 and 1990 136

VIII. Possible Plant Locations (County and City), 1982 F.M.O. Class I Prices, and Whether Location had an Existing Plant in 1982 154

IX. The 32 BEAs and the Related 1982 Data Used to Estimate Fluid Milk Demand and 1982 Per Capita Fluid Milk Consumption 158

X. The 32 BEAs and the Related 1990 Data Used to Estimate Fluid Milk Demand and 1990 Per Capita Fluid Milk Consumption 160

XI. Model I - Least Cost 1982 Existing Plant System, Plant Summary, Cost and Revenue 162

XII. Model II - Optimum 1982 Minimum Total Cost Market Organization Plant Summary, Cost and Revenue 165

XIII. Model III - Optimum 1982 Minimum Processor Cost Market Organization Plant Summary, Cost and Revenue 166

Table Page

XIV. Model IV - Optimum 1982 Maximum Producer Returns Market Organization Plant Summary, Cost and Revenue 168

XV. Model V - Optimum 1990 Minimum Total Cost Market Organization Plant Summary, Cost and Revenue 170

LIST OF FIGURES

Figure Page

1. Contra-Seasonal Patterns of Milk Production and Fluid Milk Utilization 4

2. The Southwest Study Area Analyzed in This Research Project. . . 7

3. Average Cost Curves Illustrating Potential Economies of Size . 30

4. The Long-Run Planning System for a Firm Showing Alternative Vertical and Horizontal Structural Combinations 32

5. Market Supply and Demand Relationships for Illustrating a Spatial Equilibrium 37

6. Flow Diagram of the Optimization Routine for Searching Alternative Plant Configurations 58

7. The 587 County Southwest Study Area 64

8. The 99 Possible Fluid Milk Processing Plant Locations Identified in the Study Area 66

9. The 32 Bureau of Economic Analysis (BEA) Areas Identified in the Study Area Used to Estimate Fluid Milk Demand for 1982 and 1990. 71

10. Average 1982 Class I Milk Price Effective in the Study Area in Dollars per Hundredweight 78

11. Model I - Least Cost Existing 1982 Plant Locations and Plant Demand Service Areas 87

12. Model I - Least Cost Existing 1982 Plant Locations and Supply-Side Bulk Milk Shipments 88

13. Model II - Optimum 1982 Minimum Total Cost Plant Locations and Plant Demand Service Areas 91

14. Model II - Optimum 1982 Minimum Total Cost Plant Locations and Supply-Side Bulk Milk Shipments 92

Figure Page

15. Model III - Optimum 1982 Minimum Processor Cost Plant Locations and Plant Demand Service Areas 95

16. Model III - Optimum 1982 Minimum Processor Cost Plant Locations and Supply-Side Bulk Milk Shipments 97

17. Model IV - Optimum 1982 Maximum Producer Returns Plant Locations and Plant Demand Service Areas 99

18. Model IV - Optimum 1982 Maximum Producer Returns Plant Locations and Supply-Side Bulk Milk Shipments 100

19. Model V - Optimum 1990 Minimum Total Cost Plant Locations and Plant Demand Service Areas 103

20. Model V - Optimum 1990 Minimum Total Cost Plant Locations and Supply-Side Bulk Milk Shipments 104

CHAPTER I

INTRODUCTION

The fluid milk industry has experienced dramatic structural evolution in the past 30 years. Technological innovations and institutional developments have resulted in many changes in the manner in which fluid milk is marketed from producers to consumers. Advancements in technology have included sanitary and efficient movements of bulk milk over long distances, refrigeration techniques which extend fluid milk shelf life, and larger, more efficient fluid milk processing plants. Several of the more prevalent institutional changes have been the elimination of local milk sheds, organization of regional milk cooperatives, and integration of corporate food chains into fluid milk processing.

Each stage of the fluid milk marketing channel has been restructured to some extent by these historical developments. Participants and their level of involvement and influence over other firms in the industry have been altered during recent years, especially those companies processing and distributing fluid milk products in the United States. Regional milk cooperatives and corporate food chains have undertaken strategies to expand control within the marketing channel through vertical integration into fluid milk processing. Vertical integration has played the dominant role in restructuring the entire fluid milk industry since the 1960's.

Vertical integration provides a tool which a firm can use to extend its market power beyond a single stage of the market channel. Coordination of multiple functions of milk marketing through integration has been shown to improve control over the physical product through elimination of transactions between stages and direct lines of communications. From the firm's point of view, reductions in various cost factors through coordination and profits gained from multiple stage operations are motives for integration. From the point of view of the industry, cost reductions and lower retail milk prices, if passed on to the consumers, result in improved industry performance and the expansion (through price) of demand for fluid milk products.

Regional Milk Cooperatives and Industry Structure

The role of regional milk cooperatives in the structure of the milk industry has been interesting to observe. To fully understand the development of regional cooperatives, the characteristics of milk production and consumption need to be reviewed. Milk is a highly perishable and easily contaminated commodity produced in locations geographically distant from major consumption areas. Milk also exhibits contraseasonal demand and supply patterns which could result in large deficits or surpluses in milk availability. These factors have influenced the creation of regional milk cooperatives and the integration into various stages of the marketing channel.

The creation of regional milk cooperatives can be attributed to all three of the above factors. Individual farmers and local cooperatives were subjected to a great deal of risk in marketing milk due to the fact that the number of processing firms were declining while sizes were increasing during the years following World War II. As a result, there were fewer, more distant buyers requiring large quantities of bulk milk for their needs. Farmers and local cooperatives, unable to market milk efficiently for the large buyers, joined and merged together to form regional cooperatives. Regional cooperatives consisting of many producer-members were able to coordinate bulk milk sales to large dairy processors and reduce cost of milk assembly. One regional cooperative primary function was to act as a bargaining association for farmers and assist them in the disposal of all of their production. However, regional milk cooperatives have extended their operations beyond bargaining and assembly to achieve better service for their members.

Excess supplies of member milk associated with operating and seasonal reserves necessary for the fluid market have caused milk cooperatives to vertically integrate into the manufacture of hard products such as butter, cheese and non-fat dried milk. The contraseasonal patterns of milk production and fluid milk consumption are of special interest in analyzing the reasons for integration by regional cooperatives. Figure 1 illustrates that milk supply is seasonally at its peak when demand for fluid milk is low and fluid milk demand is at it peak in November when supply is at its lowest point. Biologically, farmers cannot adjust their production levels to avoid potential milk surpluses and/or deficits due to seasonality. Production levels high enough to ensure ample supplies of milk during the fall and winter months result in surpluses during the spring

CONTRA-SEASONAL PATTERNS OF MILK
PRODUCTION AND FLUID MILK UTILIZATION

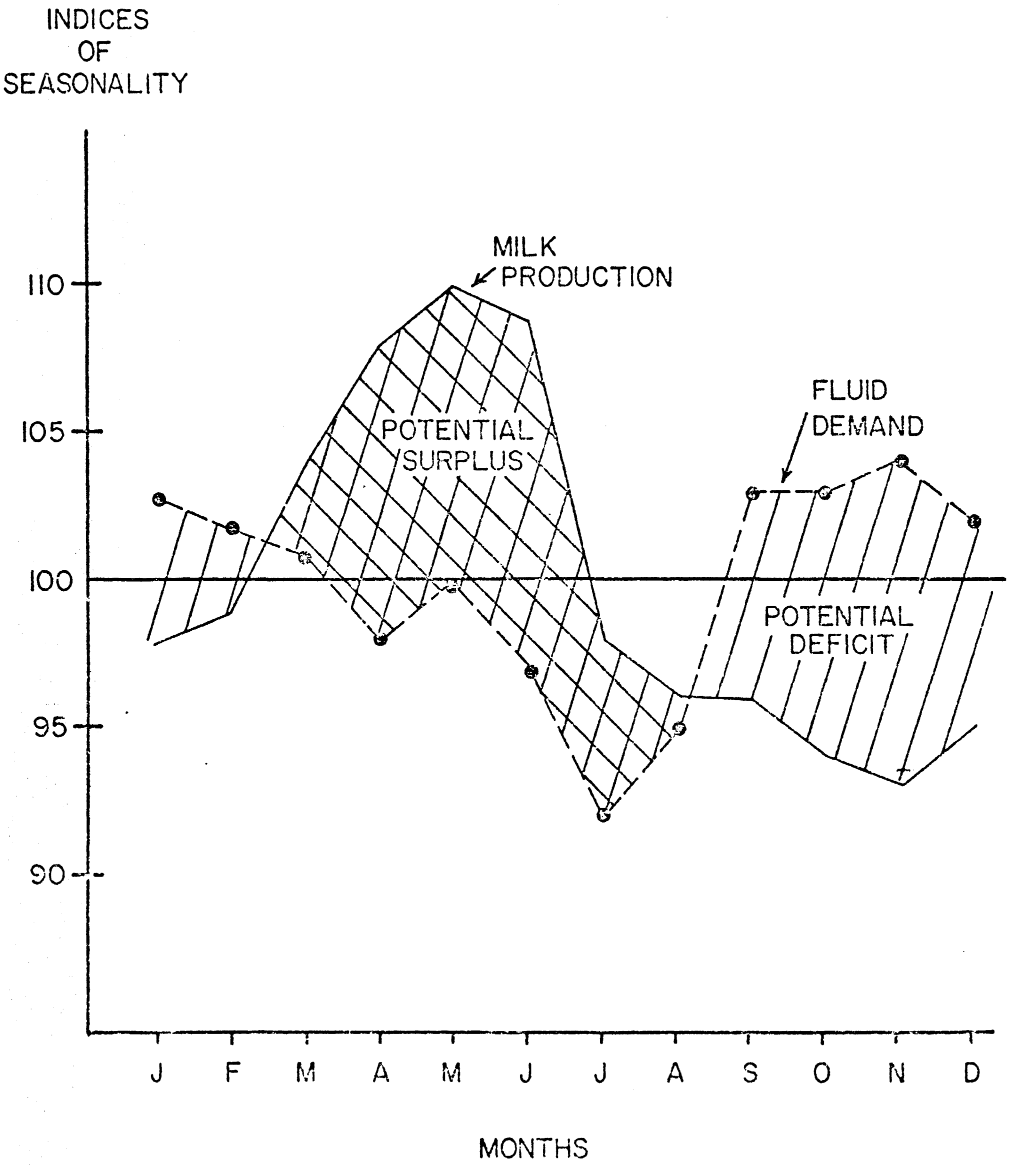


Figure 1. Contra-Seasonal Patterns of Milk Production and Fluid Milk Utilization.

and summer months. Therefore, milk cooperatives have integrated into hard product manufacturing to handle excess fluid milk supplies of their members to the point where it was estimated that, of total U. S. production, 50 percent of natural cheese, 75 percent of butter, and 85 percent of dry milk products were manufactured by cooperatives in 1983 [40].

Fluid milk processing has been performed by regional milk cooperatives since their creation and several of the largest cooperatives have undertaken aggressive integration strategies to expand their market share in the fluid milk market. Diversification of operations, potential profits, and expansion of market power offer attractive incentives for improved coordination of activities and increased producer-member returns through fluid milk processing. Vertical integration provides the vehicle for cooperatives to realize these potential gains.

The Problem

The fluid milk industry has undergone many changes in its fundamental economic environment resulting in modifications in the manner fluid milk is marketed. Vertical integration in the fluid milk processing stage of the marketing channel has played an important role in the restructuring of the industry since the 1960's. Vertically integrated regional milk cooperatives have had an impact on altering the composition of the industry in certain sections of the United States. However, regional cooperatives have not uniformly chosen to integrate forward into processing fluid milk. One major milk cooperative has been unique in not pursuing aggressive policies to move into the fluid processing industry.

The southwestern portion of the nation, illustrated in Figure 2, is one region whose milk industry has not been influenced by cooperatives processing of fluid products and is the market area of the cooperative described above. However, should a cooperative decide to undertake a strategy of vertical integration and begin processing fluid milk, questions concerning potential plant locations and size must be addressed. Market penetration strategies need to be formulated in context with industry costs and revenue structures.

The purpose of this analysis is to estimate costs and revenues of fluid milk processing plants in the Southwest and determine the optimum number, size, and locations of plants under various conditions. Penetration strategies will be based upon the results of the various optimum plant configuration analysis. The optimum market structures provide the needed guidelines for evaluating the benefits and costs of cooperative fluid milk processing in the Southwest.

Objectives of the Study

The overall objective of this study is to evaluate the performance of the fluid milk processing industry in 1982 and analyze the potential for vertical integration by regional milk cooperatives into fluid milk processing by the year 1990. The primary goal of this project is to estimate the costs of and returns to fluid milk

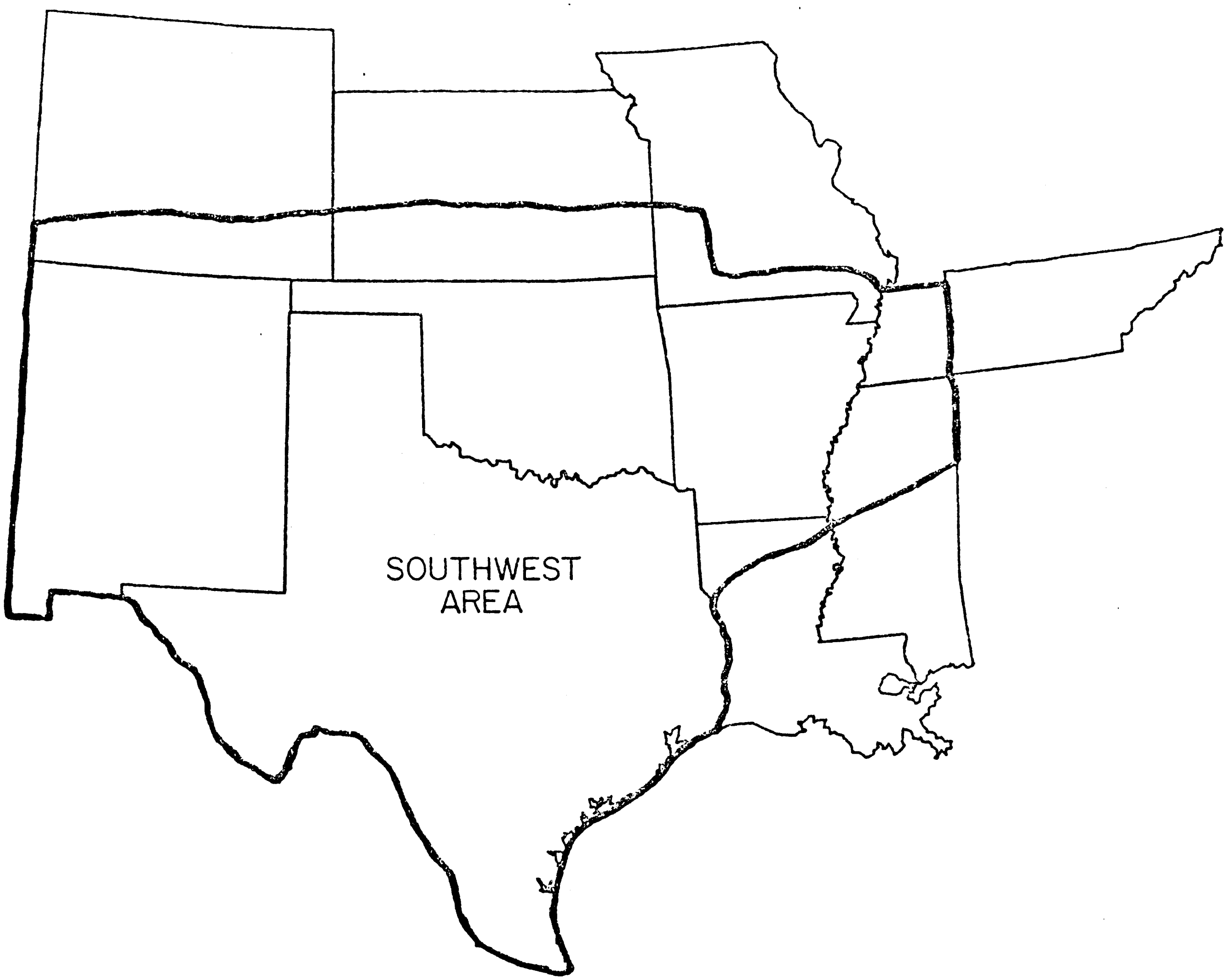


Figure 2. The Southwest Study Area Analyzed in This Research Project.

processing and determines the optimum plant configurations under various optimization functions. More specifically, the objectives of the study are to:

1. Estimate demand for fluid milk products for 1982 and forecast fluid milk demand for 1990 in the Southwest.
2. Estimate cost functions associated with processing and marketing fluid milk products for the following categories:
    a. assembly costs,
    b. processing costs,
    c. raw milk costs, and
    d. distribution costs.
3. Develop a spatial equilibrium model of the fluid milk industry to evaluate market performance and determine optimum processing plant systems under the following optimization criteria:
    a. minimize total system costs,
    b. maximize processor returns, and
    c. maximize farmer-producer returns.
4. Evaluate various cooperative vertical integration strategies into the fluid milk processing industry.
5. Identify potential problems which may be encountered by regional milk cooperative becoming vertically integrated into the fluid milk processing industry.

Organization

The first chapter of this dissertation includes a brief introduction of the fluid milk industry and the creation and development of regional milk cooperatives. The research problem and objectives are also presented.

Chapter II reviews the historical background of the fluid milk marketing industry and a discussion of the technological and institutional developments which have led to changes in how milk is processed and marketed. The stages of the fluid milk marketing channel are summarized along with the types of firms performing each stage's function. The final portion of this chapter presents the vertical integration theory utilized in this research project.

Chapter III presents the literature review of spatial equilibrium models. The chapter begins with a discussion of the theoretical development and economic basis of spatial allocation-equilibrium analysis. The last section reviews selected equilibrium models with distinctions made between exact and approximate solution procedures.

Chapter IV describes the model used to estimate the market performance and optimal plant systems. It discusses the divisions of the model and how cost estimates and optimization of objective functions are derived. The final part of the chapter presents the flexibilities and limitations of the model.

Chapter V discusses the market delineations used in the study area, demand and supply estimation procedures, and fluid milk processing costs functions. The types and sources of background data are detailed along with how they were utilized in the cost functions.

Chapter VI presents the results of the study. It summarizes the findings of the analysis between the existing 1982 plant system and the various optimum plant systems arrived at under different objective functions. Also presented are the optimum minimum total costs plant system for 1990 and the four cooperative market penetration strategies. Comparisons of volume processed, operating margins, and returns to owner's equity are made between market strategies.

Chapter VII, the final chapter, summarizes the findings of this research project and attempts to draw some conclusions from the plant location analysis. Limitations of the analysis procedure and suggestions for improvements are detailed in this chapter. The chapter ends with directions needed for future research.

The Appendix contains the tables of data and results that were too lengthy to be included in the body of the dissertation or were of background data used in the analysis. These tables were placed in the section to permit easy flow of research results, but may be of interest to other researchers.

CHAPTER II

VERTICAL INTEGRATION AND STRUCTURE OF THE FLUID MILK INDUSTRY

The past 100 years has seen the development of fluid milk marketing into a well-structured industry. Demographic, technological, and institutional changes during this era gave rise to a need for a fluid milk industry to produce, process, package and distribute milk to satisfy consumer demand. Continual evolution in the marketing environment led to significant re-structuring of the industry where firms experienced a shift in their level of involvement and importance within the marketing channel. The years since World War II have seen important changes in the type and number of participants in the industry. Several of the structural changes experienced over this recent period are a continuing trend toward fewer fluid milk processors, introduction of producer cooperatives as raw milk assemblers and bargaining associations, and vertical integration by firms into more than one stage in the market channel. Each of these factors has had an important impact on the traditional manner which milk is moved from producers to consumers. To provide a better understanding of the fluid milk industry, this chapter provides a review of the stages of the marketing channel and its participants, historical background of industry development and its structural evolution, and vertical integration theory and supporting literature.

The significance of producer cooperatives and vertical integration in recent industry evolution and the research objectives provide the basis of this project. Investigating the historical background provides an invaluable insight to the underlying reasons affecting structural make-up which gave rise to cooperative organizations and vertically integrated firms. There are two publications which describe vertical integration and cooperation in both the general and specific context. Cook et al. [10] provide a general description of cooperatives and industry integration, while Cook and Combs [11], convey specific information concerning a particular cooperative's integration experience into fluid milk processing. These publications describe the market structure, historical development, and economic reasoning on which to base this research project.

Fluid Milk Marketing Channel

There are five stages of the Grade A (milk eligible for fluid use) milk marketing channel which perform the following functions; (1) farm production, (2) procurement, (3) processing, (4) distribution, and (5) retailing. Prior to the era of cooperatives and inter-stage integration, proprietory processors dominated the industry through direct purchases of raw milk from producers, processing fluid milk supplies, and distributing fluid products directly to consumers via home-delivery routes and to retailers. During this era, the primary participants and their related function were farmers producing raw milk, farmers and handlers selling/procuring milk directly to/for processing plants, proprietory processors packaging fluid products and distributing milk to retailers, groceries, restaurants, and institutions, and processors selling fluid milk products to consumers. However, the roll of proprietory processors has been decreased within the industry structure during the past 20 years.

The introduction of producer cooperatives and vertical integration projects undertaken by supermarkets and cooperatives have altered the make-up of the marketing channel. Producer cooperatives now dominate the production and procurement stages and control about 90 percent of Grade A milk supplies. Proprietory processors remain the primary participants in the processing and distribution market stages; however, these are the stages which have been penetrated by both grocery chains and cooperatives. Lough [31], reports that national, regional, and local proprietory processors have experienced a decrease in market share of fluid milk sales from 87 percent in 1964 to less than 70 percent in 1979 while supermarkets and cooperatives have increased their market share by a corresponding amount. Integrated supermarket chains have become the dominant force in the retail fluid market stage as home delivery sales volume has decreased while grocery sales volume has increased in recent years.

Although the functions of the marketing channel have remained constant over the years, the participants and their level of involvement and importance with the channel have changed significantly. The stages of the industry have become less distinct as firms have linked together successive stages of milk marketing via vertical integration. With cooperatives linking the production, procurement, processing and distribution stages and corporate food chains combining the retailing, distribution, and processing activities, the structure of the industry within the market channel has experienced many changes.

Historical Background and Market Development

A historical review of fluid milk marketing during the past 100 years reveals that the process of providing fluid milk needs of the general population has evolved from basic self-sufficiency to a well-structured, highly developed industry. The milk processing industry was non-existent prior to the industrialization of the American economy and has experienced continual structural changes over this period of study. Analysis of the underlying economic and environmental factors giving rise to a particular alteration provides knowledge as to how and why the market evolution has occurred. Manchester [34, 35] described the shifts and innovations that have affected fluid milk markets; provided a comprehensive review of the changing fluid market structure; and, detailed reasons for industry modification in these publications.

The historical background of fluid milk marketing can be separated into four identifiable eras. Chronologically, these eras are self-sufficiency, early market development, horizontal integration, and vertical integration and each era describes a particular set of environmental, technical, and economic factors which are linked to market conditions and development. The following sections describe the market eras and the causal factors associated with market evolution.

Self-Sufficiency Era

The population of the United States prior to the 1880's was predominately rural in nature and was isolated from trading centers by distance and poor transportation facilities. Therefore, rural families provided the majority of their consumption needs through self-sufficient farms. Typically, these farms met 100 percent of the food requirements and fluid milk needs were satisfied through self-sufficiency. Rural families met their demand needs for fluid milk by owning and milking the family milk cow(s). Since refrigeration equipment was not available and travel impractical for a large portion of the population, milk requirements were met on a day-to-day basis. No practical means were available for preserving and transporting fluid milk from producers to consumers. Potential consumers were too far apart to provide an incentive for marketing fluid milk. However, a shift in the demographic make-up of the population was to bring the self-sufficiency era to an end.

The increasing industrialization of the economy in the 1880's brought about many changes in the socio-economic make-up of the population. With the opening of plants and factories, the demographic framework was altered from rural to urban as the general population migrated from farms to work in industrial complexes located in cities. As more and more people moved to towns and cities, the need for a fluid milk market began to emerge because families were no longer able to provide for their own fluid milk needs. Innovations in refrigeration and electrification of cities promoted the demand for a fluid milk marketing industry. The end of the self-sufficiency era was initiated primarily by a movement of the general population from rural to urban areas and perpetuated further by adoption of refrigeration technology.

Early Market Development Era

The period from late 1800's to the early 1900's was the period which marked the early development of fluid milk marketing. The early years of this period saw the majority of fluid milk marketed by farmers producing milk and selling directly to consumers (described as producer-dealers). The technological advances in homogenization and pasteurization techniques led to the introduction of a more formal entity in the market channel to process and distribute milk. Dairies took possession of raw milk from farmers and processed and bottled it into fluid milk products which they usually delivered directly to consumers. These milk processors were local in nature serving a small geographic areas. Although there were a few national and regional fluid processors, the vast majority of these firms were small local dairies whose market area was restricted to a single city or county. The continued existence of these companies was perpetuated by the adoption of sanitation regulations by local municipalities and other governmental bodies which created small market areas called milksheds. Milksheds usually coincided with the marketing areas of dairy firms and seldom did local dairies sell products in more than one milkshed. The era of locally processed and distributed fluid milk continued until World War II.

The beginning of the end of this market structure was initiated by the adoption of reciprocal sanitation agreements which disorganized the marketing areas established under milksheds. Reciprocal sanitation agreements permitted the movement of milk from different marketing areas in such a manner that processing firms could take advantage of the cost efficiencies associated with economies of size. Other factors affecting a change in the industry were improved highways and increased sales of fluid milk by large supermarket chains. In general, the disorganization of milksheds led to an end of locally processed and distributed milk.

Federal Milk Marketing Orders. Another development during this period, and perhaps; the most important event in milk marketing history was the creation and adoption of a government controlled milk pricing system. The Agricultural Adjustments Acts (AAA) of 1933 and 1937 provided the mechanism to ensure farmers a specific price for their milk depending on its use (fluid vs. hard products) and processing location (distance from Eau Claire, Wisconsin). Prior to the adoption of this legislation, the market environment was very unstable and producers were unable to quickly adjust their production levels to coincide with consumption levels; therefore, farmers and consumers alike were vulnerable to the instability of the market. Farmers were either producing too much milk and, without a market, forced to dump their production, or not producing enough milk to meet demand while consumers failed to find products to meet their needs. The basic premise of the AAA legislation which created federal milk orders is to stabilize the market environment in order to ensure a continuous ample supply of milk by assuring farmers a minimum price for their production.

The basic milk pricing system remains intact and has been effective in stabilizing the milk marketing environment. It is important to point out that this system does not control milk quantity in any way, it merely prices milk. The milk pricing mechanism is administered by the Dairy Division of U.S. Department of Agriculture (U.S.D.A.) through federal milk marketing orders. Federal milk orders were effective in 49 marketing areas during 1982 under which milk handlers and processors were required to pay not less than certain minimum class use prices. Approximately 80 percent of the Grade A milk (eligible for fluid use) or about 70 percent of total milk supply was produced under federal orders in 1982. Several publications provide detailed descriptions of federal market orders and milk statistics are published by the Agricultural Marketing Service of the U.S.D.A. and are entitled Questions and Answers On Federal Milk Marketing Orders [53] and Federal Milk Order Statistics, 1982 Annual Summary [55]. Historically, the federal milk order system has influenced the structure and performance of the milk industry.

Horizontal Integration Era

The widespread adoption of reciprocal sanitation agreements during the 1950's brought about a major restructuring of the fluid milk industry. Small cost-inefficient dairies were unable to compete with large processors who penetrated markets that were protected by sanitation regulations. The ease of moving milk between geographic areas changed the number and size of processors as the number of fluid processors decreased and the size of firms increased dramatically during the era. Manchester [34] published a review of the structural changes that occurred in the industry between 1947 and 1965 and reported that while the volume of fluid milk processed increased over 60 percent, the number of commercial processors fell more than 50 percent and the number of producer-dealers decreased about 85 percent during this period. The large cost-efficient commercial processors were able to take advantage of economies of size which placed local dairies at a comparative disadvantage to national and regional dairy companies. The inefficient-sized firms were quickly absorbed by larger processors through merger/acquisitions or were forced out of business.

As nationally-based commercial processors extended their geographic sales areas and market share through acquisition of other processing firms, they became more powerful within the milk marketing channel and were the dominant force in the industry. Several of the largest processing firms gained enough market power through horizontal integration that they were suspected of such predatory practices as price fixing and price discrimination against smaller less-powerful market participants. As a result, the Federal Trade commission (FTC) of the U.S. Government issued complaints against four national and one regional dairy processing firms and were granted consent settlements in the mid-1960's which placed a 10-year ban on further horizontal acquisition and merger activity. Parker [40] analyzed this period of horizontal integration and reports what impact the ban has had on the structure of the fluid milk market. Parker's study described the end of the horizontal integration era and the beginning of the vertical integration era of fluid milk marketing.

Vertical Integration Era

Although some participants in the marketing channel have been vertically integrated since the 1930's, the FTC complaints and restructuring of the industry began in earnest during the 1960's as firms linked two successive stages of fluid milk marketing through the means of vertical integration. Corporate food chains who traditionally were retailers and producer cooperatives who were producers/assemblers of raw milk have become vertically integrated into fluid processing have been successful in altering the structure of the fluid milk industry during this era. Integrated supermarkets increased their share of the fluid milk market from 3.3 percent in 1964 to 16.8 percent in 1979 while cooperatives expanded their share from 9.7 to 13.5 percent over the same period [32]. Cooperatives and food chains continue to extend their market share through vertical integration and have become a legitimate threat to proprietory processors and their position in the industry.

The era of vertical integration has seen the trend toward fewer and larger processing facilities continue into the 1980's, as illustrated in Table I. Between 1965 and 1979, the total number of fluid milk processing plants have been cut in half and the number of plants processing less than 4 million pounds per month decreased from 2146 to 777, but each of the plant size categories greater than 4 million pound increased in number during these years. The structural evolution away from small local dairies has been perpetuated during this era as new and remodeled plants replace existing less-efficient

TABLE I

SIZE DISTRIBUTION OF FLUID MILK PROCESSING PLANTS IN THE U.S., 1965, 1970 and 1979

Monthly Sales Volume of Packaged Milk Product	Number of Plants in 1965	1970	1979	Percentage Change 1965 to 1979
Thousand Pounds				Percent
Less than 100	495	220	116	-77
100- 499	855	444	245	-71
500- 999	300	183	127	-58
1,000- 1,999	266	205	117	-57
2,000- 2,999	128	108	99	-23
3,000- 3,999	102	82	71	-30
4,000- 4,999	48	65	65	+35
5,000- 9,999	120	138	185	+54
10,000-14,999	30	38	63	+91
15,000-19,999	12	18	18	+50
20,000-29,999	7	12	21	+200
30,000 and over	-	-	8	-
TOTAL	2,366	1,513	1,135	-52

Source: Manchester [34, p. 6] and Lough [32, p. 8] facilities. Vertical integration by firms into fluid milk processing has and is continuing to modify the fluid milk marketing industry.

Vertical Integration Theory

Vertical integration has been a very important factor in restructuring the fluid milk marketing industry during the past two decades. Producer cooperatives, as well as other firms, have been attempting to increase their market returns by integrating into successive stages of the milk marketing channel. To understand the process of and justification for vertical integration, a review of the motivational influences, economic efficiencies, and supporting literature will be made within the context of economic theory and fluid milk marketing practices.

The theoretical basis for vertical integration can be found in a number of publications in economic literature. Bain [1] presents a general overview of environmental settings in which business organizations are established and describes the economies of vertical integration. Two other publications written by Baligh and Richartz [2] and Mighell and Jones [37] convey in depth analyses of marketing channels, market structure development, and interaction among market participants. Also, a number of working papers have been published under the North Central Project 117 studying various aspects of vertical integration and market structure and performance within the U.S. food industry. These publications provide the theoretical underpinnings of vertical integration theory and market structures on which this research project is based.

An important fact to remember when analyzing the vertically integrated market organization is that vertical integration is not a new phenomenon in market development. Prior to the machine era, production, processing and distribution were unified under the control of a single firm. A single person generally owned the product throughout the marketing process, as was the case in the early development of fluid milk marketing. A farmer produced raw bulk milk, processed and packaged milk, distributed milk, and sold milk directly to consumers. Adoption of machine technology separated the marketing process into a number of specialized activities performed by firms confining themselves to a single function. The current trend toward a more unified market through vertical integration is a return to the coordinated control system maintained by the original fluid milk market structure.

Definitions

Vertical integration is defined as that type of market organization which comes into existence when two or more successive stages of production and/or marketing of a product are combined under one management (i.e., under the control of the same firm). It is this single firm control feature which differentiates integration and coordination. Coordination among stages occurs both externally and internally to firms and is required for the product to move from one stage to the next. Vertical coordination external to the firm is usually controlled by prices, market structures and institutions whereas internal coordination is mandated by the firm's decision makers. Vertically integrated firms do not transfer ownership/title of the product between the stages under their control.

Vertical and horizontal integration are fundamentally different concepts. Horizontal integration combines two or more similar firms performing the same functions at the same stage of production or marketing. As stated above, vertical integration incorporates two or more stages or functions of the channel. Both of these types of organizations attempt to expand the firm's market power within the industry structure, however, they accomplish this identical end through markedly different means. Horizontal integration improves market power by extending geographic area and/or increasing the market share controlled by the firm. On the other hand, vertically integrated firms strive to extend their control over the product as it moves from the producer to the ultimate consumer. Each of these strategies attempts to exploit the economies arising from the market organization which will be discussed later in this study.

Recalling the development of the fluid milk marketing industry, horizontal integration characterized structural changes from the 1920's to the 1960's. Farmers joined forces and formed cooperatives to assist them in marketing raw milk, leading fluid processing companies acquired/merged with other processing firms to extend geographic markets, and corporate food chains combined efforts and built supermarkets to enhance their positions in the retail market. However, since the Federal Trade commission issued a ban against merger and acquisition activities by the eight largest processing firms [40], firms have attempted to strengthen their market positions through the means of vertical integration. Corporate supermarket chains, in particular, have vertically integrated into fluid milk processing, as well as farmer cooperatives. Historically, horizontal and vertical integration have played important roles in the development of fluid milk marketing.

Horizontal and vertical integration activities are easy to differentiate in the context of economic theory; however, it appears more difficult to separate the economies associated with these operations. Mighell and Jones [37, p. 18] state that "Horizontal expansion must often be employed if the vertical expansion is to accomplish its purpose". In other words, firms probably pursued horizontal integration to attain the size and scale of operations required to realize the advantages of a vertically integrated organization. The relationship between vertical and horizontal integration and their efficiencies will be discussed in detail later in this report.

The direction of an integration movement affects the goals, motives, and decision criteria considered by the firm's decision-makers. The direction of the integration describes the manner in which the firm is extending its control within the channel. "Forward" integration refers to those acquisitions which extends the firm's operation nearer to the ultimate or final consumer. On the other hand, those activities which combine successive stages of the marketing channel toward the original raw product is referred to as "backward" integration.

The distinction between these two types of vertical integration can be made within the context of fluid milk marketing. Producer cooperatives, which have expanded their activities to include fluid milk processing along with production and procurement, have integrated "forward" toward the final consumer. "Backward" integration describes the measures undertaken by food chains who have extended their operations to comprise both processing and retailing marketing functions. Although the difference between "forward" and "backward" integration may be subtle, this refinement is an important factor in the firm's decision to undertake vertical integration as a method to expand market power and increase profits.

In order to fully comprehend the role of vertical integration in the fluid milk market, consideration must be given to defining and describing the terms "partially integrated" and "fully integrated" within the text of this project. The term "fully integrated" refers to a type of vertical organization which a firm has control in every stage of the channel. In other words, a "fully integrated" firm performs each and every function of the industry from production to retailing, in some degree. The phrase "in some degree" is intended to convey that a "fully integrated" firm does not have to attain self-sufficiency between each stage of the marketing channel. The term "fully integrated" indicates that a firm maintains control over the product throughout the entire channel but may rely on other firms to trade with between stages.

Examples of "fully and partially integrated" firms can again be found in the fluid milk market. Several firms have become "fully integrated" and are involved in each stage of the channel. These firms (i.e., Braums) can be characterized as large corporate raw milk producers who have integrated forward all the way to the consumer. These firms are usually regional in nature and typically retail fluid milk products through specialty or convenience stores. The majority of vertical integration activity has involved "partially integrated" firms. Corporate food chains and producer cooperatives generally have not integrated into every stage of the market channel and have stopped short of becoming "fully integrated" by failing to extend their operations into raw milk production and retailing, respectively.

Motivational Factors

Profits are the primary motivation for firms to undertake vertical integration. Most decisions to integrate are directed toward increasing profits or avoiding losses within the firm's operations. The action may be economically efficient because of lower costs or improved allocation of resources. The integration may be taken to enhance market power or prevent other market participants from gaining market advantages through the means of monopolistic or oligopolistic activities. Although profits are the most visible reason for integrating, several other incentives exist and may be the dominant inducement for which a particular firm chooses to vertically integrate. Mighell and Jones [37, p. 18] list the following factors as motives for integration: "Reducing risk, reducing costs, improving management, gaining bargaining power, improving market position, assuring adequate inputs, investing surplus reserves, developing new technology, and obtaining additional capital". Each of these reasons for integration has an impact on firm profitability and provides the impetus for the majority of integration activity.

Motivational factors which have influenced firms within the fluid milk industry to vertically integrate correspond to those factors listed above. However, the type of firm and direction of the integration movement affect which motives are most important to the decision process. Corporate food chains, which have integrated "backward" in the marketing channel, pursued vertical integration activities primarily to reduce distribution cost and improve management of fluid milk supplies [40]. Producer cooperatives, on the other hand, state that improving market power and reducing risk associated with adequate Class I milk outlets were the dominant objectives for undertaking "forward" integration operations [40]. Although the objectives were quite different between the two firm types, it is doubtful that such action would have been undertaken if the firm's profits were not expected to increase under the vertical market structure.

Economic Efficiencies

Economics has been defined by some authors as a science of efficiency - efficiency in the use of scarce resources [33]. Specifically, economics is a study of how and in what manner inputs are combined to produce outputs in the proper form, place, and time to satisfy consumer wants. Firms in a competitive environment must be able to produce those outputs efficiently, or in a least cost - maximum value manner. Organizational changes, both horizontally and vertically, have enabled firms to lower costs of operations by attaining optimum size and optimum market structure to achieve economic efficiency. Profits and economic efficiency are closely related terms, and firms can effect their profits through efficiencies which reduce operational costs. Vertical integration may accomplish this goal of increased profits from several sources of economies: (1) combining technologically complementary processes under a single ownership, (2) elimination of expenses of purchase-sale transactions incurred when moving products between successive stages, (3) elimination of excess profits to supplier or customer firms, and (4) improved coordination and control of inputs and outputs at successive stages (i.e., reduction of inventories) [1].

Maximum economic efficiencies attributed to vertical integration may be realized only if a firm has attained a minimum optimum-size operation at each stage of market involvement. In other words, economies of size must be gained before acquiring maximum economies to vertical control. Figure 3 illustrates how economies of size can be realized through the operation of efficient-size plants. In the context of fluid milk processing, let LAC represent the long-run average cost function for a hypothetical processing plant. If the plant were of optimal size, it would be processing Q_o pounds of fluid milk at an average cost of C_o. Any other plant processing more or less fluid milk than Q_o would increase the average cost beyond C_o. For example, a plant processing only Q_1 pounds would incur an average cost of C_1 and a plant processing Q_2 pounds of milk would result in an average cost of C_2.

There exists a minimum optimum plant size and a range of efficient-sized plants in the fluid milk industry. Larger operations are generally more efficient or have lower costs than smaller ones;

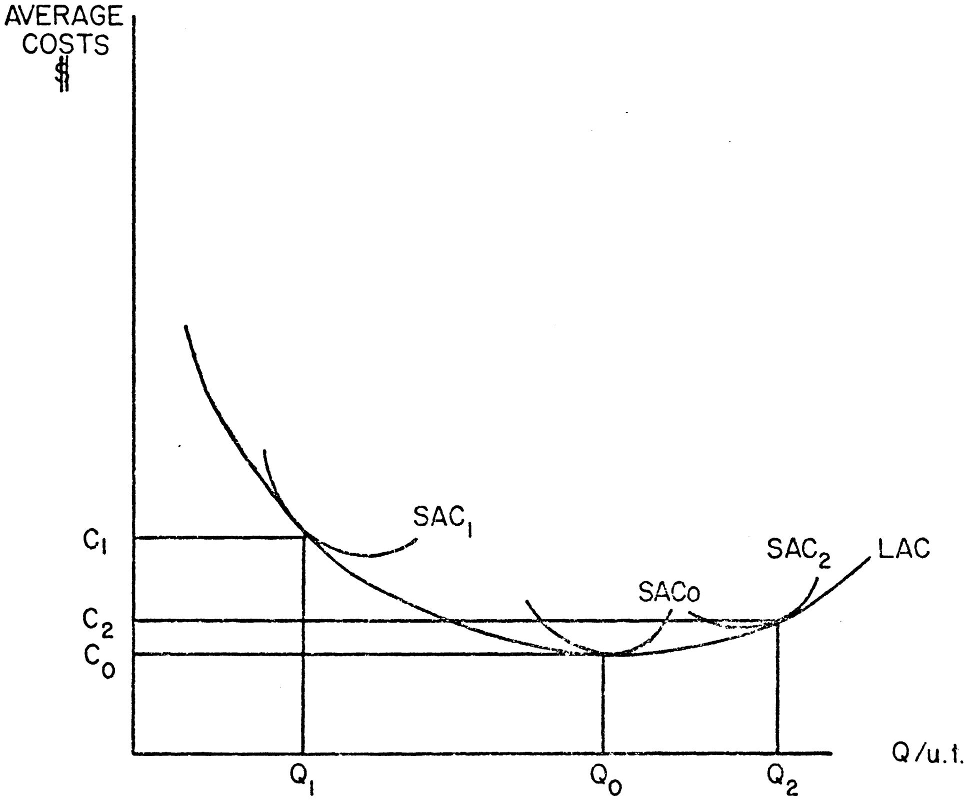


Figure 3. Average Costs Curves Illustrating Potential Economies of Size.

however, increases in size beyond the minimum-optimum scale may not lead to further increases in technical efficiency. Once this minimum-optimum operation is attained, additional efficiencies may be gained via economies of large scale distribution. Therefore, advantages of vertical integration may be realized once the firm attains the minimum-optimum scale of operation in each of the market stage which it is vertically integrated. Horizontal integration is one method of acquiring an efficient scale of operation; hence, it is difficult to separate the economic efficiencies arising from vertical integration from those arising from horizontal integration.

Efficiencies attained through vertical integration are derived from two basic sources: (1) economies of size at a single stage, and (2) economies of coordination between successive stages of the marketing channel. The planning process of a firm considering vertical integration must incorporate a two-dimensional analysis in determining the optimum number of stages to vertically integrate in and the optimum size of operations at each relevant stage. An elementary model analyzing the vertical and horizontal structure possibilities for a firm is shown in Figure 4. Blaich [4] presented this simplistic model to illustrate the shape of the cost curves associated with intra-stage and inter-stage expansion through vertical integration.

The lowest long-run average cost for a single stage of operation is represented by the constant function, a. The function, b, represents the cumulative lowest average cost of operating two successive stages together. Functions c through f are defined in a similar manner. The declining portion of each of the curves, (i.e., a

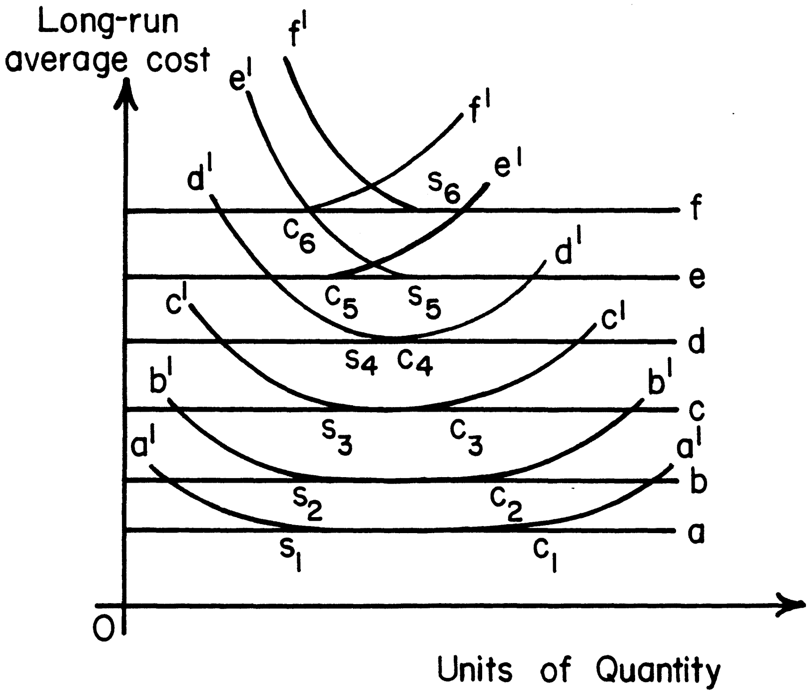


Figure 4. The Long-Run Planning System for a Firm Showing Alternative Vertical and Horizontal Structural Combinations.

to S_1) represents the efficiencies gained through operations at each level of integration. The shape of these curves indicate that as each additional vertical stage is undertaken, the aggregate cost-structure increases and the minimum-optimum scale of output (S_1, S_2,...,S_6) increases, or shifts to the right. Limitations of managerial abilities and capital restrict the firm's ability to efficiently coordinate and finance additional stages within the marketing channel. The upward sloping portions of the average cost curves represent these limitations (i.e., C_1 to a') at successive levels if vertical integration. These limitations decrease the maximum efficient scale of operation and shift the relevant points of reference to the left (C_1, C_2,..., C_6). Thus, the range of efficient scale of operations decreases as successive stages are added under the firm's control. The illustration depicts a situation where a firm would be forced to limit the number of vertical stages below horizontal cost curve E. Any firm organization including stage E could lower its average cost by fragmenting its structure and limiting its vertical integration to include only stages A through D. The efficient structural possibilities (under perfect competition) are located inside the triangle S_1S_4 C_4 C_1.

Blaigh's model is conceptual in nature and is limited to forward integration movements only. For a firm considering backward or a combination of backward and forward structural expansions, the cost curves depicted in Figure 4 may be quite different. However, the elementary model provides a conceptual guide for economic analysis for vertical integration strategies and coincides with the problem analyzed in this research project.

CHAPTER III

SPATIAL EQUILIBRIUM MODELS

Agricultural products typically are produced in locations geographically separated from those locations where the products are consumed. Interregional trade provides a mechanism for establishing price-quantity relationships and product flows between supply deficit and surplus markets. Spatial equilibrium analysis is defined as the study of the distribution of economic flows and transactions over economic space [47]. Spatial equilibrium models are computer analysis tools designed to answer questions such as:

> "How many plants should we have?"
> "Where should our plants be located?"
> "How large should each plant be?"
> "Where should the raw material processed
> in each plant be obtained?"
> "What customers should be serviced by each plant?".

These are key questions posed by businessmen and economists in determining efficient product flows within the industry's marketing channel [50]. The answers to each of these questions are interrelated and have an impact on the profitability of individual firms and on the industry's structure and performance.

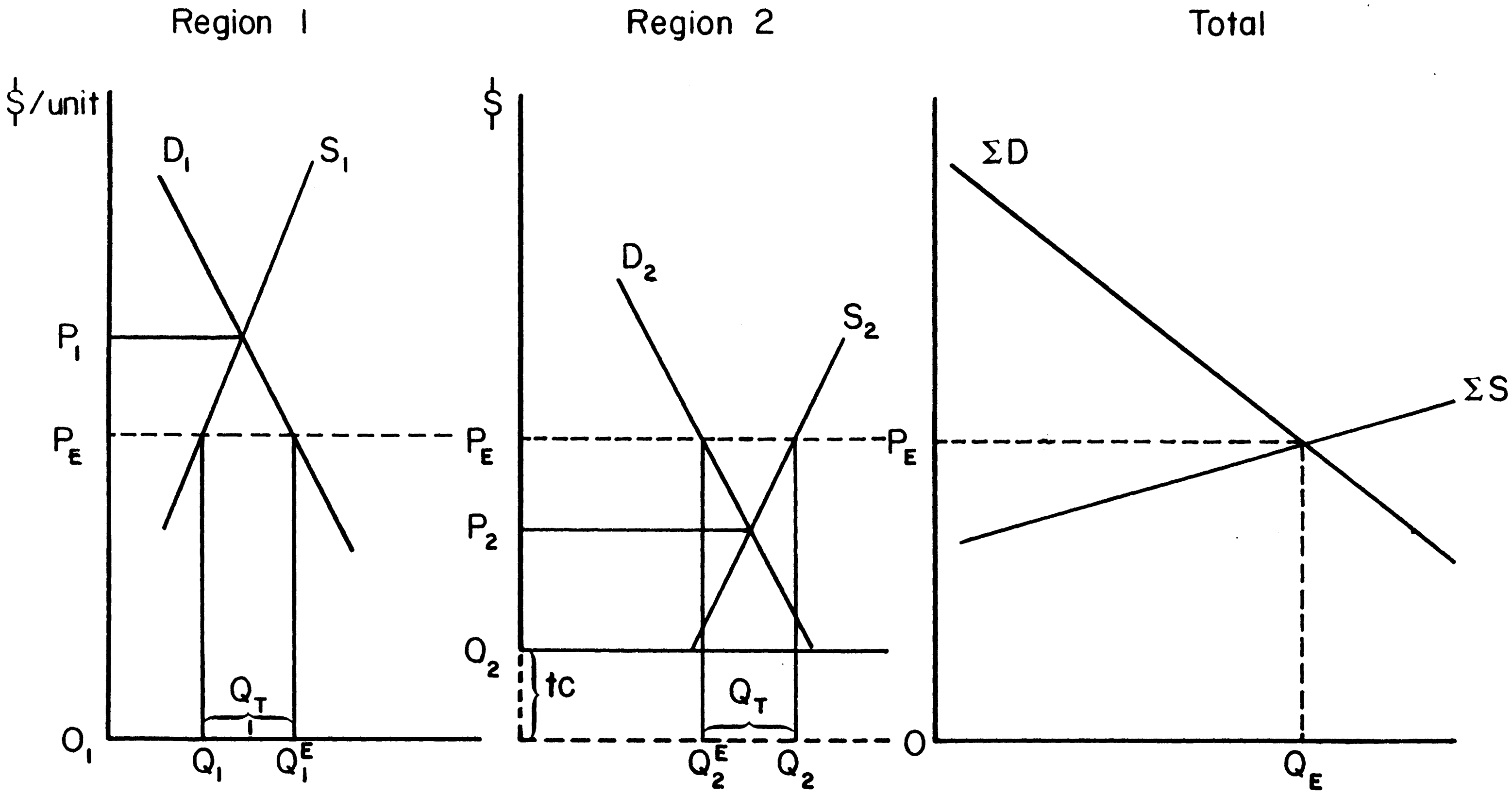
Theory of Spatial Models

Location theory and economic theory provide the basis for spatial equilibrium analysis. Von Thunen [59] is credited as the first economist to conceive and develop the theory of location and based this theory on examination of transportation costs in relation to agricultural production and population centers. The most important analysis tool derived from Von Thunen's investigation was a set of concentric circles around a central city to determine production locations of commodities based upon product perishability and bulkiness. Von Thunen's work was further developed by Weber, Losch, and other economists into a formal theory of spatial equilibrium.

The development of computer analysis, particularly linear programming, in the 1940's permitted the advancement of location theory through empirical analysis. Economists, such as Samuelson, Koopmans, Dantzig, Enke and others, have applied this programming tool to determine the minimum transportation costs of product flows from producers to consumers under specific assumptions about prices, demand and supply, and costs. Spatial equilibrium models have evolved beyond the restrictive confines of linear programming to include separable programming, reactive programming, quadratic programming, and dynamic programming models.

The basic economic concept on which these models are based is that sellers strive to maximize the net price received for their products while buyers attempt to minimize the total price paid for products. The spatial aspect of this situation is critical to reaching an equilibrium in the market place. Transportation costs associated with product flows from surplus to deficit markets decreases the net price received by sellers and increases the total price paid by buyers. Therefore, the basic objectives of spatial equilibrium theory and its models are: (1) to determine equilibrium market prices, (2) to determine equilibrium consumption and production patterns, and (3) to determine the minimum cost flows of commodities between surplus and deficit markets. The equilibrium price for any one market must not differ from the price in any other market by more than the transportation cost between the locations. Once this market pricing structure is found, the price-quantity market relationships are in equilibrium.

The concept of price-quantity equilibrium among spatially separated markets is easy to illustrate. Figure 5 describes two markets (Regions 1 and 2) which are separated but not isolated from one another. Regional supply and demand curves are shown as D_1 and S_1 for Region 1 and D_2 and S_2 for Region 2 and market clearing prices and quantities are depicted as P_1 and Q_1 for Region 1 and as P_2 and Q_2 for Region 2. Transportation costs between regions are assumed to equal tc per unit. Prior to interregional adjustments, the difference between P_1 and P_2 is greater than tc which provides incentives for producers in Region 2 to sell product in Region 1 and for consumers in Region 1 to purchase product in Region 2. As these incentives move product from Region 2 to Region 1, reduced product quantities in Region 2 drives up prices while increased availability of product in Region 1 moves the product price down. Product continues to move from Region 2 to Region 1 until:



tc=TRANSPORTATION COST PER UNIT FROM REGION 2 TO REGION 1.

Figure 5. Market Supply and Demand Relationships for Illustrating a Spatial Equilibrium.

$$P_1 - P_2 = tc$$

or when product price in Region 1 equals price in Region 2 plus transportation costs. Under this condition, incentives no longer exist for interregional movements of product and the price-quantity relationships are said to be in equilibrium.

The summation of individual regional demand and supply curves are shown on the total market graph of Figure 5. The intersection of total market demand and supply curves identifies the market equilibrium price, P_E, and market equilibrium quantity, Q_E. Tracing the market equilibrium price across the individual regions' demand and supply curves, it is found that Region 1 is a deficit market (i.e., $P_E < P_1$) and Region 2 is a surplus market (i.e., $P_E > P_2$). The quantity of product transferred from Region 2 to Region 1 to achieve equilibrium equals Q_T. It is important to remember that equilibrium price differs between the regions by the amount of the transfer costs and, if transportation costs were equal to zero, more product would be transferred between Regions 1 and 2 and the equilibrium price in each market would be identical .

Selected Spatial Equilibrium Models

Several spatial equilibrium models have been developed to analyze a variety of plant location and transportation problems. In general, these models were built to assist decision-makers in both the private and public sectors in determining the number, size and location of plants which would improve firm profitability or industry performance. The primary objective of these models has been to minimize transportation costs of product movements within the marketing channel, typically characterized as transportation or transshipment problems. Of these optimization routines minimizing transportation costs are by far the most common type of model; however other models have been developed and empirically tested which minimize and/or maximize a variety of economic criteria.

The size of the problem and the computational difficulties related to large numbers of origins and destinations dictates the type of computer programming routine selected to solve the optimization problem. These computational problems have led to the use of a number of algorithms to solve the location-transportation problem while efficiently managing computer capacity. The general procedures employed are exact methods which lead to proven least-cost solutions and approximate methods which lead to acceptable solutions but cannot be proven to be the least-cost solution. Approximate methods typically are used when the empirical problem becomes too large to be efficiently solved through the traditional exact method procedures.

Each of these procedures has an obvious limitation. Exact methods are limited as to the size of problem that can be solved efficiently and approximate methods result in solutions which cannot be proven to be optimal. Reviewing selected empirical studies employing the two methods provides a point of reference in selecting an acceptable and efficient procedure to solve location-transportation models.

Exact Method Procedures

Complete Enumeration.

The most common and simplest exact method used to solve transportation problems is complete enumeration.

Stollsteimer [50] introduced this procedure to analyze all possible combinations of plant locations as the number of plants is allowed to vary from 1 to a maximum of n in relation to transportation cost. The procedure was simplified by assuming linear processing costs and all plants considered equi-distant from a single demand destination. The model calculates the total processing and raw material assembly costs for each combination of plant locations using a linear programming procedure.

The procedure is intuitively simple and an optimal solution is guaranteed because complete enumeration of all possible plant combinations are tested and compared in relation to the objective function. However, the number of possible plant locations increases dramatically as the maximum number of plant locations and/or the number of plants in a given system is allowed to increase. For example, the number of different combinations of plants in a system of given size is calculated as follows:

$$c = n!/r!(n - r)! \qquad (3.1)$$

where

c = number of different combinations of plant locations,

n = maximum number of plant locations, and

r = number of plants in the system.

If the maximum number of plants were assumed to be six (6), there exists six (6) unique combinations of one (1) plant, 15 combinations of two (2) plants and, 20 different combinations of three (3) plants. Considering the maximum number of plants were doubled to twelve (12), the number of different plant combinations would increase to 12, 66, and 220 for plant systems sizes of 1, 2, and 3; respectively. Summing the number of total plant combinations from 1 to the maximum plant locations in the equation

$$C = \sum_{r=1}^{n} n!/r!(n - r)! = \sum_{r=1}^{n} \binom{n}{r} \qquad (3.2)$$

the summation can be reduced to the following:

$$C = 2^n - 1 \qquad (3.3)$$

where

C = total number of plant combinations 1 to the maximum number of plant locations, and

n = maximum number of plant locations.

Recalling the maximum number of plants used in the above example, the total number of different plant combinations is 63 and 4095 when n is equal to 6 and 12; respectively. If n were doubled again to 24, there exists 16,777,215 different plant combinations which only emphasizes the impact of plant system size on complete enumeration procedures.

The Stollsteimer model calculates and analyzes each combination of plant location in relation to all other possible plant location combinations and then selects that plant configuration which satisfies the optimization routine's objective function. The complete enumeration procedure is best suited for problems of manageable size. However, as shown above, the number of possible plant locations affects the number of combinations dramatically. As the size of the plant system grows, the number of possible combinations increases geometrically which taxes computer capacity and makes this model inappropriate for large scale problems.

Extensive modifications have been made to the basic linear programming model and assumptions put forth by Stollsteimer. The initial work on the linear programming model was directed toward altering the assumptions and restrictions of the procedure. Reactive programming devised by Hurt and Tramel [18] permits demand and supply quantities to adjust and reach an equilibrium as market prices change in relation to interregional shipments. In general, reactive programming is an iterative linear programming process which provides solutions to a variety of problems which could not be attempted under traditional linear programming assumptions.

Separable programming was formulated by Kloth and Blakley [26] to modify the linear restriction placed on processing cost functions. Separable programming represents the nonlinear processing function as a series of linear segments and approximates the cost function through piecewise linear functionals. However, the basic linear programming procedure is used to solve the objective function and estimate interregional flows. Although these models were developed to expand the capabilities of linear programming techniques, both reactive and separable programming are complete enumeration methods and are subject to the restrictions placed on them relative to the size of the problem.

Implicit Enumeration. An attractive alternative to complete enumeration has been devised and empirically tested by Fuller, Randolph and Klingman utilizing network formulation [14]. Implicit enumeration is a complete enumeration procedure which decreases the number of combinations considered while maintaining the optimal solution. The total number of combinations examined is significantly reduced by searching a network of branches and nodes of a logic tree and continuing along a specific branch only if improvement can be found to a previously enumerated combination. The optimal solution is that combination of plants which satisfies the objective function. The procedure has been found to be mathematically equivalent to complete enumeration methods and estimated to be 100 to 150 times faster than the best available linear programming techniques.

Branch and bound programming is another large location-transportation problem technique which solves the objective function through a sequence of linear programming solutions. Khumawala [22] modified the branch and bound algorithm to obtain progressively lower bounds of the objective function until the optimum is reached. These methods are considered superior to heuristic procedures employed in some techniques to reduced the number of combinations tested and evaluated by the model. Under enumeration, mathematical rules are maintained which ensure a global optimum is found instead of possible local optima which may be detected under heuristic models.

Approximate Method Procedures

Most of the empirical plant location-transportation problems are too large for practical solution even under the most sophisticated of exact method procedures. As a result, a number of heuristic techniques were developed to reduce the number of combinations considered in large problems. Approximate methods are algorithms devised to compare the trade-offs between the gains in efficiency realized through fewer combinations tested with the losses associated with not finding a proven optimal solution.

One-Point Moves. A major group of approximate solution methods are derived from a algorithm developed by Manne [36] which is based upon the fact that the total cost curve is traditionally shown to be envelope-shaped in relation to number of plant locations. This technique is known as steepest-ascent-one-point-move algorithm, or SAOPMA, and has been employed in a study by Warrack and Fletcher [60] which eliminates the one plant which would lower costs the most within the existing system. The procedure begins with all the possible plants included in the system and eliminates plants, one at a time, until total costs can no longer be decreased. Warrack and Fletcher also tested a procedure which started with a system with no plants and includes that plant which would result in the lowest cost system. Iterations of one-point moves continue until an addition of a single plant will not reduce total system costs.

One-point move techniques reduce the number of possible combinations considered significantly. In fact, the number of combinations examined is calculated using the following equation:

$$K = [n(n-1)/2] + n \qquad (3.4)$$

where

K = total number of combinations examined, and

n = number of possible plants.

Recalling the complete enumeration example assuming n equals 24, the number of plant combinations considered under one-point move techniques would total 300 as compared to almost 17 million combinations (i.e., $2^n - 1$) tested by a complete enumeration method. However, locating the optimal solution via one-point move procedures is unlikely because the procedure described above does not permit a plant to be reintroduced to (extracted from) the system once that plant has been eliminated from (included in) the plant configuration. Problems which consider a number of plants in relatively close proximity to one another would find this limitation to affect the usefulness of locating an acceptable solution through one-point move techniques.

Combination Improvement. An heuristic algorithm used by Hardy [15] attempts to avoid the obvious limitations of one-point move methods by including an intermediate step which calculates the best plant combination for any given number of plants. Hardy developed a model which calculated the impact of plants individually as they effect the objective function. King et al. [24] presents a modified Hardy procedure which selects the best plant system of given size and calculates the costs of selecting a non-optimal plant location. However, each successive solution of plant size n+l is based upon the previous n-plant solution which coincides with basic difficulties of one-point move methods.

Combination improvement methods provide additional information which permits the programmer to build a heuristic algorithm to strive toward optimization of the model. These procedures cannot be shown to yield a global optimum and can handle location-transportation problems of moderate size efficiently.

CHAPTER IV

THE MODEL

The computer model designed to solve the specified plant location problem had to meet several criteria. First, the model had to be capable of calculating and evaluating four different categories identified in fluid milk marketing. Second, the optimization routine had to be flexible enough to handle both minimization and maximization objective functions. Third, the spatial equilibrium procedure used must be able to separately allocate market areas which simultaneously may be identified as supply origins, fluid milk processing plant locations, and demand destinations. Fourth, the algorithm had to be very efficient in order to handle a large spatial equilibrium problem. A spatial allocation algorithm was devised for this fluid milk plant location optimization problem but was also found to be flexible enough to use in a number of similar allocation-transportation problems.

A number of spatial equilibrium models were reviewed with respect to the objectives of this research, and although models were found which could satisfy some of the specified objectives, no single spatial allocation procedure was identified which met all model criteria. Therefore, a technique was formulated which combined selected attributes of tested spatial allocation models to meet the criteria stated above. Most importantly, the algorithm was designed to efficiently evaluate a large allocation-transportation problem with respect to four different cost categories and various minimization and maximization objective functions. The overall objective of the model was to allocate spatially the appropriate number, size, and location of fluid milk processing plants such that the objective function is satisfied within the constraints of the problem.

Heuristic algorithms, like the one devised for this analysis, are usually employed when the size and complexity of the problem makes exact solution methods too costly or too time consuming for practical use. Heuristic procedures seek acceptable solutions rather than optimum solutions based upon a number of factors such as computer budget constraints and quality of the estimated solution. The technique used in this research is a heuristic method which evaluates improvements in solution quality with respect to computer costs and attempts to attain the best solution possible within the limitations of computer fund availability.

Formulation of the Model

A review of existing spatial allocation models failed to find a procedure which satisfied the special needs in modeling the industry-wide costs and returns of marketing fluid milk products within the scope of the problem. However, two procedures were found which addressed most of the conditions stated and provided the computational basis on which to formulate this model. These techniques fell into the classes of spatial models known as (1) one-point move methods and (2) combination improvement check methods. In general terms, the model utilized for this problem searches for the optimum solution through a series of one-point moves through which a suboptimal solution was reached, and thereby improved upon by iteratively searching new combinations of plants until an acceptable solution was identified.

The IBM programming language PL/1 was chosen to perform the optimization procedure for the following reasons. Modelling the unique features of fluid milk marketing was facilitated by PL/1 because of its ease and flexibility in programming diverse and complex models. Also, PL/1 has the ability to manipulate a large number of program statements very quickly and efficiently. Finally, established debugging conventions were available to locate programming and modelling errors through PL/1.

Divisions of the Model

There are four-basic divisions in the model. First, the product distribution portion of the model allocates supply and demand points with respect to the principles of comparative advantage and calculates costs and revenues for individual plants and for all plants specified in the fluid milk system. Second, an elimination routine selects plants one at a time and removes them from the system of plants until eliminating additional plants would no longer improve the objective function. Third, the combination improvement section systematically adds plants to the suboptimal elimination plant system and searches for plant combinations which improve suboptimal solutions. Fourth, the final portion of the model is a report writer which presents the summarized and detailed reports of the results. All of the model's divisions are described in more detail in the following portions of this report.

Production Distribution Analysis

Product distribution requires that the costs of fluid milk products be minimized for each market area to satisfy spatial equilibrium conditions. This section of the model allocates county demand and supply areas to the individual fluid milk processing plant which can service the market most efficiently. Allocation of demand and supply areas to plants are determined on a least-cost basis for given plant systems. Because the model was designed to determine demand and supply areas for plants separately, a discussion of each procedure and supporting assumptions was necessary.

Demand Allocation. Demand areas were allocated to plants according to the minimum distribution and raw milk costs. Distribution costs were defined as the per mile costs of transporting packaged fluid milk from processing plants to demand counties while raw milk costs were those federal market order Class I prices paid by processors for bulk raw milk. These two factors were used in conjunction with county demand requirements to modify the matrix of distances between given plant locations and demand areas. The mileage matrix was transformed by multiplying each of the distances by the product of the following factors relevant to a specific plant and county pair:

1. county demand requirements in hundredweight,
2. plant raw milk costs in dollars per hundredweight, and
3. distribution costs in dollars per hundredweight per mile.

The resulting matrix has been denoted as the IMPACT matrix and contains the weighted demand-side costs between given plant systems and demand areas.

The IMPACT matrix provides an easy method to evaluate product distribution between demand areas and plants. The demand area was simply assigned to the plant which had the lowest weighted demand-side costs thereby ensuring that consumers in that county receive milk from the cheapest source available. The plant sizes, which were not known a priori, were determined by adding the demand quantities of all counties assigned to the individual plants.

The product distribution analysis for fluid milk product was designed to provide least-cost milk product value and distribution demand area configurations. This has been accomplished under the following assumptions:

1. a given number and location of processing plants exist in the market system,
2. fluid milk demand quantities are known and fixed,
3. all of a county's demand requirements were assigned to a single plant,
4. individual plant processing volume equals the sum of the demand quantities of counties assigned to the plant,
5. total plant system processing volume equals the sum of all county area demand requirements,
6. all milk consumed in the study area was processed in the study area (no imports), and
7. all fluid milk products processed in the area were consumed in the study area (no exports).

Under these assumptions, the above procedure yields plant sizes and service areas that result in a least-cost raw milk and distribution market configuration.

Supply Allocation. Allocations of supply areas were assigned after the plant processing volumes were estimated in the demand allocation procedure. Once the plant sizes were known, raw milk was drawn from supply areas in a manner which minimize assembly costs under the given plant system. Assembly costs were defined as the transportation costs per mile associated with bulk raw milk shipments from supply counties to processing plants. In order to accomplish this goal, a matrix of distances between milk supply origins and plant destinations was transformed by multiplying the mileages by the assembly costs per mile. The data in this matrix were the supply-side cost estimates which were direct functions of mileage because the per-mile assembly cost figure was a constant.

A procedure for assigning supply areas to processing plants was devised to ensure that all plants got a chance to draw supply from its own county and other nearby counties before other more distant locations. This technique - designated as a looping procedure - allows each plant to draw raw milk supply from the nearest, or cheapest, available supply area. If the plant did not pull enough supply from its closest county to satisfy its processing requirements, the plant searched for the next closest county containing milk supplies. The looping procedure continues with plants drawing supplies from the closest counties containing milk supplies until all plants have satisfied their raw milk requirements.

The looping procedure used to allocate supply areas to given plant systems based on assembly costs cannot be shown to provide the minimum transportation cost solution, however, the technique represents a logical method of selecting supply areas through efficient use of computer time and capacity. It is believed that this procedure would yield acceptable solutions to least-cost supply area allocation problems.

The following assumptions were used in the raw milk product distribution analysis:

1. plant number, location, and size are given,
2. supply area quantities are known and fixed,
3. the amount of supply drawn from an area cannot exceed its available supply,
4. the amount of supply received by a plant equals the amount of fluid milk processed,
5. the amount of total raw milk supply received by all plants equals the amount of fluid milk processed by all plants, and
6. any excess raw milk supply remain in the county where produced.

Summary. The product distribution procedure evaluates the market performance of given fluid milk processing plant systems very quickly and efficiently. It allocates demand and supply areas to individual plants, estimates plant sizes, and calculates costs and returns for individual plants as well as for the plant system. Empirical testing found that this procedure accomplished the described results for a system of 100 plants, 600 demand areas, and 400 supply areas in less than three seconds on an IBM 3081 main frame computer.

Elimination Routine

The elimination routine is the primary section of the optimization technique utilized in this model. It is used in conjunction with the combination improvement subroutine described later in this report to solve for the number, size, and location of processing plant which optimized selected minimization and maximization objective functions. The purpose of this routine is to eliminate plants, one at a time, until an intermediate solution was reached. This intermediate solution is defined as the plant configuration which provides a local optimum based on the plant elimination path but is not inferred as being a global optimum solution.

The steps used to obtain the intermediate solution can be best shown through an example, but since the elimination path and local optimum solution differs between optimization functions, the example employs the total costs minimization objective for illustration purpose. The other two objective functions used in this study are minimization of processor costs and maximization of producer returns and are discussed in Chapter VI.

Minimization of Total Cost.

The objective of this procedure was to minimize total costs. The algebraic notation of this objective function is:

$$\text{Minimize TC} = \sum_{i=1}^{s} \sum_{j=1}^{P} AC_{ij}Q_{ij} + \sum_{j=1}^{P} PC_jQ_j + \sum_{j=1} RMC_j\,Q_j + \sum_{j=1}^{P} \sum_{k=1}^{D} DC_{jk}\,Q_{jk} \qquad (4.1)$$

or

$$\text{minimize TC} = TAC + TPC + TRMC + TDC$$

where

TC = total combined fluid milk marketing costs,

TAC = total assembly costs,

TPC = total processing costs,

TRMC = total raw milk costs,

TDC = total distribution costs,

AC_{ij} = assembly costs per cwt. for shipping bulk raw milk from supply area i to plant location j,

Q_{ij} = quantity of raw milk shipped from supply area i to plant location j in cwt.,

PC_j = fluid milk processing costs per cwt. at plant location j,

Q_j = quantity of milk processed at plant location j in cwt.,

RMC_j = raw milk costs per cwt. for shipping fluid milk products from plant location j to demand area k,

DC_{jk} = distribution costs per cwt. for shipping fluid milk products from plant location j to demand area k,

s = number of supply areas utilized out of a total 380 supply areas S,

p = number of plant location utilized out of a total 99 possible plant location P, and

D = all 587 demand areas.

A plant system location variable, L_{pq}, must be specified to differentiate plant systems of size p which can have many different locational combinations q.

Using this minimization objective, the elimination routine begins with a given plant system of any number ($p < P$) and location, and computes TC_p (this value of TC was calculated in the product distribution section of the model). Then, two questions were addressed:

1. "Can TC be lowered by eliminating one plant from the system of plants?", and
2. "Which plant would lower TC by the greatest amount if eliminated?"

To determine if and which plants were to be removed from plant system, an iterative process of asking these questions was performed until elimination of one plant would no longer lower TC. The plant system at this point is identified as the intermediate solution.

The steps of the elimination routine are listed as:

1. Retrieve the stored value of TC_p from the product distribution section of the model.
2. Calculate TC_{p-1} for every p-1 plant combinations.
3. Test if $TC_p > TC_{p-1}$ for every p-1 plant combinations; and if so, proceed to Step 4.
4. Eliminate the plant associated with TC_{p-1} which lowers TC by the greatest amount.
5. Identify TC_{p-1} as TC_p and repeat steps one through four until TC can no longer be reduced by eliminating one plant.

Operationally, the computer program identifies those plants in the system from those eliminated from plant system through use of two arrays, or lists. The USEABLE plant list contains all those plant locations used in the system while the ELIM list identifies all of the plant locations not initially selected or removed through the elimination routine for the plant system. When a plant is eliminated by the procedure, the location was pulled from the USEABLE list and placed on the ELIM list. Recalling that the total number of possible plant locations equals 99, the number of plants in both lists must sum to 99. For example, if the initial number of plant locations selected equaled 40 and the elimination procedure removes 15 plants before an intermediate solution is reached, there would be 25 locations remaining on the USEABLE list and 74 listed in the ELIM array. These two plant lists are important in verification of the model and to the combination improvement subroutine.

The elimination routine is performed exactly in the same manner for the other two objective functions. The algebraic notation for each function is listed and discussed in Chapter VI.

Combination Improvement

The combination improvement subroutine is designed to search for the optimum plant system solution. This portion of the model is a subsection of the elimination routine and its purpose is to add selected plants to the plant system obtained in the intermediate solution found in the elimination routine. Once these plant locations are added to the intermediate solution's plant system, the elimination procedure is activated again and plants are eliminated following the same steps as before. The purpose of this subroutine is to allow the elimination routine to iteratively search for the optimum solution through revised plant location combinations.

The procedure used in selecting plants to be added to the intermediate solution is rather naive but is utilized because of its simplicity and ease of operation. An arbitrary number of plants selected from the ELIM plant list previously discussed are added to those plants to the USEABLE list containing the plant locations associated with the intermediate solution. The number of plants added may be any number less than or equal to P - p; however, the appropriate number added should be large enough to alter the plant system so an improved solution can be found yet small enough as to not return the system of plants to the initial configuration.

Optimization Procedure. The steps of the optimization procedure, which includes both the elimination and combination improvement routines, are illustrated in flow chart form in Figure 6 and are as follows:

1. Record the intermediate solution derived from the initial elimination routine.
2. Select a specified number of plants from the ELIM plant list.
3. Add those plants to the USEABLE plant list.
4. Return to the elimination routine where a revised intermediate solution is calculated.
5. Compare the revised solution to the intermediate solution; if improved, proceed to step 6 and if not improved, skip to step 7.
6. The revised solution becomes the intermediate solution and repeat steps 1 through 5.

OPTIMIZATION ROUTINE

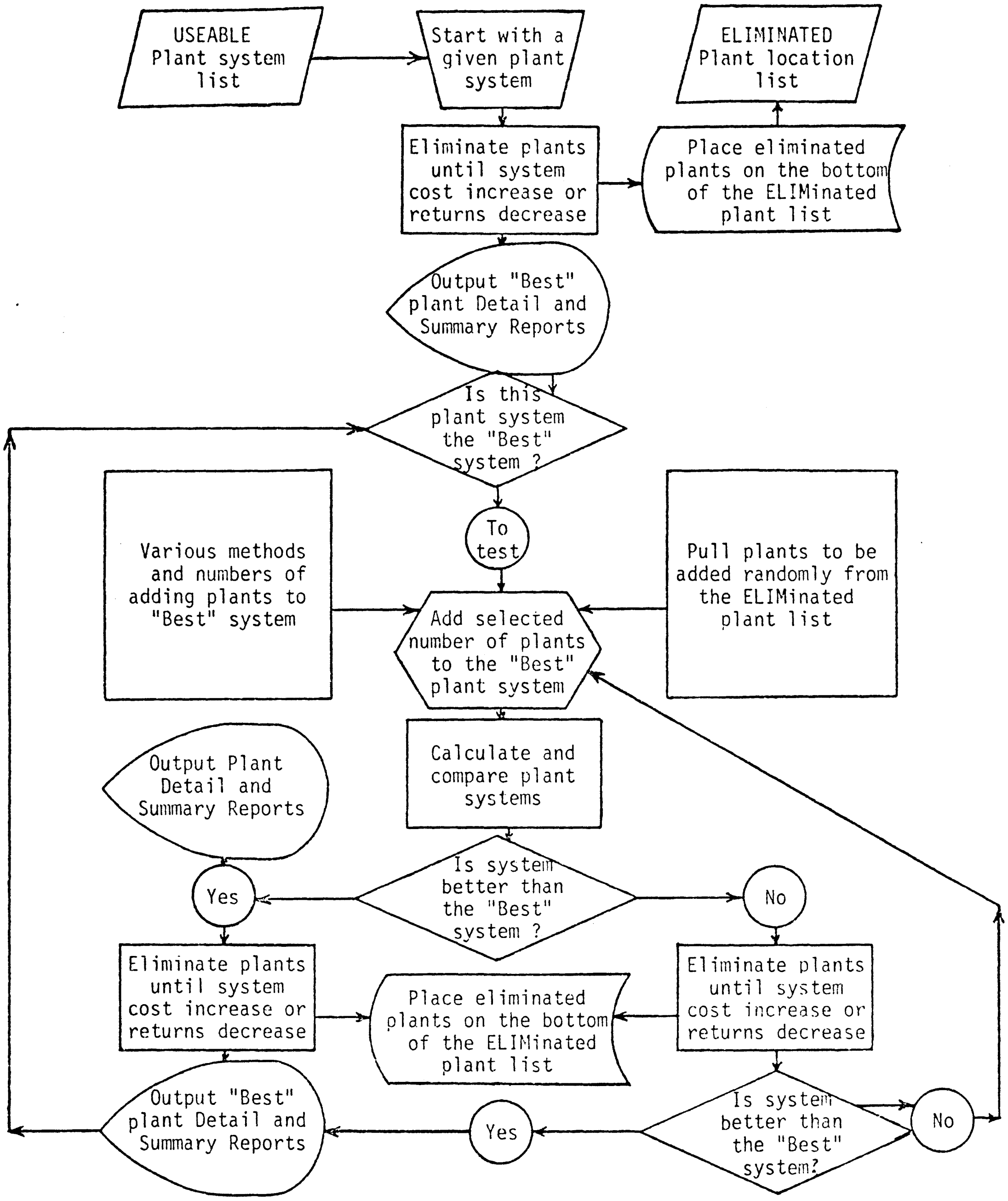


Figure 6. Flow Diagram of the Optimization Routine for Searching Alternative Plant Configurations.

7. Evaluate the intermediate solution as to its acceptability as an optimum solution; if acceptable, the intermediate solution becomes the optimum solution and if unacceptable, repeat steps 1 through 5.

The procedure has been denoted as POST (Plant Optimization Search Technique) by the author. An acceptable solution for each of the objective functions was found after approximately ten minutes of computer time. For a problem of large size, the POST model has been viewed by experienced computer programmers as being very efficient.

Presentation of Results

The fourth and final section of the model presents the results of the optimization procedure. This section is designed to be a report writer to display the product distribution analysis and the various costs and revenue calculations for each processing plants location as well as for the total system of plants. The report writer presents the model results in two different types of reports. First, the Summary Report shows the various costs and revenue variables calculated for each plant and for the total system of plants. Second, the Detailed Report displays the raw milk and processed milk production distribution shipments between all supply areas, plant locations, and demand areas for each plant location configuration.

These two reports permit the researcher to verify all product shipments as to their validity and to analyze the plant allocation solutions as to their acceptability as an optimum solution. From these presentations of results, comparison of alternative fluid milk market conditions can be readily made and decisions made relative to profitability of individual plant locations and to the performance of the dairy industry.

Summary

The attributes of the PL/1 programmer language utilized in this model permitted almost complete programming flexibility, which was necessary to model the fluid milk industry effectively. Institutional changes like revisions in Class I milk price and technological innovations such as lower processing costs have an impact on the optimum industry structure. Therefore, flexibilities have been placed in the model to permit the researcher to easily change important costs and revenue parameters without modifying the model. However, there were some limitations to the model which restricted the capabilities and types of solutions derived by the model.

Flexibilities of the Model

Many of the parameters used by the model can be changed without restructuring the procedure of how the optimization routine searches for the optimum solution. All of the costs functions can be manipulated to be of any functional form as long as the variables used by the equations are available to the model. Also, the Class I milk prices, which are costs of raw milk at plant locations, may be changed for any one or all possible plant locations. An array of fixed plant costs can be entered into the model to reflect relative costs structures among plants. These flexibilities allow the costs structures used in fluid milk market analysis to be readily modified to almost any level or form desired.

Important to the analysis of specific plant systems and computer time required to find an acceptable "optimum" solution, the model allows the researcher to start the model from any combination of plant locations $(p < P)$. This permits calculation of costs and allocation of production distribution for an existing or projected plant system very quickly and inexpensively. Also, the point from which the optimization procedure starts has an impact on efficiently finding an optimum solution. Empirical testing revealed that beginning the analysis under a system with all plants resulted in poor "optimum" solutions at greater expense. It was found that an acceptable solution could be efficiently estimated if the initial plant system located processing facilities in the cities denoted as SMSA (Standard Metropolitan Statistical Area).

Limitations of the Model

The model limitations are directly related to the restrictions placed on the model by computer capacity and computer funds availability rather than the inability to design the model to accomplish the desired results. These limitations are related to the fixed supply and demand quantities, fixed retail fluid milk product prices, and no plant size capacity restrictions found in the model.

The fixed supply and demand quantities and retail milk prices prohibits this model from allowing for price and quantity adjustments as changes in the marketing system occur. The large size of the problem forces most of the background data to be handled outside of the optimization routine; therefore, prices and quantities are not adjusted within the optimization procedure. This restriction limits the model from finding the spatial price equilibrium market structure.

The inability to restrict processing plant capacity proved to be a problem when attempting to model market structure of the 1982 existing plant system. The product distribution procedure could not restrict the number of counties (or demand) assigned to a plant which prohibited the procedure from reflecting existing cost structures and distribution of product. There is no economic reason for restricting plant processing capacities for the optimization procedure because the desired results are the optimum size of plant to satisfy the objective function.

In general, the POST model provides the researcher a flexible procedure to determine least cost product distribution under given plant systems and optimum plant number, size, and locations under a variety of objective functions. However, as is the case with all modelling techniques, the quality of the results is dependent on the validity of the data used in the model.

CHAPTER V

MARKET DELINEATION, BASIC DATA, AND COST ESTIMATES

Many different types of data are required to analyze the fluid milk industry within the spatial equilibrium framework. Fluid milk demand and Grade A milk supply data are needed for each geographic market and time period. Transportation costs associated with assembly of raw milk supply and distribution of processed fluid milk products must be known for each potential shipping link. Processing costs and federal market order Class I milk prices must be determined for each plant location. The sources and procedures for obtaining or generating the necessary data for operating and optimizing the model are described in this chapter.

Market Delineation

The basic objective of this research is to evaluate the potential of a regional milk cooperative vertically integrating into the fluid milk processing industry in the southwest portion of the United States. The Southern Region of Associated Milk Producers, Inc. (AMPI) is the dominant milk cooperative in this ten-state area; therefore the study area selected corresponds approximately to the geographic area of its influence. Figure 7 shows the 587 county study area analyzed by this research project.

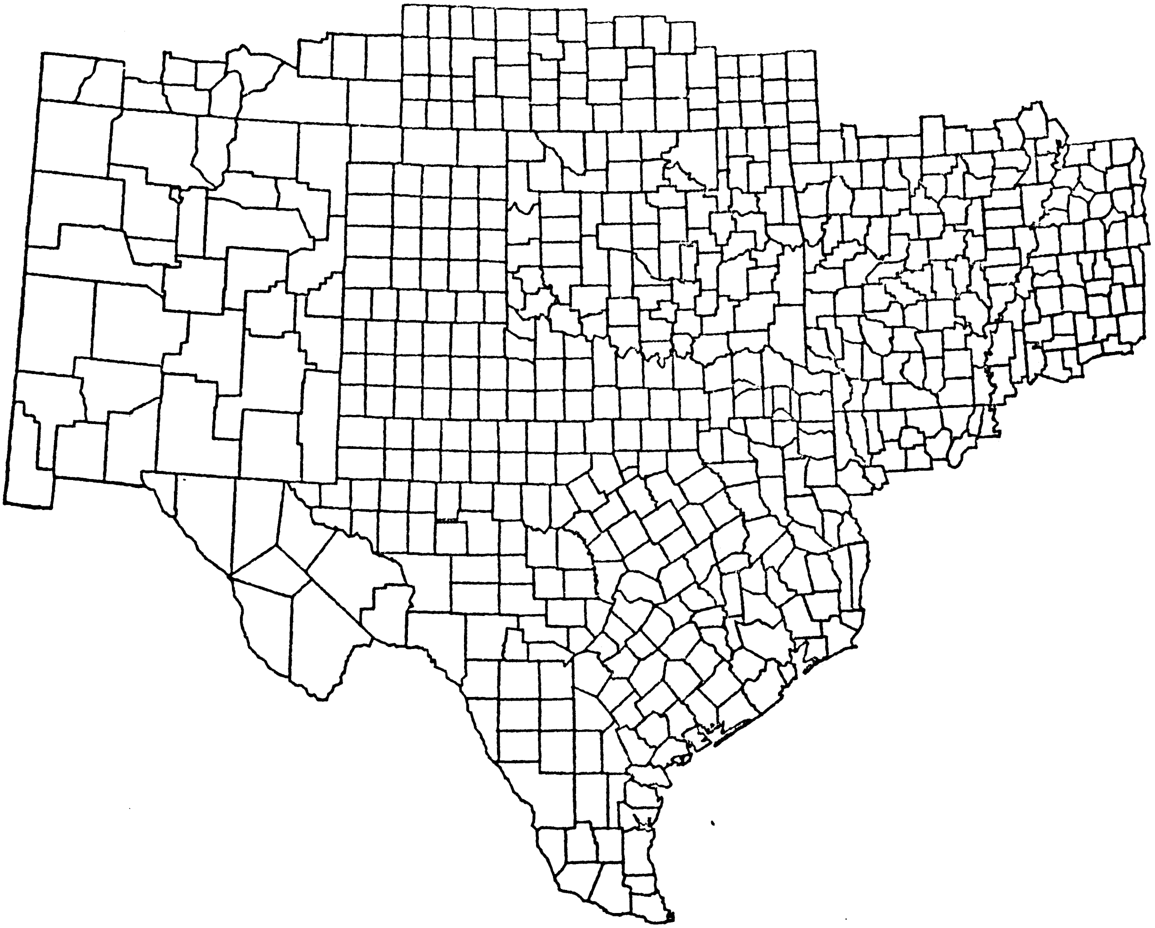


Figure 7. The 587 County Southwest Study Area.

Individual counties represent market areas that serve as both production and consumption locations. The center of each county has been selected as the point of reference where all milk production and consumption is assumed to have taken place. This point of reference also serves as the origin and destination of all exports or import into the county market. The county center reference point eliminates the need to estimate assembly and distribution costs within individual counties.

Ninety-nine counties were selected out of the total 587 counties as potential fluid milk processing plant locations. These 99 possible plant locations, shown in Figure 8, were chosen based upon two criteria; (1) did the county contain an operating fluid milk plant in 1982, and (2) was the county's population large enough (exceed 50,000 in 1982) to support the employment needs of a processing plant. As was the case for production and consumption, the center of the county serves as a reference point for all shipments to and from fluid milk plants.

Fluid Milk Demand Estimates

The demand for fluid milk is dependent on retail milk prices but is also significantly affected by a number of socioeconomic and environmental variables. Studies estimating fluid milk demand by Purcell [43], Raunikar, Purcell and Elrod [44], Boehm and Babb [7], Blaylock and Smallwood [5] and Boehm [6] have found that fluid milk consumption is influenced by retail milk prices, consumer income, age and racial composition of the population, and selected seasonal and

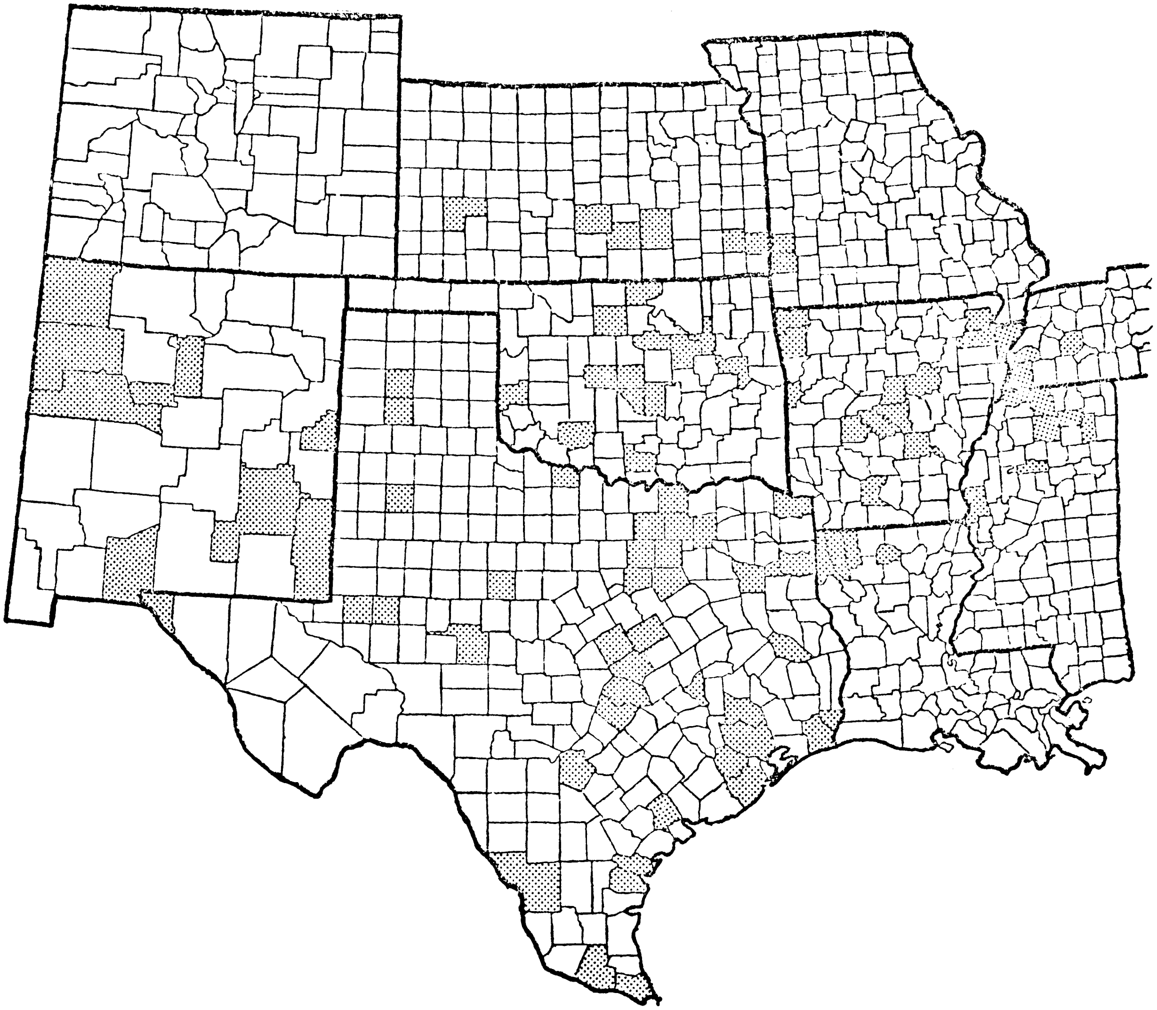


Figure 8. The 99 Possible Fluid Milk Processing Plant Locations Identified in the Study Area.

locational factors. These studies typically have measured demand as either household consumption or per capita consumption. For the purposes of this research, the per capita definition of demand is used because of its suitability to the analysis.

Individual demand markets are represented by counties, as stated previously; therefore, total demand estimates are calculated for each county and time period. County fluid milk demand is determined by multiplying county-level population by per capita consumption estimates. The total symbolizes the total pounds of processed fluid milk products required to satisfy consumer wants under given conditions. All of the 587 counties have an estimated level of fluid milk demand for the study years 1982 and 1990 and are defined as the demand-side destinations in the model (Table VII, Appendix A).

Demand Function

Boehm [6] developed a comprehensive fluid milk demand equation for aggregated regions of the United States and used it to project fluid consumption through the year 1990. Boehm identified 16 explanatory variables and used ordinary least squares (OLS) and combined cross-section time series (CSTS) regression techniques to estimate average daily per capita consumption. The demand function used in the model is based upon Boehm's CSTS equation but has been revised to include only those explanatory variables available for this analysis.

The fluid milk demand equation utilized is of the following form:

$$\begin{aligned} Q = a + b_1 \text{ (RMP)} + b_2\text{(INC)} + b_3 \text{ (BLKP)} + b_4 \text{ (LT5)} + \\ b_5 \text{ (5-19)} + b_6 \text{ (45-64)} + 6_7 \text{ (GT65)} \end{aligned} \tag{5.1}$$

where

Q = Fluid milk consumption in pounds per 1000 persons per day,

RMP = Retail milk price in cents per half-gallon,

INC = Average per capita personal income in dollars,

BLKP = Number of black persons per 1000 population,

LT5 = Number of persons per 1000 less than 5 years old,

5-19 = Number of persons per 1000 between the ages of 5 and 19 years,

45-64 = Number of persons per 1000 between the ages of 45 and 64 years, and

GT65 = Number of persons per 1000 population age 65 and older.

Parameter estimates utilized in the above equation were those values of b_1 through b_7 reported by Boehm and listed in Table II. The quantity intercept, a, was revised for use in this model's setting to correspond to 1980 census data. Mean values of dependent and independent variables were used to adjust the intercept value to reflect the changes and omissions made in Boehm's regression model. After estimates of fluid milk demand were calculated, daily consumption per 1000 population figures were modified to annual consumption per capita in pounds to coincide with other model parameters.

Independent Variables. Socioeconomic data were found to be available at several levels of aggregation to satisfy the model's needs, but not all were suitable for the analysis. Because

TABLE II

FLUID MILK DEMAND REGRESSION EQUATION PARAMETER COEFFICIENTS

Parameter	Notation	Parameter Estimate
Intercept	a	3.174
Retail Milk Price (RMP)	b_1	-1.475
Per Capita Income (INC)	b_2	0.011
Black Population (BLKP)	b_3	-0.708
Population <5 (LT5)	b_4	3.305
Population 5-19 (5-19)	b_5	0.103
Population 45-64 (45-64)	b_6	3.328
Population >65 (GT65)	b_7	-0.442

county-level data are not available for the majority of the independent variables used to calculate fluid milk demand, the only aggregated population and income data available and deemed as appropriate were based on areas known as Bureau of Economic Analysis areas (BEA). BEA are groups of counties identified as being influenced by a particular metropolitan city, and the data reflect total characteristics for all counties within a single BEA. There are 32 complete and partial BEAs within the study area as illustrated in Figure 9.

Since the BEA data are simply aggregations of county data, it was decided to estimate fluid milk demand for each of the 32 areas and to use these per capita consumption figures to represent individual county per capita demand within each BEA. Total personal income and population composition data for BEAS were reported by Holdrich [18] for the census years 1970 and 1980 and projections were made for years 1985, 1990, 1995 and 2000. Table XV of Appendix A shows the per capita consumption rates and background data used to estimate fluid demand by BEA.

Retail fluid milk prices are not published for individual counties or BEAs, but the Federal Market Order Class I (fluid milk) prices are reported by the United States Department of Agriculture [55] for all market order areas. Since the demand function is estimated at the BEA aggregation level, average 1982 Class I milk prices were collected for the major city within each BEA and multiplied by the farm-retail marketing spread ratio [56]. The resulting prices represents the retail milk prices used to estimate per capita fluid milk consumption.

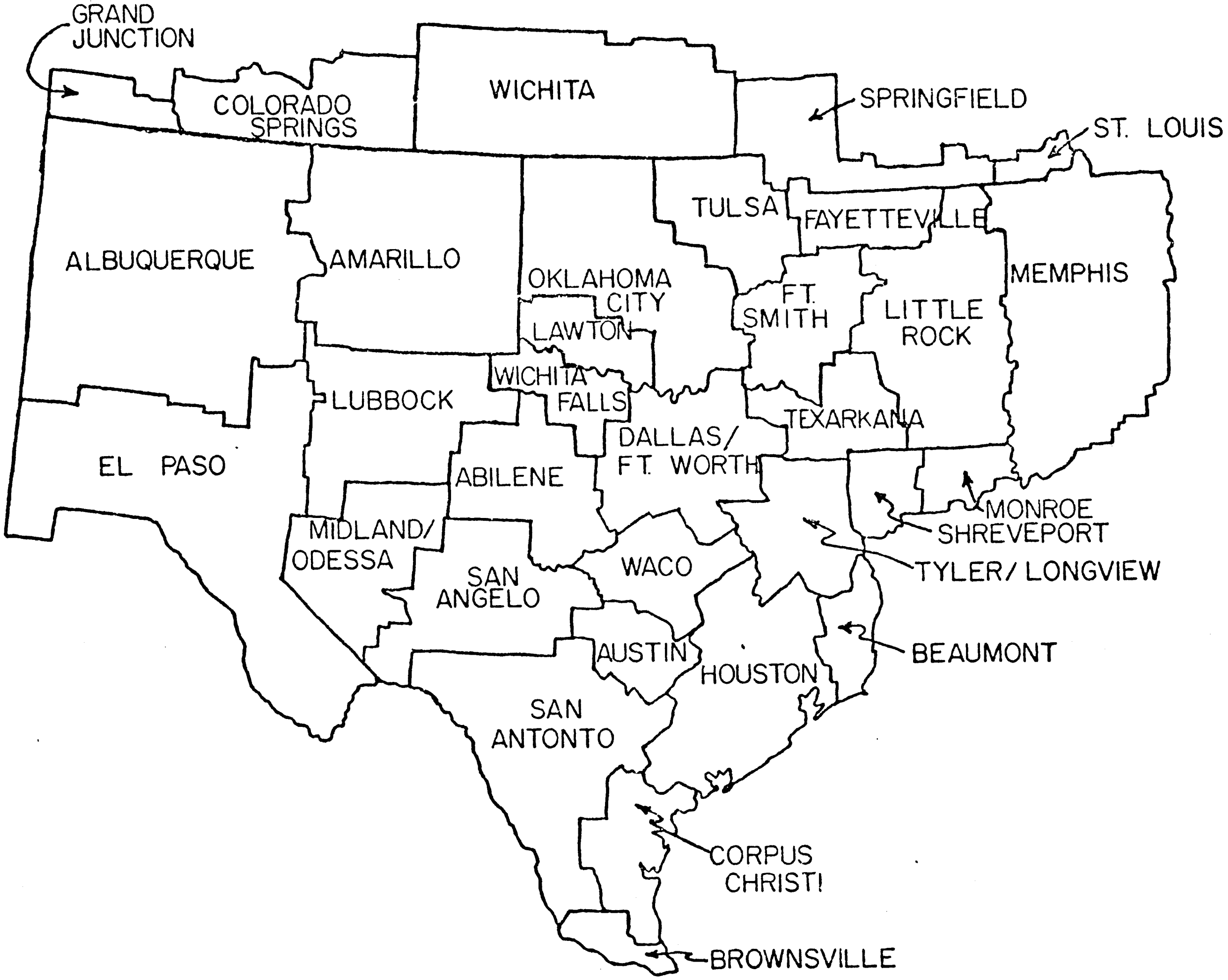


Figure 9. The 32 Bureau of Economic Analysis (BEA) Areas Identified in the Study Area Used to Estimate Fluid Milk Demand for 1982 and 1983.

Population Estimates

County population census and projection figures were reported and published by Holdrich [17] of the National Planning Association in Washington, D.C. Total county population data were available for selected years between 1970 and 2000 but not for 1982, the base year of this research. Therefore, as was the case with the BEA information, 1982 population totals were estimated through interpolation between the years 1980 and 1985. County population data for 1982 and 1990 are listed in Table VII, Appendix A.

Raw Milk Supply Estimates

Milk eligible for fluid use is defined as Grade A milk and all milk sold under federal orders is classified as Grade A milk. In 1982, market administrators reported [55] that over 80 percent of total U. S. Grade A milk production was marketed under federal orders while the remainder was disposed of under state orders or by producer-handlers. Since no state orders are effective within the study area and quantities of fluid eligible milk marketed by producer-handlers are relatively small, raw milk supply estimates are represented by producer deliveries to handlers operating under federal market orders.

Market administrators are responsible for monitoring and enforcing the rules set forth by federal milk orders which require the collection of a great deal of data. Total county producer deliveries, defined as county milk production in this analysis, are collected by market administrators. However, the data collected were for the month of December for selected years. To analyze the data to conform with the other variables, the December county totals were normalized to correspond to average annualized monthly figures and multiplied by twelve to represent annual totals. Data for December, 1981 were made available from unpublished reports by market administrators [53] and were modified to represent 1982 annual county milk production totals. Of the total 587 counties, only 380 were identified as milk producing counties in December, 1981 and these 380 counties are the raw milk supply origins used in the location-allocation equilibrium model (Table VII, Appendix A).

Future milk production supply is difficult to predict in the face of a changing federal milk price support program. Farmers adjust their level of milk production in response to changes in prices received for milk, which is heavily influenced by the federal program. Consequently, the 1982 county milk supply totals are also used for the corresponding 1990 supply estimates. Any supply quantities in excess of total fluid milk demand are assumed to remain in the counties and not transported to milk manufacturing facilities for the purposes of this research project.

Cost Estimates

Transportation Costs

Two of the four cost components calculated and evaluated by the spatial equilibrium analysis were assembly costs and distribution costs. Both of these factors were defined as transportation costs related to shipments of raw bulk milk and processed fluid milk products within the marketing system. As mentioned previously, the total amount of milk assembled and distributed equals the total quantity of milk demanded and the cost of surplus milk transportation is not a part of this research.

Assembly Costs. Assembly costs are defined as those expenses incurred when shipping bulk raw milk from county supply origins to fluid milk processing plants. Kletke [25] reported that AMPI estimated the cost of shipping bulk milk to average $0.30 per hundred weight per one hundred miles in the Southern Region during the late 1970's. Subsequent inquiries with AMPI officials indicated that this figure remains a valid estimate for assembly costs in the study area for the early 1980's and assumed to be the same in real terms in 1990.

Assembly costs are a function of mileage, therefore, a mileage matrix of distances between all 380 supply origins and all 99 processing plant destinations was required. The mileage data are Great Arc distances (based on longitude and latitude locations) from county seat to county seat for all supply origins and plant destinations specified in the assembly costs matrix. These data were modified to reflect road mileage by multiplying the Great Arc distance by the factor 1.138. This constant was estimated by Deason [12] of AMPI, Inc. by comparing a sample of Great Arc distances with actual road mileages.

A supply-side cost matrix was generated for use in the equilibrium analysis by converting the transformed Great Arc distances by the shipping cost estimates to obtain a matrix of relative shipping costs between all locations. These relative costs estimates are utilized by the model in selecting supply origins for plant locations within a particular plant configuration. Assembly costs are the total of those weighted costs times the amount of bulk milk supplied by a selected supply origins to a plant destination. There exists a unique set of assembly costs for each plant location system.

Distribution Costs. Transportation costs realized from shipping processed fluid milk products from plant locations to demand locations are defined as distribution costs. Several studies [8], and [13] generally found distribution costs to be function of mileage and quantity shipped over a particular route. Using this information, officials of AMPI were interviewed and asked to estimate the average 1982 shipping cost of distributing fluid milk products from processing plant to wholesale distribution centers. The figure arrived at was \$0.45 per hundredweight per one hundred miles for the Southern Region of AMPI and, as assumed with assembly costs, are assumed to be the same in 1990.

A mileage matrix consisting of 99 plant origins and 587 county demand destinations contained Great Arc distances that are transformed by multiplying each distance by the factor 1.138 (same as the factor used to modify the supply-side distances) used as the demand-side mileage matrix. These distances underwent two additional conversions before they were used in the model. First, these road mileage estimates were converted to cost estimates between locations by multiplying the distances by the distribution costs (\$0.45/cwt./100 miles). Second, since the model assumes that all of a county's demand must be supplied from single plant, the cost estimates between and individual county and all 99 plants were weighted by the total demand quantity for that county. The resulting demand-side cost matrix was used in the analysis to determine distribution costs by simply totaling up costs between all identified shipping routes.

Separate demand-side cost matrices exist for each of the analysis years, 1982 and 1990. This is necessary because demand quantities for each county are unique for 1982 and 1990. These demand-side cost matrices, like the supply-side matrix, are derived exogeneously to the model but used by the model to calculate transportation costs of assembling and distribution milk within a selected plant configuration.

Plant Costs

The other two cost components evaluated within the model's equilibrium analysis are identified as raw milk costs and processing costs. The costs are defined as plant costs because each factor is directly related to the size or location of certain processing plants within a system of plants.

Raw Milk Costs. Raw milk costs are the prices paid by fluid milk processors for raw milk supplies delivered to plant locations times the quantities of milk processed. Raw milk prices paid by processors are identified as Class I milk prices administered by the Dairy Division of the U.S. Department of Agriculture. Class I milk prices are based upon the location of milk processors and not dependent on the location of milk production. In other words, all of a plant's milk supply is priced exactly the same without respect to where the milk was produced or from whom the milk was purchased.

Average 1982 Class I milk prices were collected and derived for all 99 possible plant locations from several governmental publications

[55, 39, 40]. Figure 10 illustrates the geographical regions and the federal market order prices effective in the study area. Raw milk prices are assumed to be the same for 1982 and 1990 due to the reasons described in the milk supply estimates section. No economies to size were attributed to raw milk purchases; these costs are simply a function of Class I prices and plant processing quantities.

Processing Costs. Significant economies to size have been attributed to processing raw milk into packaged fluid milk products. Several studies have reported that there were large economies to be gained as the volume of milk processed by a single plant facility increases, but these economies declined as increasing volumes were processed. Parker [40] reported that the minimum optimum plant size processed 40,000 quarts of milk per day during the late 1960's, and evidence provided by Lough [31] indicated that this minimum plant size has increased to approximately 80,000 quarts per day by the late 1970's. In general, the processing costs functions estimated in the literature were non-linear in nature and based on processing volume of milk.

Cobia and Babb [9] reviewed a number of studies estimating fluid milk processing costs and estimated an industry processing cost function. The equation:

$$PC = 11.763\ V^{-.11507} \qquad (5.2)$$

where

PC = fluid milk processing costs in cents per quart, and

V = volume of milk processed in quarts per day;

was based upon data adjusted to the 1961 price level for processing

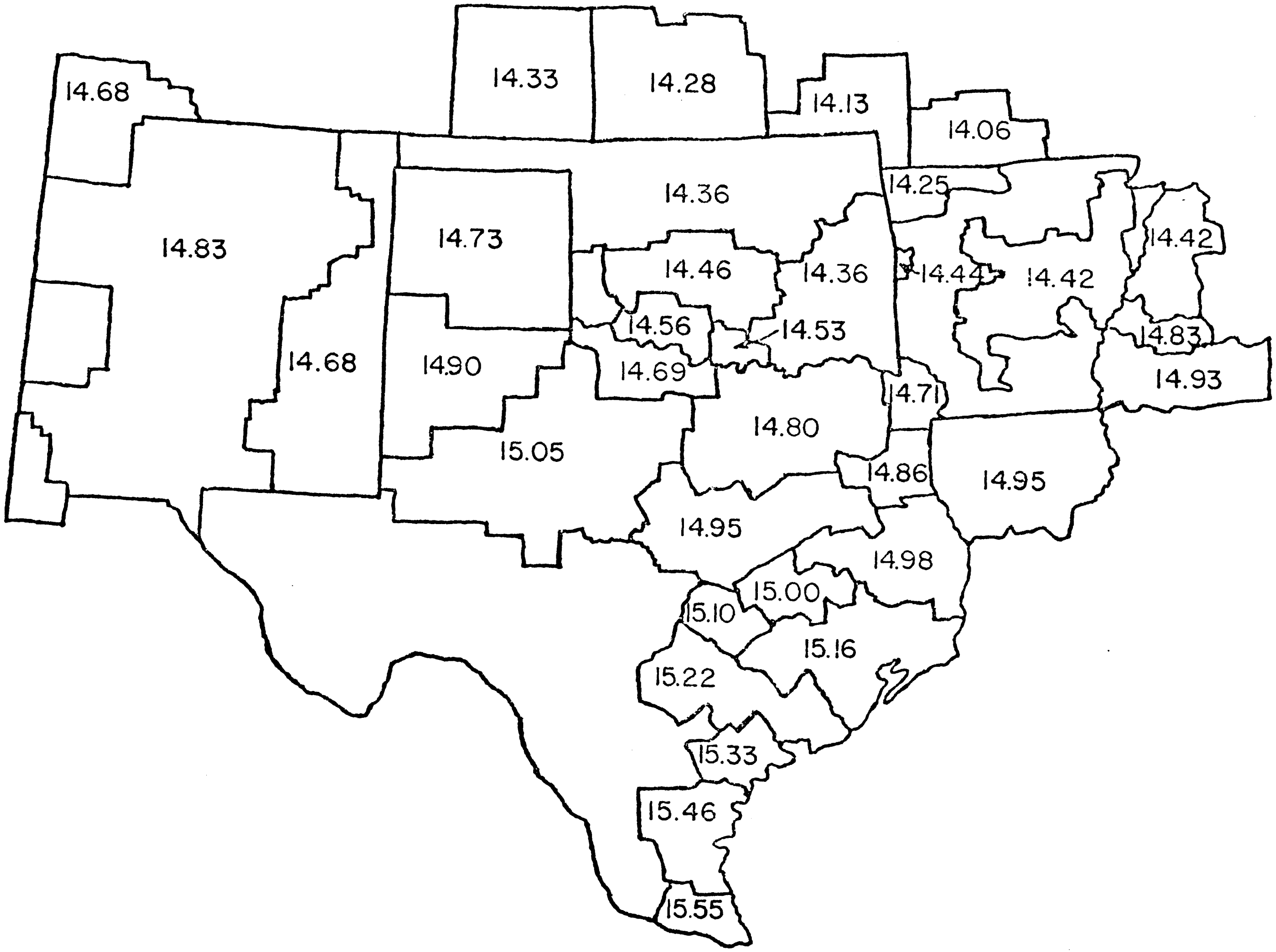


Figure 10. Average 1982 Class I Milk Price Effective in the Study Area in Dollars per Hundredweight.

and packaging fluid milk products. These data and cost function were determined to be too old to be updated, but the non-linear form of the equation was thought to be valid. Therefore, the processing cost function derived for this analysis is consistent with Cobia and Babb's equation and based on processing plant costs and size data collected in 1980 and 1981.

Jones [21] reported the costs and returns of 30 sample firms by plant size operating in the milk industry. These fluid milk processing costs data were adjusted to coincide with 1982 price levels and used to estimate the following equation:

$$PC = 26.693\ V^{-.1052} \qquad (5.3)$$

where PC and V are defined the same as in the Cobia and Babb equation. The above equation was estimated by transforming the data to natural logarithms and using ordinary least squares regression technique. The values were computed by the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) programming package.

Although no empirical evidence has been found to support a U-shaped envelope average cost curve, economic theory has maintained that as plant size expands beyond an optimum plant size diseconomies to size result in increasing average costs per unit of output [29]. The above processing costs function does not reflect diseconomies to size; therefore, a maximum plant size was determined to limit reductions in processing costs and to correspond to plant volumes in the study area.

Plant Capacity

Parker [40] found that new plants constructed in the 1960's ranged in size from 172,000 to 423,000 quarts per day and the largest plant size category used by Jones [21] averaged about 450,000 quarts of milk processed per day. Bulk 1981 sales data to study area milk processors provided by AMPI indicated that the largest plants processed in excess of one million pounds, or about 500,000 quarts, per day. In order to permit construction of new plants based on current technology, the maximum feasible size of plant used in this project is limited to 1.25 million pounds per day, or over 580,000 quarts per day, operating under a 5-day week.

A single plant location or county is capable of containing more than one fluid milk processing plant. A review of existing 1982 plants in the study area found several separate plants situated within a single processing location. This affects the processing cost function and in order to accommodate multiple plants for a single location and reflect the proper cost for processing, the cost function is revised by multiplying the processing cost computed in the cost function represented by Equation 5.1 above by a constant percentage. The percentage used to alter the computerized processing cost is based upon the amount of fluid milk processed at that location. A percentage increase can be used to revise the processing cost because the cost equation is logarithmic function.

The maximum feasible plant size is 1.25 million pounds of fluid milk processed per day, as stated above, or 325 million pounds per year. When the processing volume of a single location exceeds 325 million pounds, then the processing cost is multiplied by the percentages found in Table III. These percentages are used to reflect the cost of processing fluid milk products in a single county, or processor location, whose volume surpasses the maximum feasible plant

TABLE III

PERCENTAGE INCREASES IN FLUID MILK PROCESSING COSTS TO REPRESENT MULTIPLE PLANT LOCATIONS

Processing Volume (million pounds/year	Number of Plants	Constant Used To Revise Plant Costs
Less than 325	1	1.00000
325 - 650	2	1.07564
650 - 975	3	1.12252
975 - 1,300	4	1.15701
1,300 - 1,625	5	1.18449
1,625 - 1,950*	6*	1.20743

*No processing location was found processing more than 1,950 million pounds per year in any of the model runs made to estimate costs for this analysis.

size. Also, these revised processing cost totals represent multiple plants of equal size within the plant location.

Plant Size Categories and Conversion

Confusion is often encountered when attempting to convert millions of pounds per year to quarts per day or some other plant size that is familiar. In order to provide reference points for comparison, Table IV lists selected plant size categories used in this study and illustrates several commonly used plant size units in relation to each other. These size categories assume 5-day a week, or 260-day a year, processing schedules.

TABLE IV

PLANT SIZE CATEGORIES AND VARIOUS SIZE UNIT DESIGNATIONS

Plant Size Category	lbs/month	lbs/year	quarts/day	gallons/week	lbs/day
	(millions)	(millions)	(thousands)	(thousands)	(thousands)
1	< .1	< 1.2	< 2.1	< 1.7	< 4.6
2	.1 < .2	1.2 < 2.4	2.1 < 4.3	1.7 < 3.4	4.6 < 9.2
3	.2 < 1.0	2.4 < 12.0	4.3 < 21.5	3.4 < 17.2	9.2 < 46.2
4	1.0 < 2.0	12.0 < 24.0	21.5 < 42.9	17.2 < 34.3	46.2 < 92.3
5	2.0 < 4.0	24.0 < 48.0	42.9 < 85.9	34.3 < 68.7	92.3 < 185
6	4.0 < 7.0	48.0 < 84.0	85.9 < 150	68.7 < 120	185 < 323
7	7.0 < 12.0	84.0 < 144.0	150 < 258	120 < 206	323 < 554
8	12.0 < 24.0	144.0 < 288.0	258 < 515	206 < 412	554 < 1,108
9	24.0 & over	288.0 & over	515 & over	412 & over	1,108 & over
Maximum Feasible Plant Size	≃27.1	325.0	≃580	≃465	1,250

CHAPTER VI

ANALYSIS AND RESULTS

The objective of this research project is to estimate the potential for regional milk cooperatives vertically integrating into the fluid milk processing industry in the southwest region of the United States. The measurement of potential profitability gained through integration is accomplished by the comparison of optimum fluid milk market organizations to various regional milk cooperative strategies to penetrate the industry. To obtain knowledge of industry performance, the current 1982 plant locations are compared to the alternative optimum plant configurations and, based on the industry cost and performance, formulate and evaluate cooperative penetration strategies.

Two different types of analyses and results are presented in this chapter. First, five plant allocation models are described, and the resulting production distribution patterns and plant configurations are presented graphically. Second, four unique cooperative fluid milk market penetration strategies are tested and evaluated with respect to estimated construction and acquisition costs of new and existing fluid milk processing plants. In general, these results describe least cost or optimum fluid milk market organizations and represent the most efficient methods to assemble, process, and distribute fluid milk products in the Southwest.

Model I - Least Costs Product Distribution for the Existing 1982 Plant Locations

Model I is designed to estimate the market performance of the existing 1982 plant system by calculating the least cost product distribution market areas for individual processor locations. The first portion of the POST model, the product distribution section, was utilized to calculate the costs and revenue structures which reflect the performance of the milk marketing industry. The results of Model I do not represent an optimum marketing system; however, they represent minimum transportation and raw milk costs for distributing fluid milk products and assembling raw milk given specified plant numbers and locations.

A review of regulated handler lists published by federal order market administrators [56] revealed that there were dairy plants processing milk in 60 locations during 1982 from which fluid milk products were marketed to the study area. Fluid milk consumption was estimated to be approximately 6,118 million pounds in the 587 counties while milk eligible for fluid use totaled about 7,406 million pounds in the 380 producing counties identified in the study area. The 1982 consumption and production totals were derived from the estimation procedures described in Chapter V.

Given the 1982 market conditions, the product distribution procedure described above and in Chapter IV estimated the least cost marketing areas for each of the given plant locations along with the lowest assembly costs. Initial attempts to solve this market problem found that not all 60 processing locations were included in the least cost plant configuration. Revisions in selected parameters of the product distribution allocation procedure were made to ensure that all 60 plant locations were included as part of the existing plant system representation. First, the distribution costs were increased ten-fold from $0.40 to $4.00 per hundred-weight per 100 miles, and second, an additional array was added to reflect processing cost with respect to the reported size of the location's processing capacity. These adjustments in the relative cost structures of the processing locations were effective in allocating demand areas to all 60 existing plant locations. The modifications were used in allocating market areas only and not used in the calculation of either distribution cost or processing cost. These costs were estimated using the cost functions discussed in Chapter V.

The demand areas receiving fluid milk shipments from plant locations based on least cost source of processed products are illustrated in Figure 11. The supply areas shipping bulk milk to processing locations are shown in Figure 12. The volume of milk processed, assembly cost, processing costs, raw milk costs, and distribution costs for each of the 60 plant locations are listed in Table XI, Appendix A.

The existing least cost plant configuration under 1982 market conditions placed 64 processing facilities in 60 locations. Multi-plant locations were necessary when individual location processing volume exceeded the maximum (325 million pounds) single plant capacity. Multiple plants of equal size were located at plant nodes 60 (San Antonio), 67 (Dallas), and 76 (Houston) as might be expected due to their large populations. The San Antonio and Dallas

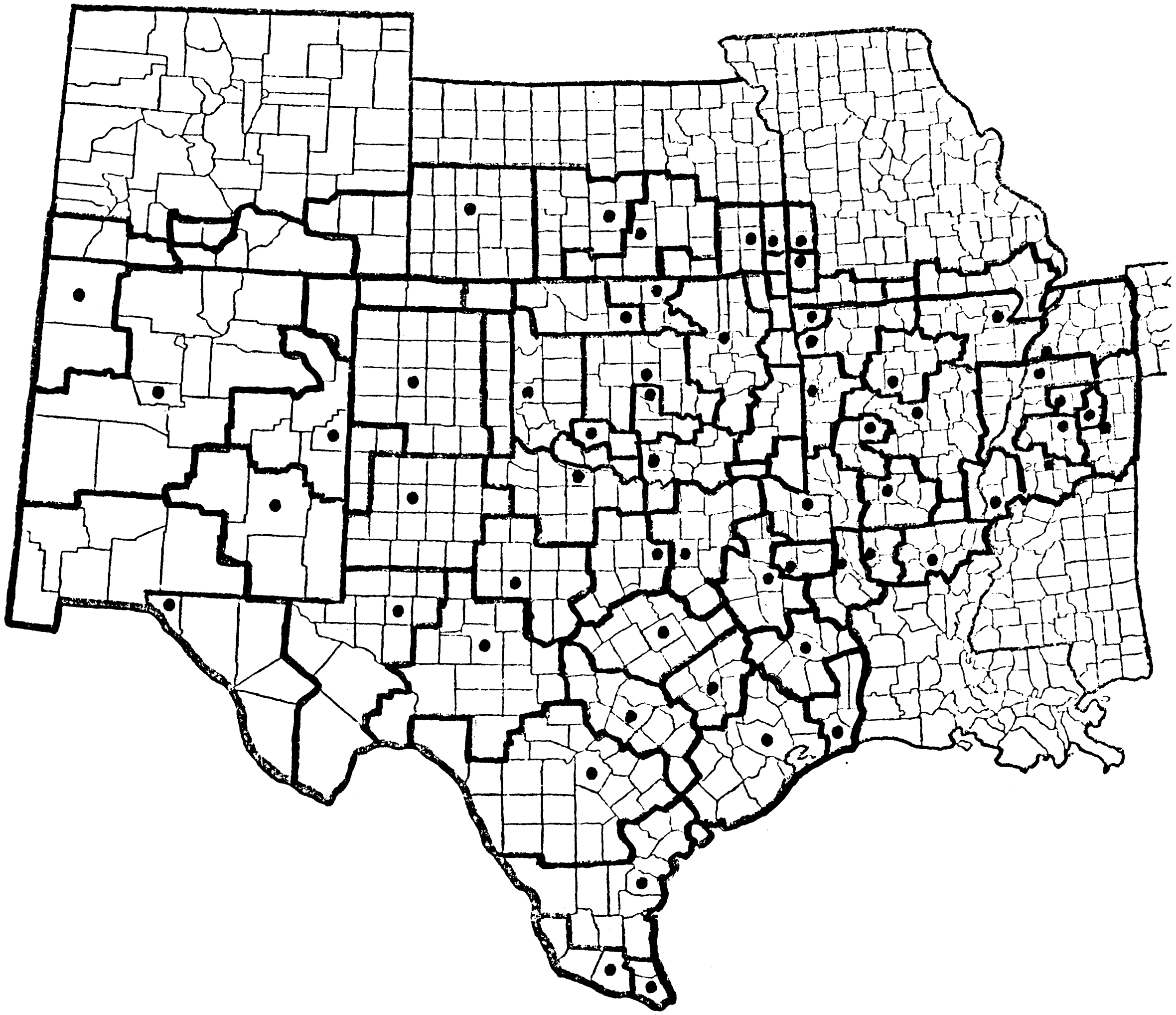


Figure 11. Model I - Least Cost Existing 1982 Plant Locations and Plant Demand Service Areas.

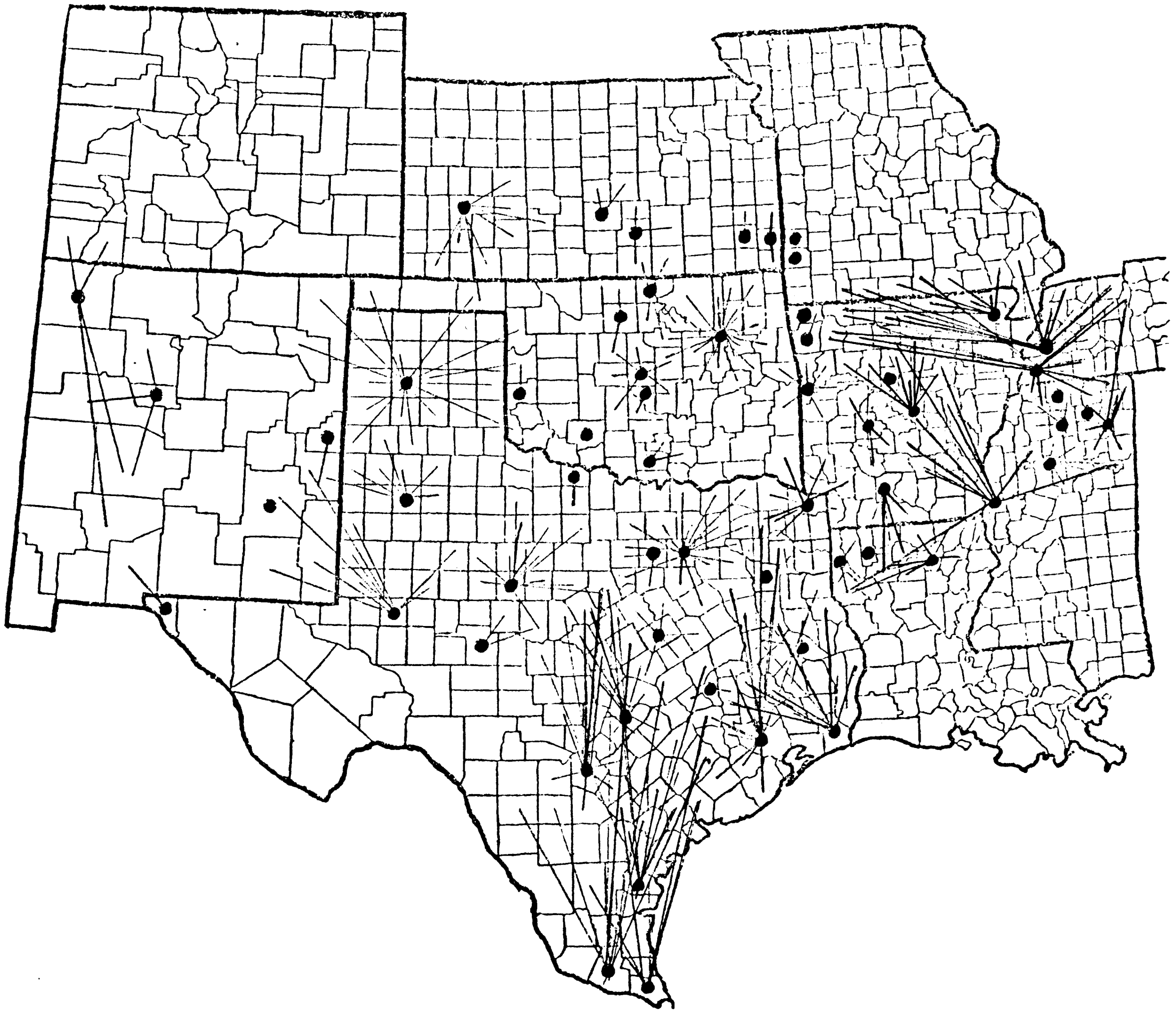


Figure 12. Model I - Least Cost Existing 1982 Plant Locations and Supply-Side Bulk Milk Shipments.

locations had two plants and the Houston location contained three facilities to process the least cost demand requirements.

The total plant system cost for the existing 1982 market organization was $1,136.2 million or $18.57 per hundredweight. Assembly costs amounted to $17.0 million or $0.28 per hundredweight, while distribution costs totaled $5.8 million or $0.09 per hundredweight. The processing cost of the 64 plants was estimated as $207.6 million and the raw milk cost averaged $14.81 per hundredweight which totaled $905.9 million. The low distribution cost associated with the existing 60 plant location systems are consistent with the conclusion of Parker [40] that new processing plants are being built in locations where the cost of distribution can be minimized.

These costs represented the least cost product distribution configuration given the 1982 plant locations and fluid milk demand and supply estimates. These results are to be compared with the other three 1982 optimum market organizations and provide a benchmark form which to evaluate efficiencies to be gained from possible market restructuring.

Model II - Optimum 1982 Minimum Total Cost Market Organization

Model II was formulated to determine the optimum number, size, and location of processing plants that would minimize the total costs of fluid milk marketing under 1982 conditions and assumption. The combined product distribution and optimization procedures of the POST model discussed in Chapter IV was used to optimize the total cost minimization function described previously. It was assumed that there were 99 possible plant locations. These locations were selected because either they had an existing processing facility or the county in which the plant could be located had a 1982 population estimate greater than 50,000. A population base of at least 50,000 was required to demand sufficient quantities of fluid milk for the plant to survive and staff the processing facility. No plant processing capacity restrictions were placed on any of the locations and any location was capable of containing multiple plant facilities.

The minimum total cost market organization included 25 plants situated in 21 processing locations. Multi-plant processing locations were identified as plant node 60 (San Antonio), 2 plants; 63 (Bryan, Texas), 3 plants; and 92 (Ft. Worth), 2 plants. The demand market areas for the 21 processing locations are depicted in Figure 13 and the raw milk supply origins for each location are illustrated in Figure 14. The cost and revenue data for each location were placed in Table XII, Appendix A.

The total cost for assembly, processing, raw milk, and distributed amounted to $1,123.9 million which is a potential decrease in costs of $0.20 per hundredweight when compared with the least cost existing 60-plant location organization. Processing cost totaled $193.1 million while raw milk cost totaled $899.6 million or a decrease of $14.5 million and $6.3 million, respectively, versus the existing plant system.

Transportation costs associated with the assembly and distribution of fluid milk made up the other three percent. Assembly cost was $15.2 million and distribution cost summed to $15.9 million or an increase of $10.1 million over the existing system's

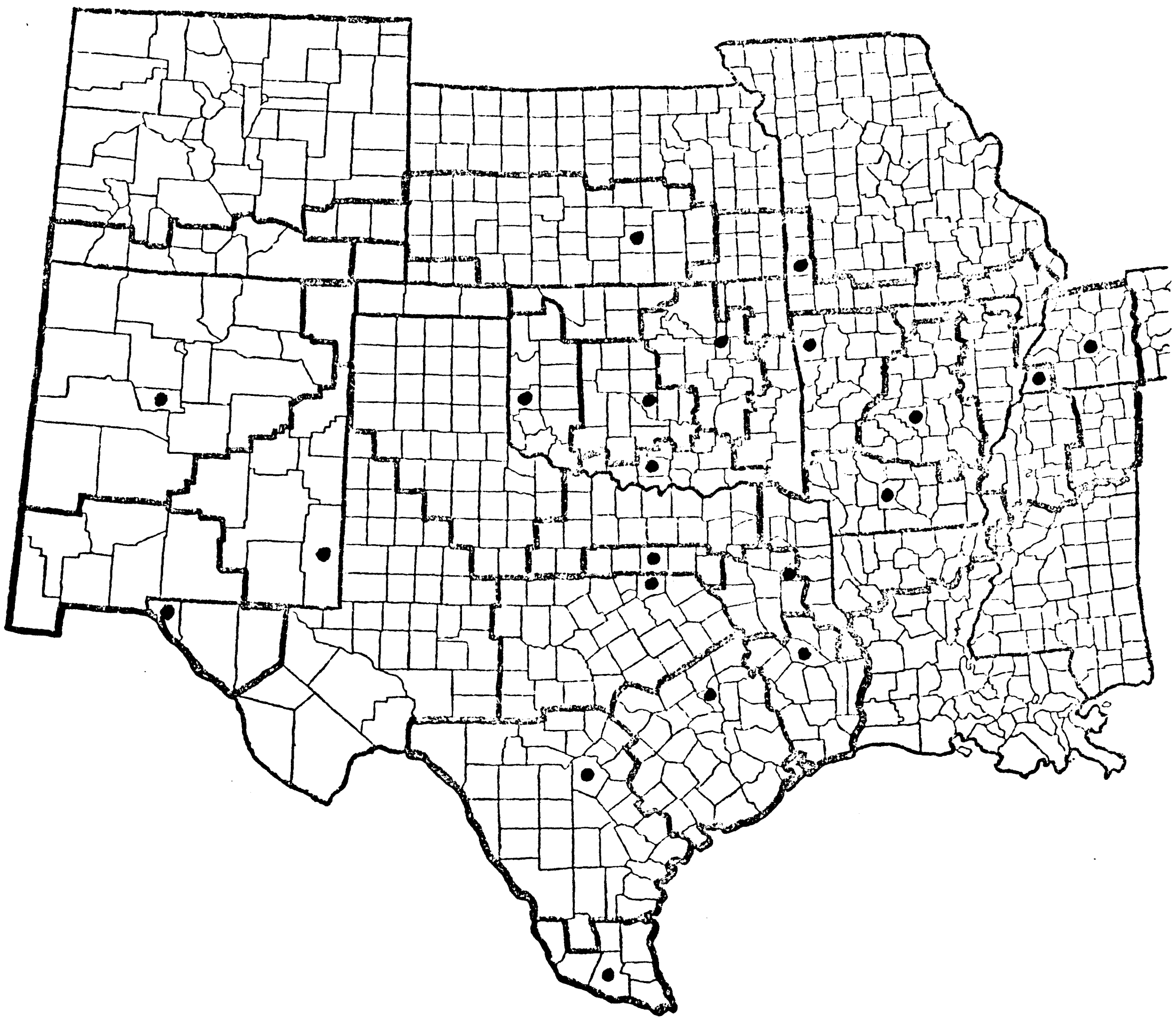


Figure 13. Model II - Optimum 1982 Minimum Total Cost Plant Locations and Plant Demand Service Areas.

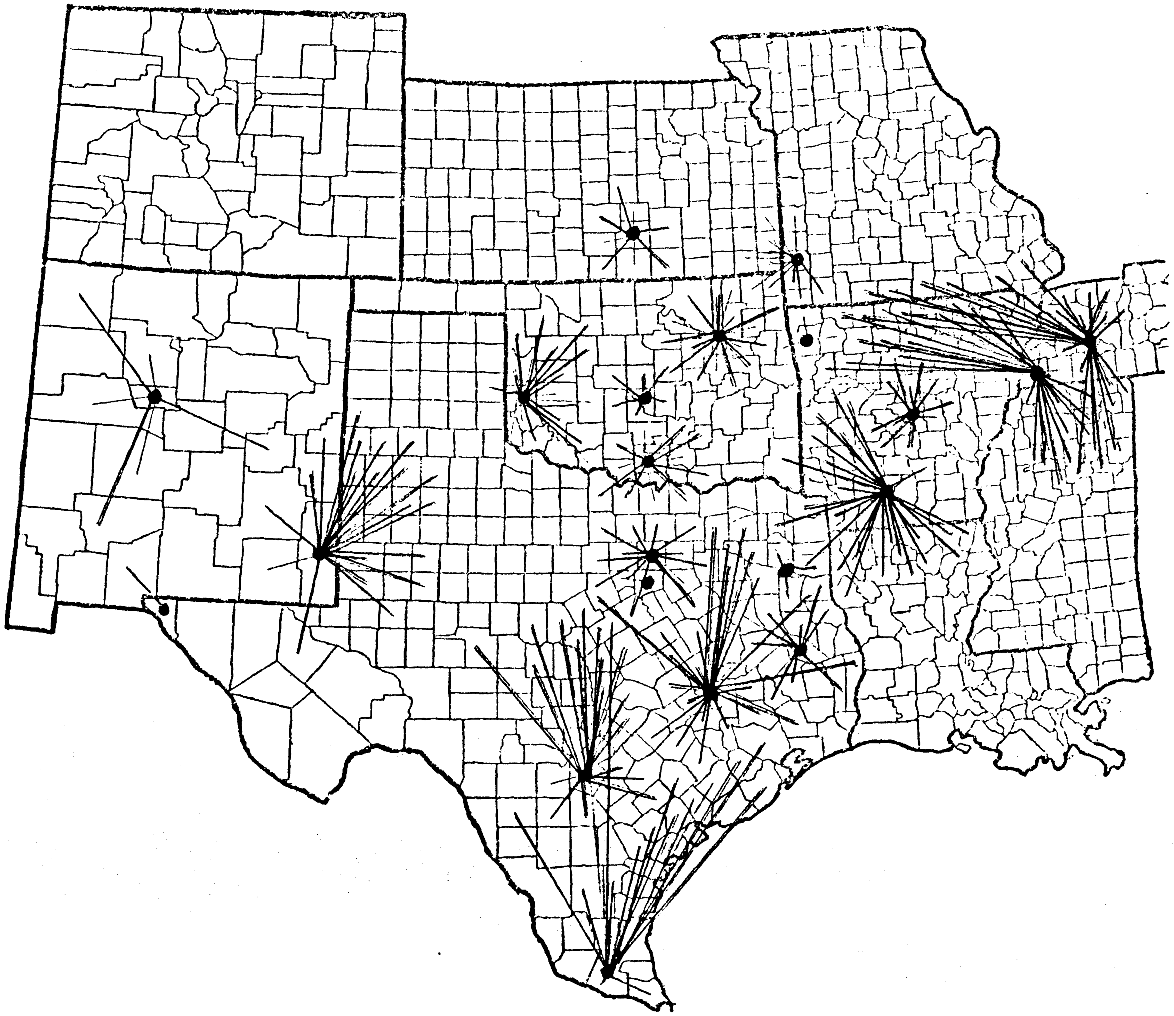


Figure 14. Model II - Optimum 1982 Minimum Total Cost Plant Locations and Supply-Side Bulk Milk Shipments.

distribution cost. These cost data demonstrate that the minimum total cost solution was derived by decreasing raw milk and processing costs through fewer plant locations but at the expense of increasing distribution cost.

The elliptical shape of the fluid milk marketing areas and the location of the plants within the marketing areas shown in Figure 11 indicate that something other than transportation costs were affecting the model's total cost minimization solution. Analyzing the Class I milk pricing areas in Figure 10 in Chapter V, it becomes apparent that raw milk costs were having an impact on the shape of the marketing areas. In general, plant locations in northern and eastern portions of the study area have a comparative advantage over southern and western locations due to the fact that Class I milk prices increase with distance from Eau Claire, Wisconsin (see Chapter II for details).

Model III - Optimum 1982 Minimum Processor Cost Market Organization

The objective of Model III was to minimize processor costs in the study area for 1982. The objective function of this model's optimization routine was slightly different from the previous model. Although very similar to Model II, Model III's objective function was formulated to minimize raw milk cost, processor cost, and distribution costs. Since processors do not pay for the cost of assembling raw milk, it was not included in the objective function. Algebraically, the notation of the processor cost minimization function is:

$$\text{Minimize } P_{cr}C = \sum_{j=1}^{P} PC_j Q_j + \sum_{j=1}^{P} RMC_j Q_j + \sum_{j=1}^{P} \sum_{k=1}^{P} DC_{jk} Q_{jk} \qquad (6.1)$$

or

minimize $P_{cr}C = TPC + TRMC + TDC$

where

$P_{cr}C$ = total combined processor operating costs,

and

all other variables are defined as before in Chapter IV for the total cost minimization function.

This objective function could also be viewed as a maximization of processor margin because total revenue remains fixed regardless of the type of model optimized or given plant system selected and because processor margin was defined as total revenue minus total processor costs. Total revenue was fixed because it is a function of retail milk prices and fluid milk consumption which were both assumed to be fixed in the analysis.

The optimization procedure for Model III was conducted under the same market conditions and assumptions as Model II. The plant configuration solution derived under minimization of processor costs consisted of 26 plant locations and 28 processing facilities. The multiple plant locations were plant node 67 (Dallas), two plants; and plant node 76 (Houston), two plants. Figure 15 shows the processed milk marketing areas for each plant location. Tabular data of individual plant volume, costs and revenue are found in TableXIII Appendix A. Total processor cost equalled \$1,107.8 million or about \$18.11 per hundredweight. Raw milk cost totaled \$902.2 million, processing cost amounted to \$194.2 million, and distribution cost summed to \$11.6 million.

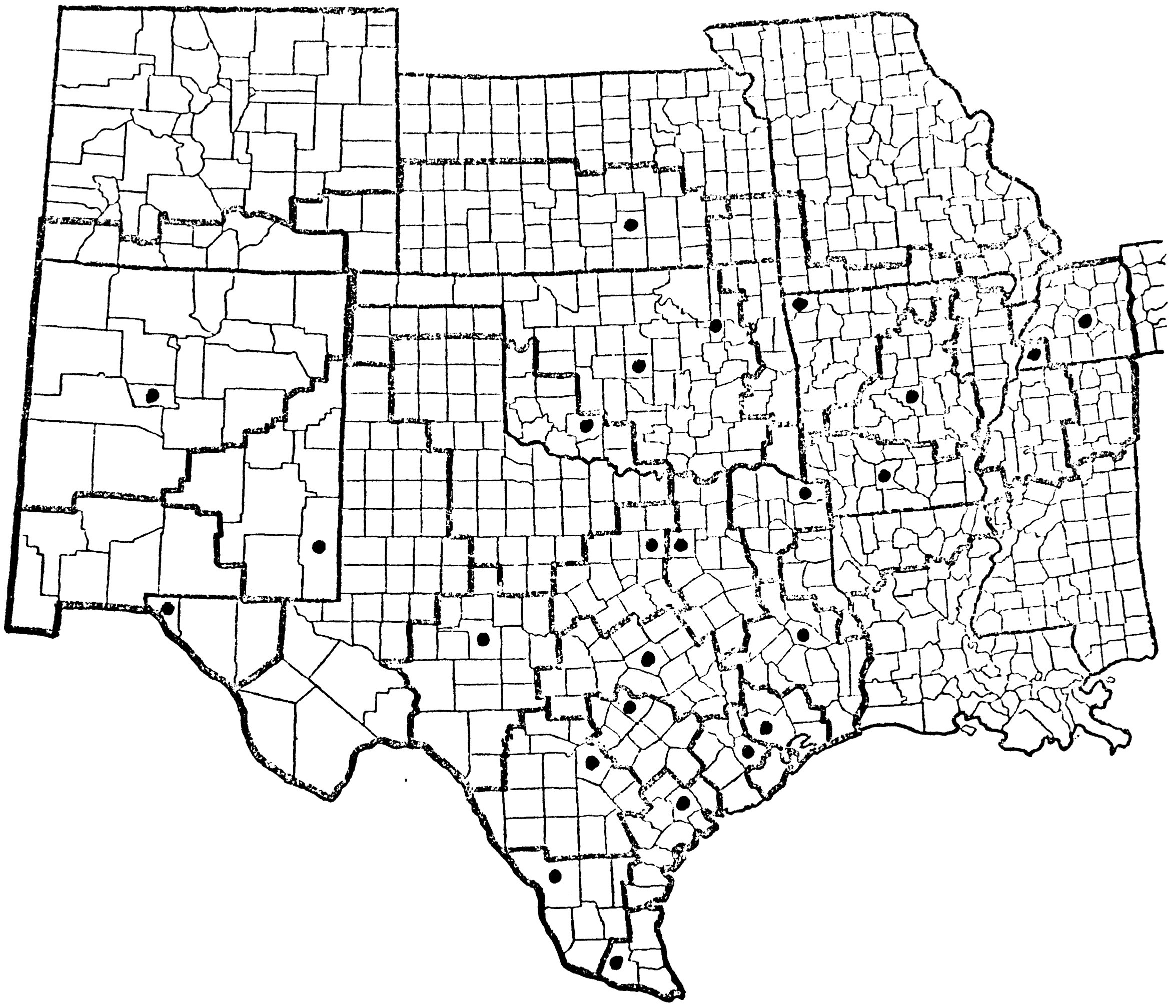


Figure 15. Model III - Optimum 1982 Minimum Processor Cost Plant Locations and Plant Demand Service Area.

Although total costs and assembly costs were not part of the optimization routine, the system cost for these variables provide a basis for comparison with other models. Total cost was $1,125.4 million or $18.39 per hundredweight. Assembly cost was $17.5 million or $2.3 million more than the comparable figure in Model II. The raw milk shipments of Model III are graphically illustrated in Figure 16.

Model IV - Optimum 1982 Maximum Producer Returns Market Organization

The optimization procedure of Model IV was fundamentally different from the other models in this analysis. The objective function of this model was to maximize producer returns. Since producers receive their revenues in the form of raw milk sales and generally are required to pay for the assembly cost of their production, producer returns have been defined as raw milk sales minus assembly costs for this analysis. The producer returns maximization function notation is as follows:

$$\text{maximize } PR = \sum_{j=1}^{P} RMC_j Q_j - \sum_{i=1}^{s} \sum_{j=1}^{P} AC_{ij} Q_{ij} \qquad (6.2)$$

or

$$\text{maximize } PR = TRMC - TAC$$

where,

PR = total producer returns, and

All other variables and assumptions are specified as in the total cost minimization function.

The economic theory supporting this type of maximization problem has been found to be somewhat different than the underlying theory of minimization functions. An accepted theoretical base of economies and

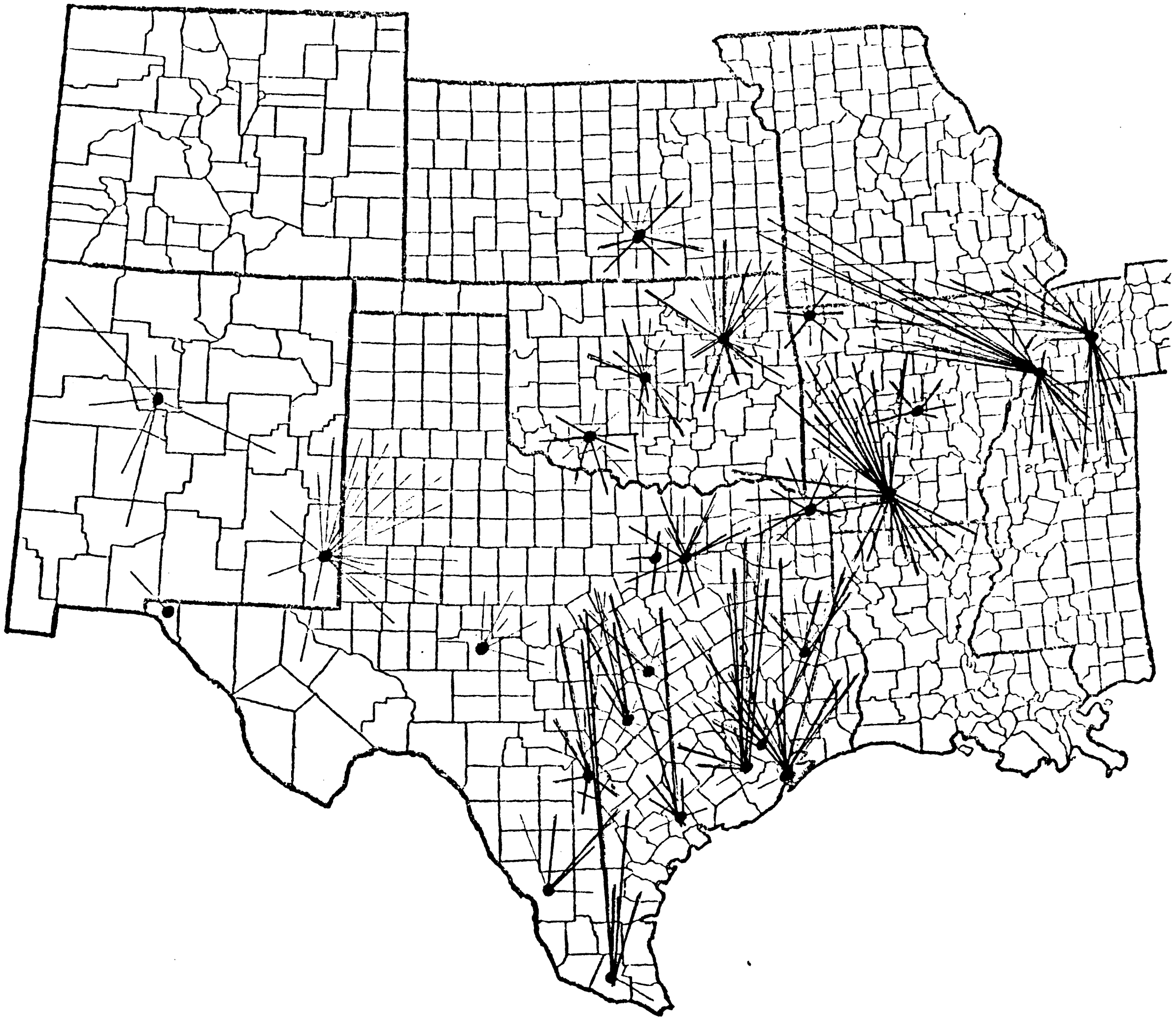


Figure 16. Model III - Optimum 1982 Minimum Processor Cost Plant Locations and Supply-Side Bulk Milk Shipments.

diseconomies to size of plants supports the theoretical U-shaped average cost curve used in minimization functions. However, analysis of empirical data shows the raw milk costs increase as plant locations move south, assembly cost decrease as plants are located nearer to production areas and, in general, more milk was produced in the northern portion of the study area. Therefore, the assumption employed to justify the maximization function was that there exists an optimum number of centrally located plants that would maximize producer returns.

The maximum producer returns market organization placed 46 plants in 40 locations. Reviewing Table XIV, Appendix A, which contained plant summary data, shows that multi-plant locations were situated at plant nodes 24 (Memphis), two plants; 68 (Denton, Texas), two plants; 81 (Ft. Worth), two plants; 91 (Tyler, Texas), three plants; and 99 (Austin), two plants. The raw milk shipments illustrated in Figure 17 indicate the supply areas from which processing plants receive their bulk raw milk needs under Model IV. Raw milk cost amounted to $902.3 million while the assembly costs summed to $10.6 million. The assembly cost was $4.6 million or about 30 percent less than the comparable figure in total cost minimization model (Model II).

The marketing areas of processing plants are shown in Figure 18. Other cost totals were: total cost, $1,133.2 million; processing cost, $201.8 million; and distribution cost, $18.5 million. An interesting comparison can be made between assembly and distribution costs calculated in Model III and Model IV. The processor cost minimization procedure depicted in Model III estimated distribution

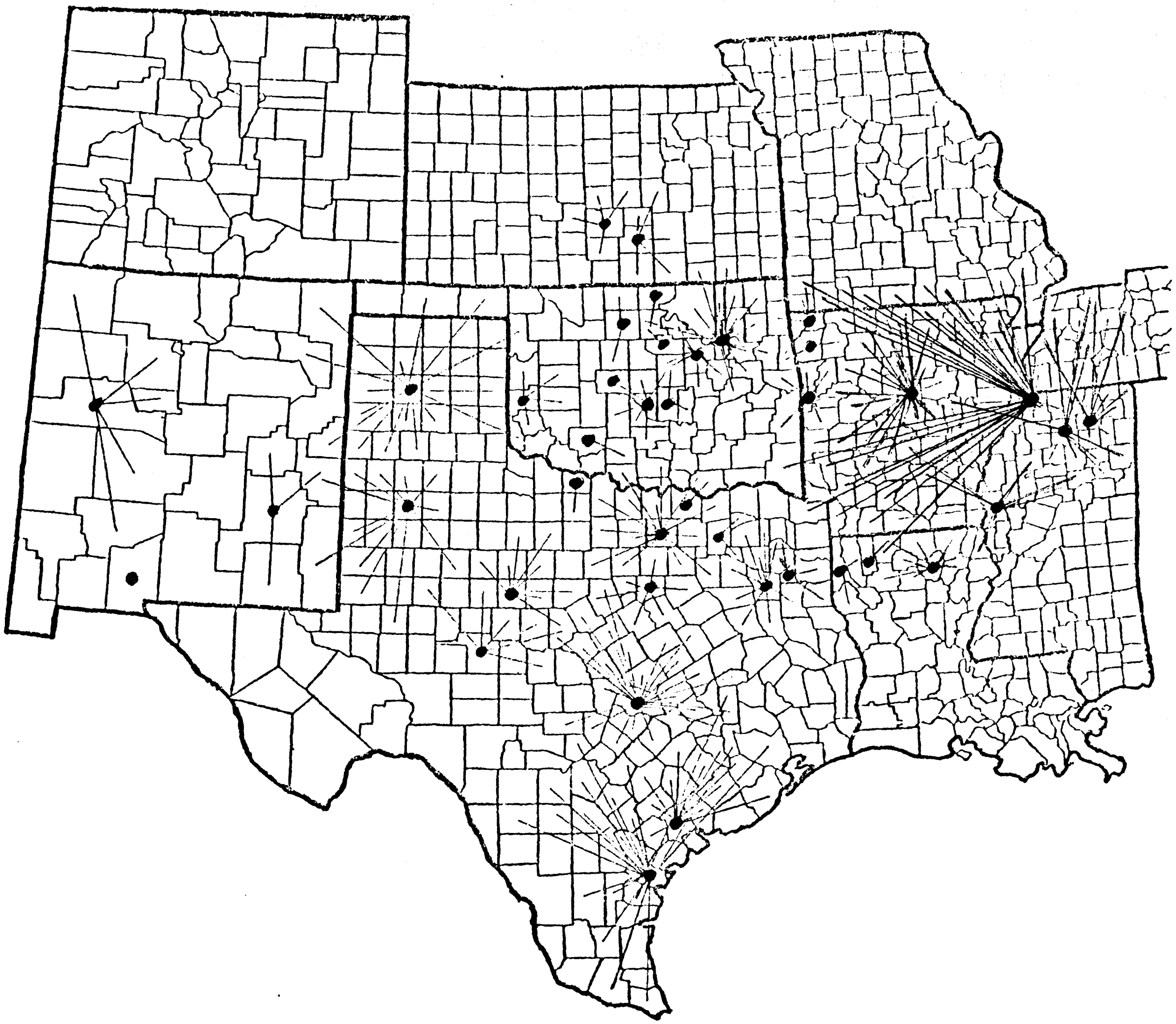


Figure 17. Model IV - Optimum 1982 Maximum Producer Returns Plant Locations and Supply-Side Bulk Milk Shipments.

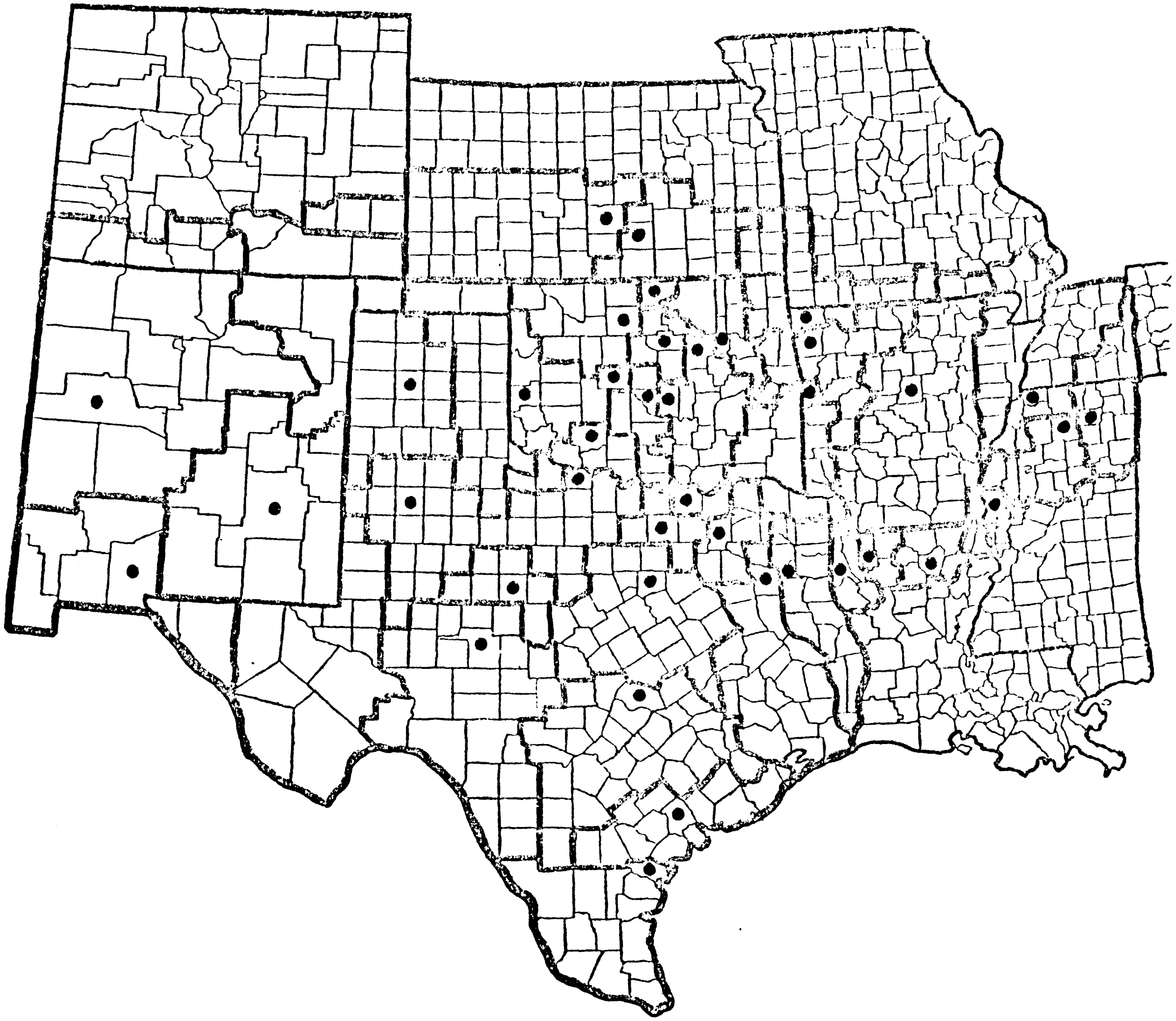


Figure 18. Model IV - Optimum 1982 Maximum Producer Returns Plant Locations and Plant Demand Service Areas.

cost of $11.6 million and assembly cost of $17.5 million. In Model IV's producer returns maximization procedure, the comparable figures for distribution cost was $18.5 million while assembly cost totaled $10.6 million. These data indicate that potential transportation cost savings for processors versus producers was the significant factor in determining optimum market organizations for Model III and Model IV.

Model V - Optimum 1990 Minimum Total Cost Market Organization

Model V was designed to determine the optimum number, size, and location of processing plants which would minimize total cost under projected 1990 market conditions. The optimization procedure cost estimates, number of possible plant locations, and raw milk supply quantities were identical to those found in Model II. However, the one exception was the fluid milk demand requirements. Fluid milk consumption was projected to be different in 1990 due to changes in population levels and other related variables. The demand function described in Chapter V was used to project to be 7,064 million pounds in 1990, or over 15 percent greater than estimated 1982 total area consumption. All price conditions for Class I milk and retail milk were assumed to be the same real prices as the 1982 milk prices. The county fluid milk consumption estimates for 1990 were listed in Table VII, Appendix A.

The results of the minimum 1990 total cost optimization indicated that the optimum plant configuration consisted of 28 processing facilities and 23 plant locations. Table XV, Appendix A contains the individual plant volume, cost, and revenue data and Figure 19 and Figure 20 illustrate the fluid milk plant marketing areas and raw milk shipments determined in Model V, respectively. Multi-plant locations were plant nodes 66 (Temple, Texas), two plants; 76 (Houston), three plants; and 92 (Ft. Worth), three plants.

The cost categories were higher in 1990 than in 1982 primarily due to the increased level of fluid milk consumption. Total cost was $1.299.5 million or $18.40 per hundredweight. The plant costs associated with Model V were processing costs, $222.2 million, and raw milk cost, $1,040.7 million. Transportation cost totaled $20.3 million for assembly and $16.2 million for distribution of fluid milk.

Comparison of the Market Organizations

Table V shows the comparative cost and revenue total for the market organizations derived in the five models discussed in this chapter. The cost categories most affected by the different estimation procedures involved transportation costs. Distribution cost ranged from a low of $5.8 million for the 1982 existing plant system to a high of $18.5 million for the maximum producer return organization, or a percentage difference of 219 percent. Assembly cost for the 1982 models range form $10.6 million in Model IV to $17.5 million in Model III, or 65 percentage difference between the two optimization procedures. The total cost minimization models for 1982 and 1990 are similar in many respects. Total cost was approximately 16 percent greater in 1990 than in 1982 while fluid milk consumption increased by 15 percent between the two market periods.

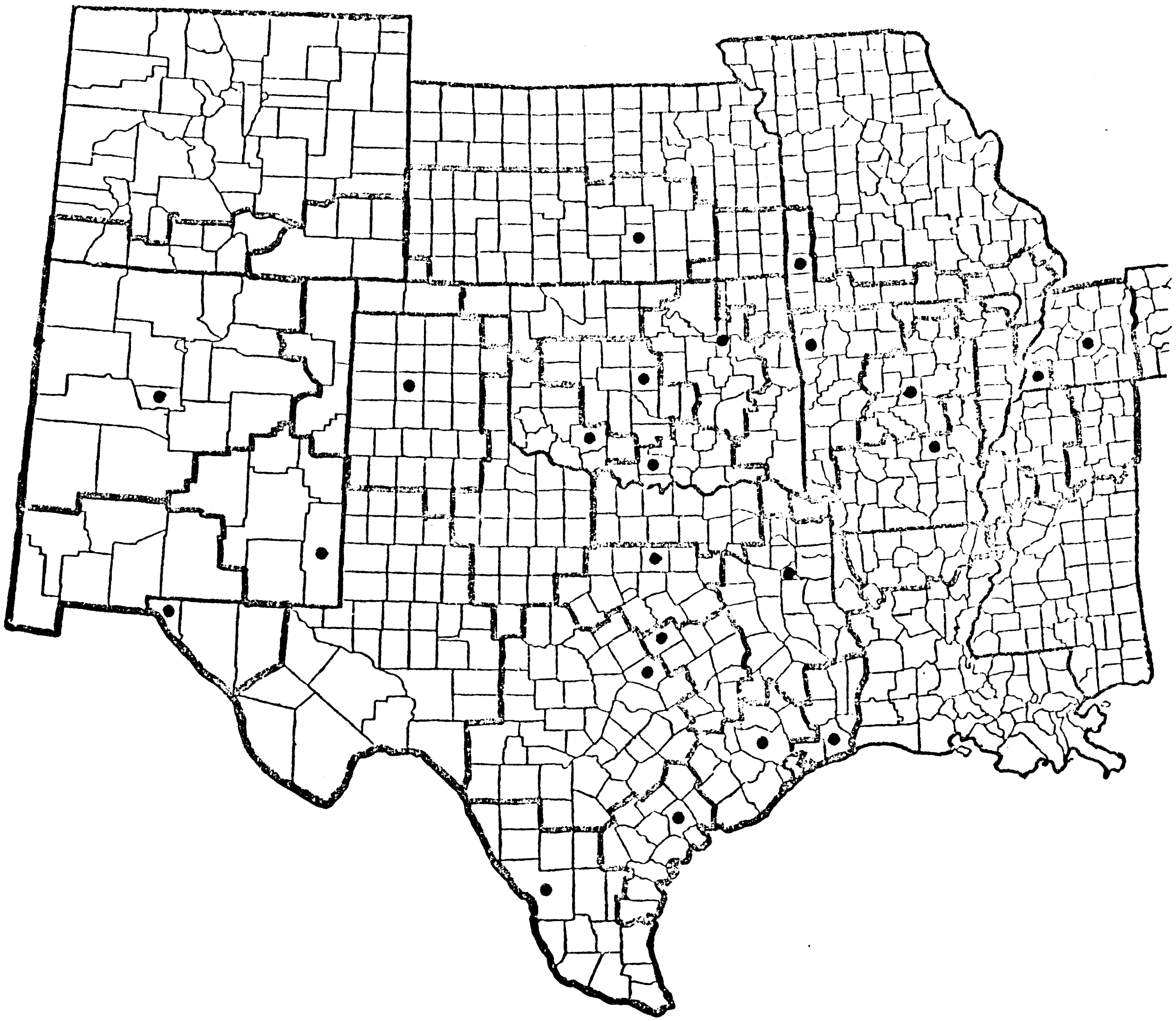


Figure 19. Model V - Optimum 1990 Minimum Total Cost Plant Locations and Plant Demand Service Areas.

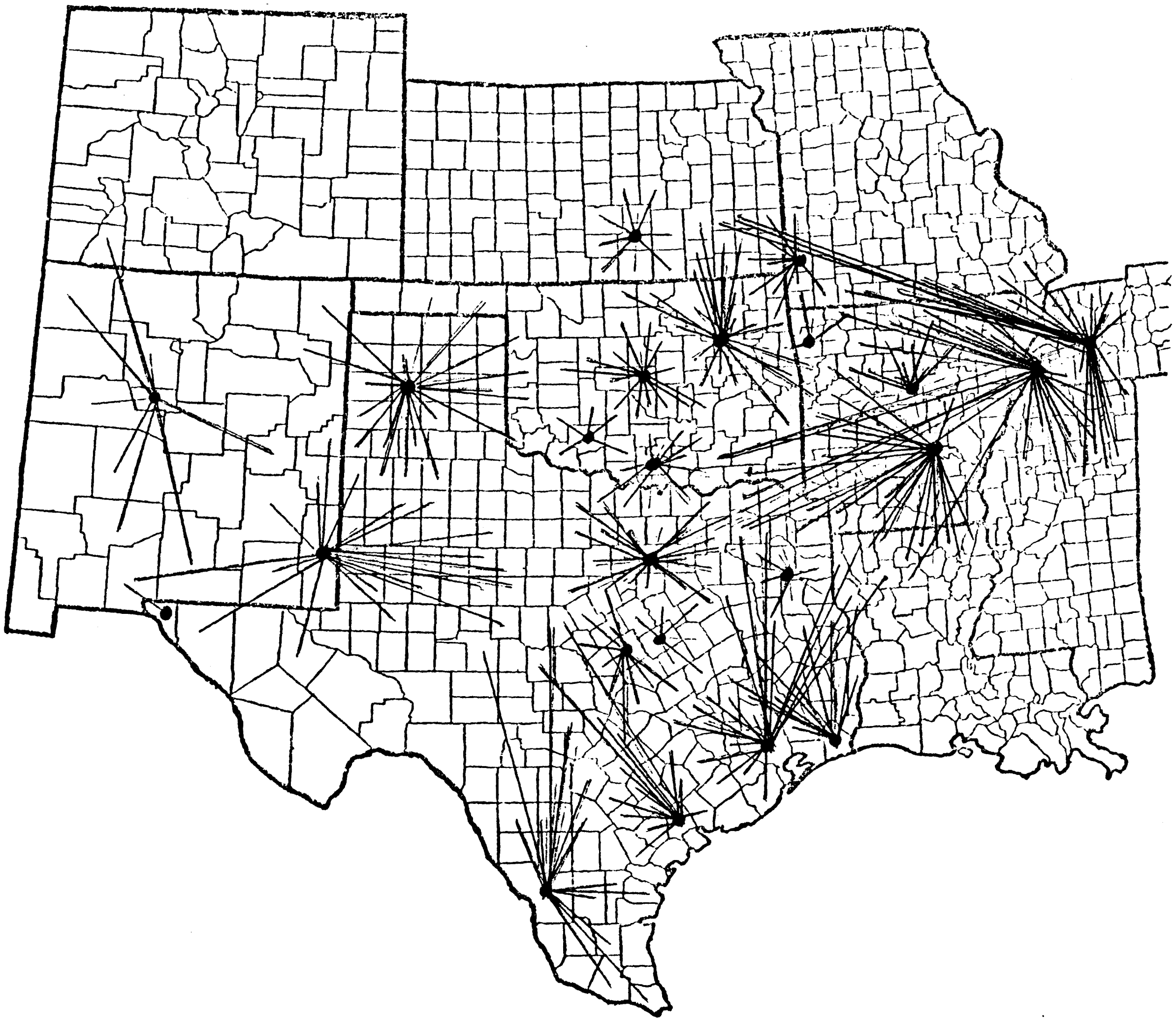


Figure 20. Model V - Optimum 1990 Minimum Total Cost Plant Locations and Supply-Side Bulk Milk Shipments.

TABLE V

COMPARISONS OF COST STRUCTURES OF THE EXISTING AND OPTIMUM PLANT SYSTEMS

	Model I 1982 Existing Plants	Model II 1982 Optimum Plants	Model III 1892 Optimum Processor Plants	Model IV 1982 Optimum Producer Plants	Model V 1990 Optimum Plants
Total Pounds Processed	6,118	6,118	6,118	6,118	7,064
No. of Plant Locations	60	21	26	40	23
No. of Plant Facilities	64	25	28	46	28
Assembly Cost (AC)	$17.00	$15.20	$17.50	$10.60	$20.30
AC/cwt.	0.28	0.25	0.29	0.17	0.29
Distribution Cost (DC)	5.90	15.90	11.60	18.50	16.30
DC/cwt.	0.09	0.26	0.19	0.30	0.23
Processing Cost (PC)	207.60	193.10	194.20	201.80	222.20
PC/cwt.	3.39	3.16	3.17	3.30	3.15
Raw Milk Cost (RMC)	905.90	899.60	902.00	902.30	1,040.70
RMC/cwt.	14.81	14.70	14.74	14.75	14.73
Total Cost (TC)	1,136.20	1,123.90	1,125.40	1,133.20	1,299.50
TC/cwt.	18.57	18.37	18.39	18.52	18.40
Processor Cost (PcrC)	1,119.30	1,108.60	1,107.80	1,122.70	1,279.10
PcrC/cwt.	18.30	18.12	18.11	18.35	18.11
Producer Returns (PR)	889.00	884.40	884.40	891.80	1,020.30
PR/cwt.	14.53	14.46	14.46	14.58	14.44
Net Revenue (NR)	565.70	578.10	576.50	568.70	666.60
NR/cwt.	9.25	9.45	9.42	9.30	9.44

Differences in the total cost and net revenue figures indicated that there was a potential increase in efficiency of $0.20 per hundredweight between the existing and minimum total cost plant systems. Net revenue under Model I amounted to $9.25 per hundredweight while net revenue totaled $9.45 per hundredweight under Model II, or only a two percent potential gain in revenues.

Regional Cooperative Vertical Integration Strategies

Vertical integration provides the tool for regional milk cooperatives to enter the fluid milk processing industry. Backward integration into fluid processing may be accomplished through a number of penetration strategies available to cooperatives. The purpose of this section of the analysis was to evaluate four vertical integration strategies in relation to capital requirements and cooperative producer-member returns. These data were used to evaluate the potential for cooperative fluid milk processing and to serve as guidelines for decision-makers of cooperative policies.

The market penetration strategies chosen for this analysis were denoted as:

1. Strategy I - 25% Share of Study Area Served from Optimum Plant Locations,
2. Strategy II - 100% Share of Selected Optimum Markets Served,
3. Strategy III - 25% Share of Selected Markets Served,

and

4. Strategy IV - 25% Share of Study Area Served from Selected Plant Locations.

These strategies were evaluated under 1990 market conditions. These conditions assumed the 1990 demand milk demand quantities, the 1982 raw milk supply quantities, and the 1982 Class I and retail milk prices.

The methodology used to evaluate cooperative fluid milk processing penetration strategies was similar to the procedure devised by Roof [46] to rate several cooperative's performance as fluid processors. Roof utilized the statement of operations to indicate the success or failure of individual cooperatives vertically integrated into fluid milk processing. Since data used to build the statement of operations were not available for this textbook problem, Roof's sample cooperative data provided reference points on which to estimate the financial data needed to construct a statement of operations for each of the penetration strategies.

Operating Statement Data

The data required to construct a statement of operations for the vertical integration strategies were derived from several sources. The fluid milk sales, raw milk cost, and processing cost were obtained from the Summary Report of the POST model using 1990 market conditions. Additional data were obtained from a processor costs analysis performed by Jones [21]. Jones' estimates for other milk costs, wholesale delivery cost, and general and administrative costs were collected for the average-size plant and updated (through the use of the consumer price index) to represent 1982 costs. These revised costs per hundredweight processed were: other milk costs, \$3.91; wholesale delivery cost, \$2.70; and general and administrative cost, \$0.95. The remaining operating statement variables needed were new plant investment and acquisition costs.

An engineering cost study of fluid milk processing plants done by Fischer, Hammond, and Hardie [13] in 1977 provided the investment and related construction cost data to formulate a capital investment cost estimating equation. These engineering cost data were used to estimate the following equation:

$$I = 3370.32\ G^{0.56198} \tag{6.3}$$

where,

I = capital investment cost of a fluid milk processing plant,

and

G = volume processed in gallons per week.

The estimated investment costs derived from this function were updated to reflect comparable 1982 baseline data through the use of a capital investment index [58], or by the factor 1.515. This equation was utilized to calculate new 1982 plant investment and existing plant acquisition costs used in the statements of operation.

Acquisition Costs. Several industry trends require that existing plant acquisition cost be included in the evaluation of cooperative vertical integration strategies. The general industry trend toward fewer and larger plants has resulted in many smaller-sized dairies being closed or acquired by other processors. Cooperatives have been acquiring these inefficient plants to expand market share, gain product label recognition, and/or expand market area by using them as distribution centers [11].

Empirical evidence shown in Table I of Chapter II indicates that all plant categories with sales volume less than four million pounds per month decreased in numbers between 1965 and 1979 while all categories of plants with sales volume of four million pounds per month or more increased in number over this period of time. Therefore, it is assumed that all plants with estimated processing volume of less than four million pounds per month were acquired by the cooperative as part of each market penetration strategy.

There were 28 plant locations of the existing plants system found which were classified as being of less than minimum optimum size. Using the capital investment cost equation described above, the acquisition costs associated with 100 percent of these 28 plants' construction costs were calculated to be $53.8 million. Assuming that book value was 50 percent of costs of new investment at the time of acquisition, the existing plant acquisition cost was estimated as $26.9 million. Both of these acquisition cost assumptions are used in the statement of operation analysis for each of the strategies.

Interest Expense. The cost of borrowed capital was estimated for the each strategy in relation to its new plant investment and existing plant acquisition costs. Discussion with personnel of the Bank for Cooperatives who were familiar with regional milk cooperative financing indicated that most loans for capital investments in fluid milk processing plants have a ten-year loan length, and have an average 1982 interest rate of 11.5 percent with a two percent capital stock investment. Adjusting for the capital stock requirement, the effective interest rate for 1982 was approximately 11.75 percent. The usual percentage of the investment financed by the Bank for Cooperatives has been 80 percent which requires the regional cooperative to finance the remaining 20 percent from owner's equity or some other source.

The assumptions used in this analysis are that capital investment costs for new and existing plants are financed either through 100 percent owner's equity or through borrowed capital from the Bank of Cooperatives. The terms of this type of loan are 80 percent financing at a 11.75 percent interest with a ten-year amortized repayment schedule. Borrowed capital under these conditions assume 20 percent owner's equity.

The Strategies

Strategy I. The first vertical integration strategy evaluated was a rather naive approach to obtaining a 25 percent share of the total Southwest fluid milk market. The statement of operation data used to evaluate Strategy I were calculated under the following conditions:

1) the optimum 1990 minimum total cost market organization existed,
2) the cooperative built 23 plants in each of the optimum locations of sufficient size to process 25 percent of each locations's fluid milk demand, and
3) the cooperative acquired the 28 inefficient plants and removed them from operation.

The 23 plant locations are the same as those locations in model V described in the previous section of this chapter.

Strategy II. The vertical integration strategy represented in this approach attempts to situate cooperative plants in those optimum 1990 plant locations which were not part of the existing 1982 plant configuration. Under this procedure, cooperative facilities processed 11.8 percent of total demand from six plant locations. The market conditions of Strategy II were:

1) the existing 1982 plant system was in place,
2) the cooperative built a plant in the six optimum 1990 locations not containing a 1982 plant and processes 100 percent of those six market's demand, and
3) the cooperative acquired the 28 inefficient plant and removed them from operation.

The six cooperative plant locations were identified as plant nodes 7 (Pine Bluff, Arkansas), 37 (Hobbs, New Mexico), 55 (Jackson, Tennessee), 66 (Killeen, Texas), 96 (Victoria, Texas), and 97 (Laredo, Texas).

Strategy III. The market penetration plan described in this strategy locates plants in the locations described as primary fluid milk demand markets and captures 25 percent of the fluid milk market in each location. The evaluation of Strategy III was conducted under these conditions:

1) the existing 1982 plant system was in place,

2) the cooperative built eight plants in primary market locations of sufficient size to process 25 percent of each market demand, and
3) the cooperative acquired the 28 inefficient plants removed them from operations.

The primary fluid milk demand market described above were Little Rock (node 10), Wichita (node 19), Albuquerque (node 33), Oklahoma City (node 51), Memphis (node 56), San Antonio (node 60), Dallas (node 67, and Houston (node 76). Total volume of fluid milk product processed by the cooperative under Strategy III was 11.8 percent.

Strategy IV. Strategy IV depicted an aggressive market penetration procedure in which the cooperative located plants in eight geographically strategic markets and gained control over 25 percent of total area demand. The strategy's market conditions were as follows:

1) these eight geographically strategic plant locations were allowed to ship to all demand areas
2) the cooperative built eight plants in the strategic locations of sufficient size to process 25 percent of each market demand or total area demand, and
3) the cooperative acquired the 28 inefficient plants and removed them from operation.

The geographically strategic locations are the same as the primary locations except that Albuquerque (node 33) was replaced by Clovis, New Mexico (node 35). One of the plant location's 25 percent market share exceeded the maximum plant capacity, so for this market, cooperative processing volume was limited to the single plant capacity. Cooperative processing accounted for 24.7 percent of total fluid milk demand. The remaining demand was assumed to be processed by efficient-sized 1982 plants.

Evaluation of Vertical Integration Strategies

As discussed earlier, the fluid milk processing cooperative evaluation procedure developed by Roof was employed to indicate the successfulness of the four specified vertical integration procedures.

The statement of operations for each penetration strategy was detailed in Table VI. The most profitable vertical integration procedure for the cooperative was Strategy IV. This aggressive strategy built only eight plants and controlled 25 percent of the market. Eight strategic plants were constructed at a cost of $80.4 million and were estimated to yield a return of $40.6 million on fluid milk sales of $484.6 million. Percentage returns for this penetration strategy ranged from 30.3 percent for 100 percent owner's equity and 100 percent acquisition value to 119.2 percent under a 20 percent owner's equity position and assuming aa 50 percent "book" value acquisition cost.

The vertically integrated cooperative described in Strategy I was estimated to have fluid milk sales of $491.5 million with an operating margin of $35.7 million. The 23 plants built in optimum 1990 locations cost $98.6 million and including the two existing inefficient plant acquisition cost alternatives, the percentage return for a 100 percent owner's equity position was 28.4 percent at the book value cost and 23.4 percent at the new value acquisition alternative.

TABLE VI

STATEMENTS OF OPERATIONS FOR THE FOUR SELECTED COOPERATIVE MARKET PENETRATION STRATEGIES

	Strategy I	Strategy II	Strategy III	Strategy IV
	- - - - - - - - - - - - millions	of units - - - - - - - - - -		
Pounds of Milk Processed	1,766.1	832.7	833.1	1,741.4
Number of Coop Plants	23	6	8	8
Fluid Retail Sales	$ 491.5	$ 231.3	$ 232.2	$ 484.6
Raw Milk Cost	260.2	121.7	124.7	256.7
Other Product Cost	69.1	32.6	32.6	68.1
GROSS MARGIN	$ 162.3	$ 77.0	$ 75.1	$ 159.8
OPERATING COSTS:				
Processing Cost	$ 62.2	$ 27.6	$ 28.4	$ 55.6
Wholesale Delivery Cost	47.7	22.5	22.5	47.0
General and Administrative	16.8	7.9	7.9	16.5
OPERATING MARGIN	$ 35.7	$ 19.0	$ 16.3	$ 40.6
New Plant Investment	$ 98.6	$ 35.8	$ 41.0	$ 80.4
Return at 100% Equity	$ 35.7	$ 19.0	$ 16.3	$ 40.6
Percent Return on Equity				
New Plants Plus 50% Acquis. Value	28.4%	29.8%	23.9%	37.9%
New Plants Plus 100% Acquis. Value	23.4%	21.2%	17.1%	30.3%
Return at 20% Equity	$ 18.1	$ 10.1	$ 6.4	$ 25.6
New Plants Plus 50% Acquis. Value	72.0%	79.1%	49.6%	119.2%
Return at 20% Equity	$ 14.3	$ 6.4	$ 3.0	$ 21.8
New Plants at 100% Acquis. Value	46.9%	35.7%	15.7%	81.3%

However, if the plant investment cost was through borrowed capital, the comparable percentage return figures at 20 percent owner's equity were 72.0 and 46.9 percent on "returns" of $22.0 million. Both Strategy IV and Strategy I assumed a total market share of 25 percent.

It was difficult to ascertain the difference in the success potentials of Strategies I and II. Both statements of operations indicated similar percentage returns, however; Strategy II obtained this comparable rate of return on new plant capital investments of $35.8 million that was 64 percent less than Strategy I's investment requirement. The amount of fluid milk processed by the 6 cooperative plants totaled to 832.7 million pounds or about 12 percent of 1990 study area demand.

Strategy III represented a market penetration approach which built eight plants in primary demand markets and captured 25 percent of those markets. The cooperative processing volume amounted to almost 12 percent, or approximately the same as Strategy II. Fluid milk sales totaled $232.3 million compared to $231.3 million in the previous strategy, but operating margin was lower in Strategy III than in Strategy II. Reviewing the raw milk cost and processing cost categories for the two approaches indicated that both of these costs were higher than in Strategy II, resulting in the lower operating margin. The percentage return on the 20 percent owner's equity position assuming 100 percent acquisition value was 15.7 percent which was the lowest rate of return recorded for the four strategies.

In general, all of the cooperative vertical integration strategies evaluated were potentially profitable marketing approaches. The lowest percentage return estimated was 15.7 percent while the highest return recorded was 119.2 percent for the four procedures. This analysis indicated that vertical integration into fluid milk processing by regional milk cooperatives could be successful in expanding market power and improving producer-member returns by 1990.

Underestimation of Distribution Costs. The assumptions and procedures used to evaluate all but one of the four penetration strategies underestimates the cost of distributing the fluid milk products from cooperative processing centers to demand areas. Strategies I, III and IV asumed that cooperative plants processed 25 percent of the respective market's demand and then distributed that quantity to the individual plants' demand areas. Distributing fluid products in the manner (with cooperatives supplying 25 percent and proprietory processors supplying 75 percent of total market demand) represents a duplication of services which is not accounted for by the plant location model developed and used in this analysis. A representative distribution cost total reflecting this duplication may be as much as four times the cost estimated with respect to the cooperative's operations. As a result, caution should be used when viewing these distribution cost totals and the corresponding rates of return of cooperative processing plant investment for these three vertical integration strategies.

Potential Problem Areas

The final part of the analysis of cooperative fluid milk processing is the identification of potential problems which may be encountered by a vertically integrated regional cooperative. Two areas of probable difficulty are the head-on competition of cooperatives with its bulk milk customers and the risk of Department of Justice action and various other legal actions which might be taken against the processor-cooperative firm. Although other problem areas may potentially exist for the cooperative, these two topics were identified during discussions with the management of cooperatives as being critical to their decision to undertake fluid milk processing as part of their operations.

No attempt is made to quantify the amount of impact or weight these two factors would have on processing plant locations or the profitability of a vertically integrated cooperative in the study area. These points are discussed in this analysis as to their probable effect on and importance to the cooperative decision-making process when considering fluid milk processing operations.

Conflict With Customers-Competitors

Regional milk cooperatives have had as their primary market functions assembling producer milk and representing producers in the sale of raw bulk milk to processors. If a cooperative became vertically integrated into fluid milk processing, the relationship between the cooperative and its bulk milk customers would be altered and perhaps, become strained due to the direct competition for fluid milk product sales. In order to minimize the potential conflict between a cooperative studying vertical integration alternatives and its customer-competitor processors, the managers need to know at what level of processing involvement would be tolerable to other processors before adverse market action was taken by market participants to preserve fluid milk market shares.

The level of involvement by cooperatives into the fluid milk processing industry is critical to their profitability and ability to service their producer-members. A vertically integrated regional cooperative performing as an assembler and processor must balance its activities to maintain its position in the marketing channel and not to jeopardize its profitability in either activity. Other processors may feel that the cooperative is a threat to their operations and choose to not purchase their bulk milk requirements from the cooperative and thereby harming the cooperative overall profitability and operations. Retaliatory actions such as these are important to the aggressiveness of cooperative policies in penetrating the fluid milk products market. Potential gains from processing fluid milk must be weighed against potential losses from bulk raw milk sales by the cooperative.

Discussions with cooperative and industry personnel did not yield a definitive level of market involvement which the processing cooperative could be assured of avoiding conflict with its customer-competitors. However, factors noted during these conversations were the current competitive position of processors in the market, the size and market share of processors, and degree of integration by corporate food chains into milk processing in the regional market. Agreement existed in that the cooperative's management must be cognizant of the potential problems of market conflict which may arise from the unique relationship of the cooperative as both an assembler and processor of milk.

Risk of Litigation

Regional milk cooperatives have had to defend themselves in several court cases since their rise to prominence in the late 1960's. The U.S. Department of Justice has filed suits against several of the large milk cooperatives claiming that predatory actions were taken by these cooperatives in an effort to exercise monopolistic control over the milk market [13]. Several other suits have been filed against cooperatives claiming a variety of damages all of which have cost the cooperatives a great deal of money to defend themselves in court. Given this historical perspective, the risk of further litigation against a vertically integrated regional milk cooperative is strong and should be considered when evaluating marketing alternatives.

Fluid milk processors which have their market power threatened by an integrated cooperative could choose to take legal action in an effort to maintain their share of the fluid market. Whereas, the Justice Department could possibly view a cooperative extending its control over milk supplies into the processing sector as unfair and predatory practices and file suit against such procedures. Possible litigation such as these could result in an expense to the cooperative which may effect the profitability of the overall operation. Unfortunately, quantifying the probable impact of litigation is very difficult and therefore cannot be employed as part of this research project. However, the risk and cost of litigating cases against a fluid milk processing cooperative should be included as an integral part of the analysis of vertical integration alternatives.

CHAPTER VII

SUMMARY AND CONCLUSIONS

Summary

The fluid milk industry has undergone many structural changes during the past 25 years with the fluid milk processing sector experiencing significant adjustments in the number and types of firms operating as fluid processors. Vertical integration by corporate food chains and regional milk cooperatives has been one of the most important factors in altering the manner in which fluid milk products are processed and distributed to retail outlets. Several technological and institutional developments have promoted this trend toward vertically integrated dairy processors.

Regional milk cooperatives have become involved in the fluid milk processing industry in many regions of the United States. The Southwest region of the nation is an exception with the dominant milk cooperative maintaining a policy of being fluid milk assemblers only. Economic pressures are forcing this cooperative to consider vertical integration into fluid milk processing. The central objective of this study was to evaluate the performance of the current fluid milk processing industry and to evaluate the potential of a regional cooperative becoming vertically integrated as a dairy processor by the year 1990 in the Southwest.

The Southwest study area contains 587 demand areas, 99 possible plant locations, and 380 supply areas. Market areas were counties, with all milk shipments originating from county centers and ending at county centers. Fluid milk demand was estimated to be 6,118 million pounds in 1982 and projected to be 7,064 million pounds in 1990. This 15.5 percent increase in fluid milk consumption was a function of population growth and changes in socio-economic characteristics of the population. The supply of milk eligible for fluid use totaled to 7,406 million pounds in 1982 and was assumed to be the same for 1990. All milk supplies in excess of fluid demand were left in the supply counties and not considered in this analysis.

A plant allocation model was built to efficiently search for optimum plant number, size, and locations under selected objective functions and to calculate the costs associated with assembly, processing, raw milk, and distribution of fluid milk in the study area. The efficiency of the current 1982 plant system was measured by comparing the costs of marketing milk under least-cost market areas for 60 existing plant location to the optimum total cost plant configuration. Additional optimum plant systems were estimated for a minimum processor cost function and a maximum producer return function to test the sensitivity of the model to changes in market conditions and model parameters. An optimum 1990 minimum total cost plant configuration was also determined to provide an estimate for efficiency under a projected increase in fluid milk demand levels.

Vertical integration strategies were formulated and tested through the use of the plant allocation model. Cost and revenue data calculated in the model and other cost variables were used to evaluate each of these cooperative market strategies. The potentials of fluid milk processing operations were measured through the rates of return on capital investment requirements for the various market penetration approaches. These data are to provide guidelines in assisting cooperatives in making decisions in relation to the potential fluid milk processing.

Conclusions

Efficiencies of Industry Structure

The performance of the 1982 fluid milk processing industry was found to be fairly efficient in relation to the minimum total cost plant configuration. Although the number, size, and location of the optimum processing plants were substantially different from the existing industry structure, the estimated reduction in total marketing cost was $12.3 million or only 1.1 percent of total system costs. The existing 60 plant locations' total cost was $1,136.2 million while the optimum 23 plant location configuration's assembly, processing, raw milk, and distribution costs totaled $1,123.9 million. Significant reductions in processing costs were gained at the expense of increased distribution costs under these systems. The optimum system's fewer but larger plants were able to realize economies of size related to milk fluid processing which amounted to $14.5 million but at the expense of increasing distribution costs $10.2 million. Given the relatively small percentage savings of the optimum plant system, the performance of the existing 60 fluid processing plants was shown to be efficient on the whole in marketing fluid milk products through the marketing channel.

The other two plant allocation models tested for 1982 market conditions revealed that optimum plant locations were sensitive to transportation costs. The optimum plant configuration derived under Model III minimized processor cost and consisted of 26 plant locations which were similar to the plant system which minimized total costs. Transportation cost calculated under Model III were assembly cost, $17.5 million, and distribution cost, $11.6 million. Model IV, in contrast maximized producer returns and contained 40 plants locations in its optimum plant configuration. The assembly cost totaled $10.6 million while distributed cost amounted to $18.5 million under Model IV. The marketing areas of plant locations derived in the optimum producer returns model are similar to the marketing areas of the existing 60 plant system.

Processing cost also has an impact on plant system optimization. The economies of size related the large volume processing plants supports the continued historical trend toward fewer and large dairy firms which dates back to the 1930's. Evidence provided by the minimum total cost system and the minimum processor cost system, consisting of 21 and 26 plant locations, respectively, indicates that economies of size does affect optimum plant configurations.

Raw milk cost has been shown to affect the shape of the marketing areas served by processing plants. Raw milk cost represent the Class I federal market order price paid by processors for raw fluid milk and these prices generally increase as potential plant locations move south and west. This results in elliptical-shaped plant marketing areas with the plant located in the northern and/or eastern portions of the service area. The Class I pricing structure gives northern plants a comparative cost advantage over southern plants.

Model V optimized the 1990 minimum total cost objective function and located 23 plant sites which processed 7,064 pounds of fluid milk. The total cost per hundredweight under 1982 market conditions was $18.37 and $18.40 under 1990 market conditions (assuming real prices), infering that the marketing costs were practically the same in these analysis years. The plant configuration derived in Model V represents an efficient fluid milk marketing system in 1990.

Potential of Fluid Milk Processing

Four fluid milk processing market penetration strategies were analyzed to determine the potential profitability of vertically integrated cooperatives. Each of these approaches were found to provide positive returns to capital investment costs for new plant construction and existing plant acquisitions. The percentage returns on 100 percent owner's equity and 20 percent owner's equity ranged from 15.7 percent to 119.2 percent for the approaches tested. Even at the lowest rate of return, the fluid milk processing venture would be expected to pay for itself in less than seven years. The analysis indicates that a vertically integrated cooperative can potentially increase producer-member returns or cooperative profits by processing fluid milk product in the Southwest study area by the year 1990, assuming that no conflicts on pricing policies exist to prohibit acquiring market shares at prevailing price spreads.

Problems of Cooperative Processors

Two major problem areas are reviewed with respect to a vertically integrated cooperative. First, the cooperative must balance its level of involvement in the fluid milk processing market with its activities in the raw bulk milk market to preserve its relationship with processors who are potentially both customers and competitors with the processing cooperative. Probable marketing conflicts which could result may affect the profitability of the cooperative's entire operations. Second, proper evaluation of vertical integration alternatives must incorporate a review of the risk and cost of legal action taken potential problems were not quantified and used in the analysis, however; these should be considered by the management of cooperative prior to aggressively integrating into the fluid milk processing industry.

Limitations

There were several limitations identified in the model which affected the optimization and/or the product distribution procedures. The most restrictive factors were the assumptions of fixed supply and demand quantities and fixed raw milk and retail prices which limited the type of optimization solved by the model. In a spatial equilibrium analysis, prices and quantities are allowed to adjust to each other until market equilibrium conditions are satisfied. The fixed quantity and price variables limits this analysis as a plant location-product distribution problem which was imposed on this analysis because of the extremely large size of the marketing problem.

Another factor affecting the analysis of the existing plant system was the inability to restrict processing plant capacities. The production distribution procedure allocated processing volume to plants by identifying those demand markets which that plant serves on a least cost basis. However, when plant capacity was known and the product distribution procedure exceeded this capacity, there was no method to limit plant processing volume and re-direct that volume to another plant. This limitation did not present a problem to the optimization procedure but it did limit the model's ability to reflect the marketing costs incurred under the existing 1982 plant system. Because of this limitation, the cost of the existing fluid milk industry was underestimated.

The basic marketing areas identified in this study were counties. All shipments of raw and processed milk were assumed to occur between county seats. No assembly and distribution costs were assigned to intra-county transportation of milk. All intra-county milk movements were consequently ignored. However, these shipments were not considered to affect the optimization and production distribution procedures to a great extent. Given the size of the problem, the ability of the model to efficiently solve a detailed shipping problem such as this was seriously questioned.

Need for Further Research

Regional milk cooperatives have generally functioned within the industry's marketing channel as assemblers of raw milk and as bargaining associations representing producer-members in the sale of bulk milk to processors. The primary source of income for cooperatives was from bulk milk sales and from sales of products processed from milk supplies not needed for the fluid market only. However, if cooperatives vertically integrate into fluid milk processing, the cooperative and its raw milk customers would enter into direct competition. Since a vertically integrated cooperative has two sources of income, the problem for the cooperative becomes one of trade-off between raw milk sales and processed milk sales. In other words, at what level of fluid milk processing can the cooperative penetrate the market and avoid conflict with its raw milk customers, the processed milk competitors. This customer-competitor relationship presents a major question to regional cooperative management; "How and where can the cooperative enter the fluid processing industry without losing raw milk sales revenue?".

No research exists which addresses this question. Most cooperative decisions made in relation to this customer-competitor conflict has been made on "gut" feelings by management. Comparative analysis of the benefit-loss relationships between these two cooperative income sources should provide some insight on how management can minimize the potential for intra-stage and inter-stage market conflicts.

The basic issue of how cooperative fluid milk processing can affect the level of fluid milk consumption needs further research. Vertically integrated cooperatives may improve market performance by eliminating the economic profits distributed to proprietory milk processors. If the cooperatives choose to pass any savings on to consumers in the form of lower retail milk prices, fluid milk consumption would be expected to increase. The research question concerns how can cooperatives maximize the returns of producer-members through either profits from processing operations, or an increased Class I utilization percentage. As in the previous problem there is a question of trade-offs.

Other areas for further research include cooperative pricing strategies and evaluation of additional market penetration strategies. Cooperatives often sell raw milk to processors at prices somewhat different from the federal market order prices. Research is required to determine which pricing strategy can alter the long-term plant configuration in favor of increased efficiency and the trade offs between maximum producer returns and minimum consumer prices in a long run setting. Four market penetration alternatives were reviewed in this study. Additional strategies need to be identified and evaluated particularly in light of the potential customer-competitor conflict discussed earlier.

SELECTED BIBLIOGRAHY

[1] Bain, Joe S. Industrial Organization. New York: John Wiley & Sons, Inc., 1959.

[2] Baligh, H. H. and L. E. Richartz. Vertical Market Structures. Boston: Allyn and Bacon, Inc., 19.

[3] Baumol, W. J., J. C. Panzar and R. D. Willig. Contestable Markets and the Theory of Industry Structure. New York: Harcourt Brace Jonvanovich, Inc., 1982.

[4] Blaich, O. P. "Integration in Theory With an Application to Hogs." Journal of Farm Economics, Vol. 42, No. 5 (December, 1960), pp. 1280-1293.

[5] Blaylock, J. R. and D. M. Smallwood. Effects of Household Socioeconomic Features on Dairy Purchases. Technical Bulletin No. 1686. Washington, D. C.: U. S. Department of Agriculture, Economic Research Service, August, 1983.

[6] Boehm, William T. The Household Demand for Fluid Milk in the United States with Regional Consumption Projections Through 1990. Research Division Bulletin 120. Blacksburg, Virginia: Virginia Polytechnic Institute and State University, December, 1976.

[7] Boehm, W. T. and E. M. Babb. Household Consumption of Beverage Milk Products. Station Bulletin No. 75. West Lafayette, Indiana: Purdue University, Agricultural Experiment Station, Department of Agricultural Economics, March, 1975.

[8] Cobia, D. W. and E. M. Babb. Determining the Optimum Size Fluid Milk Processing Plant and Sales Area. Research Bulletin No. 778. Lafayette, Indiana: Purdue University, Agricultural experiment Station, May, 1964.

[9] Cole, R. H., C. T. Murchinson, B. E. Estes, J. W. Boatwright, and K. S. Carlson. Vertical Integration in Marketing. Bulletin 74. Urbana, Illinois: University of Illinois, Bureau of Economic and Business Research, 1952.

[10] Cook, H. L., Leo Blakley, Robert Jacobson, Ronald Knutson, Robert Mulligan, and Robert Strain. The Dairy Subsectors of American Agriculture: Organization and Vertical Coordination. North Central Regional Research Publication 257, Madison, Wisconsin: University of Wisconsin, November, 1978.

[11] Cook, H. L. and R. P. Combs. Prarie Farm, Inc.: Economic Impact of a Dairy Cooperative. ACS Research Report 12. Washington, D. C.: U. S. Department of Agriculture, Agricultural Cooperative Service, July, 1982.

[12] Deason, Charles. Unpublished Study. San Antonio, Texas, 1979.

[13] Eisenstat, Phillip, Robert T. Masson and David Roddy. An Economic Analysis of the Associated Milk Producers, Inc. Monopoly. Washington, D. C.: U. S. Department of Justice, 1971.

[14] Fischer, M., J. Hammond, and W. Hardie. Fluid Milk Processing and Distribution Costs. Station Bulletin 530. St. Paul, Minnesota: University of Minnesota, Agricultural Experiment Station, 1979.

[15] Fuller, S. F., Paul Randolph, and Darwin Klingman. "Optimizing Subindustry Marketing Organizations: A Network Analysis Approach." American Journal of Agricultural Economics Vol. 58, No. 3 (August, 1976), pp. 425-436.

[16] Hardy, William E. A Computer Program for Locating Economic Facilities. Agricultural Economic Series 24. Auburn, Alabama: Auburn University, Agricultural Experiment Station, March, 1973.

[17] Holdrich, Martin K. "U. S. Regional Projections 1981-2000." 1981 Regional Economic Projection Series, REPS Report No. 81-R-1, Washington, D. C.: National Planning Association, May, 1982.

[18] Holdrich, Martin K. "U. S. Regional Projections 1981-2000." 1981 Regional Economic Projection Series, REPS Report No. 81-R-3, Washington, D. C.: National Planning Association, June, 1982.

[19] Hurt, V. G. and T. T. Tramel. "Alternative Formulations of the Transhipment Problem," Journal of Farm Economics, Vol. 47, No. 3 (August, 1965), pp. 763-773.

[20] Jones, W. Webster. Milk Processor - Distributors' Sales, Costs, and Margins, 1979. ERS-666. Washington, D. C.: U. S. Department of Agriculture, Economic Research Service, October, 1981.

[21] Jones, W. W. Milk Processor - Distributors' Sales, Costs, and Margins, 1980-81. Agricultural Economics Reort No. 497. Washington, D. C.: U. S. Department of Agriculture, Economics Research Service, April, 1983.

[22] Khumawala, B. "An Efficient Branch and Bound Algorithm for the Warehouse Location Problem." Management Science, Vol. 18, No. 4 (December, 1972), pp. 618-39.

[23] King, G. A., and S. H. Logan. "Optimum Location Number, Number and Size of Processing Plants with Raw Product and Final Product Shiments." Journal of Farm Economics, Vol. 46, No. 1 (February, 1964).

[24] King, R. A., R. A. Dahlgran, A. A. McDermed and D. L. Peters. Evaluation of Alternative Plant Locations. Economics Special Report No. 52. Raleigh, North Carolina: North Caroline State University, Department of Economics and Business, June, 1979.

[25] Kletke, Marilyn G. "Efficiencies in Coordination of Fluid Milk Supplies Through Cooperative Mergers in the Southwest." (Ph.D. Thesis, Oklahoma State University, 1981).

[26] Kloth, Donald W. and Leo V. Blakley. Optimum Market Organizations of the Fluid Milk Industry in the United States Under Alternative Marketing Strategies. Technical Bulletin No. T-133. Stillwater, Oklahoma: Oklahoma State University, Agricultural Experiment Station, October, 1971.

[27] Kottke, Marvin. "Spatial, Temporal, and Product-Use Allocation of Milk in an Imperfectly Competitive Dairy Industry." American Journal of Agricultural Economics, Vol. 52, No. 1 (February, 1970), pp. 33-40.

[28] Lasley, F. A., Webster Jones, and Leah Sitzman. Milk Dealers' Sales and Costs: A Trend Analysis, 1952-77. ESCS-62. Washington, D. C.: U. S. Department of Agriculture, Economics, Statistics, and Cooperatives Service, January, 1980.

[29] Leftwich, Richard H. The Price System and Resource Allocation. 5th Edition. Hinsdale, Illinois: The Dryden Press, 1973.

[30] Ling, K. D. Dairy Product Manufacturing Costs at Cooperative Plants. ACS Research Report No. 34. Washington, D. C.: U. D. Department of Agriculture, Agricultural Cooperative Service, November, 1983.

[31] Lough, Harold W. Fluid Milk Processing Market Structure. ESS Staff Report No. AGESS 810415. Washington, D. C.: U. S. Department of Agriculture, Economics and Statistics Service, April, 1981.

[32] Lough, Harold and Richard Fallert. Central Milk Programs in Southern Food Chains. ERS Report AGERS-43. Washington, D. C.: U. S. Department of Agriculture, Economics Research Service, September, 1977.

[33] McConnell, Campbell R. Economics Principles, Problems, and Policies. 4th Edition. New York: McGraw-Hill, 1969.

[34] Manchester, Alden C. The Structure of Fluid Markets: Two Decades of Change. Agricultural Economic Report No. 137. Washington, D. C.: U. S. Department of Agriculture, Economic Research Service, July, 1968.

[35] Manchester, Alden C. Market Structure, Institutions, and Performance in the Fluid Milk Industry, Agricultural Economic Report No. 248. Washington, D. C.: U. S. Department of Agriculture, Economic Research Service, January, 1974.

[36] Manne, A. "Plant Location Under Economies-of-Scale: Decentralization and computation." Management Science, Vol. 11, No. 2 (March, 1964), pp. 213-235.

[37] Mighell, Ronald L. and L. A. Jones. Vertical Coordination in Agriculture. Agricultural Economic Report No. 19. Washington, D. C.: U. S. Department of Agriculture, Economic Research Service, February, 1963.

[38] Office of the Federal Register, National Archives and Records Service, Code of Federal Regulations. Title 7-Agriculture, Parts 1060 to 1119, Washington, D. C., 1978.

[39] Office of the Federal Register, National Archives and Records Service. Code of Federal Regulations. Title 7-Agriculture, Parts 1120 to 1119, Washington, D. C., 1978.

[40] Parker, Russell C. Economic Report on the Dairy Industry. Staff Report of the Federal Trade Commission, Washington, D. C., March, 1973.

[41] Polopolus, Leo, "Optimum Plant Numbers and Locations for Multiple Product Processing. "Journal of Farm Economics, Vol. 47, No. 2 (May, 1965), pp. 287-295.

[42] Potts, R. B., and R. M. Oliver. "Flows in Transportation Networks." Mathematics in Science and Engineering, Volume 90. New York: Academic Press, 1972.

[43] Purcell, Joseph, C. Analysis of Demand for Fluid Milk and Fluid Milk Substitutes in the Urban South. Technical Bulletin N. S. 12. Athens, Georgia: University of Georgia College of Agriculture, Georgia Agricultural Experiment Stations, October, 1957.

[44] Raunikar, Robert, J. C. Purcell and J. C. Elrod. Spatial and Temporal Aspects of the Demand for Food in the United States: I. Fluid Milk. Research Bulletin 61. Athens, Georgia: University of Georgia, College of Agriculture Experiment Stations, June, 1969.

[45] Robinson, T. H. and E. M. Babb. Forecasts of U. S. Dairy Product Consumption, 1977-1981. Station Bulletin No. 186. West Lafayette, Indiana: Purdue University, Agricultural Experiment Station, Department of Agricultural Economics, March, 1978.

[46] Roof, James B. Cooperative Fluid Milk Processing: A Perspective of Opportunities and Problems. ACS Research Report No. 31. Washington, D. C., Agricultural Cooperative Service, November, 1983.

[47] Scott, Allen J. An Introduction to Spatial Allocation Analysis. Resource Paper No. 9. Washington, D. C.: Association of American Geographers, Commission on College Geography, 1971.

[48] Shannon, R. E. and J. P. Ignizio. "A Heuristic Programming Algorithm for Warehouse Location." AIIE Transactions, Vol. II, No. 4 (December, 1979), pp. 334-339.

[49] Steenbrink, Peter A. Optimization of Transport Networks. London: John Wiley & Sons, 1974.

[50] Stollsteimer, J. F. "A Working model for Plant Numbers and Locations." Journal of Farm Economics, Vol. 45, No. 3 (August, 1963), pp. 631-645.

[51] Takayama, T. and G. G. Judge. "Spatial Equilibrium and Quadratic Programming." Journal of Farm Economics, Vol. 46, No. 1 (February, 1964), pp. 67-93.

[52] Tornqvist, Gunnar, S. Nordbeck, B. Rystedt, and P. Gould. Multiple Location Analysis. Mathematical and Regional Geography No. 12, The Royal University of Lund, Sweden, Department of Geography, 1971.

[53] U. S. Department of Agriculture, Agricultural Marketing Service. Questions and Answers on Federal Milk Marketing Orders. AMS-559, Washington, D. C., May, 1977.

[54] U. S. Department of Agriculture, Agricultural Marketing Service. Soulces of Milk for Federal Order Markets by State and County. AMS-565 (1978), Washington, D. C., March, 1978.

[55] U. S. Department of Agriculture, Agricultural Marketing Service. Federal Milk Order Market Statistics 1982 Annual Summary. Statistical Bulletin No. 698, Washington, D. C., August, 1983.

[56] U. S. Department of Agriculture, Economic Research Service. Developments in Farm to Retail Price Spreads for Food Products in 1982. Agricultural Economic Report No. 500, Washington, D. C., May, 1983, pp. 36-39.

[56] U. S. Department of Agriculture, Economic Research Service. Review of Existing and Alternative Federal Dairy Programs Staff Report No. AGE 840121, Washington, D. C., January, 1984.

[57] U. S. Department of Commerce, Bureau of Economic Analysis. Business Conditions Digest, Vol, 23, No. 4 (April, 1983), pp.103.

[58] U. S. Department of Commerce, National Bureau of Standards. Counties and County Equivalents of the States of the United States. FIPS Publication 6-1, Washington, D. C., June, 1970.

[59] Von Thunen, J. H. The Isolated State. Chicago: Loyola University Press, 1960.

[60] Warrack, A. A. and L. B. Fletcher. "Plant Location Model Suboptimization for Large Problems." American Journal of Agricultural Economics. Vol. 52, No. 4 (November, 1970), pp. 587-590.

APPENDIX

TABLE VII

COUNTY MILK PRODUCTION AND POPULATION, FLUID MILK DEMAND, AND FLUID MILK SALES REVENUE, 1982 and 1990

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
ARKANSAS				000's		
Arkansas	0	24	5,599	$1,518	25	6,103
Ashley	0	27	6,164	1,671	28	6,827
Baxter	1,693	30	7,644	2,048	40	10,602
Benton	81,913	83	21,347	5,719	104	27,711
Boone	17,090	27	7,050	1,889	33	8,782
Bradley	0	14	3,209	870	15	3,546
Calhoun	0	6	1,420	385	7	1,568
Carroll	43,312	17	4,349	1,165	20	5,328
Chicot	0	18	4,100	1,112	18	4,390
Clark	1,920	24	5,410	1,467	25	5,958
Clay	1,920	21	4,033	1,093	23	4,577
Cleburne	9,991	18	4,114	1,115	22	5,331
Cleveland	1,920	8	1,843	500	9	2,075
Columbia	1,920	27	5,924	1,638	29	6,681
Conway	42,820	20	4,611	1,250	23	5,428
Craighead	1,920	65	12,484	3,384	72	14,601
Crawford	3,701	39	10,043	2,726	48	13,061
Crittenden	0	50	9,602	2,603	52	10,611
Cross	0	21	3,971	1,077	22	4,415
Dallas	0	11	2,441	662	11	2,702
Desha	0	20	4,569	1,239	20	4,921
Drew	0	18	4,169	1,130	19	4,631
Faulkner	66,263	48	11,115	3,013	58	13,870
Franklin	34,685	15	3,975	1,079	18	5,021
Fulton	23,102	10	2,381	646	12	2,871
Garland	2,438	72	16,645	4,512	81	19,587
Grant	1,920	13	3,071	832	15	3,594
Greene	3,259	31	6,053	1,641	35	7,047
Hempstead	2,602	24	5,361	1,483	28	6,472
Hot Spring	4,585	27	6,298	1,707	30	7,237
Howard	1,920	14	3,063	847	16	3,712
Independence	3,347	31	7,148	1,938	35	8,539

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
ARKANSAS continued			000's			
Izard	7,238	11	2,574	698	13	3,136
Jackson	1,920	22	5,001	1,356	23	5,452
Jefferson	0	92	21,058	5,709	96	23,133
Johnson	3,246	18	4,110	1,114	20	4,776
Lafayette	0	10	2,268	627	11	2,552
Lawrence	3,107	19	3,602	976	20	4,050
Lee	0	17	3,352	909	15	3,058
Lincoln	0	13	3,080	835	14	3,281
Little River	0	15	3,199	885	17	3,990
Logan	59,240	21	5,371	1,458	24	6,531
Lonoke	39,258	36	8,159	2,212	40	9,577
Madison	29,797	12	3,047	816	14	3,668
Marion	9,511	12	3,094	829	15	4,043
Miller	2,362	39	8,516	2,355	43	10,068
Mississippi	0	60	11,456	3,106	60	12,191
Monroe	0	14	3,204	869	14	3,281
Montgonery	2,261	8	1,857	503	10	2,292
Nevada	0	11	2,483	687	12	2,830
Newton	3,714	8	2,087	559	10	2,543
Quachita	1,920	31	7,051	1,912	31	7,574
Perry	0	8	1,724	467	8	2,026
Phillips	0	35	6,665	1,807	34	6,946
Pike	0	11	2,347	649	11	2,598
Poinsett	0	27	5,218	1,415	28	5,630
Polk	2,653	18	4,621	1,254	22	5,954
Pope	5,684	40	9,285	2,517	46	11,169
Prairie	7,212	10	2,331	632	10	2,509
Pulaski	4,674	348	80,094	21,713	382	92,244
Randolph	1,920	17	3,348	908	20	4,010
St. Francis	0	31	5,976	1,620	32	6,500
Saline	2,766	55	12,669	3,434	64	15,318
Scott	2,274	10	2,600	706	12	3,183
Searcy	13,995	9	2,335	625	10	2,731
Sebastian	22,749	99	25,597	6,949	117	32,022
Sevier	0	15	3,186	881	17	3,838
Sharp	1,920	15	3,549	962	19	4,583

TABLE VII continued

State and County	1982 Milk Production (lbs.)	1982 Population (No.)	1982 Fluid Demand (lbs.)	1982 Sales Revenue ($)	1990 Population (No.)	1990 Fluid Demand (lbs.)
ARKANSAS continued			000's			
Stone	1,276	9	2,133	578	11	2,533
Union	1,920	50	11,446	3,103	54	12,905
Van Buren	33,182	14	3,209	870	16	3,932
Washington	65,089	104	26,946	7,219	123	32,958
White	18,037	52	12,016	3,257	59	14,136
Woodruff	0	11	2,574	698	11	2,726
Yell	10,497	17	3,999	1,084	19	4,607
COLORADO						
Alamosa	0	12	2,843	790	13	3,095
Archuleta	0	4	986	269	4	1,071
Baca	0	5	1,280	356	5	1,306
Bent	0	6	1,398	388	6	1,402
Conejos	0	8	1,848	514	8	1,934
Costilla	0	3	735	204	3	750
Huerfano	0	6	1,516	421	6	1,547
La Plata	5,962	28	7,349	2,002	31	7,995
Las Animas	0	15	3,521	978	15	3,603
Montezuma	1,945	17	4,402	1,199	18	4,677
Otero	0	23	5,365	1,491	23	5,561
Prowers	0	13	3,123	868	14	3,288
Rio Grande	0	11	2,497	694	11	2,587
KANSAS						
Allen	24,037	16	4,104	1,086	18	4,521
Barber	7,415	7	1,735	466	6	1,643
Barton	4,206	32	8,407	2,257	32	8,265
Bourbon	19,212	16	4,171	1,104	18	4,599
Butler	19,263	46	12,170	3,267	49	12,526
Chase	4,699	3	881	236	3	847
Chautauque	3,827	5	1,345	361	5	1,335
Cherokee	4,699	23	5,826	1,542	25	6,407
Clark	0	3	694	186	3	642
Comanche	2,741	3	683	183	3	642
Cowley	3,259	37	9,907	2,660	38	9,857

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
KANSAS continued	- - - - - - - - - - - - -	- - - - - - - -	000's	- - - - - - - -	- - - - - - - -	- - - - - - - -
Crawford	7,920	39	9,873	2,613	42	10,800
Edwards	4,118	4	1,137	305	4	1,078
Elk	4,699	4	1,041	279	4	1,027
Finney	0	24	6,512	1,748	27	6,853
Ford	7,831	25	6,560	1,761	26	6,597
Grant	0	7	1,900	510	8	1,951
Gray	0	5	1,382	371	5	1,386
Greeley	0	2	491	132	2	488
Greenwood	8,956	9	2,338	628	9	2,233
Hamilton	0	3	667	179	3	642
Harper	7,086	8	2,082	559	8	2,002
Harvey	22,635	31	8,257	2,217	33	8,393
Haskell	4,699	4	1,025	275	4	1,027
Hodgeman	7,048	2	603	162	2	565
Kearney	0	3	929	249	4	950
Kingman	18,543	9	2,402	645	9	2,336
Kiowa	0	4	1,078	289	4	1,052
Labette	23,810	27	6,840	1,811	28	7,286
Lane	0	2	657	176	2	616
McPherson	29,671	27	7,254	1,947	28	7,290
Marion	50,651	14	3,603	967	14	3,491
Meade	4,497	5	1,281	344	5	1,258
Montgomery	10,951	43	11,072	2,931	48	12,298
Morton	0	4	934	251	4	898
Neosho	22,938	19	4,949	1,310	21	5,426
Ness	4,699	5	1,201	322	5	1,155
Pawnee	1,402	8	2,151	577	8	2,053
Pratt	4,838	10	2,760	741	10	2,669
Reno	37,515	66	17,518	4,703	68	17,506
Rice	6,859	12	3,176	853	12	3,055
Rush	4,699	4	1,190	320	4	1,104
Scott	0	6	1,559	418	6	1,540
Sedgwick	92,069	370	98,667	26,489	381	97,718
Seward	0	17	4,606	1,237	18	4,620
Stafford	2,829	6	1,500	403	5	1,386

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
KANSAS continued	000's					
Stanton	0	2	625	168	2	616
Stevens	4,699	5	1,276	342	5	1,283
Sumner	12,656	25	6,709	1,801	26	6,699
Wichita	0	3	801	215	3	770
Wilson	3,650	12	3,172	840	14	3,514
Woodson	2,804	5	1,189	315	5	1,292
LOUISIANA						
Beinville	11,027	17	3,200	899	17	3,454
Bossier	18,795	84	16,137	4,536	95	18,938
Caddo	5,255	257	49,590	13,938	276	54,691
Claiborne	26,538	17	3,336	938	18	3,593
De Soto	94,203	26	5,052	1,420	28	5,578
East Carroll	0	12	2,174	611	12	2,301
Jackson	1,592	18	3,247	913	19	3,628
Lincoln	6,467	40	7,510	2,111	45	8,679
Morehouse	1,592	35	6,516	1,831	37	7,236
Ouachita	1,592	142	26,405	7,421	158	30,757
Red River	0	11	2,049	576	11	2,263
Richland	6,695	22	4,134	1,162	23	4,525
Union	9,196	22	4,000	1,124	24	4,583
Webster	9,170	44	8,581	2,412	48	9,509
West Carroll	5,646	13	2,401	675	13	2,613
MISSISSIPPI						
Alcorn	2,185	34	6,519	1,767	38	7,634
Benton	0	8	1,589	431	9	1,802
Bolinar	0	46	8,859	2,402	47	9,477
Calhoun	1,339	16	3,059	829	17	3,402
Carroll	0	10	1,901	515	10	2,086
Chickasaw	5,166	18	3,490	946	19	3,908
Clay	8,564	22	4,137	1,122	23	4,718
Coahoma	0	37	7,100	1,925	37	7,533
De Soto	19,983	57	10,895	2,953	68	13,791
Grenada	0	21	4,102	1,112	23	4,617
Itawamba	0	21	4,052	1,099	23	1,252

TABLE VII continued

	- - - - - - - - 1982			- - - - - - - - -	- - - 1990	- - -
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
MISSISSIPPI continued	- - - - - - - - - - -		000's	- - - - - - - - - - - -		
Lafayette	2,185	32	6,157	1,669	36	7,310
Lee	15,738	59	11,295	3,062	66	13,305
Leflore	0	42	8,039	2,179	43	8,748
Marshall	16,964	30	5,784	1,568	33	6,723
Monroe	2,185	37	7,112	1,928	40	7,999
Montgomery	5,217	14	2,601	705	14	2,876
Panola	2,185	29	5,488	1,488	30	6,095
Pontotoc	14,084	21	4,122	1,117	24	4,799
Prentiss	9,726	25	4,733	1,283	27	5,508
Quitman	0	12	2,394	649	12	2,430
Sunflower	0	35	6,704	1,817	35	7,169
Tallahatchie	2,185	17	3,294	893	17	3,443
Tate	39,043	20	3,929	1,065	22	4,435
Tippah	9,865	19	3,683	998	21	4,253
Tishmingo	1,895	19	3,641	987	21	4,253
Tunica	0	10	1,836	498	9	1,843
Union	10,168	22	4,260	1,155	24	4,880
Washington	0	73	14,050	3,809	76	15,471
Webster	2,766	10	2,005	544	11	2,207
Yalobusha	5,292	13	2,567	696	14	2,896
MISSOURI						
Barry	17,381	25	6,456	1,709	29	7,493
Barton	0	12	2,967	785	13	3,307
Butler	1,794	38	9,185	2,431	39	9,524
Dunklin	0	37	7,085	1,921	39	7,938
Howell	15,448	30	7,624	2,018	34	8,836
Jasper	49,135	89	22,800	6,035	99	25,449

TABLE VII continued

State and County	1982 Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	1990 Population (No.)	Fluid Demand (lbs.)
MISSOURI continued			000's			
McDonald	16,635	15	3,940	1,043	18	4,547
New Madrid	0	23	4,414	1,197	23	4,718
Newton	20,235	42	10,749	2,845	48	12,453
Oregon	4,585	10	2,675	708	12	2,971
Ozark	7,415	8	2,111	559	10	2,454
Pemiscot	0	25	4,795	1,300	25	5,042
Ripley	0	13	3,078	815	14	3,312
Stoddard	2,059	29	7,064	1,870	30	7,324
Stone	14,892	16	4,212	1,115	20	5,245
Taney	2,046	22	5,569	1,474	27	7,028
Vernon	8,147	20	5,154	1,364	22	5,632
NEW MEXICO						
Bernalillo	57,560	432	102,558	28,593	489	115,549
Catron	0	3	650	181	3	709
Chaves	86,233	52	13,194	3,679	56	13,554
Colfax	0	14	3,288	917	15	3,476
Curray	13,730	43	12,253	3,393	47	13,357
De Baca	13,730	3	593	165	3	591
Dona Ana	238,414	100	25,426	7,089	116	28,303
Eddy	13,730	49	12,349	3,443	52	12,652
Grant	0	27	6,875	1,917	31	7,484
Guadalupe	0	4	1,058	295	4	1,041
Harding	0	1	304	84	1	287
Hidalgo	0	6	1,568	437	7	1,658
Lea	27,182	57	14,440	4,045	62	15,478
Lincoln	0	11	2,695	751	13	3,074
Los Alamos	0	18	4,251	1,185	19	4,588
Luna	13,730	16	4,135	1,153	19	4,656
McKinley	0	57	13,622	3,798	64	15,041
Mora	0	4	987	275	4	970
Otera	13,730	46	11,666	3,253	51	12,482
Quay	2,463	11	3,020	836	11	3,016
Rio Arriba	0	30	7,074	1,972	32	7,639
Roosevelt	93,610	16	4,007	1,123	16	4,107
Sandoval	13,730	37	8,815	2,458	48	11,281

TABLE VII continued

	- - - - - - - - - 1982	- - - - - - - - -			- - - 1990 - - -	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
NEW MEXICO continued	- - - - - - - - - - -		000's	- - - - - - - - - - -		
San Juan	15,423	85	20,060	5,593	99	23,507
San Miguel	0	23	5,437	1,516	24	5,605
Sante Fe	0	78	18,523	5,164	90	21,355
Sierra	13,730	9	2,215	618	10	2,340
Socorro	22,850	13	3,112	868	15	3,547
Taos	0	20	4,626	1,290	21	4,848
Torrance	0	8	1,817	507	9	2,010
Union	13,730	5	1,349	374	5	1,350
Valencia	109,803	64	15,083	4,205	75	17,713
OKLAHOMA						
Adair	40,458	19	4,969	1,331	22	5,971
Alfalfa	2,059	7	1,720	467	7	1,728
Atoka	7,187	13	3,189	867	15	3,657
Beaver	15,498	7	1,964	544	7	2,039
Beckman	12,732	20	4,791	1,303	22	5,385
Blaine	11,115	14	3,331	906	15	3,682
Bryan	11,873	31	7,267	2,022	33	8,183
Caddo	10,888	31	7,628	2,074	33	8,241
Canadian	25,313	60	14,663	3,986	76	18,911
Carter	3,360	44	10,865	2,954	49	12,148
Cherokee	22,900	32	7,767	2,097	36	8,924
Choctaw	2,375	18	4,569	1,240	20	5,488
Cimarron	0	4	1,022	283	4	1,005
Cleveland	12,694	141	34,637	9,416	179	44,835
Coal	5,558	6	1,499	408	7	1,678
Comanche	39,662	114	22,531	6,167	124	23,170
Cotton	0	8	1,478	405	9	1,591
Craig	13,035	15	3,925	1,039	17	4,341
Creek	4,863	61	14,906	4,024	68	16,928
Custer	10,863	27	6,506	1,769	29	7,364
Delaware	27,599	25	6,441	1,725	30	7,952
Dewey	1,781	6	1,455	396	6	1,578
Ellis	23,646	6	1,382	376	6	1,478

TABLE VII continued

State and County	1982 Milk Production (lbs.)	1982 Population (No.)	1982 Fluid Demand (lbs.)	1982 Sales Revenue ($)	1990 Population (No.)	1990 Fluid Demand (lbs.)
OKLAHOMA continued			000's			
Garfield	8,779	64	15,638	4,251	70	17,408
Garvin	11,065	28	6,883	1,871	30	7,414
Grady	130,645	41	9,970	2,710	47	11,647
Grant	4,977	6	1,582	430	6	1,603
Greer	2,375	7	1,372	376	7	1,348
Harmon	2,375	5	887	243	5	880
Harper	7,187	5	1,151	313	5	1,202
Haskell	0	11	2,936	797	13	3,567
Hughes	2,375	14	3,523	958	15	3,757
Jackson	2,375	31	6,111	1,673	34	6,363
Jefferson	2,375	8	1,668	456	9	1,759
Johnston	19,768	11	2,597	706	12	2,956
Kay	9,082	50	12,340	3,331	52	13,001
Kingfisher	25,869	14	3,537	962	16	3,957
Kiowa	7,692	13	2,527	692	14	2,545
Latimer	0	10	2,615	710	12	3,183
Leflore	3,234	42	10,943	2,971	50	13,665
Lincoln	63,623	27	6,722	1,827	32	7,915
Logan	6,101	28	6,844	1,861	33	8,241
Love	0	8	1,867	507	8	2,079
McClain	39,498	21	5,198	1,413	25	6,362
McCurtain	1,200	38	9,738	2,644	44	12,183
McIntosh	1,705	16	3,896	1,052	17	4,276
Major	18,580	9	2,205	599	10	2,530
Marshall	0	11	2,675	727	13	3,156
Mayes	41,898	33	8,189	2,211	38	9,471
Murray	18,315	12	2,993	814	13	3,256
Muskogee	33,447	68	16,633	4,490	72	17,773
Noble	7,048	12	2,885	779	13	3,132
Nowata	5,570	12	2,861	772	13	3,107
Okfuskee	2,375	11	2,739	744	12	2,931
Oklahoma	13,301	579	141,788	38,545	632	158,223
Okmulgee	4,445	40	9,715	2,623	42	10,341
Osage	14,460	40	9,887	2,669	45	11,087
Ottawa	14,627	34	8,623	2,283	37	9,637

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
OKLAHOMA continued			000's			
Pawnee	2,375	16	3,852	1,040	17	4,325
Payne	35,797	64	15,740	4,249	72	17,823
Pittsburg	0	42	10,757	2,920	47	12,842
Pontotoc	22,370	33	8,172	2,222	37	9,343
Pottowatomie	20,248	57	13,914	3,782	65	16,181
Pushmataha	0	12	3,153	856	14	3,842
Roger Mills	35,228	5	1,176	320	5	1,227
Rogers	13,364	49	12,100	3,266	62	15,337
Seminole	2,741	28	6,776	1,842	29	7,289
Sequoyah	2,375	32	8,348	2,266	40	10,839
Stephens	12,227	45	8,823	2,415	51	9,582
Texas	1,263	18	5,150	1,426	19	5,544
Tillman	4,421	13	2,476	678	14	2,527
Tulsa	8,450	481	117,914	31,833	524	130,280
Wagoner	14,842	45	10,942	2,954	57	14,070
Washington	2,375	49	12,006	3,241	53	13,100
Washita	7,086	14	3,390	922	14	3,607
Woods	0	11	2,660	723	11	2,730
Woodward	2,375	22	5,370	1,460	25	6,337
TENNESSEE						
Benton	11,886	15	2,952	800	17	3,483
Carroll	505	29	5,545	1,503	31	6,298
Chester	0	13	2,521	683	15	2,997
Crockett	0	15	2,905	788	16	3,240
Decatur	0	11	2,144	581	12	2,471
Dyer	2,880	35	6,808	1,846	38	7,776
Fayette	21,877	26	4,953	1,343	28	5,589
Gibson	11,318	50	9,648	2,615	53	10,773
Hardeman	11,886	24	4,668	1,265	26	5,245
Hardin	0	23	4,406	1,195	25	5,144
Haywood	2,223	21	3,945	1,069	21	4,334
Henderson	0	22	4,233	1,148	25	4,982
Henry	6,265	29	5,661	1,535	33	6,602
Lake	0	8	1,443	391	8	1,539

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
TENNESSEE continued			000's			
Lauderdale	3,890	25	4,841	1,312	28	5,609
McNairy	0	23	4,445	1,205	26	5,184
Madison	6,063	76	14,643	3,970	83	16,828
Obion	3,890	33	6,427	1,742	36	7,310
Shelby	4,396	791	152,213	41,264	853	172,697
Tipton	4,661	34	6,454	1,750	37	7,391
Weakley	27,637	34	6,477	1,756	37	7,493
TEXAS						
Anderson	13,743	40	8,798	2,458	46	10,567
Andrews	2,779	14	4,184	1,184	17	5,002
Angelina	0	67	14,802	4,135	78	18,075
Aransas	0	15	3,950	1,148	18	4,739
Archer	110,649	8	1,925	532	10	2,302
Armstrong	2,779	2	574	159	2	603
Atascosa	22,269	26	6,572	1,881	30	7,559
Austin	0	18	4,130	1,177	20	4,880
Bailey	2,779	8	2,077	582	8	2,079
Bandera	0	8	1,903	545	9	2,341
Bastrop	2,779	26	5,567	1,580	32	7,286
Baylor	0	5	1,272	351	6	1,430
Bee	2,779	26	6,916	2,010	28	7,240
Bell	2,829	164	31,357	8,813	188	35,731
Bexar	36,757	1,016	257,890	73,792	1,147	291,880
Blanco	8,311	5	1,042	296	6	1,304
Borden	0	1	229	64	1	225
Bosque	8,071	14	2,630	739	15	2,845
Bowie	19,124	77	17,011	4,704	87	20,228
Brazoria	2,779	178	40,405	11,516	214	51,323
Brazos	7,137	99	22,515	6,417	213	29,553
Brewster	0	8	1,966	548	8	2,048
Briscoe	0	3	735	204	2	689
Brooks	6,884	8	2,231	649	9	2,317
Brown	52,015	34	8,902	2,519	38	9,630
Burleson	1,655	13	2,870	818	14	3,377

TABLE VII continued

State and County	1982 Milk Production (lbs.)	1982 Population (No.)	1982 Fluid Demand (lbs.)	1982 Sales Revenue ($)	1990 Population (No.)	1990 Fluid Demand (lbs.)
TEXAS continued	000's					
Burnet	2,779	19	4,040	1,147	24	5,465
Caldwell	0	25	5,214	1,480	28	6,486
Calhoun	0	20	4,488	1,279	21	4,933
Callahan	2,779	11	2,969	840	13	3,260
Cameron	2,779	220	59,171	17,298	267	70,812
Camp	22,079	10	2,105	582	11	2,529
Carson	0	7	1,923	533	7	1,982
Cass	0	30	6,697	1,852	35	8,189
Castro	11,381	11	3,032	840	11	3,074
Chambers	0	19	4,393	1,252	23	5,484
Cherokee	73,463	39	8,713	2,434	45	10,312
Childress	0	7	1,992	552	7	2,039
Clay	55,047	10	2,524	697	12	2,956
Cochran	0	5	1,212	339	5	1,177
Coke	0	3	877	248	4	1,008
Coleman	8,905	10	2,738	775	11	2,734
Collin	10,497	157	36,825	10,246	211	52,246
Collingsworth	0	5	1,321	366	5	1,321
Colorado	6,379	19	4,298	1,225	20	4,694
Comal	0	38	9,673	2,768	46	11,656
Comanche	156,450	13	3,357	950	14	3,511
Concho	0	0	786	222	3	822
Cooke	85,640	28	6,621	1,842	30	7,538
Coryell	2,779	61	11,718	3,293	80	15,191
Cottle	0	3	749	207	3	824
Crane	0	5	1,417	401	5	1,561
Crockett	0	5	1,283	363	6	1,539
Crosby	2,779	9	2,256	632	9	2,254
Culberson	0	3	861	240	4	926
Dallam	0	7	1,878	520	7	1,953
Dallas	15,953	1,602	374,707	104,258	1,771	439,121
Dawson	0	16	4,114	1,152	17	4,133
Deaf Smith	15,486	22	6,189	1,714	24	6,750
Delta	12,770	5	1,123	312	5	1,190

TABLE VII continued

State and County	1982 Milk Production (lbs.)	1982 Population (No.)	1982 Fluid Demand (lbs.)	1982 Sales Revenue ($)	1990 Population (No.)	1990 Fluid Demand (lbs.)
TEXAS continued			000's			
Denton	17,658	153	35,819	9,966	194	48,006
De Witt	23,797	19	4,312	1,229	20	4,694
Dickens	0	4	891	250	4	877
Dimmit	0	12	2,954	845	13	3,283
Donley	0	4	1,177	326	4	1,235
Duval	18,202	12	3,294	957	13	3,343
Eastland	6,960	20	5,178	1,465	22	5,392
Ector	0	120	35,929	10,166	143	41,375
Edwards	0	2	507	145	2	509
Ellis	21,233	62	14,388	4,003	68	16,911
El Paso	68,499	496	126,252	35,199	570	138,883
Erath	409,301	23	5,475	1,523	26	6,546
Falls	2,779	18	3,823	1,085	18	4,138
Fannin	11,078	25	5,741	1,597	26	6,323
Fayette	20,109	19	4,307	1,228	20	4,790
Fisher	6,581	6	1,537	435	6	1,480
Floyd	2,779	10	2,464	690	9	2,354
Foard	0	2	573	158	3	654
Fort Bend	2,779	142	32,280	9,200	192	45,934
Franklin	72,895	7	1,670	465	8	1,984
Freestone	0	15	3,257	925	18	3,958
Frio	8,690	14	3,593	1,028	16	4,046
Gaines	2,779	13	3,401	953	15	3,657
Galveston	0	200	45,233	12,892	216	51,610
Garza	0	5	1,349	378	6	1,378
Gillespie	11,027	14	3,537	1,012	16	4,072
Glasscock	0	1	402	114	2	463
Goliad	2,779	5	1,188	339	6	1,317
Gonzales	4,143	17	4,319	1,236	18	4,555
Gray	0	26	7,556	2,092	27	7,698
Grayson	26,387	91	21,309	5,929	96	23,730
Gregg	0	104	22,948	6,411	121	28,062
Grimes	83,543	14	3,128	892	15	3,497
Guadalupe	5,166	48	12,276	3,513	56	14,277
Hale	6,543	38	9,593	2,687	39	9,818

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
TEXAS continued			000's			
Hall	0	6	1,585	439	5	1,551
Hamilton	55,552	8	1,614	454	9	1,726
Hansford	0	6	1,768	490	6	1,781
Hardeman	0	7	1,649	455	8	1,817
Hardin	0	42	9,677	2,758	47	10,409
Harris	19,679	2,509	568,798	162,112	2,924	700,339
Harrison	2,779	54	11,950	3,339	61	14,159
Hartley	0	4	1,194	331	5	1,408
Haskell	2,779	8	2,009	568	8	1,956
Hays	3,436	43	9,245	2,624	56	12,616
Hemphill	0	6	1,625	450	7	2,097
Henderson	13,907	45	10,004	2,795	56	13,000
Hidalgo	19,300	298	80,263	23,464	367	97,406
Hill	35,911	25	4,885	1,373	28	5,216
Hockley	0	24	5,988	1,677	27	6,387
Hood	17,835	20	4,628	1,288	29	7,117
Hopkins	608,079	26	6,055	1,685	28	7,017
Howard	2,779	33	9,934	2,811	35	9,975
Hudspeth	2,779	3	687	192	3	683
Hunt	11,343	57	13,317	3,705	63	15,696
Hutchinson	0	26	7,562	2,094	27	7,842
Irion	0	1	385	109	2	451
Jack	2,779	7	1,750	487	8	1,909
Jackson	2,779	13	3,047	868	14	3,305
Jasper	3,549	32	7,275	2,073	35	7,679
Jeff Davis	0	2	418	118	2	414
Jefferson	0	235	58,280	16,610	260	57,640
Jim Hogg	0	5	1,340	383	6	1,451
Jim Wells	23,860	37	9,713	2,823	39	10,188
Johnson	155,225	71	16,564	4,609	83	20,631
Jones	2,779	17	4,559	1,290	18	4,589
Karnes	16,016	14	3,481	996	15	3,690
Kaufman	2,779	40	9,340	2,599	43	10,737
Kendall	13,806	11	2,852	816	14	3,588

TABLE VII continued

State and County	1982 Milk Production (lbs.)	1982 Population (No.)	1982 Fluid Demand (lbs.)	1982 Sales Revenue ($)	1990 Population (No.)	1990 Fluid Demand (lbs.)
TEXAS continued			000's			
Kenedy	0	1	132	38	1	132
Kent	0	1	289	82	1	251
Kerr	0	30	7,582	2,169	35	8,882
Kimble	0	4	1,107	313	5	1,220
King	0	0	102	29	0	100
Kinney	0	2	584	167	2	585
Kleberg	0	34	8,915	2,591	36	9,477
Knox	2,779	5	1,380	390	5	1,329
Lamar	31,767	43	9,545	2,640	49	11,436
Lamb	2,779	19	4,761	1,334	19	4,859
Lampasas	3,764	12	2,385	670	14	2,731
La Salle	0	6	1,406	402	6	1,476
Lavaca	12,000	19	4,352	1,240	20	4,790
Lee	0	11	2,441	693	14	3,058
Leon	0	10	2,194	625	10	2,395
Liberty	2,779	49	11,067	3,154	54	13,435
Limestone	2,779	20	3,903	1,097	21	4,002
Lipscomb	0	4	1,091	302	4	1,092
Live Oak	0	10	2,623	762	12	3,027
Llano	0	11	2,284	648	14	3,036
Loving	0	1	174	49	0	29
Lubbock	2,779	216	55,017	15,411	241	60,285
Lynn	0	9	2,179	610	9	2,179
McCulloch	4,964	9	2,358	667	10	2,547
McLennan	48,036	173	33,236	9,341	185	35,162
McMullen	0	1	203	58	1	204
Madison	6,505	11	2,484	708	12	2,970
Marion	0	11	2,377	664	12	2,804
Martin	0	5	1,435	406	5	1,532
Mason	0	4	1,010	286	4	1,114
Matagorda	0	39	8,795	2,507	43	10,274
Maverick	0	33	8,343	2,387	40	10,053
Medina	2,779	24	6,029	1,725	27	6,744
Menard	0	2	625	177	3	633
Midland	2,779	86	25,773	7,292	104	29,925

TABLE VII continued

State and County	1982 Milk Production (lbs.)	1982 Population (No.)	1982 Fluid Demand (lbs.)	1982 Sales Revenue ($)	1990 Population (No.)	1990 Fluid Demand (lbs.)
TEXAS continued			000's			
Milam	14,943	23	4,444	1,249	25	4,779
Mills	7,869	5	870	245	5	910
Mitchell	0	9	2,376	672	9	2,307
Montague	19,465	18	4,174	1,161	20	4,855
Montgomery	5,949	141	31,863	9,081	198	47,299
Moore	2,779	17	4,903	1,358	20	5,601
Morris	0	15	3,322	919	18	4,060
Motley	0	2	499	140	2	501
Nacogdoches	41,203	49	10,900	3,045	60	13,811
Navarro	5,810	36	8,371	2,329	38	9,299
Newton	2,779	14	3,130	3,130	892	3,240
Nolan	2,779	18	4,606	1,303	19	4,690
Nueces	6,518	271	71,666	20,830	290	76,451
Ochiltree	0	10	2,744	760	10	2,786
Oldham	2,779	2	660	183	2	689
Orange	0	86	19,733	5,624	92	20,486
Palo Pinto	2,779	25	5,732	1,595	26	6,447
Panola	14,981	21	4,749	1,327	25	5,701
Parker	78,389	47	10,949	3,047	55	13,737
Parmer	2,779	11	3,181	881	12	3,332
Pecos	0	15	4,490	1,270	17	4,944
Polk	2,779	26	5,830	1,662	31	7,472
Potter	0	98	28,076	7,775	98	28,007
Presido	0	5	1,324	369	5	1,316
Rains	34,028	5	1,170	325	6	1,438
Randall	17,570	77	22,191	6,145	88	25,364
Reagan	0	4	1,160	328	6	1,486
Real	0	3	645	184	3	713
Red River	4,711	16	3,590	993	18	4,083
Reeves	2,779	16	4,838	1,369	18	5,262
Refugio	0	9	2,448	712	9	2,448
Roberts	0	1	356	99	1	402
Robertson	2,779	15	3,359	957	16	3,712
Rockwall	0	16	3,673	1,022	21	5,133
Runnels	12,568	12	3,213	909	13	3,449

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
TEXAS continued			000's			
Rusk	12,480	43	9,472	2,646	49	11,262
Sabine	0	9	2,052	585	10	2,131
San Augustine	0	9	1,995	557	10	2,294
San Jacinto	2,779	12	2,738	780	15	3,568
San Patricio	0	59	15,587	4,530	65	16,980
San Saba	0	6	1,550	439	6	1,618
Schleicher	0	3	770	218	3	902
Scurry	2,779	19	4,858	1,374	20	5,116
Shackelford	2,981	4	1,054	298	5	1,129
Shelby	3,928	24	5,237	1,463	26	6,025
Sherman	0	3	919	254	3	948
Smith	19,755	134	29,603	8,270	156	36,150
Somervell	0	4	1,039	289	3	1,339
Starr	0	29	7,737	2,262	35	9,396
Stephens	0	10	2,660	753	11	2,859
Sterling	0	1	331	94	1	371
Stonewall	0	2	629	178	2	602
Sutton	0	5	1,427	404	7	1,724
Swisher	2,779	10	2,762	765	10	2,729
Tarrant	48,226	889	208,040	57,885	997	247,122
Taylor	2,779	112	29,487	8,343	122	30,621
Terrell	0	2	438	124	2	478
Terry	0	15	3,707	1,038	15	3,732
Throckmorton	2,779	2	540	153	2	502
Titus	10,193	22	4,859	1,347	26	5,938
Tom Green	25,136	87	23,363	6,610	101	26,848
Travis	16,774	447	95,053	26,984	566	127,302
Trinity	0	10	2,199	627	11	2,563
Tyler	0	17	3,873	1,104	19	4,239
Upshur	94,292	30	6,598	1,843	35	8,087
Upton	0	5	1,405	397	5	1,475
Uvalde	0	23	5,857	1,676	26	6,668
Val Verde	0	37	9,434	2,700	43	10,943
Van Zandt	39,940	33	7,636	2,125	37	9,274
Victoria	2,779	70	15,977	4,554	78	18,560

TABLE VII continued

	1982				1990	
State and County	Milk Production (lbs.)	Population (No.)	Fluid Demand (lbs.)	Sales Revenue ($)	Population (No.)	Fluid Demand (lbs.)
TEXAS continued	000's					
Walker	2,779	44	10,020	2,856	54	12,980
Waller	6,328	21	4,652	1,326	23	5,604
Ward	0	14	4,298	1,216	16	4,684
Washington	24,062	22	5,087	1,450	24	5,820
Webb	0	103	26,050	7,454	118	30,107
Wharton	2,779	41	9,222	2,628	43	10,250
Wheeler	2,779	7	2,061	571	8	2,183
Wichita	2,779	126	31,726	8,762	152	36,903
Wilbarger	0	17	4,157	1,148	20	4,773
Willacy	0	18	4,825	1,411	20	5,308
Williamson	14,728	84	17,797	5,052	116	25,996
Wilson	51,838	17	4,385	1,255	20	4,963
Winkler	0	10	3,043	841	12	3,325
Wise	169,283	28	6,448	1,794	31	7,712
Wood	90,275	26	5,689	1,589	30	6,952
Yoakum	2,779	8	2,154	603	9	2,354
Young	2,779	20	5,072	1,401	26	6,227
Zapata	0	7	1,756	502	8	2,138
Zavala	2,779	12	3,023	864	13	3,308

TABLE VIII

POSSIBLE PLANT LOCATIONS (COUNTY AND CITY), 1982 F.M.O. CLASS I PRICES, AND WHETHER LOCATION HAD AN EXISTING PLANT IN 1982

State and County	Plant Node Number	City	1982 Class I Price	1982 Existing Plant
			($/cwt)	
ARKANSAS				
Benton	1	Bentonville	14.25	Yes
Craighead	2	Jonesboro	14.42	No
Faulkner	3	Conway	14.42	Yes
Garland	4	Hot Springs	14.42	Yes
Greene	5	Paragould	14.42	Yes
Jefferson	6	Pine Bluff	14.42	No
Mississippi	7	Blytheville	14.42	No
Ouachita	8	Camden	14.42	Yes
Pulaski	9	Little Rock	14.42	Yes
Saline	10	Little Rock	14.42	No
Sebastian	11	Ft. Smith	14.44	Yes
Washington	12	Fayetteville	14.25	Yes
White	13	Little Rock	14.44	No
KANSAS				
Butler	14	El Dorado	14.28	Yes
Crawford	15	Pittsburg	14.13	Yes
Finney	16	Garden City	14.33	Yes
Neosho	17	Chaute	14.13	Yes
Reno	18	Hutchinson	14.28	Yes
Sedgwick	19	Wichita	14.28	Yes
LOUISIANA				
Bossier	20	Bossier City	14.95	No
Caddo	21	Shreveport	14.95	Yes
Ouachita	22	Monroe	14.95	Yes
Webster	23	Minden	14.95	Yes

TABLE VIII continued

State and County	Plant Node Number	City	1982 Class I Price	1982 Existing Plant
			($/cwt)	
MISSISSIPPI				
De Soto	24	Memphis	14.53	No
Grenada	25	Grenada	14.83	Yes
Lafayette	26	Oxford	14.56	Yes
Lee	27	Tupelo	14.83	Yes
Marshall	28	Red Bank	14.53	Yes
Union	29	New Albany	14.56	Yes
Washington	30	Greenville	14.93	Yes
MISSOURI				
Barton	31	Lamar	14.13	Yes
Jasper	32	Joplin	14.13	Yes
NEW MEXICO				
Bernalillo	33	Albuquerque	14.83	Yes
Chaves	34	Roswell	14.83	Yes
Curry	35	Clovis	14.68	Yes
Dona Ana	36	Las Cruces	14.83	No
Lea	37	Hobbs	14.68	No
McKinley	38	Gallup	14.83	No
San Juan	39	Farmington	14.68	Yes
Santa Fe	40	Santa Fe	14.83	No
Valencia	41	Albuquerque	14.83	No
OKLAHOMA				
Beckham	42	Elk City	14.52	Yes
Canadian	43	Oklahoma City	14.56	No
Carter	44	Ardmore	14.53	Yes
Cleveland	45	Norman	14.46	Yes
Comanche	46	Lawton	14.56	Yes
Creek	47	Tulsa	14.36	No
Garfield	48	Enid	14.36	Yes
Kay	49	Ponca City	14.36	Yes
Muskogee	50	Muskogee	14.36	No
Oklahoma	51	Oklahoma City	14.46	Yes
Payne	52	Stillwater	14.36	No
Pottowatomie	53	Shawnee	14.46	No
Tulsa	54	Tulsa	14.36	Yes

TABLE VIII continued

State and County	Plant Node Number	City	1982 Class I Price	1982 Existing Plant
			($/cwt)	
TENNESSEE				
Madison	55	Jackson	14.29	No
Shelby	56	Memphis	14.42	Yes
Tipton	57	Covington	14.42	Yes
TEXAS				
Angelina	58	Lufkin	14.98	Yes
Bell	59	Temple	14.95	No
Bexar	60	San Antonio	15.22	Yes
Bowie	61	Texarkana	14.71	Yes
Brazoria	62	Houston	15.16	No
Brazos	63	Bryan	15.00	Yes
Cameron	64	Brownsville	15.55	Yes
Collin	65	Dallas	14.80	No
Coryell	66	Killeen	14.95	No
Dallas	67	Dallas	14.80	Yes
Denton	68	Denton	14.80	No
Ector	69	Odessa	15.05	No
Ellis	70	Dallas	14.80	No
El Paso	71	El Paso	14.83	Yes
Fort Bend	72	Houston	15.16	No
Galveston	73	Galveston	15.16	No
Grayson	74	Sherman	14.80	No
Gregg	75	Longview	14.86	Yes
Harris	76	Houston	15.16	Yes
Harrison	77	Marshall	14.86	No
Hidalgo	78	Edinburg	15.55	Yes
Hunt	79	Greenville	14.80	No
Jefferson	80	Beamont	15.16	Yes
Johnson	81	Fort Worth	14.80	No
Lubbock	82	Lubbock	14.90	Yes
McLennan	83	Waco	14.95	Yes
Midland	84	Midland	15.05	Yes
Montgonery	85	Houston	15.16	No
Nueces	86	Corpus Christi	15.46	Yes
Orange	87	Beaumont	15.16	No
Potter	88	Amarillo	14.73	Yes
Randall	89	Amarillo	14.73	No

TABLE VIII continued

State and County	Plant Node Number	City	1982 Class I Price	1982 Existing Plant
			($/cwt)	
TEXAS (Continued)				
San Patrico	90	Corpus Christi	15.46	No
Smith	91	Tyler	14.86	Yes
Tarrant	92	Fort Worth	14.80	Yes
Taylor	93	Abilene	15.05	Yes
Tom Green	94	San Angelo	15.05	Yes
Travis	95	Austin	15.10	Yes
Victoria	96	Victoria	15.33	No
Webb	97	Laredo	15.36	No
Wichita	98	Wichita Falls	14.69	Yes
Williamson	99	Austin	15.10	No

TABLE IX

THE 32 BEAs AND THE RELATED 1982 DATA USED TO ESTIMATED FLUID MILK DEMAND AND 1982 PER CAPITA FLUID MILK CONSUMPTION

	BEA Code	RMP ¢/Half-gal	INC $/year	BLKP No/1000	LTS No/1000	5-19 No/1000	45-64 No/1000	GT65 No/1000	Per Capita Fluid Milk Consumption lbs./year
Memphis	55	1.166	4,341	299	76	248	193	132	192
St. Louis	107	1.138	5,541	142	74	234	196	123	244
Springfield	108	1.138	4,345	29	61	221	207	166	256
Fayetteville	109	1.152	4,117	49	70	227	203	154	268
Ft. Smith	110	1.167	3,973	82	69	240	212	154	259
Little Rock	111	1.166	4,477	176	69	232	205	143	230
Shreveport	117	1.209	4,292	307	76	246	198	134	193
Monroe	118	1.209	3,792	302	77	255	190	131	186
Texarkana	119	1.189	4,467	218	68	228	212	169	221
Tyler/Longview	120	1.201	4,826	204	65	226	212	164	221
Beaumont	121	1.226	5,450	228	70	239	212	123	248
Houston	122	1.226	6,284	202	82	246	185	86	227
Austin	123	1.221	4,963	109	75	235	167	103	213
Waco	124	1.209	4,924	177	63	206	183	147	192
Dallas/Ft. Worth	125	1.196	5,898	152	83	238	180	92	234
Wichita Falls	126	1.188	6,151	89	62	212	211	167	252
Abilene	127	1.217	5,239	56	60	203	225	210	263
San Angelo	128	1.217	5,441	40	66	218	213	171	269
San Antonio	129	1.230	4,533	65	86	260	182	105	254
Corpus Christie	130	1.250	4,753	49	85	246	189	106	264
Brownsville	131	1.257	2,957	8	100	295	175	113	269
Midland/Odessa	132	1.217	6,389	68	79	234	221	105	299
El Paso	133	1.199	4,027	44	89	265	173	89	255
Lubbock	134	1.205	5,097	69	82	242	186	114	255

TABLE IX continued

	BEA Code	RMP ¢/Half-gal	INC $/year	BLKP No/1000	LTS No/1000	5-19 No/1000	45-64 No/1000	GT65 No/1000	Per Capita Fluid Milk Consumption lbs./year
Amarillo	135	1.191	5,787	46	75	235	214	132	288
Lawton	136	1.177	4,622	140	70	221	168	123	198
Oklahoma City	137	1.169	5,349	114	68	228	202	134	245
Tulsa	138	1.161	5,575	139	68	225	206	130	245
Wichita	139	1.154	5,954	69	69	218	208	144	267
Colorado Springs	158	1.195	4,801	55	78	238	170	91	240
Grand Junction	159	1.171	4,829	58	71	244	202	125	262
Albuquerque	160	1.199	4,873	149	86	271	181	90	237

TABLE X

THE 32 BEAs AND THE RELATED 1990 DATA USED TO ESTIMATE FLUID MILK DEMAND AND 1990 PER CAPITA FLUID MILK CONSUMPTION

	BEA Code	RMP ¢/Half-gal	INC $/year	BLKP No/1000	LTS No/1000	5-19 No/1000	45-64 No/1000	GT65 No/1000	Per Capita Fluid Milk Consumption lbs./year
Memphis	55	116.6	5,548	281	74	221	197	142	202
St. Louis	107	113.8	6,781	157	79	216	191	126	244
Springfield	108	113.8	5,488	32	64	199	204	172	257
Fayetteville	109	115.2	5,099	55	76	211	204	153	268
Ft. Smith	110	116.7	4,974	79	74	217	218	156	274
Little Rock	111	116.6	5,569	160	72	208	207	152	241
Shreveport	117	120.9	5,270	292	75	219	199	148	198
Monroe	118	120.9	4,720	273	75	224	193	142	195
Texarkana	119	118.9	5,491	204	69	200	217	177	233
Tyler/Longview	120	120.1	5,951	181	66	199	213	173	232
Beaumont	121	122.6	6,669	235	70	214	206	141	222
Houston	122	122.6	8,029	203	84	227	188	93	240
Austin	123	122.1	6,179	104	78	220	169	104	225
Waco	124	120.9	6,053	154	63	187	173	154	190
Dallas/Ft. Worth	125	119.6	7,298	160	88	223	184	94	248
Wichita Falls	126	118.8	7,773	98	60	193	205	187	243
Abilene	127	121.7	6,730	64	59	177	219	241	251
San Angelo	128	121.7	6,976	41	67	197	209	186	266
San Antonio	129	123.0	5,577	67	90	242	177	114	254
Corpus Christie	130	123.0	5,957	54	86	225	187	124	264
Brownsville	131	125.7	3,689	7	102	264	170	129	265
Midland/Odessa	132	121.7	8,208	73	75	209	216	133	288
El Paso	133	119.9	4,833	49	92	247	162	104	244
Lubbock	134	120.5	6,700	72	83	222	179	130	250

TABLE X continued

	BEA Code	RMP ¢/Half-gal	INC $/year	BLKP No/1000	LTS No/1000	5-19 No/1000	45-64 No/1000	GT65 No/1000	Per Capita Fluid Milk Consumption lbs./year
Amarillo	135	119.1	7,349	50	77	206	212	157	288
Lawton	136	117.7	5,754	162	71	205	161	131	187
Oklahoma City	137	116.9	6,719	125	70	211	203	139	250
Tulsa	138	116.1	6,999	151	70	204	207	140	249
Wichita	139	115.4	7,595	83	69	197	200	161	256
Colorado Springs	158	119.5	5,967	64	82	224	169	93	235
Grand Junction	159	117.1	6,169	72	74	221	199	137	258
Albuquerque	160	119.9	6,317	165	87	251	180	103	236

TABLE XI

MODEL I - LEAST COST 1982 EXISTING PLANT SYSTEM, PLANT SUMMARY, COST AND REVENUE

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
				000's			
1	518	17	61	1,933	7,394	9,407	4,487
3	541	18	102	2,009	7,810	9,941	4,711
4	262	31	14	1,051	786	4,883	2,247
5	1,044	397	194	3,617	15,067	19,277	8,859
8	339	59	36	1,323	4,899	6,319	2,936
9	1,718	233	180	5,647	24,786	30,847	15,750
11	802	62	82	2,865	11,581	15,582	7,190
12	655	22	92	2,383	9,337	11,836	5,741
13	140	7	5	600	1,984	2,598	1,119
16	463	95	135	1,754	6,710	8,706	3,987
17	313	12	35	1,231	4,426	5,705	2,586
18	492	23	66	1,845	7,033	8,969	4,253
19	1,374	68	64	4,624	19,632	24,390	12,513
21	829	67	39	2,938	12,380	15,425	7,833
22	625	146	56	2,235	9,531	11,841	5,673
23	151	6	7	641	2,259	2,915	1,332
25	219	28	22	895	3,254	4,199	1,748
26	196	18	18	811	2,863	3,712	1,819
27	579	63	79	2,134	8,594	10,872	4,837
28	73	2	1	337	1,071	1,412	586
29	79	2	3	360	1,156	1,523	630
30	382	174	32	1,473	5,715	7,395	2,982
31	81	6	5	367	1,147	1,527	621
32	479	16	23	1,803	6,782	8,627	4,079

TABLE XI continued

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
	- - - - - - - - -	- - - - - - - - -	- - - - - - - - -	- - - - 000's - - - -	- - - - - - - - -	- - - - - - - - -	- - - - - - - - -
33	1,838	185	275	5,998	27,673	33,722	17,526
34	426	14	97	1,623	6,265	8,000	3,916
35	307	15	36	1,210	4,512	5,775	2,762
39	517	223	115	1,929	7,598	9,865	4,477
42	376	22	69	1,452	5,472	7,016	3,290
44	396	35	55	1,517	5,750	7,358	3,488
45	548	24	35	2,033	7,937	10,031	4,890
46	313	10	12	1,232	4,565	5,820	2,761
48	287	23	39	1,139	4,127	5,330	2,483
49	319	30	31	1,251	4,582	5,895	2,705
51	2,344	272	176	7,465	33,899	41,804	21,896
54	2,325	343	208	7,401	33,393	41,347	21,453
56	2,151	773	118	6,904	31,025	38,821	19,507
57	852	379	216	3,014	12,286	15,896	7,201
58	467	37	49	1,761	7,002	8,851	4,288
60	3,634	1,477	323	11,873	55,320	68,994	35,014
61	708	95	88	2,554	10,417	13,156	6,379
63	460	32	34	1,739	6,912	8,718	4,397
64	639	391	9	2,333	9,951	12,685	6,022
67	5,398	1,014	337	16,917	79,904	98,173	51,999
71	1,814	177	191	5,927	26,905	33,202	17,379
75	438	25	22	1,664	6,519	8,231	4,024
76	7,854	5,559	447	24,690	119,071	149,768	74,085

TABLE XI continued

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
				000's			
78	897	543	26	3,157	13,957	17,684	8,543
80	980	403	50	3,419	14,871	18,744	9,213
82	1,038	287	106	3,598	15,473	19,465	9,640
83	996	70	124	3,468	14,902	18,565	9,469
84	992	401	135	3,456	14,942	18,935	9,148
86	1,694	248	295	5,574	26,190	33,308	15,708
88	1,022	279	153	3,549	15,065	19,047	9,275
91	897	78	104	3,151	13,336	16,676	8,372
92	2,639	203	111	8,291	39,069	47,675	25,790
93	663	139	80	2,409	9,982	12,611	6,155
94	420	33	52	1,601	6,323	8,010	3,879
95	1,528	476	102	5,035	23,086	28,751	14,659
98	616	40	63	2,247	9,014	11,365	5,588
PLANT SYSTEM TOTALS	61,180	16,960	5,762	207,581	905,925	1,136,229	565,671

TABLE XII

MODEL II - OPTIMUM 1982 MINIMUM TOTAL COST MARKET ORGANIZATION PLANT SUMMARY, COST AND REVENUE

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
	- - - - - - - -	- - - - - - - -	- - - - - - - -	- - - - - - 000's	- - - - - - - -	- - - - - - - -	- - - - - - - -
8	3,121	1,307	1,157	9,633	45,016	56,845	29,869
9	2,143	242	272	6,882	30,916	38,313	19,808
12	1,947	110	481	6,315	27,752	34,660	17,921
19	2,707	265	738	8,480	38,657	48,142	24,730
32	1,788	171	456	5,852	25,273	31,754	15,788
33	2,369	394	629	7,527	35,141	43,692	22,279
37	2,948	895	1,313	9,152	43,279	54,641	28,235
42	1,955	365	1,002	6,337	28,387	36,092	17,932
44	2,692	404	1,043	8,438	39,118	49,005	25,752
45	2,946	291	357	9,149	42,613	52,410	27,760
54	2,422	368	253	7,676	34,781	43,079	22,349
55	2,199	844	640	7,041	31,427	39,953	19,543
56	2,991	1,079	435	9,272	43,135	53,923	27,171
58	1,609	237	526	5,326	24,115	30,206	15,491
60	5,167	2,008	1,214	16,265	78,642	98,130	50,257
63	9,726	4,411	3,766	29,895	145,897	183,971	93,086
71	1,796	175	177	5,876	26,647	32,876	17,219
75	1,094	65	165	3,771	16,265	20,268	10,302
78	1,561	866	141	5,181	24,276	30,466	15,158
81	1,902	87	618	6,185	28,158	35,050	18,383
92	6,087	931	537	18,835	90,097	110,402	58,981
PLANT SYSTEM TOTALS	61,180	15,255	15,930	193,097	899,602	1,123,885	578,015

TABLE XIV

MODEL IV - OPTIMUM 1982 MAXIMUM PRODUCER RETURNS MARKET ORGANIZATION PLANT SUMMARY, COST AND REVENUE

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
	- - - - - - - - - - -	- - - - - - - - - - -	- - - - - - - - - - -	000's	- - - - - - - - - - -	- - - - - - - - - - -	- - - - - - - - - - -
21	728	56	18	2,619	10,877	13,582	6,886
24	3,652	1,698	809	11,925	53,071	67,504	31,410
1	1,561	103	404	5,181	22,246	27,936	13,533
30	227	58	14	923	3,392	4,389	1,816
42	615	44	180	2,252	8,934	11,411	5,505
34	1,407	169	718	4,722	20,661	26,273	13,218
94	722	114	290	2,601	10,878	13,885	6,666
82	1,264	366	248	4,291	18,841	23,748	11,793
26	547	147	131	2,029	7,975	10,283	4,565
23	151	6	7	641	2,259	2,915	1,332
91	8,444	1,396	6,179	26,344	125,490	159,411	80,806
22	518	72	33	1,931	7,745	9,783	4,779
48	386	33	57	1,485	5,550	7,127	3,379
53	490	30	96	1,840	4,003	9,064	4,324
74	270	9	8	1,079	16,608	5,100	2,425
88	1,127	278	240	3,872	1,772	21,000	10,272
49	123	6	-	534	45,055	2,313	1,017
3	3,124	394	853	9,640	15,044	55,943	28,823
12	1,055	55	216	3,651	12,230	18,968	9,473

TABLE XIV continued

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
	- - - - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - - 000's	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -	- - - - - - - - - -
29	840	125	169	2,976	12,230	15,500	7,271
46	417	15	35	1,590	6,072	7,713	3,714
99	5,311	1,626	1,931	16,670	80,199	100,427	51,130
52	360	12	26	1,395	5,175	6,609	3,145
43	222	7	13	908	3,223	4,152	1,907
47	455	51	74	1,720	6,538	8,385	3,935
68	4,604	620	611	14,670	68,142	84,044	44,063
79	535	37	68	1,988	7,922	10,172	4,860
54	1,934	281	140	6,276	27,774	34,472	17,684
45	2,112	181	182	6,791	30,540	37,695	19,721
90	2,966	1,123	1,164	9,202	45,859	57,350	28,990
18	945	69	439	3,309	13,505	17,324	8,159
81	4,145	412	874	13,355	61,353	75,996	39,888
41	2,272	287	757	7,251	33,704	42,001	21,274
11	1,024	89	334	3,553	14,786	18,764	9,230
19	1,554	90	118	5,162	22,200	27,571	14,133
36	1,671	57	289	5,508	24,789	30,644	15,959
75	1,254	90	351	4,259	18,635	23,337	11,831
93	482	82	32	1,812	7,264	9,193	4,464
96	1,031	211	284	3,574	15,805	19,876	9,580
98	618	41	90	2,264	9,092	11,488	5,707
PLANT SYSTEM TOTALS	61,180	10,563	18,500	201,181	902,334	1,701,901	568,687

TABLE XV

MODEL V - OPTIMUM 1990 MINIMUM TOTAL COST MARKET ORGANIZATION PLANT SUMMARY, COST AND REVENUE

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
	- -	-	-	000's	- -	-	-
3	2,195	210	348	7,031	31,664	39,255	20,273
6	3,006	1,199	1,239	9,313	43,347	55,100	27,691
12	2,429	166	649	7,698	34,627	43,142	22,551
19	2,822	285	779	8,803	40,307	50,175	25,797
32	2,039	226	529	6,582	28,821	36,159	18,051
33	2,625	526	661	8,250	38,933	48,372	24,726
37	3,014	998	1,390	9,337	44,255	55,982	28,915
44	2,508	372	787	7,921	36,451	45,533	23,953
46	1,763	192	694	5,780	25,682	32,349	16,595
51	3,039	384	227	9,405	43,947	53,964	28,656
54	2,728	550	288	8,538	39,176	48,554	25,143
55	2,483	1,394	717	7,849	35,485	45,446	21,744
56	3,056	1,403	335	9,452	44,073	55,265	27,592
66	6,469	1,423	2,966	19,888	96,713	120,992	63,323
71	1,974	199	193	6,392	29,276	36,062	18,977
75	3,106	346	728	9,591	46,166	56,833	30,131
76	9,492	6,257	468	29,250	143,901	179,877	90,657
80	1,091	439	72	3,762	16,551	20,826	10,290

TABLE XV continued

Plant Node No.	Plant Area Demand (cwt.)	Bulk Milk Assembly Cost ($)	Processed Fluid Milk Distribution Cost ($)	Plant Processing Cost ($)	Raw Fluid Milk Cost ($)	Total Cost ($)	Net Operating Revenue ($)
	- 000's -						
83	1,033	78	221	3,582	15,452	19,335	9,940
88	1,677	514	461	5,525	24,704	31,206	15,312
92	7,959	1,321	802	24,986	117,803	144,913	76,621
96	1,616	373	441	5,345	24,781	30,941	15,813
97	2,509	1,459	1,250	7,923	38,541	49,174	23,830
PLANT SYSTEM TOTALS	70,644	20,324	16,258	222,214	1,040,667	1,299,465	666,589

VITA

Cary William Herndon, Jr.

Candidate for the Degree of

Doctor of Philosophy

Thesis: VERTICAL INTEGRATION BY REGIONAL MILK COOPERATIVES IN THE SOUTHWEST: POTENTIALS AND PROBLEMS

Major Field: Agricultural Economics

Biographical:

Personal Data: Born in Sugar Land, Texas, September 29, 1952, the son of Mr. and Mrs. Cary W. Herndon, Sr.

Education: Graduated from Alief High School, Alief, Texas in May, 1971; received the Bachelor of Science degree in Agricultural Economics from Texas A&M University, College Station, Texas, in May, 1975; received the Master of Agriculture degree in Agricultural Economics from Texas A&M University in December, 1977; completed requirements for the Doctor of Philosophy degree in Agricultural Economics from Oklahoma State University in July, 1984.

Professional Experience: Research Associate, Department of Agricultural Economics, Texas A&M University, May, 1976 through May, 1977; Research Associate, Texas Transportation Institute, Texas A&M University, June, 1977 through August, 1979; Graduate Research Assistant, Department of Agricultural Economics, Oklahoma State University, September, 1979 through March, 1984.

Professional Organizations: American Agricultural Economics Association, Southern Agricultural Economics Association, Western Agricultural Economics Association.