GIS AND THE DAIRY INDUSTRY: EXAMINING THE ROLES OF GOVERNMENT REGULATION AND DAIRY COOPERATIVES IN THE SHIPMENT OF FLUID MILK

by

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(ABSTRACT)

This thesis deals with the use of Geographic Information Systems (GIS) in the transport of raw fluid milk from its origin on the farm to the processing plant. Current applications of GIS in transportation planning are discussed. Spatial, physical, administrative and legal constraints affecting the shipment of fluid milk are outlined, especially the roles of government legislation and dairy cooperatives. GIS is used to evaluate milk hauling efficiencies on both local and regional scales. The case study focuses on Rockingham and Augusta counties in northwestern Virginia and the surrounding hinterland. On the local scale GIS network functions are used to determine optimal routes for milk trucks between dairy farms in these counties and the processing plant in Mt. Crawford, Virginia. Comparisons are made between the results achieved by GIS and the results obtained through traditional methods of route planning. A regional scale case study uses GIS allocation functions to evaluate the effect of government regulations (Federal and State Order Markets) on the efficiency of hauling fluid milk from farms in the study area to plants outside the region. Results indicate that government regulations and cooperative decisions shape the morphology of fluid milk shipment and that GIS is a useful tool

for regional milk marketing. Finally, a mail survey assesses the present use of automated systems and GIS among dairy cooperatives, and the possibility of future implementation of such systems in the dairy industry.

DEDICATION

This thesis is dedicated to my wife, Kimberly, who has unselfishly endured a difficult pregnancy over the last several months. With this work requiring much of my time, she has been able to make do because of her strong courage, and lots help from her family. I also dedicate this thesis to Dianne Morrill, the late wife of my Major Professor, Dr. Bob Morrill. Even though I never met her, I can see through her husband the humanitarian qualities that she must also possess.

ACKNOWLEDGMENTS

I would like to sincerely thank my committee members, Bob Morrill, Bill Carstensen, and Bob James, for encouraging my efforts in this work and for their insights into the thesis. I wish to thank Craig Jones at Valley of Virginia Cooperative for taking time to explain the details of milk shipment. I also owe a great deal to my mother and father, who have continually encouraged me to "get it done." Finally, I could not have completed this work without the help of the Cosgriff family who have kept a close watch on Kimberly during her illness.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1: INTRODUCTION

GIS has gained a wider acceptance in transportation applications in recent years. Increased computing speed and the availability of GIS software have allowed for the practical application of this technology in transportation analyses. For example, the problem of determining the shortest path between two points over a road network, although theoretically possible, has only become practical, on a large scale, within the last decade. Other GIS functions that deal with the allocation of resources from multiple sources to multiple centers is another area where faster computing and improved algorithms have allowed for growth in the number and quality of practical applications. Indeed the transportation industry is one industry "ripe for GIS technology," (Francica, 1992).

One industry where GIS has not been widely implemented for use in transportation planning is the dairy industry. Transportation planning in the dairy industry normally involves the shipment of milk in two phases. First, raw milk is picked up at the farm by trucks and shipped to the processing plant. Second, after being processed and packaged, milk is sent to the retail location. This thesis focuses primarily on the transport of milk from the farm to the processing plant.

Raw milk is generally divided into two grades based on quality. Grade A refers to that milk suitable for fluid consumption. Grade B, or manufacturing grade milk, is suitable for being made into ice cream, cottage cheese, yogurt, cheese, butter, and powder milk (Jesse and Cropp, 1994). For pricing purposes, milk is further grouped into classes according to its use. Class I refers to milk fluid milk. Class II includes milk used for "soft" products such as ice cream. Class III milk will be processed into butter or cheese and Class IV refers to milk that will be made into dry powder milk products. The data and operations included in this thesis deal strictly with the production and shipment of Grade A milk. Prices for raw fluid milk listed in this thesis refer to the Class I (fluid) price.

The planning of fluid milk hauling routes from the production point on the farm to the processing plant involves several constraints that make it both an interesting possibility and a challenge in the development of a GIS. The selection of optimal routes for visiting farms and then moving the milk on to the plant is constrained by at least three basic variables: distance from farm to plant, the amount of milk collected at each farm, and the fluid capacity of the truck. Ultimate route selection is also affected by factors difficult to code into a GIS, such as farm milking schedules, farmer preference and tradition.

The highly perishable nature of milk and its extremely bulky nature are unique physical characteristics that impose time and size constraints upon transport planning. By law, milk can remain on a farm after milking for no longer than 48 hours. Normally milk is picked up from dairy farms by refrigerated trucks every other day. In some cases, where milk production exceeds the capacity of the farm's holding tank, milk must be picked up every day. In general, two types of trucks are used for the shipment of fluid milk. Tractor-trailers can carry up to 47,300 pounds (5500 gallons) of milk, straight trucks hold only 30,100 pounds (3500 gallons). These size restrictions limit the number of farms that can be serviced in one trip by each truck. For example, in Virginia in 1995, dairy farmers produced over 1.9 billion pounds of Grade A quality milk, or an average of 7867 pounds per farm every other day (Statistical Summary, 1995). Using this average, a tractor trailer could visit 6 farms per trip while the straight trucks could visit only 3.8 farms per trip. For a dairy cooperative handling milk from 300 farms, these constraints necessitate the planning of 25 trips per day using tractor trailers, or 40 trips per day with straight trucks. Due to such capacity limitations and intensive route planning requirements, the automated efficiency provided by GIS can be of great worth to the dairy industry.

Another phenomenon that gives place for the use of GIS in the dairy industry is that of increased distances over which milk must now be shipped. Both the distance between farm and processor and that between processor and retailer have increased. From 1947 to 1977, the distance between dairy farms and the milk retailer increased dramatically (Figures 1 and 2). This change can be attributed to several factors, among which are technological advances in trucking, refrigeration, highways, sanitation and packaging, (Lough and Fallert, 1977).

This thesis will deal mainly with the movement of milk between the farm and the processor. I will argue that, in addition to increased distances between farms and retailers, the average distance between farms and processing plants has also increased. These increases have created a need for better transportation planning, especially those benefits that could be provided by GIS.

In order to design a strategy for milk hauling, an attempt must first be made to understand the regulatory and administrative framework on which the dairy industry operates. This framework includes the functions of entities such as dairy cooperatives and federal and state order markets. Dairy cooperatives are organizations formed by dairy farmers. Though their size and scope of responsibilities vary, cooperatives are generally responsible for most aspects of milk marketing. Ordered markets are legislatively established regions within which the

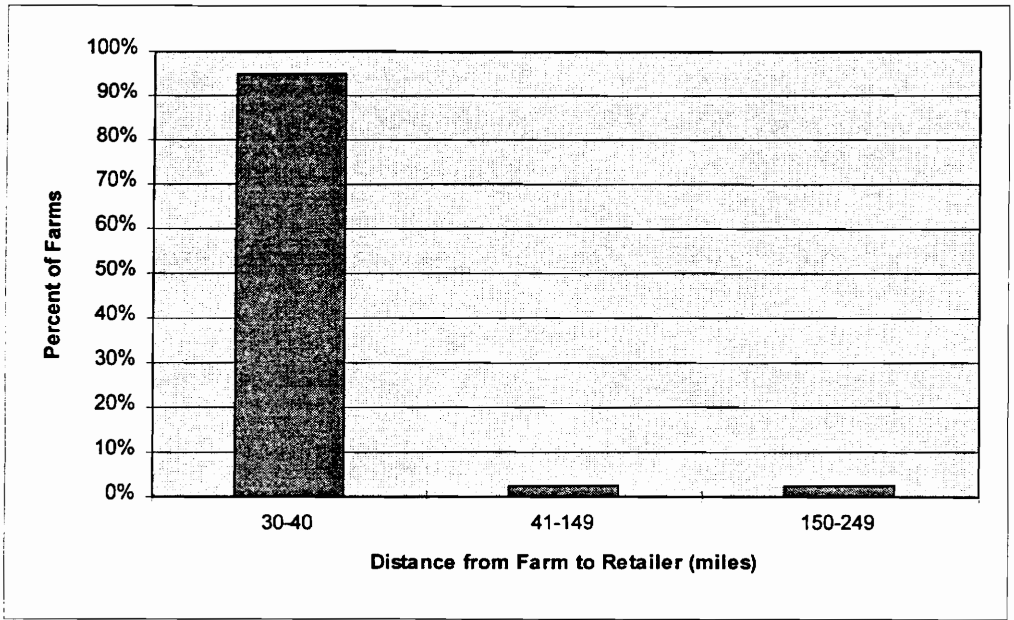


Figure 1. Percentage of U.S. dairy farms within specified distances of retailer, 1947, (Lough and Fallert, 1977).

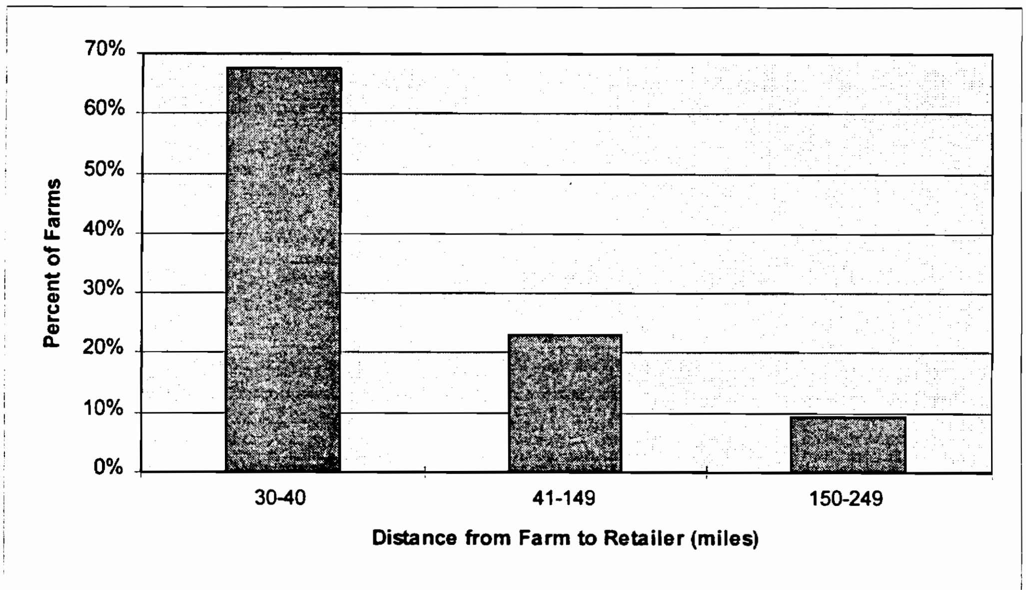


Figure 2. Percentage of U.S. dairy farms within specified distances of retailer, 1977, (Lough and Fallert, 1977).

federal or state government regulates the sale and shipment of fluid milk. Also involved in the industry are private processors, distributors and independent hauling companies.

The effect of these administrative units (cooperatives and ordered markets) on the efficiency of fluid milk hauling will be modeled using GIS functions. This will be done by comparing current milk hauling efficiency to that which would be found under a purely market driven economy. The effectiveness of GIS network functions will be measured against that of the manual methods of transportation planning used by today's dairy cooperatives. In general, two types of GIS functions are needed to effectively plan the shipment of fluid milk. First, pathfinding functions are utilized to determine the shortest paths for trucks to follow as they visit farms for milk pick up. The pathfinding functions will generally be used to model conditions on the local scale. The main objectives of these functions will be to minimize total travel distance and maximize the payload of trucks serving farms. Secondly, allocation functions will be used to determine the optimal market (plant) destination for milk. Allocation functions will be performed mainly on the regional scale. Evaluation of both pathfinding and allocation operations will be done to demonstrate the potential usefulness of GIS within the dairy industry. The feasibility of using GIS in the dairy industry on a regular basis will also be evaluated according to the results of a survey of dairy cooperatives. The survey seeks to determine the current extent of automated routing systems in the dairy industry and the attitude of dairy cooperatives toward GIS technology.

In addition to these practical applications of GIS, this thesis touches on two broader themes that have implications within political and economic geography: 1) The role of government regulations in shaping the economic landscape and, 2) The tendency of private businesses to continue traditional economic practices that may not be based on economic principles.

CHAPTER 2: GIS IN TRANSPORTATION APPLICATIONS

The emergence of GIS as an essential tool in solving transportation problems has been recognized by both government and private industry. Within both of these sectors, the advent of wide-scale GIS implementation has been important in developing solutions to such problems as route selection, allocation of resources, and facility location and management. Improved efficiencies in these critical aspects of transportation planning have, in many instances, been attributed directly to GIS technology (Gregory, 1992, Francica, 1992 and Wiersig, 1996).

State and local government officials in North Carolina have reaped the benefits that GIS has to offer with the development of a specialized GIS called 'TIMS' (Transportation Information Management System). TIMS is typical of most GIS systems in that it combines important geographic analyses with a searchable database. With access to the TIMS database local school districts are able to improve the efficiency of bus operations by locating bus stops at the most advantageous points and by routing the buses along the fastest and safest available route. TIMS also provides for the immediate retrieval of student information, including parents' work phone numbers and addresses for notification in case of an emergency. The economic impact of TIMS has been significant (Table 1).

In his Master's Thesis, "School Consolidation, Bus Routing and GIS", Dennis Mitchell outlined a method for using GIS to assess the feasibility of school consolidation and location in a

Table 1. Economic impact on school bus operating costs in North Carolina since implementation of TIMS, (Gregory, 1992).

Year	Number of Buses	Annual Mileage	Fuel Consumption (gal)
1989-90	13,231	126,353,582	20,732,383
1991-92	12,759	123,704,678	19,463,030
%change	-3.6	-2.1	-6.1

rural West Virginia county. Using GIS Mitchell was able to test five different locations as possible sites for a new consolidated high school. The rating of each location was done by allowing the GIS to calculate the overall travel time for students to each hypothetical school location. Optimal bus routes were also selected based on the shortest distance, the number of students along the route and the capacity of the bus. GIS proved to be a valuable tool providing school officials with the information they needed to make informed decisions about school consolidation, location and bus routing, (Mitchell, 1995).

Within the private sector GIS has been no less serviceable in its ability to assist in efficient transportation planning. One of the largest trucking companies in North America has implemented a nation-wide GIS to manage its assets, locate new shipping terminals and improve marketing techniques through automated map production. Yellow Freight System, Inc., (YFS) which operates 3700 tractors traveling over 640 million miles per year, has implemented a GIS that combines data from several different sources: digital road atlases, the company's current schedules and inventories, and even local zoning maps to plan for the location of new dispatch terminals and storage facilities, (Peck, 1992). In addition to location planning, GIS provides YFS with the ability to quickly display persuasive maps outlining service capabilities. This capability in itself has been valuable in winning and maintaining clientele for YFS and in management level strategic planning sessions. Compared with previous methods of transportation planning used by the company, YFS considers GIS to be no less than revolutionary. Commenting on the previous system used by YFS for dealing with the logistics of such vast amounts of data, Peck states, "That whole information gathering process relied on one person with a Rand-McNally Atlas and a marking pen at the phone calling terminal managers," (Peck, 1992).

Dairy cooperatives implement a similar system of paper maps and push pins to plan the transportation of fluid milk. Some larger cooperatives have implemented computer programs for milk routing (see Chapter 5). These models provide statistical optimization of shipment by considering peripheral data (i.e. truck maintenance costs, fuel, drivers' pay). In contrast, a GIS provides functions that model spatial data as well as attribute data. Spatial data are data that are geographic in nature. In other words, data that have definite locations and whose locations are essential in the solution of functions involving that data. For example, GIS can be used to determine the shortest path between a dairy farm and a milk processing plant, given the locations of the farm and plant and the road network connecting the two. The locations of the farm, plant and roads are what are known as spatial data. These data are usually stored as a series of X,Y coordinates in a geographic referencing scheme. Attribute data includes the amount of milk produced on average at the farm and the capacity of the plant. The ability of GIS to analyze both spatial and attribute data to produce new data are what separates this technology from other computer modeling systems.

In this thesis GIS is used to model spatial and attribute data dealing with the dairy industry. Four geographic questions are proposed, on two different scales. On a local scale: 1) In what order should a group of farms be visited so as to minimize travel distance?; and 2) Which is the shortest path between these groups of farms? On the regional scale the questions can be stated as the following: Which groups of farms should be assigned to which plants so as to minimize total travel distance? and 2) What effects do government regulations and cooperative decisions have on the regional shipment of fluid milk?

CHAPTER 3: BACKGROUND OF DAIRY INDUSTRY

In September 1994 Galen Brubaker, a career dairy farmer in Virginia, sold his entire herd of 140 Holstein cows and effectively ended a family business in operation since the early part of this century (Jackson, 1994). The disappearance of small dairy farms and the rise in the number of larger farms is a common phenomenon across the nation. On the national level, the number of operations with milk cows has fallen from over 3.6 million in 1950 to a mere 171,560 in 1992 (Figure 3). Despite the decline in farm numbers, milk production has increased, thanks to technological advancements in both feeding and breeding (Figure 4).

The number of milk handlers operating under federal order jurisdiction dropped from 2259 in 1960 to only 694 by 1992 (Figure 5). By increasing their capacity, fluid milk plants have been able to boost profits (Table 2). Increases in plant capacity have been accompanied by decreases in plant numbers. The number of Grade A fluid processing plants in the country fell by 92% between 1948 and 1992 (Figure 6). 23% more milk is being produced today than in 1960, and the hauling of this milk is being carried out by 1/3 the number of handlers.

In a spatial sense, these data illustrate an increased concentration of milk production and milk processing at fewer, more diffuse points. An increase in milk production and a decrease in the number of milk handlers of milk stresses the need for effective transportation planning among milk handlers, in which GIS can play a major role.

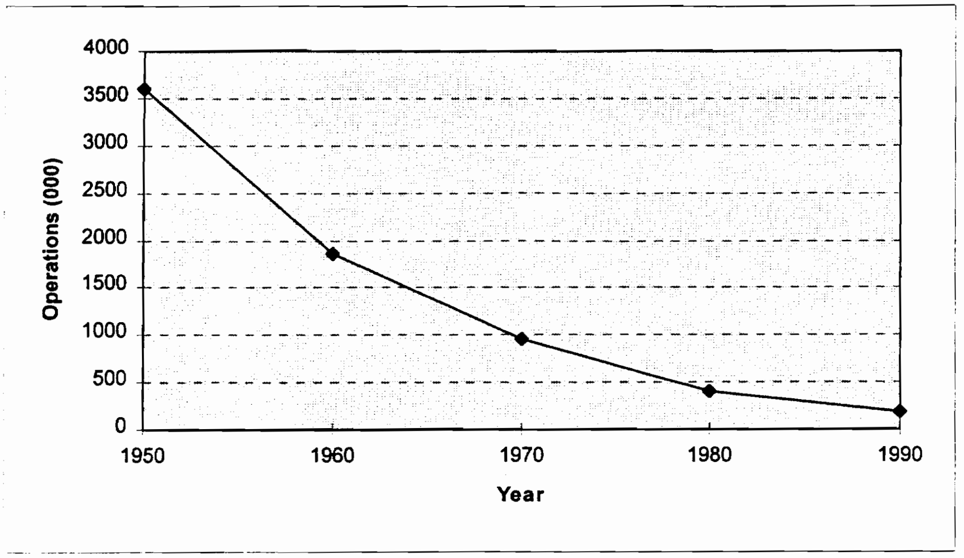


Figure 3. Operations with milk cows, 1950-1990, (Dairy Producer Highlights, 1994).

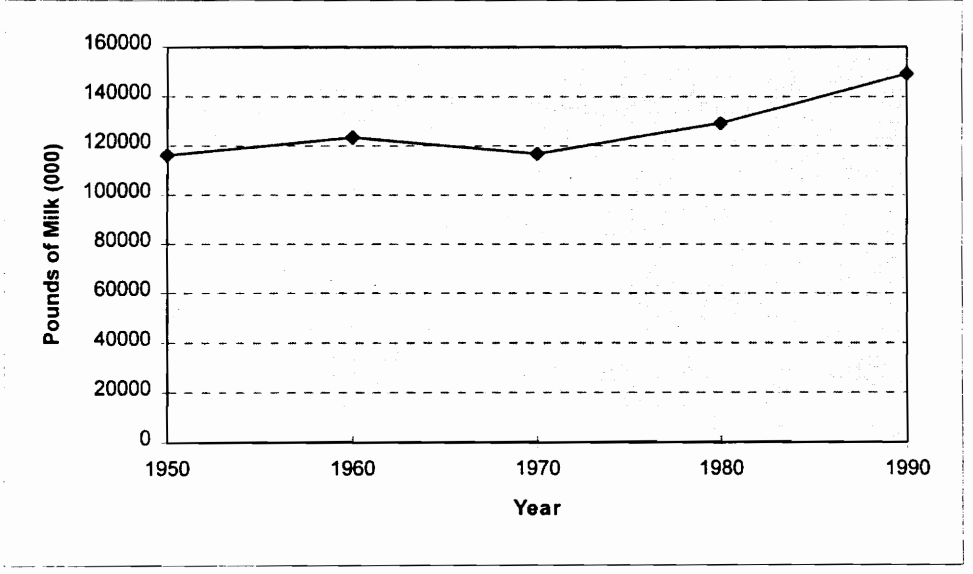


Figure 4. U.S. milk production 1950-1990, (Dairy Producer Highlights, 1994).

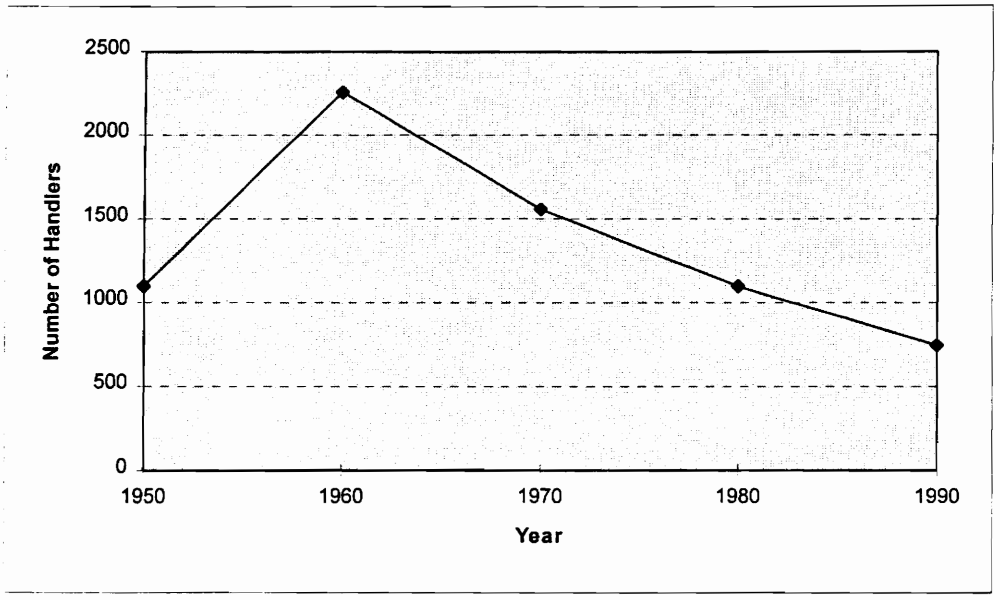


Figure 5. Number of milk handlers, 1950-1990, (Dairy Producer Highlights, 1994).

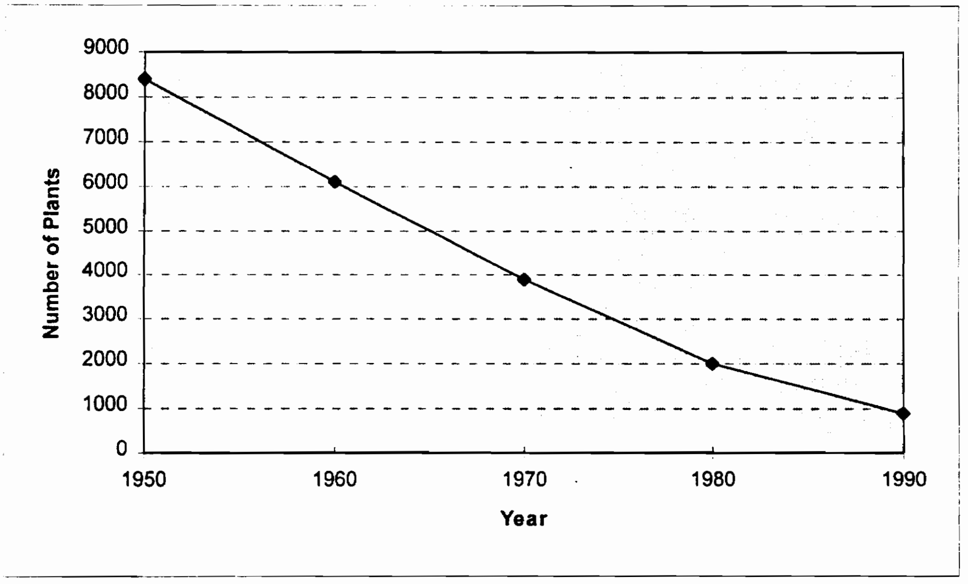


Figure 6. Number of Grade A fluid milk processing plants in the U.S., 1950-1990, (Dairy Producer Highlights, 1994).

Table 2. Cost of Processing Fluid Milk, (Lough and Fallert, 1977).

Plant Capacity (quarts per day)	Cost per quart ($)
6000	.067
800,000	.024

The Role of Government in the Dairy Industry

The role of government legislation in dairy industry trends remains relatively unexplored in recent geography journals, especially as this legislation shapes the landscape in terms of plant size and location, farm size and the morphology of commodity flow patterns.

Government regulation in the U.S. dairy industry began during the Great Depression when a system of supports was established to prevent the imminent bankruptcy of the system and to provide both price and supply stability (Manchester, 1983). This legislation, known as the Agricultural Marketing Agreement Act (AMAA), has had a direct impact on the shipment of fluid milk on the national, regional and local scales. Under the terms of the AMAA, federal orders were created to "establish fair prices for consumers and equitable returns to producers and handlers," (Jesse and Cropp, 1992). Federal orders are geographic regions within which government officials establish minimum prices for Class I milk. The federal order also serves as an accountant for milk sales in the region, monitoring the sale and shipment of milk into and out of the order. Though farmer participation in federal orders is not obligatory, (most cooperatives hold a referendum to decide on market affiliation) the large majority of all milk produced in the U.S. is marketed in these orders, (Manchester, 1983). In 1960, 80 federal orders were in operation handling more than 56% of all U.S. fluid milk sales. By 1992 the number of orders had dropped to 40, but the share of U.S. fluid sales within these orders had risen to more than 80% (Figure 7). Figure 8 shows the boundaries of the federal orders as of November 1995 and the average prices received for fluid milk in each order. Under the federal order system the average price of manufactured milk in the Minnesota-Wisconsin area is used as a base price.

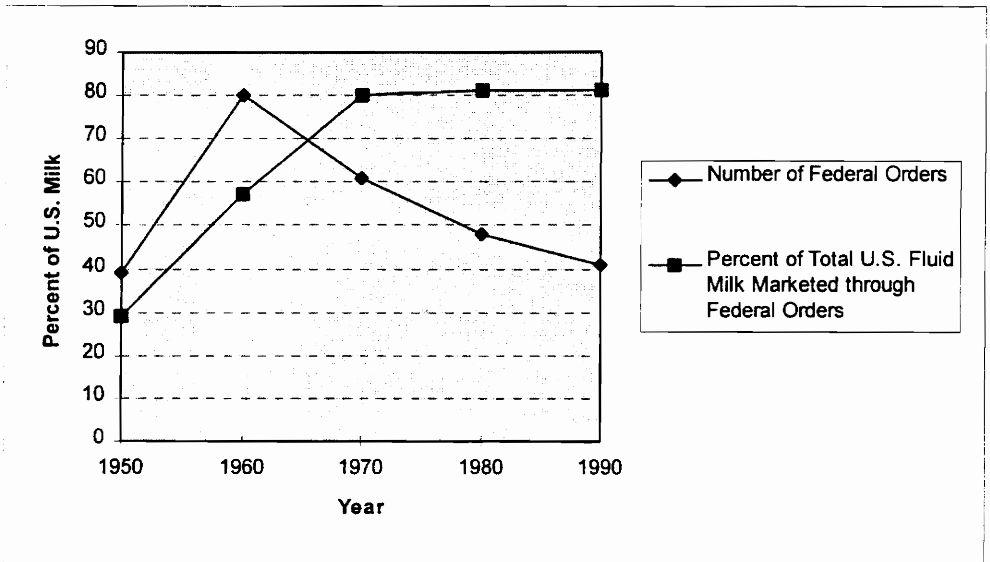


Figure 7. Number of Federal Orders and Percentage of U.S. Fluid Milk Marketed through Federal Orders, 1950-1990, (Dairy Producer Highlights, 1994).

This is known as the Minnesota-Wisconsin price (M-W Price). A distance differential is added to the M-W Price in order to formulate the minimum price for Class I fluid milk in each federal order. The federal order price is calculated as:

Federal Order Price = (MW price) + ($0.21 per hundred weight
per 100 miles distance
from Eau Claire, WI)

The MW Region was chosen as the area from which to select the base price because its traditional prominence in milk production had made the area prone to milk surpluses. Thus, to discourage surpluses to markets in this region, a higher price is now offered for milk as distance increases away from this region. The distance formula only applies to orders east of the Rocky Mountains. For federal orders located west of the Rockies a differential is added to the M-W price, but the differential is not associated with distance from Eau Claire, WI, (Jesse and Cropp, 1994).

Government intervention in the dairy industry has not been limited to the legislative branch. In their 1977 study Lough and Fallert determined that the average distance between a milk producer and the eventual retailer of that milk increased dramatically between 1947 and 1977 (Figures 1 and 2). In addition to technological advancements in trucking and refrigeration, Lough and Fallert also cite "court decisions that allowed plants to receive milk from distant suppliers," for this change in milk shipment distances (1977).

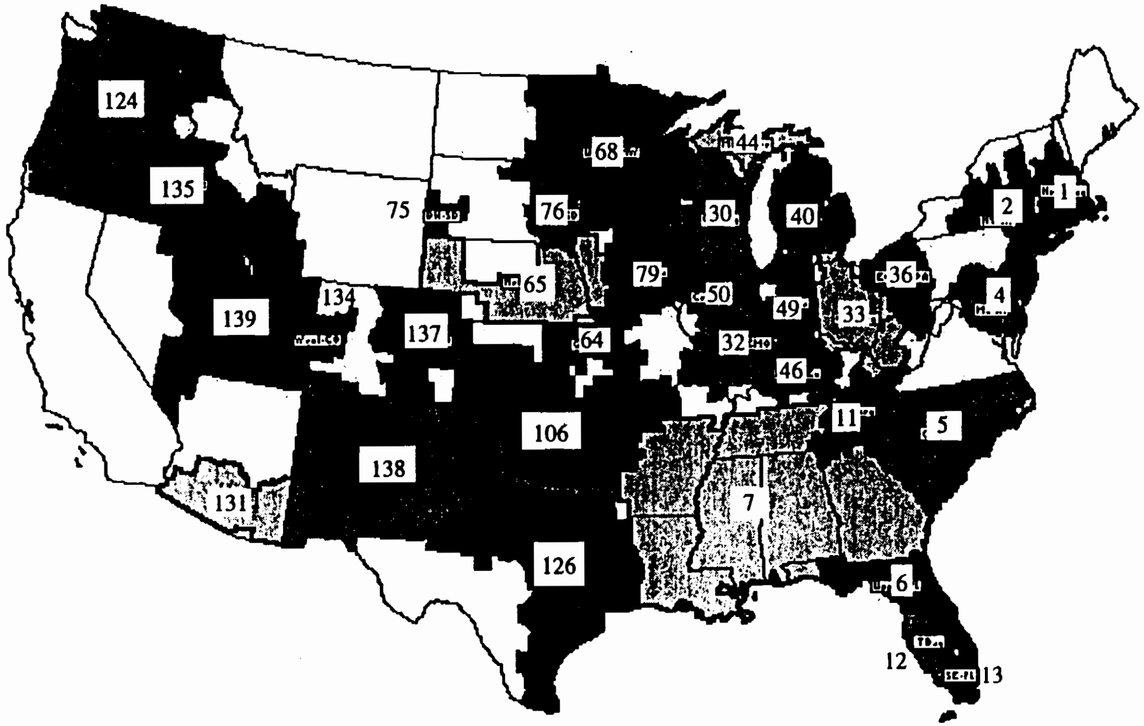
The federal order system has altered the movement of milk on the national level in several ways. The use of the MW pricing system has encouraged the flow of milk from the

Midwest region outward to areas of milk deficit (Jesse and Babb, 1992). Under these conditions, the Southern Plains and the Deep South have become market destinations for milk from the Great Lakes and the Upper Midwest. This inter-regional movement of milk is in part due to higher fluid use in the south than elsewhere, but milk is also drawn to this region by the higher prices offered under the federal order system, (McDowell et.al., 1988) (See figure 8).

The practice of removing water from milk before shipment and replacing it at the destination is called reconstitution. Under federal order restrictions reconstitution is prohibited for many inter-regional milk shipments (Cropp, 1992). This restriction on milk reconstitution has prohibited milk handlers from utilizing a potentially efficient method of long distance milk shipping. Due to the high cost of shipping milk from the Midwest the South, cooperatives and farmers in the Midwest tend to fill the majority of these shipments with low quality grade milk.

For the most part regulatory efforts have been effective in providing a 'safety net' for fluid milk prices. However, the embracing of federal orders as a panacea to the complex economic problems of milk marketing is not a widely held view among industry experts or politicians. A sentiment of dairy reform has been especially strong among producer advocates in the Midwest. A shift in milk production to the Southwest region of the country has attracted attention. Producers and processors in the south can take advantage of the higher prices offered in those regions under the federal order system, at the expense of Midwest producers.

Reform of dairy regulations has been the subject of recent congressional hearings, (Jesse and Babb, 1992; Jesse, 1992; and Cropp, 1992). Alternatives to the present policy have ranged from complete overhaul to slight modifications. Some researchers favor consolidation of federal orders into one nationwide order. Still others have called for abandonment of the MW single base point price system in favor of a multiple base point pricing system. Twenty years ago,



Order #	Name	Class I Price $
1	New England	15.43
2	New York-New Jersey	15.30
4	Mid-Atlantic	15.19
5	Carolina	15.25
6	Upper Florida	15.77
7	Southeast	15.26
11	Tennessee Valley	14.93
12	Tampa Bay	16.07
13	Southeastern Florida	16.38
30	Chicago Regional	13.57
32	S. Illinois-E. Missouri	14.09
33	Ohio Valley	14.21
36	E. Ohio-W. Pennsylvania	14.17
40	Southern Michigan	13.92
44	Michigan Upper Peninsula	13.50
46	Louisville-Lexington-Evansville	14.27
49	Indiana	14.07
50	Central Illinois	13.75
64	Greater Kansas City	14.08
65	Nebraska-Western Iowa	13.92
68	Upper Midwest	13.37
75	Black Hills, South Dakota	14.08
76	Eastern South Dakota	14.08
79	Iowa	13.71
106	Southwest Plains	14.92
124	Pacific Northwest	14.07
126	Texas	15.32
131	Central Arizona	14.69
134	Western Colorado	14.89
135	SW Idaho-E. Oregon	13.65
137	Eastern Colorado	14.89
138	New Mexico-West Texas	14.52
139	Great Basin	14.08

Figure 8. Map of Federal Orders as of November, 1995. Average Class I price for each federal order is shown.

Source: USDA

some analysts argued that federal orders had created a "complicated and cumbersome" beauracracy and caused "substantial inflexibility [in] the distribution of milk products in this country," (MacAvoy, 1977). Today, this reasoning seems to have prevailed as the total number of federal orders will be reduced from 33 to 13 within the next year (Wilson, 1996). The consolidation of federal orders may reduce some of the hauling inefficiencies that exist today in inter-regional shipment. Future changes in the base point pricing system and reconstituted milk regulations are also close at hand. Regardless of the outcome of future legislation, government involvement that in some form shapes the mobility of milk shipment will continue to be an important geographical phenomenon. This thesis is concerned with government regulations in as much as these regulations have altered the mobility of fluid milk on the local and regional scales. The effects of government intervention on milk hauling will be examined by observing how one cooperative has dealt with its situation amid the complex web of the milk industry.

Dairy Cooperatives

Originally formed as small local concerns by farmers who needed to protect their interests in the often unpredictable world of farm economics, cooperatives have grown in size and in responsibility. The main responsibilities of today's dairy cooperatives have been stated as the following: "[To] 1) gain a stronger voice in bargaining for milk prices and influencing legislation and regulations affecting them; 2) increase the efficiency of marketing; and 3) process surplus milk or, in some cases, all member milk," (James, 1995). In the U.S. dairy industry today there are 269 cooperatives. (Dairy Producer Highlights, 1994). In Virginia, 98 percent of all farmers producing Grade A milk are members of a cooperative, (James, 1995).

Cooperatives are usually responsible for the planning and scheduling of milk hauling, though they may hire independent haulers to ship the milk. Many cooperatives use their own trucks to haul raw milk, or use a combination of their own trucks plus contracted independent haulers.

Two basic decisions are necessary in order for cooperatives to plan milk hauling: route selection and market selection. Route selection entails choosing the actual route to be traveled in order to visit farms and return to the plant in a timely manner. Many cooperatives accomplish this by assigning farms to trucks, and then allowing the driver of the truck to decide which roads to travel. The order in which farms will be visited is largely determined by the time of day that milking is completed on the farm. In some regions, farmers' religious beliefs prohibit the pick up of milk on Sundays, (Jones, 1995). Because milking times and amounts of production vary throughout the year, cooperatives are constantly needing to reevaluate their hauling scenarios in order to maximize efficiencies.

Optimal market selection is a major concern for larger cooperatives that cover more than one federal or state order. As explained above, federal and state orders ensure that a minimum price will be paid for Class I milk. Market prices vary depending on the order's distance from Eua Claire, Wisconsin. Cooperatives must weigh the higher prices received in one market against the price of hauling to that market. The use of multiple trucking companies to haul milk may require additional planning, depending on the hauling costs charged by these haulers. Payments for fluid milk go directly to the cooperatives, who distribute payment among their members according to the quantity and quality of each producer's milk, (James, 1995).

In an effort to provide cooperatives with automated solutions to milk routing and allocation, this thesis examines in detail the milk hauling operations of one dairy cooperative.

One objective of this research is an attempt to assist dairy cooperatives in achieving their second objective as mentioned above: to "increase the efficiency of marketing."

The Dairy Industry in Virginia

Most milk produced in Virginia is regulated under the Virginia State Milk Commission. Under the State Milk Commission the state has been divided into three marketing regions, Eastern, Western and Southwest (Figure 9). Minimum prices for Class I (and some Class II) milk are set by the State Milk Commission in each region. State Milk Commission prices were originally set in an effort "to reflect production costs and consumer demand," (James, 1995). The criteria for setting minimum prices has now changed to better reflect supply and demand conditions in the region. 1995 State Order prices show an increase with proximity to the urban corridor of eastern Virginia (Figure 9).

Two federal orders have jurisdiction over a portion of the milk produced in Virginia. Federal Order #4 (Mid-Atlantic) covers the northern part of the state. Federal Order #11 (Tennessee Valley) jointly regulates the far Southwestern region together with the State Milk Commission (Wilson, 1996). Although federal and state orders have apparent boundaries, the determination of market participation depends not on where the farm is located, but rather where the plant is located which receives the majority of that farm's milk. For example, the Virginia Tech dairy farm holds Federal Order base. This means that even though, geographically, it is located in the Western Virginia Market, it is actually regulated under Federal Order #4. To deal with the seasonal fluctuations in milk production (production is usually higher in the Spring) and to limit milk surpluses in this part of the year a system of base-excess pricing is used by the State

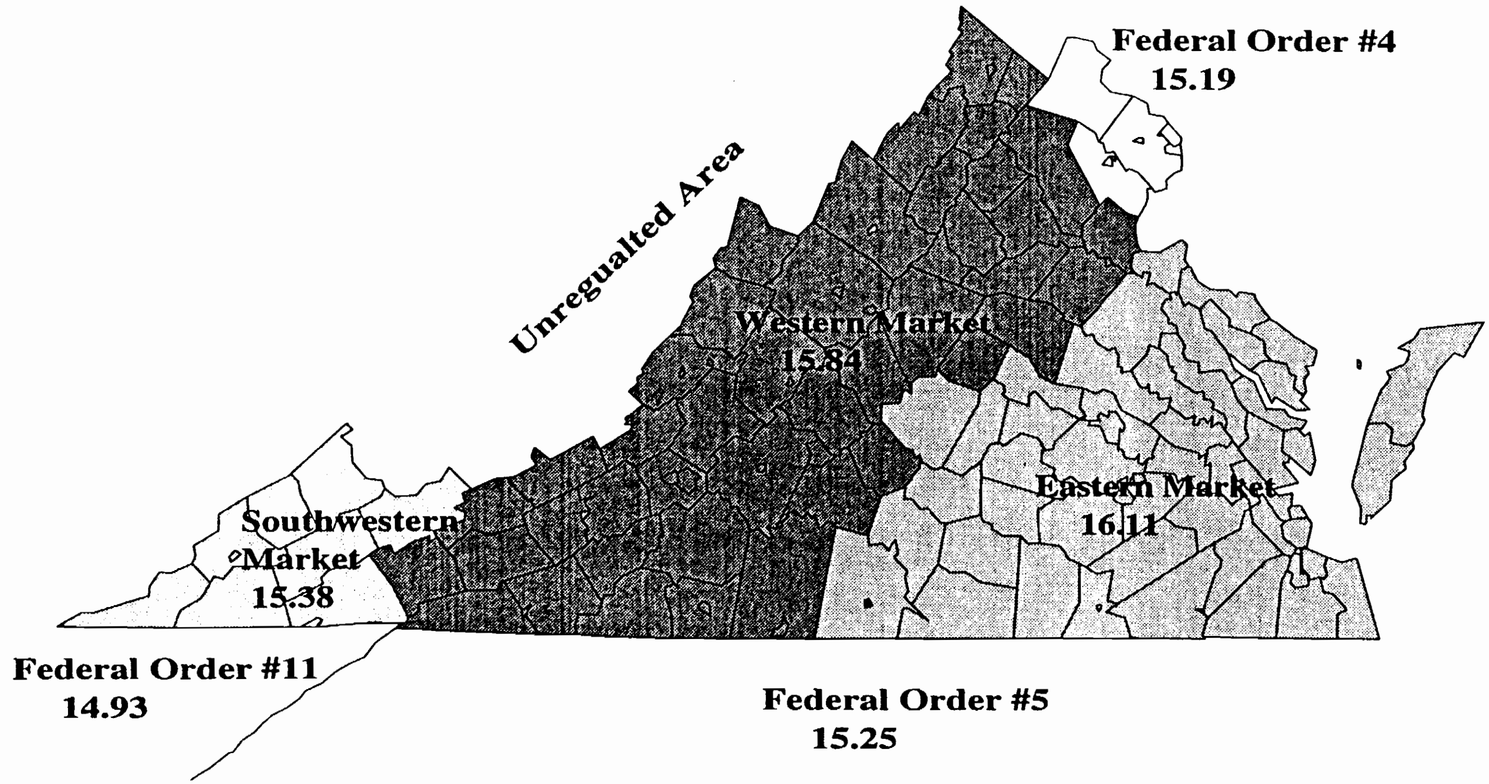


Figure 9. Extent of Virginia's State Orders and surrounding Federal Orders. (1994 average Class I price $ per cwt.)

Sources: Virginia State Milk Commission Statistical Summary, 1995 and Dairy Producer Highlights, 1996.

Milk Commission. The base system is a method of Class I fluid milk allotment. Base refers to that share of market sales of Class I milk for which a farmer can receive the Class I price. Each farmer signs up for a certain amount of base each year, and any milk produced in excess of this base amount is treated as manufactured grade milk, for which a lower price is paid (James, 1995).

A cooperative that owns base allotment in a particular order must distribute this base among its members. In essence, this means assigning certain farms to participate in that order. One effect of the base system on milk transportation occurs when a cooperative holds base in more than one federal or state order. For example, a cooperative holding State Milk Commission base must first assign that base to a certain number of member producers. The milk from the assigned farms can only be hauled to a State Milk Commission plant. The same cooperative may also hold base in the federal order. This base must also be distributed among the producers, requiring that their milk may only be sent to a federal order plant. As a result, it is to the advantage of the cooperative to assign base to farms that are located nearest to those plants where their milk must be shipped (i.e a farm assigned state order base should be one located closest to a state order plant).

Dairy industry trends in Virginia coincide with those on the national level. The number of dairy farms in Virginia declined from 1739 in 1982, to 1296 by the end of 1995, (Statistical Summary, 1983 and 1995). The number of processing plants in Virginia has dropped from 24 in 1982 to 7 in 1995 (Figure 10). Today, Virginia's milk reaches processors as distant as New York and Missouri, (Statistical Summary, 1995). The shipment of fluid milk from Virginia dairy farms to their destination plants has shifted to become a more regional event rather than a local phenomenon.

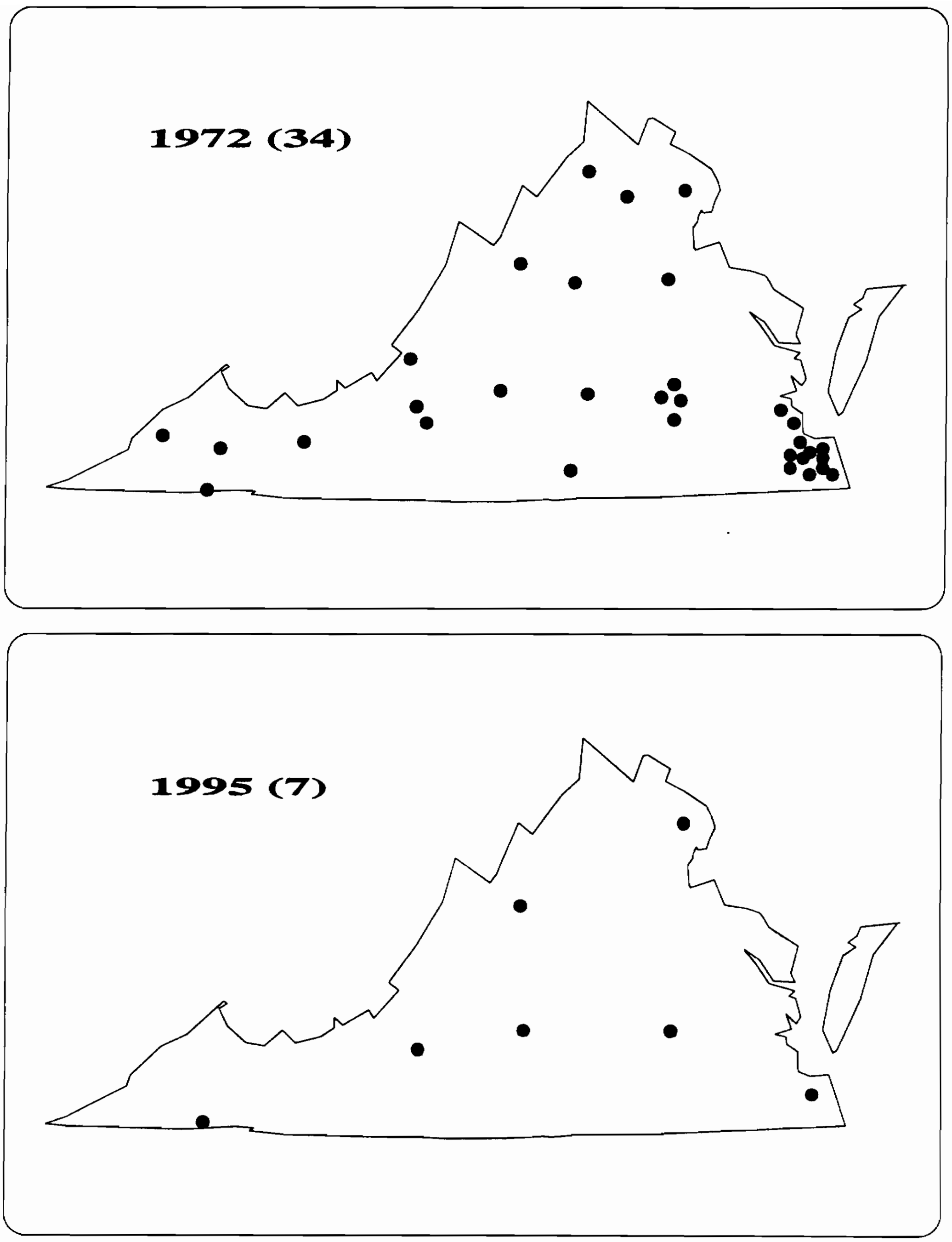


Figure 10. Grade A Milk Processing Plants in Virginia 1972-1995.

Sources: Cooke, 1972 and Virginia State Milk Commission, 1995.

CHAPTER 4: THE ARC/INFO APPROACH TO NETWORK MODELING

ARC/INFO (Environmental Systems Research Institute, Redlands, CA) is a comprehensive GIS software package with the capability of assisting researchers in solving transportation problems. The Network module of ARC/INFO includes algorithms for determining the shortest path between two or more points and allocating resources into or out from a center.

The basic elements of network analysis are:

<u>Spatial elements</u>

Arcs -- lines representing linear features (roads, streams, sewer lines, etc.)

Nodes -- points representing supply or distribution points (stores, wells, factories, etc.), located where 2 or more arcs intersect

<u>Attribute elements</u>

Arc Impedance -- a value assigned an arc that alters movement over that arc (speed limits, road conditions, etc.)

Node Impedance -- a value assigned to a node that alters movement through that node

Turn Impedance -- a value assigned to a turn that restricts turns from being made in specified directions (one way streets, interstate overpasses, etc.)

ARC\INFO uses specific tables to store values of network elements:

Arc Attribute Table -- a table containing attributes of arcs (length, impedance)

Node Attribute Table -- a table containing attributes of nodes (amount of resource)

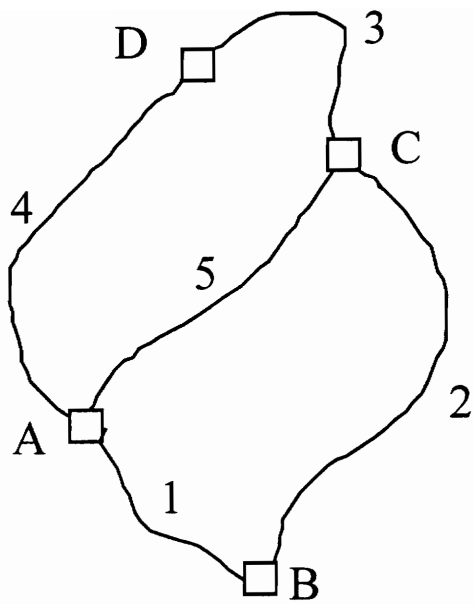
Turn Table -- a table containing the constraints on turning from one arc to another

(See Figure 11)

Path Finding

Once data have been properly formatted for ARC/INFO, network modeling can begin. The commands PATH and TOUR determine the optimal routes between nodes based on the impedance (time or other factor) or distance (the default option). PATH computes the optimal route among a pre-ordered set of nodes. TOUR calculates the optimal order in which to visit the nodes as well as the optimal route. The results from TOUR and PATH can be graphically output on the screen or listed as a series of directions along the calculated route (Figure 12). Distances calculated by these functions are the actual distances traveled along the network between these points.

The PATH and TOUR operations utilize a form of Djkstra's shortest path algorithm (ARCPLOT Command References, 1992). This recursive algorithm assumes that the shortest path between two points, O and D, will not exceed the Euclidean distance from O to D (E1), times 1.25 (R), (Figure 13). As the algorithm searches out through the network, it eliminates all those paths that exceed (E1 * R) until it reaches the destination. To reduce search time, Djkstra's algorithm also eliminates those paths where (P2 + E2) > (E1 * R). Thus, all searching is limited to an area known as the shortest path ellipses. Wasteful searching in directions away from the



Node Attribute Table (NAT)

Node-ID	Arc #'s	Demand
A	1,4,5	1000
B	1,2	2000
C	2,4,5	2500
D	3,4	1500

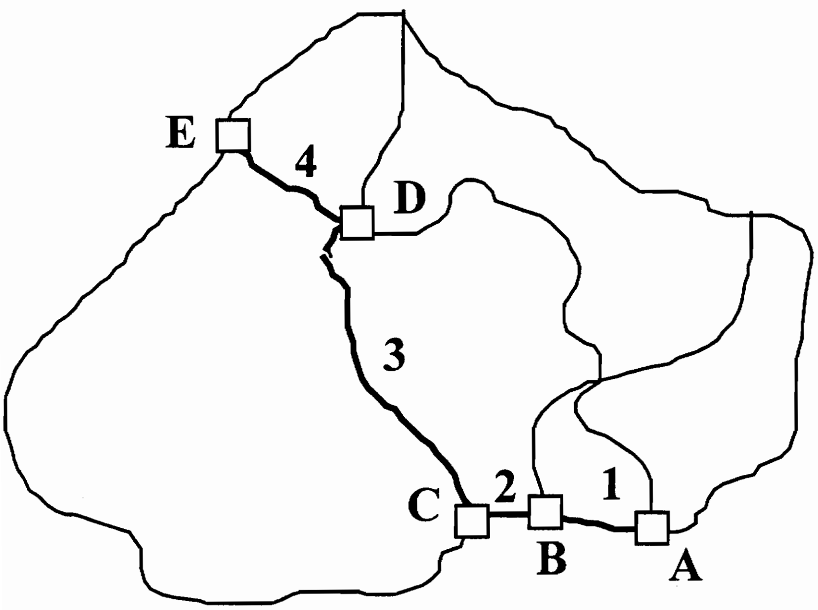
Arc Attribute Table (ATT)

Arc-ID	From node	To node	Length
1	A	B	3.4
2	B	C	6.8
3	C	D	3.5
4	D	A	6.7
5	A	C	5.1

Turn Table

Node-ID	From Arc	To Arc	Impedance
A	1	5	.5
A	5	1	-1
A	5	5	0

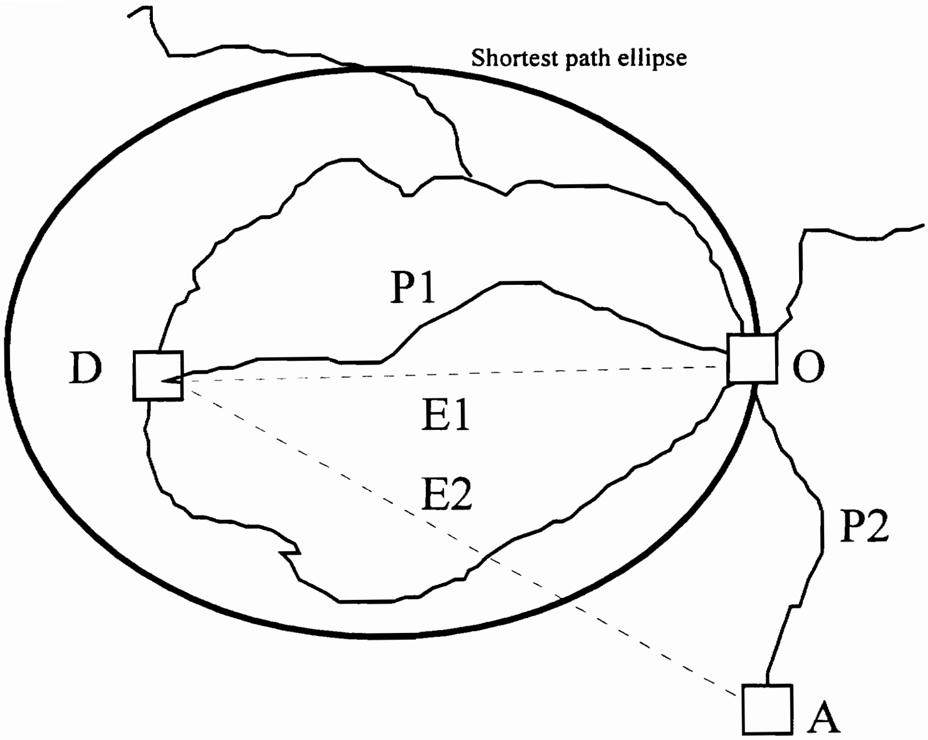
Figure 11. Network elements.



DIRECTIONS

From point A go west .2 miles on road 1 to point B.
From point B go west .1 miles on road 2 to point C.
From point C go north 1.1 miles on road 3 to point D.
From point D go west .4 mi. on road 4 to point E.

Figure 12. Output from ROUTELINES and DIRECTIONS.



O = Origin D = Destination	Stop searching P2 when: (P2 + E2) > (E1 * 1.25)
E1 = Euclidean distance (OD) E2 = Euclidean distance (AD) P1, P2 = Searched paths A, O = reached nodes	Shortest path = P1 when: P1 < (E1 * 1.25) and No other path < P1

Figure 13. Dykstras's shortest path algorithm.

destination is eliminated. Once a route is established between the origin and destination nodes (P1), this is considered the solution unless another shorter route is found by subsequent executions of the algorithm, (Nordbeck, 1962 and Daskin, 1995).

Payload Maximization

An important efficiency assessment criterion for milk haulers is payload maximization. The question of payload maximization asks: 'How can farms be grouped together so that a truck visiting these farms will be filled the closest to capacity?' ARC/INFO attempts to answer this question with the commands SPATIALORDER and COLLOCATE. SPATIALORDER assigns each node a real number value based on its location in two-dimensional space (Figure 14). This algorithm considers only the Euclidean distances between farms regardless of the road network or topography. COLLOCATE groups nodes together based on their relative location to each other and the amount of milk to be picked up at that farm. The groups are formed so that the total milk from the group does not exceed the capacity of the truck. The results from SPATIALORDER and COLLOCATE were tabulated and compared with the study cooperative's manual assignation of farms into groups (Chapter 6).

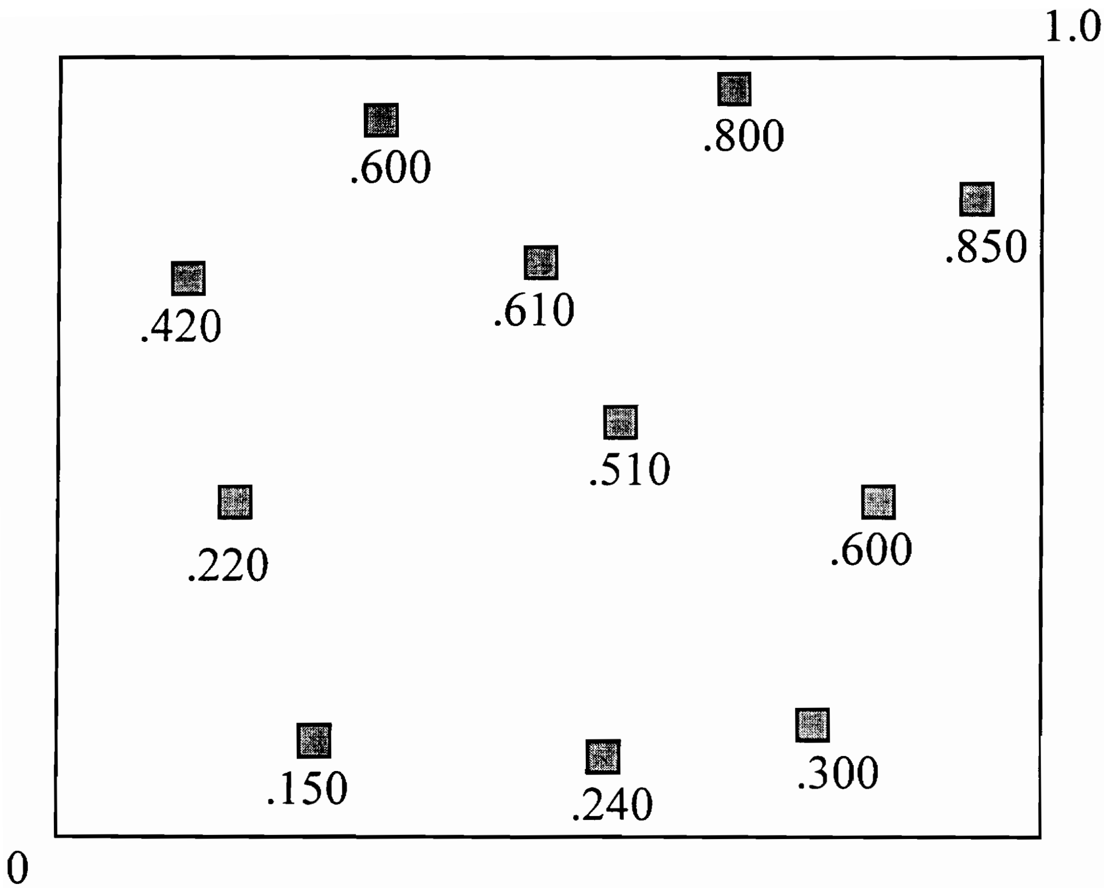


Figure 14. Example of SPATIALORDER

Allocation

ARC/INFO is also able to model the allocation of resources into or out from a center. In the case of milk shipment, this involves the assigning of farms to a processing plant based on the distance to the plant and the capacity of the plant. This is done in two steps. The LOCATEALLOCATE command first assigns all nodes to their nearest center regardless of capacity constraints. Distances between nodes and centers are calculated using the same method as pathfinding algorithms. Next, the LOCATEADJUST command allows the user to reassign nodes to the next closest center according to the capacity of the first center. In other words, if assigning all farms to the nearest center exceeds the capacity of that center, then the farms farthest from the first center are reassigned to the next closest center until the first center is brought to capacity. Once allocation has met the desired criteria, LOCATESAVE is used to save the results. The results from these operations can be viewed in both tabular and graphic form. Centers files hold results from the allocation such as average distance, total distance and total demand (resource) (Table 3). Allocation files give a detailed print out of each node, the closest center to that node and the distance from the node to the center (Table 4). In this example the nodes are farms and the centers are processing plants. Distances are distances along the network in meters. Total distance is calculated as the sum of all these distances.

Table 3. Example of Centers file.

```
          1
RKAG-ID       =4,519
RKAG#         =4,593
TOTFEATURES    =  141
TOTDEMAND      = 1120869.000
TOTDIST       = 1424730.000
TOTWDIST       =1.087774E+10
AVGDIST       =  10,104.470
AVGWDIST       =   9,704.737
FURTHDIST      =  15,123.920
FURTHEST       =2,601
ALL_TOTDIST     = 4142335.000
ALL_AVGDIST     =  16,569.340
ALT_DEMAND      = 1120869.000
ALT_TOTWDIST    =1.874816E+11
SUPPLY         = 1118000.000
          2
RKAG-ID       =12471
RKAG#         =12494
TOTFEATURES    =  92
TOTDEMAND      = 881,004.000
TOTDIST       =15339960.000
TOTWDIST       =1.468575E+11
MORE?Y
AVGDIST       = 166,738.700
AVGWDIST       = 166,693.300
FURTHDIST      = 186,584.200
FURTHEST       =1,395
ALL_TOTDIST     =42359190.000
ALL_AVGDIST     = 169,436.800
ALT_DEMAND      = 881,004.000
ALT_TOTWDIST    =1.992224E+10
SUPPLY         =  94,600.000
```

Table 4. Example of Allocation file.

Record No.	Producer No.	Plant	Distance to Plant (mi.)	Milk (lbs.)
1	16	SPF	111.9	4,415.00
2	18	SPF	124	12,028.00
3	21	SPF	116.9	6,513.00
4	103	SPF	116.1	13,942.00
5	31	SPF	116.2	4,092.00
6	38	SPF	114.7	7,378.00
7	51	SPF	126.1	7,671.00
8	58	SPF	116.6	3,913.00
9	66	SPF	118.2	6,628.00
10	68	SPF	121.3	12,528.00
11	279	MTC	0.4	7,855.00
12	74	SPF	118.7	5,829.00
13	249	MTC	0.8	16,480.00
14	226	MTC	1	21,314.00
15	338	MTC	1.1	2,559.00
16	173	MTC	1.3	29,317.00
17	155	MTC	1.4	12,688.00
18	104	MTC	1.5	5,182.00
19	126	MTC	1.6	7,324.00

Spider diagrams (Figure 15) are one way of graphically displaying the results of allocation functions. Using the *site1* and *cover#* items of the allocation file as origin and destination nodes respectively, straight lines are drawn between the nodes and their assigned centers. These diagrams are useful in visualizing varying patterns of resource allocation as will be seen in Chapter 5. Spider diagrams can be drawn from any INFO file with designated origin and destination items, (ARCPLOT Command References, 1992).

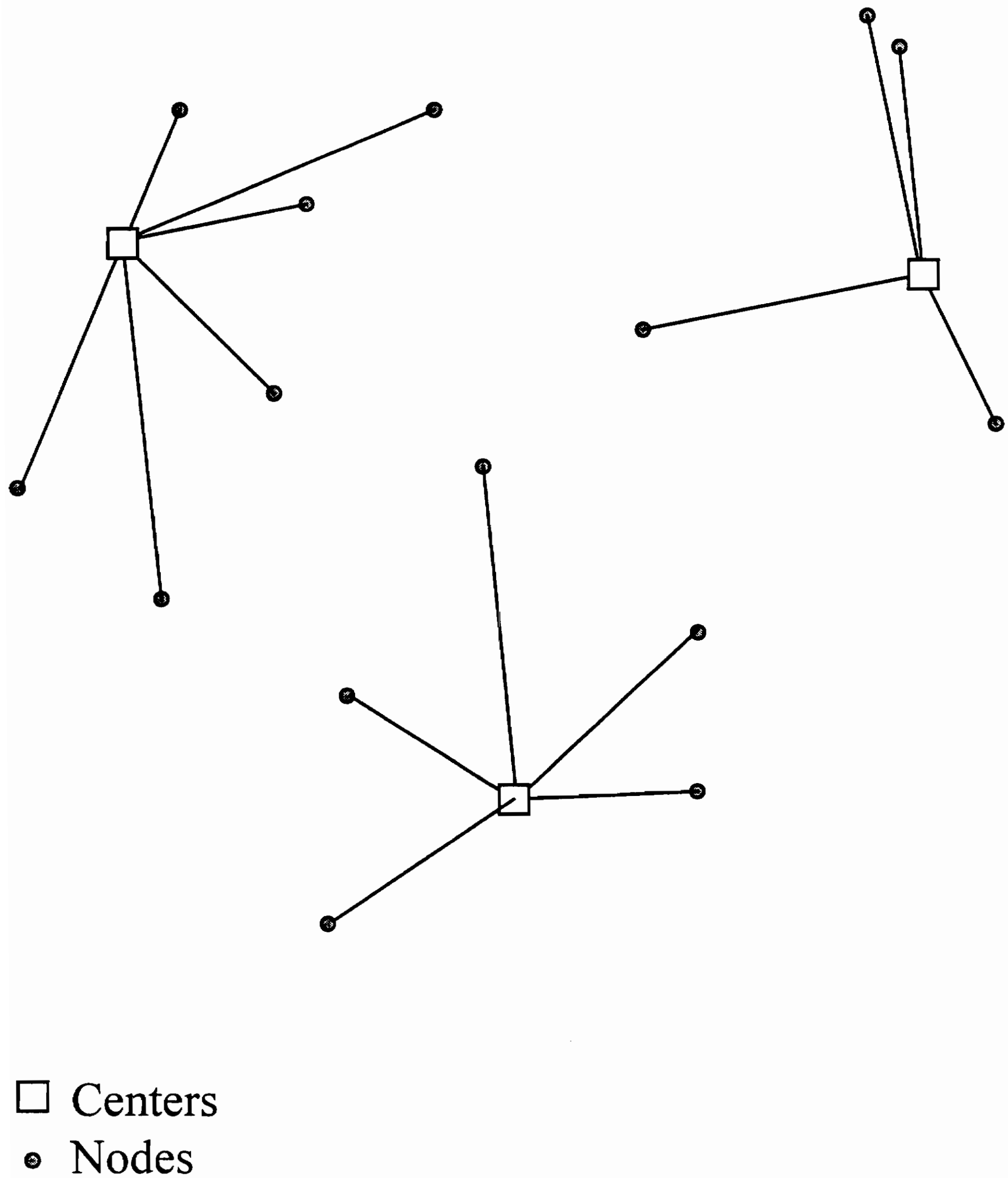


Figure 15. Example of Spider Diagram

CHAPTER 5: CASE STUDY --VALLEY OF VIRGINIA COOPERATIVE

Valley of Virginia (Mt. Crawford, Virginia) is a bargaining cooperative as well as a licensed Virginia processor/distributor (Figure 16). In addition to its responsibilities as the marketing agent for members' milk, Valley of Virginia processes raw milk at two of its own plants, Springfield and Mt. Crawford . Milk is also sold to another cooperative operating a plant in Roanoke. Most cooperative members are located in Rockingham and Augusta Counties. This study focuses on the producers within these counties and on Valley of Virginia's role as the coordinator of raw milk shipment from its member farms to the processing plants.

In this case study I attempt to accomplish four things through the use of GIS network functions:

1) Compare path finding results of GIS to those actual results obtained by the cooperative's manual method;

2) Illustrate the effect of government regulation on milk shipment in Virginia;

3) Examine the effect of the cooperative's traditional business practices on the efficiency of milk hauling; and

4) Use GIS allocation functions to plan alternative milk marketing strategies.

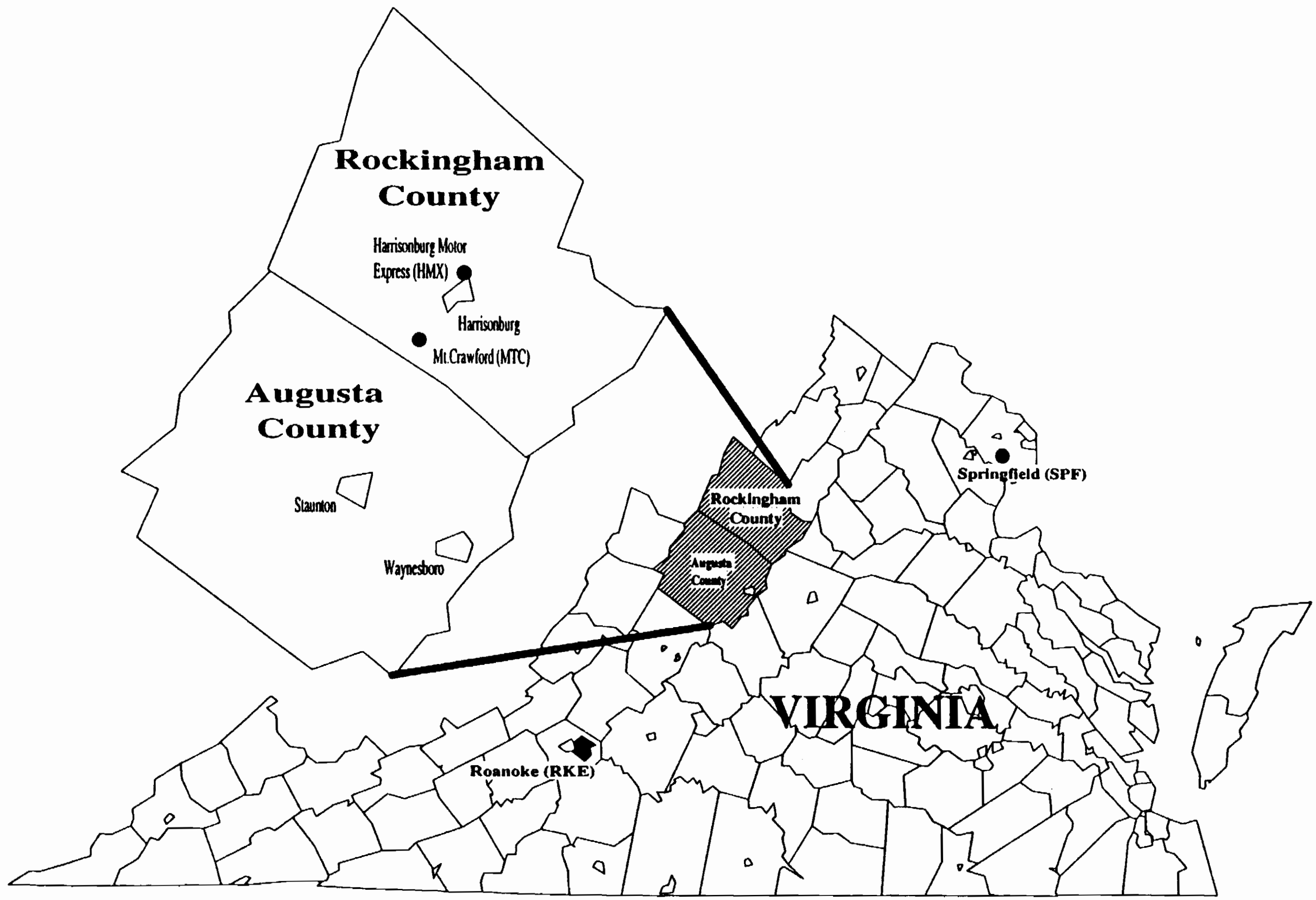


Figure 16. Map of Study Area

Obtaining and encoding data

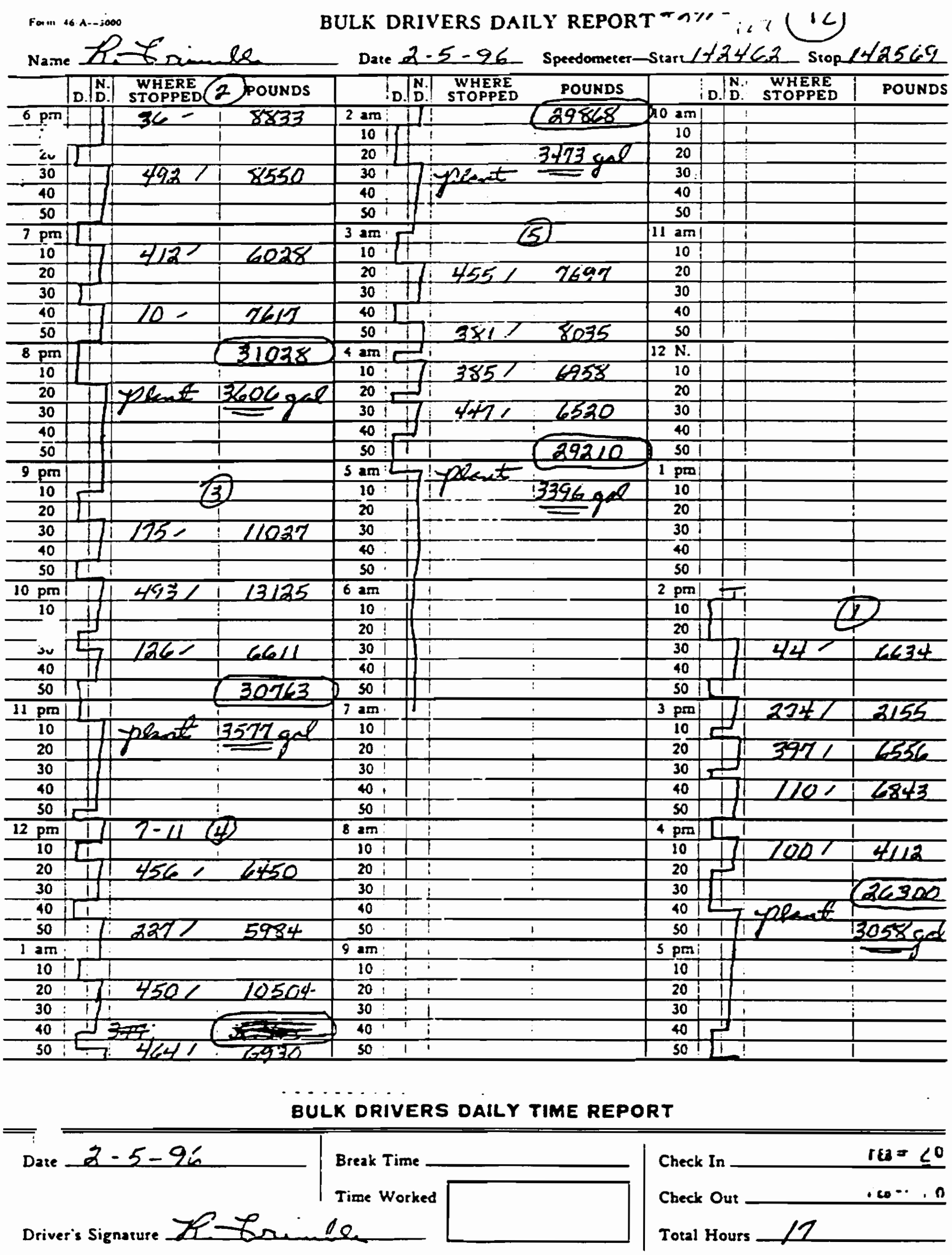
Valley of Virginia Cooperative was chosen as the study area based on its proximity to Virginia Tech, its size and its willingness to release the needed data. Valley of Virginia serves close to 300 farms in Rockingham and Augusta Counties, a manageable number for a study of this type considering that many cooperatives have several thousand members. Valley's participation in both federal and state order markets allows an analysis to be made of the effects of these government order markets on milk shipment.

Map coverage of the study area was downloaded via the Internet from the Virginia County Interactive Mapper in the form of ARC/INFO coverages derived from U.S. Tiger Census files (Virginia County Interactive Mapper). Layers include: primary, secondary, connecting and neighborhood roads. Some editing of the maps was necessary. False intersections, where an interstate passes over, but doesn't connect with secondary roads, had to be resolved. This was done by creating a TURN TABLE (Chapter 4). Roads through the city of Harrisonburg were not available from the homepage and thus were digitized and added to the map coverage.

Data collected from Valley of Virginia includes location and average milk production of each farm (Figure 17) and drivers' logs with route and mileage information (Figure 18). Farm and plant locations were transferred from the cooperative's wall map, on which the farms were marked with push-pins, to a 1:70,000 scale Transportation Department county map. From here the data were taken to the lab for input to the digital map coverage. Farms and plants are located as nodes on the digital coverage. Farm and plant attribute data were input through the keyboard and include farm ID number, average milk production per farm, and plant capacity. These are stored in the coverage's Node Attribute Table. Average milk production from the month of November 1995 was used for this study. November milk production was the closest to the

	Date	Time	Total Lbs	Stick Reading		-Tank- #	ID	Milkings	Haul	Dest	Temp
0486 Neodak Dairy	10/02/95	10:30	7,009	105	4	1	0292	4	01	50	37
	10/04/95	03:20	6,944	104	5	1	0292	4	01	50	36
	10/06/95	03:20	7,023	105	6	1	0292	4	01	50	37
	10/08/95	03:20	6,923	104	2	1	0292	4	01	50	36
	10/10/95	03:20	6,809	102	6	1	0292	4	01	50	38
	10/12/95	04:30	6,830	102	9	1	0292	4	01	50	37
	10/14/95	03:20	7,066	106	2	1	0292	4	01	50	37
	10/16/95	10:30	7,066	106	2	1	0292	4	01	50	37
	10/18/95	03:10	6,916	104	1	1	0292	4	01	50	37
	10/20/95	03:10	6,966	104	8	1	0292	4	01	50	37
	10/22/95	03:15	7,023	105	6	1	0292	4	01	50	37
	10/24/95	12:15	7,116	106	9	1	0292	4	01	50	37
	10/26/95	12:05	7,123	107	0	1	0292	4	01	50	37
	10/28/95	04:40	6,987	105	1	1	0292	4	01	50	37
	10/30/95	10:00	7,016	105	5	1	0292	4	01	50	36
	Total		104,817				Days	30.0			
0487 Four Winds Dairy	10/01/95	10:30	11,395	104	1	1	0567	4	01	50	38
	10/03/95	09:10	11,438	104	5	1	0567	4	01	50	37
	10/05/95	09:45	11,113	101	6	1	0567	4	01	50	37
	10/07/95	11:30	11,320	103	4	1	0567	4	01	50	38
	10/09/95	09:50	11,148	101	9	1	0567	4	01	50	38
	10/11/95	09:40	11,125	101	7	1	0567	4	01	50	38
	10/13/95	08:15	11,331	103	5	1	0567	4	01	50	38
	10/15/95	09:30	11,342	103	6	1	0567	4	01	50	38
	10/17/95	08:15	11,395	104	1	1	0567	4	01	50	38
	10/19/95	09:30	11,251	102	8	1	0567	4	01	50	38
	10/21/95	09:45	11,136	101	8	1	0567	4	01	50	38
	10/23/95	09:10	11,239	102	7	1	0567	4	01	50	38
	10/25/95	09:45	11,228	102	6	1	0567	4	01	50	38
	10/27/95	09:10	11,308	103	3	1	0567	4	01	50	38
	10/29/95	09:45	11,438	104	5	1	0567	4	01	50	38
	10/31/95	09:30	11,750	107	4	1	0567	4	01	50	38
	Total		180,957				Days	32.0			

Figure 17. Producer list.



Form 46 A--3000

BULK DRIVERS DAILY REPORT (12)

Name [signature] Date 2-5-96 Speedometer—Start 142462 Stop 142569

Time	D.	N.D.	Where Stopped	Pounds	Time	D.	N.D.	Where Stopped	Pounds	Time	D.	N.D.	Where Stopped	Pounds
6 pm			36 -	8833	2 am				(29868)	10 am				
10					10					10				
20					20				3473 gal	20				
30			492 /	8550	30			plant		30				
40					40					40				
50					50					50				
7 pm					3 am			(5)		11 am				
10			412 /	6028	10					10				
20					20			455 /	7697	20				
30					30					30				
40			10 -	7617	40					40				
50					50			381 /	8035	50				
8 pm				(31028)	4 am					12 N.				
10					10			385 /	6958	10				
20			plant	3606 gal	20					20				
30					30			447 /	6520	30				
40					40					40				
50					50				(29210)	50				
9 pm					5 am			plant		1 pm				
10			(3)		10				3396 gal	10				
20					20					20				
30			175 /	11027	30					30				
40					40					40				
50					50					50				
10 pm			493 /	13125	6 am					2 pm				
10					10					10				(1)
20					20					20				
30			126 /	6611	30					30			44 /	6634
40					40					40				
50				(30763)	50					50				
11 pm					7 am					3 pm			274 /	2155
10			plant	3577 gal	10					10				
20					20					20			397 /	6556
30					30					30				
40					40					40			110 /	6843
50					50					50				
12 pm			7-11 (4)		8 am					4 pm				
10					10					10			100 /	4112
20			456 /	6450	20					20				
30					30					30				(26300)
40					40					40			plant	
50			227 /	5984	50					50				3058 gal
1 am					9 am					5 pm				
10					10					10				
20			450 /	10504	20					20				
30					30					30				
40			~~377~~	~~[illegible]~~	40					40				
50			464 /	6930	50					50				

BULK DRIVERS DAILY TIME REPORT

Date 2-5-96

Break Time

Time Worked

Driver's Signature [signature]

Check In

Check Out

Total Hours 17

Figure 18. Driver's log.

average monthly production among Virginia milk producers in 1995, (Statistical Summary, 1995).

Present Valley of Virginia milk hauling scheme

Valley of Virginia's present hauling scheme is more a reaction to governmental economic policy and variable milk production rather than a fixed plan. Though many drivers have a set route, these assignments are subject to change at any time depending on the need for milk at a plant, or the availability of milk on farms.

Milk from Valley of Virginia farmers is assigned to one of three processing plants, Mt. Crawford, Roanoke, or Springfield. A variety of scenarios are used to ship milk to these plants, (Figure 19).

Milk from farms assigned to the Springfield plant under Federal Order #4 must always be shipped to Springfield where it is pooled with milk from other cooperatives. Being a pool plant means that an average or 'blend' price is paid uniformly for all milk. A percentage of this milk can be diverted to the Mt. Crawford plant at times throughout the month. The amount of diverted milk varies each month depending on needs at the Mt. Crawford plant and on the ability of Valley of Virginia to market processed fluid milk products in the Order #4 region. Mt. Crawford can divert as much milk as they want from Order #4, so long as it can match that amount with an equivalent amount of sales of processed fluid products inside the Order #4 boundary. For example, if Valley of Virginia diverts 2,000,000 pounds of raw milk from Order #4 to its Mt. Crawford plant in February, it must also sell 2,000,000 pounds of processed fluid

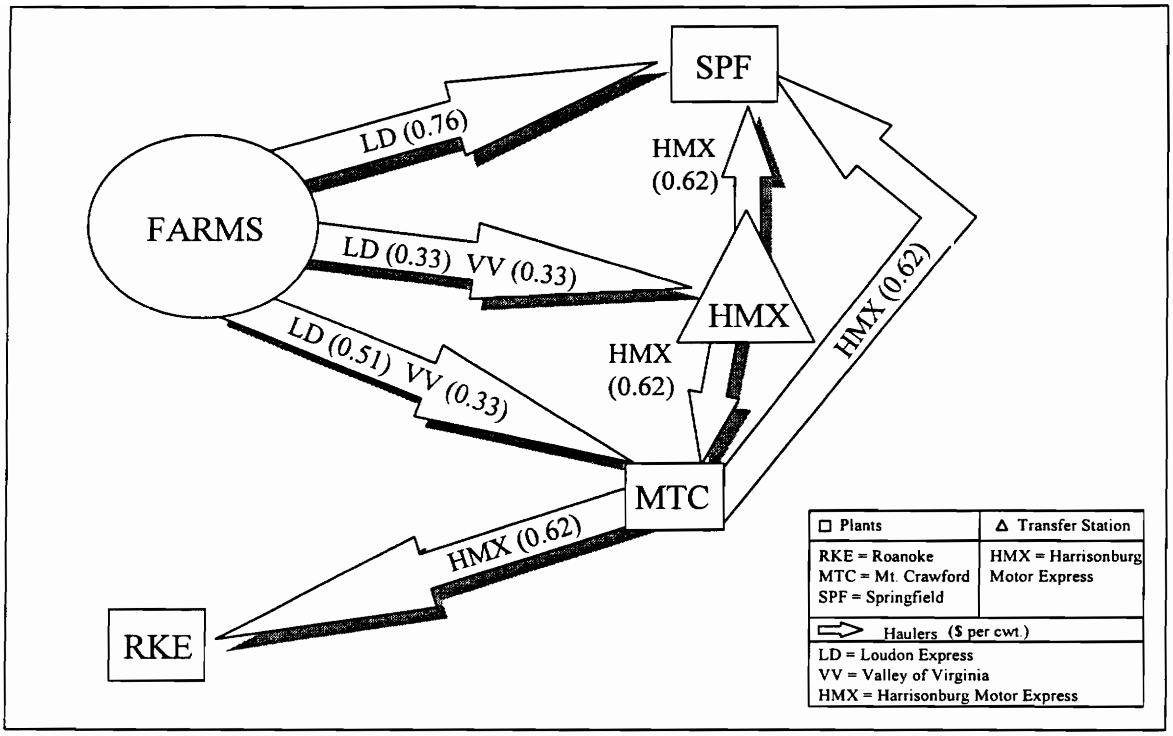


Figure 19. Present scenario of Valley of Virginia milk shipment.

milk products within the boundaries of Order #4 during February. By diverting milk to Mt. Crawford and matching it with fluid sales in Order #4, Valley of Virginia receives the highest price possible for its milk. If their fluid sales into Order #4 failed to cover the amount of diverted milk, Valley of Virginia would only receive the lower, pooled price received under the Federal Order. In addition to higher returns on their product, Valley of Virginia also benefits from diverting milk to Mt. Crawford by reducing hauling costs and mileage since Mt. Crawford is closer to the farms than Springfield. Milk reaches Springfield by direct hauling with Loudon Milk Transport, Inc. Loudon operates a fleet of 5500 gallon (47300 pound) capacity tankers. Harrisonburg Motor Express also hauls milk on 5500 gallon tankers to Springfield. Harrisonburg Express tankers, however, are not equipped with pumping facilities for on-farm pick up and must meet Valley of Virginia trucks at Harrisonburg Express or Mt. Crawford for the transfer connection before going on to Springfield.

Secondly, other farmers are assigned under a partially federally regulated contract to the Mt. Crawford plant. Because Mt. Crawford is a non-pool plant, only Valley of Virginia cooperative members can be assigned to this plant. Valley of Virginia straight trucks hold 3500 gallons (30100 pounds) and are driven by Teamsters Union drivers. Under contract these drivers may only haul milk assigned to Mt. Crawford. Most Valley of Virginia trucks deliver milk from farms to Mt. Crawford. Some may deliver to the Harrisonburg Express transfer station as well. Loudon cannot haul any milk assigned to Mt. Crawford.

Finally, a small amount of Valley of Virginia milk is sold to the Roanoke plant, a state order plant jointly owned by Valley Rich cooperative, Mid-American and Valley of Virginia. The amount of milk shipped to Roanoke depends on the amount allotted to Valley of Virginia through the base pricing system (Chapter 4). Any milk shipped to Roanoke in excess of the base allotment receives the Class II price, a significantly lower price than the Class I price (Statistical Summary, 1995). Another constraint in shipping to Roanoke is that milk going there must first be checked and weighed at Mt. Crawford, transferred to an Harrisonburg Express truck and then taken to Roanoke. Only about 11 tanker loads are shipped to Roanoke each week.

During periods of shifting demand, Harrisonburg Express will haul from Mt. Crawford to Springfield or from the transfer station to Mt. Crawford. In February, 1996, the Mt. Crawford plant experienced a temporary reduction of processing capacity due to a mechanical failure. The normal maximum capacity of 8000 gallons per hour was reduced to a mere 1500. With milk silos full from the weekend, the cooperative was desperate to empty the storage tanks to make room for the next day's incoming milk. Harrisonburg Express provided the solution. Harrisonburg Express trucks were filled with milk from the silos and then shipped to other processing locations, saving Valley of Virginia thousands of dollars. Harrisonburg Express trucks provide flexibility and other intangible advantages for the marketing of Valley of Virginia's milk. Despite this apparent benefit, the use of Harrisonburg Express trucks also obligates Valley of Virginia to ship milk through the Harrisonburg Express transfer station, a practice that may not be profitable for the cooperative.

Proportionally, the shipment of milk from Valley of Virginia farms to the three plants is depicted in Figure 20. This description of Valley of Virginia's hauling scenario and the many constraints surrounding it, although useful for outlining the major elements of their plan, is admittedly not inclusive of all the intricacies of milk marketing. Locally, Valley of Virginia must deal with variations in milking times and farmer preferences such as no Sunday pick up which is requested by Mennonite farmers. Regionally, the cooperative must consider market conditions in surrounding orders and how these affect the allocation of milk to its more distant

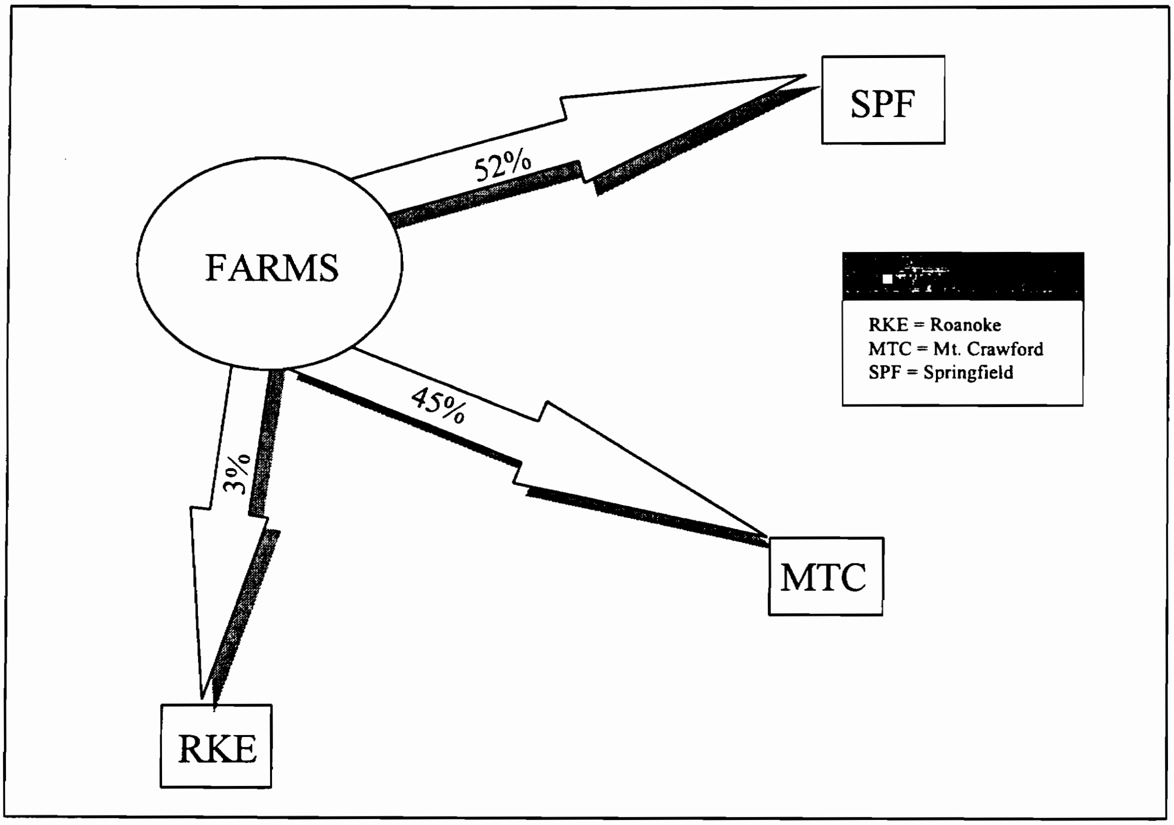


Figure 20. Distribution of milk from Valley of Virginia farms to processing plants.

plants. Even though these peripheral data are important, this thesis considers mainly those data mentioned above that can be easily put into a GIS and used for routing and allocation functions.

Valley of Virginia's Interest in the Study

While some larger cooperatives have experimented with computer based solutions for designing milk hauling routes (Jung 1991, Erba and Pratt 1994), smaller cooperatives, such as Valley of Virginia, are just beginning to investigate the advantages that this technology can offer. Valley's interest in the benefits of GIS is centered around the reduction of vehicle mileage. Currently, Valley of Virginia hauls milk from farms south of Mt. Crawford north to the Harrisonburg Express transfer station. At the same time, the cooperative hauls milk from points north of Harrisonburg Express south to the Mt. Crawford plant. Craig Jones, Field Manager for Valley of Virginia, claims that this routing overlap creates unnecessary mileage increases for the cooperative. This research uses GIS to model an alternative to this routing overlap and to measure the difference it would make in terms of mileage saved.

The second concern for Valley of Virginia is reducing mileage through the reallocation of milk to the Roanoke plant. Because Roanoke is regulated under the State Milk Commission, milk must be first be brought to Mt. Crawford, checked and weighed, then sent to Roanoke for sale. At present, milk cannot be shipped directly from the farm to Roanoke. However, by reassigning a portion of its base allotment, Valley of Virginia could begin to haul directly to Roanoke. The cooperative is interested in how GIS can model the shipment of milk to Roanoke in order to show what benefits can be gained from changing the base assignment in this way.

Operations and results

Two general approaches were taken to modeling milk flow:

1) A 'micro' or local scale approach which analyzes the routing of milk trucks and the need to maximize the available payload

2) A 'macro' or regional scale approach which analyzes the allocation of milk to different plants and markets

Micro Modeling of Milk Shipment

A 'micro' approach to modeling milk shipment involves operations made on the local scale. This approach considers only the shipment of milk from farms to the Mt. Crawford plant. This milk is carried by Valley of Virginia's own trucks driven by Teamsters Union drivers. Analyses performed in the 'micro' approach are of two types: payload maximization and path finding.

Payload maximization analysis utilizes the SPATIALORDER and COLLOCATE commands (Chapter 4). These algorithms group farms together so that no group will exceed the capacity of a truck, and so that the farms in each group are relatively close together to minimize travel distance. The percent capacity of the truck for each run was calculated by adding the total amount of milk collected along the run and then calculating this amount as a percentage of the truck's capacity. Table 5 displays the efficiency of payload maximization obtained through GIS as compared to that achieved by the cooperative's own manual planning. The cooperative's system of grouping farms produced a payload maximization percentage of 86.1%, whereas the GIS achieved a rate of only 78.8%.

Table 5. Payload Maximization. Results from COLLOCATE versus actual records.

Route System	Collocate groups	% Capacity	Actual groups	% Capacity
1	1	75.5	1	94
	2	96	2	90.3
	3	79.3	3	82.4
	4	76.9	4	78.6
	5	87.9	5	89.9
	6	43.8	6	92.9
	7	68.8		
		AVG = 65.7		**AVG = 88.0**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
2	1	90.8	1	84.8
	2	87.1	2	100
	3	72	3	99.2
	4	84.4	4	96.3
	5	96.7	5	94.2
	6	22.4		
		AVG = 75.6		**AVG = 94.9**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
3	1	94.4	1	71.2
	2	79.3	2	95.3
	3	88.8	3	95.2
	4	70.6	4	47.3
			5	24.1
		AVG = 83.3		**AVG = 66.6**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
4	1	75.5	1	78.2
	2	71.5	2	92.6
	3	96.9	3	95
	4	93.5	4	92
	5	92.6	5	89.3
	6	83.7	6	95.2
	7	28.5		
		AVG = 77.5		**AVG = 90.4**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
5	1	94.7	1	88.7
	2	83	2	89.7
	3	91.6	3	78.8

	4	67.1	4	84.3
	5	80.2	5	85.3
	6	64.9	6	87.7
		AVG = 80.3		**AVG = 85.8**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
6	1	90.2	1	91
	2	93.5	2	88.5
	3	96.6	3	95.5
	4	90.9	4	96
	5	89.6	5	93.9
	6	82.2	6	84.8
		AVG = 90.5		**AVG = 91.6**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
7	1	81.7	1	94.1
	2	57.9	2	91.5
	3	91.8	3	84.1
	4	89.3	4	88.9
	5	74.2	5	67
	6	30.7		
		AVG = 70.9		**AVG = 85.1**
Route System	**Collocate groups**	**% Capacity**	**Actual groups**	**% Capacity**
8	1	84.7	1	85.4
	2	83.4	2	73.5
	3	84.6	3	96.8
	4	94.7	4	85.9
	5	86.6	5	92.4
		AVG = 86.8		**AVG = 86.8**
		TOTAL AVG 78.8		**TOTAL AVG = 86.1**

The path finding analysis consisted of a route by route comparison between computer chosen routes (determined by the ARC/INFO TOUR command, Chapter 4) and the actual routes driven by Valley of Virginia drivers. Actual drivers' logs were obtained from the cooperative. These records contain the farm ID number and the amount of milk picked up that day. (The amount of milk is measured on the farm by the driver before loading it onto the truck). The groups determined by COLLOCATE were not used in this path finding analysis. Instead, the exact groups used by the drivers (obtained from their records) were used so as to have a more accurate comparison of travel distances. The GIS generated routes produced a daily savings of 73 miles or a monthly savings of 2190 miles, (Table 6). With 7 trucks in use, a modest savings of 313 miles per truck could be achieved each month by adopting the GIS generated routes.

Macro Modeling of Milk Transport

A "macro" approach to modeling milk shipment considers the problem on a larger, regional scale. In contrast to the local analysis of comparing individual routes, this regional analysis deals with the cooperative's marketing scheme and the allocation of milk to the optimal plant. Valley of Virginia's main interests in this study involve allocation on this scale. Optimal markets are determined based on the distance to the plant and the capacity of the plant, or, in the case of the Roanoke plant, the amount of allotted base for that plant. The present allocation of milk to plants was modeled simply by assigning each farm to the plant to which its milk is currently shipped. Figure 21 is a spider diagram depicting the actual allocation of milk from all farms to their presently assigned plant, according to Valley of Virginia data. This allocation

Table 6. Pathfinding. Results from TOUR versus actual records.

Route System	Proposed route (mi)	Actual route (mi)	Difference (+/-)
1	148	150	-2
2	91	107	-16
3	111	132	-21
4	117	126	-9
5	107	117	-10
6	126	126	0
7	188	203	-15
TOTAL(daily)	**888**	**961**	**-73**
TOTAL (monthly)	**26640**	**28830**	**-2190**

includes both transfer and direct hauling. Total distance was calculated to be 19227.8 miles, with an average farm-to-plant distance of 79.4 miles. Actual allocation to individual plants is shown in Figures 22, 23, 24 and 25. It is important to remember that the total distance is not the actual mileage required to transport milk, but it is the sum of the distances from each farm to the assigned plant. Figure 26 shows how the pattern of milk flow would appear if the allocation adhered strictly to market forces rather than to government regulations and business tradition. Under this scenario, farms were assigned to Mt. Crawford until the plant reached its capacity. After this the farms farthest from Mt. Crawford were reassigned to the next closest plant. Significant differences in mileage were obvious. Total distance dropped to 5716.0 miles and average distance was just 22.8 miles for the same number of farms and the same milk production. Individual allocation to each plant under the pure market scenario is shown in Figures 27, 28 and 29.

Another set of operations performed as part of the macro approach attempt to model the allocation of milk to the Mt. Crawford plant and the Harrisonburg Express transfer station. As mentioned above, Valley of Virginia has traditionally routed milk from points south of Mt. Crawford north to the Harrisonburg Express transfer station and vice versa. GIS allocation functions were used to model the efficiency of the present allocation (Figure 30). A new allocation model was also produced that assigned farms to the nearest plant, (Figure 31). Under the new allocation model, average farm to plant distances were reduced by 1.7 miles for both the Mt. Crawford plant and the HMX transfer station.

The direct shipment of milk from farms to the Roanoke plant was modeled. Farms that are presently assigned to Roanoke, via Mt. Crawford, are instead modeled as directly shipments

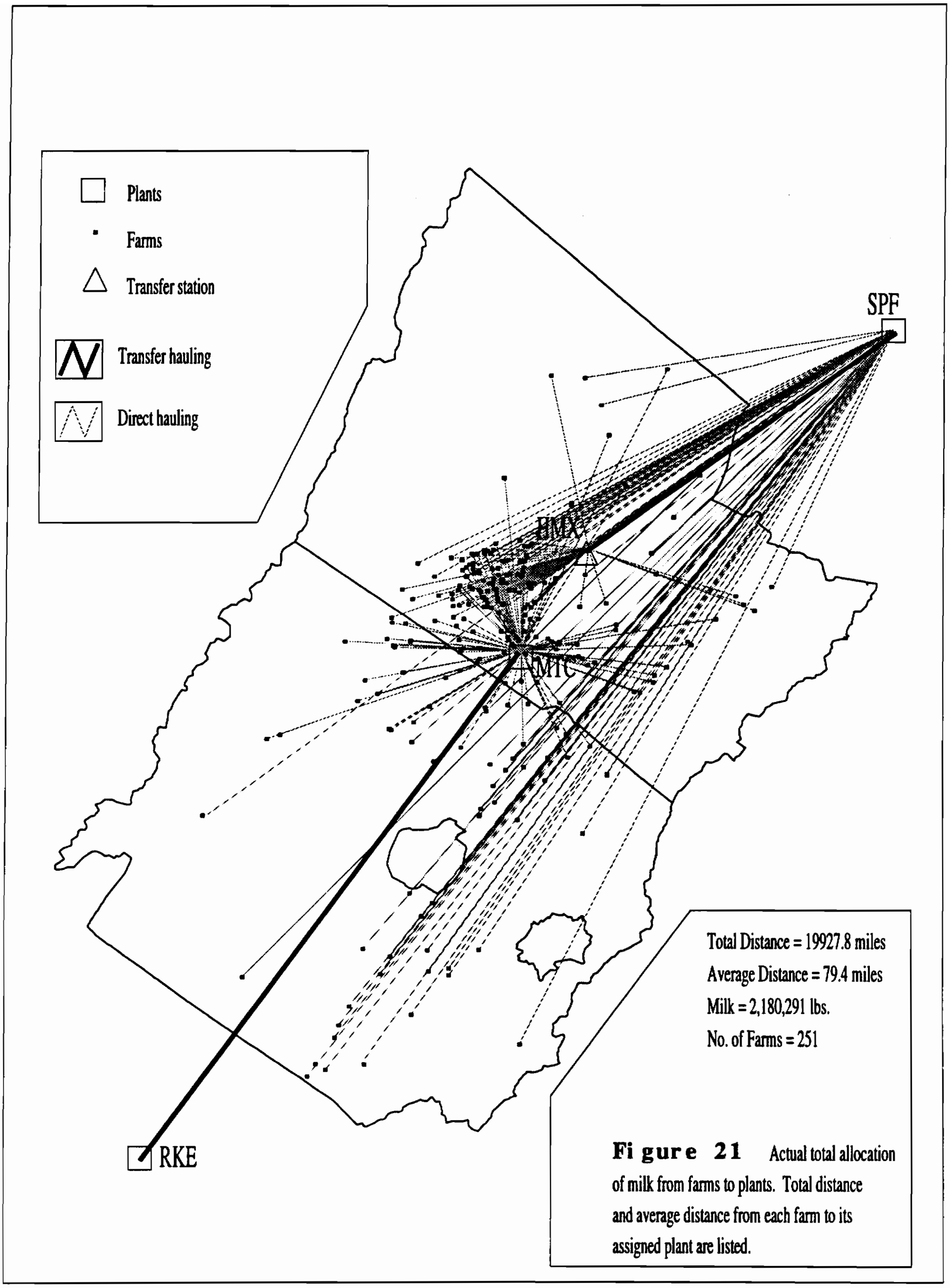


Figure 21 Actual total allocation of milk from farms to plants. Total distance and average distance from each farm to its assigned plant are listed.

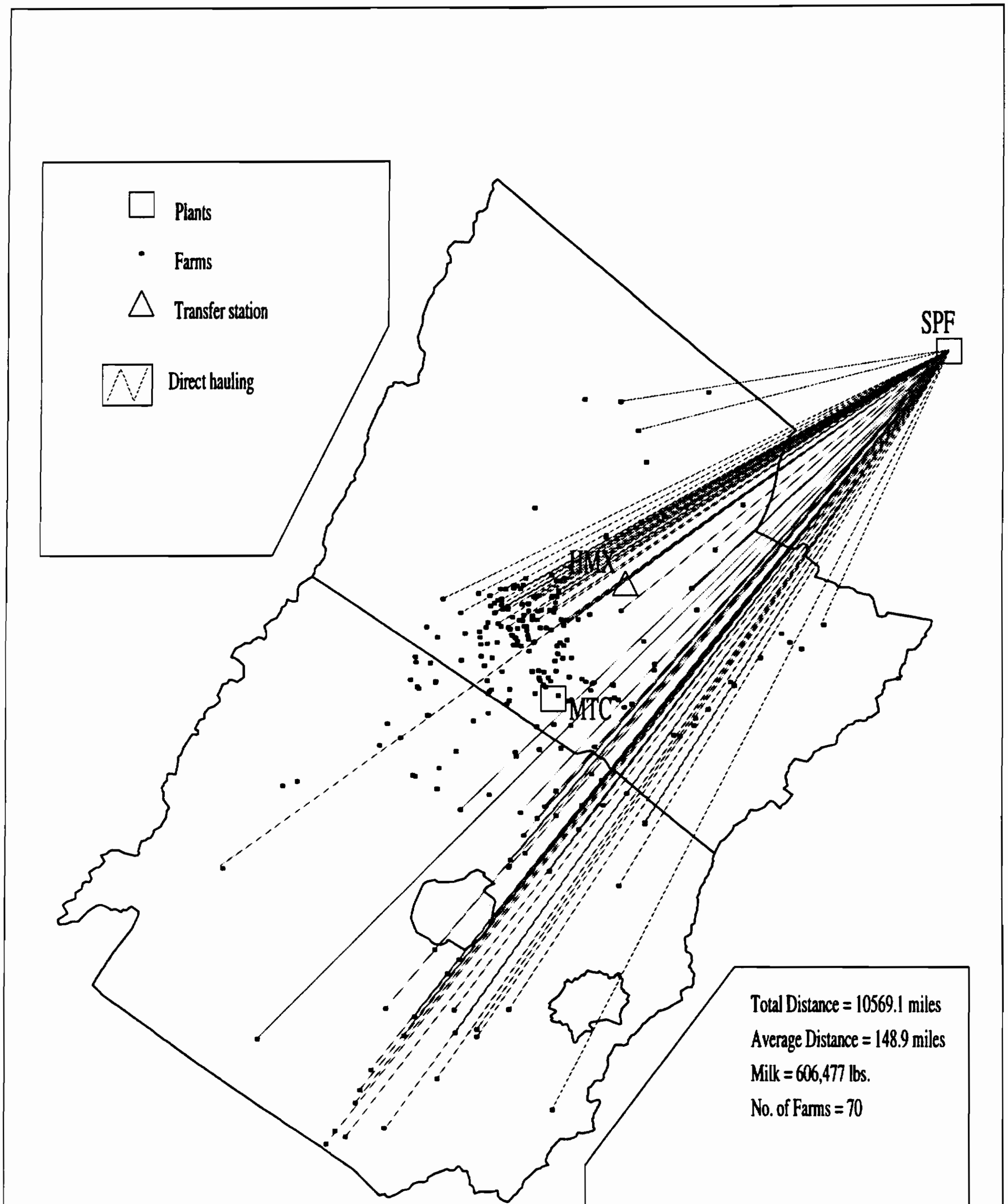


Figure 22 Actual allocation of milk from farms to Springfield plant. Total distance and average distance from each farm to the Springfield plant are listed.

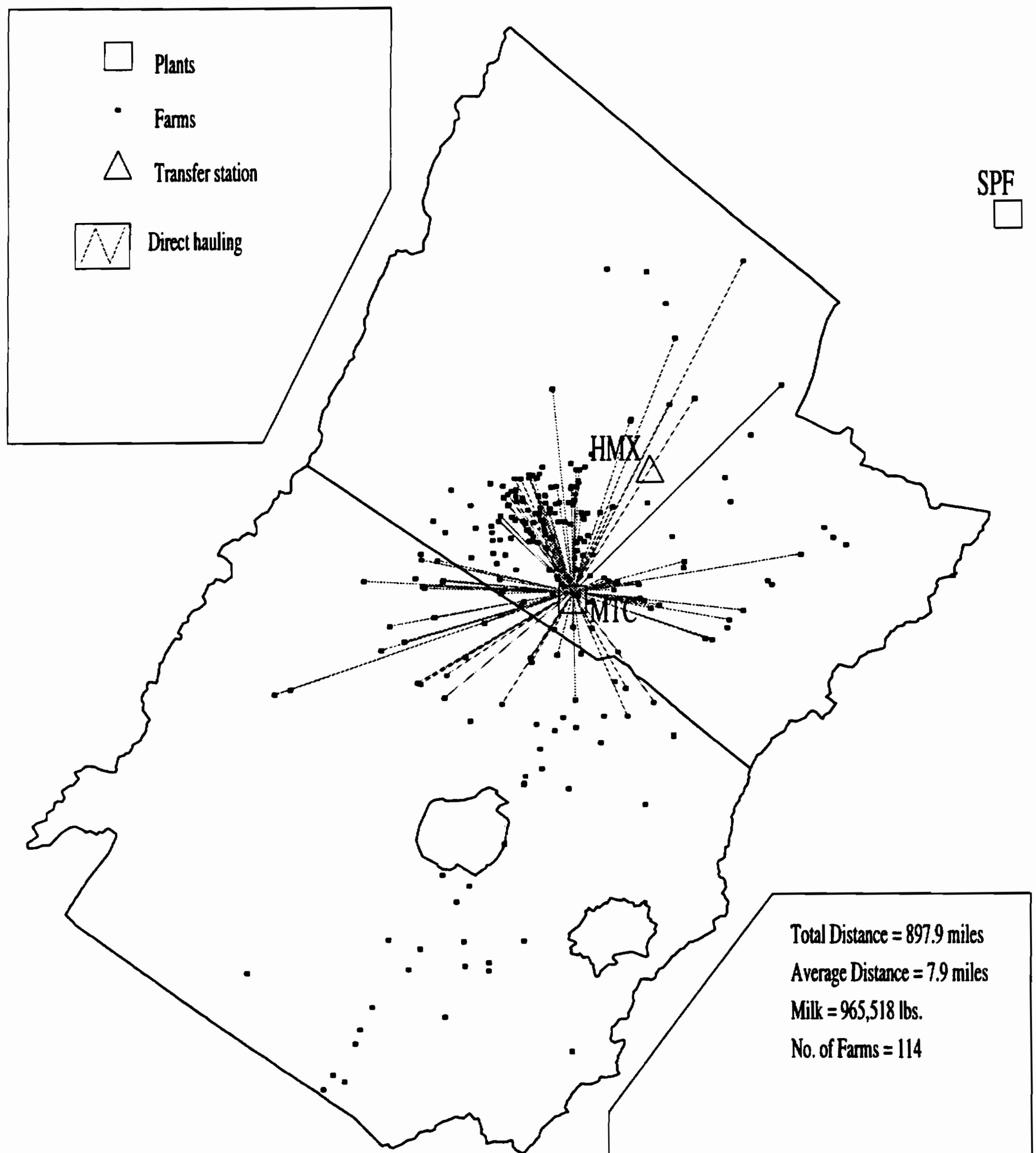


Figure 23 Actual allocation of milk from farms to Mt. Crawford plant. Total distance and average distance from each farm to the Mt. Crawford plant are listed.

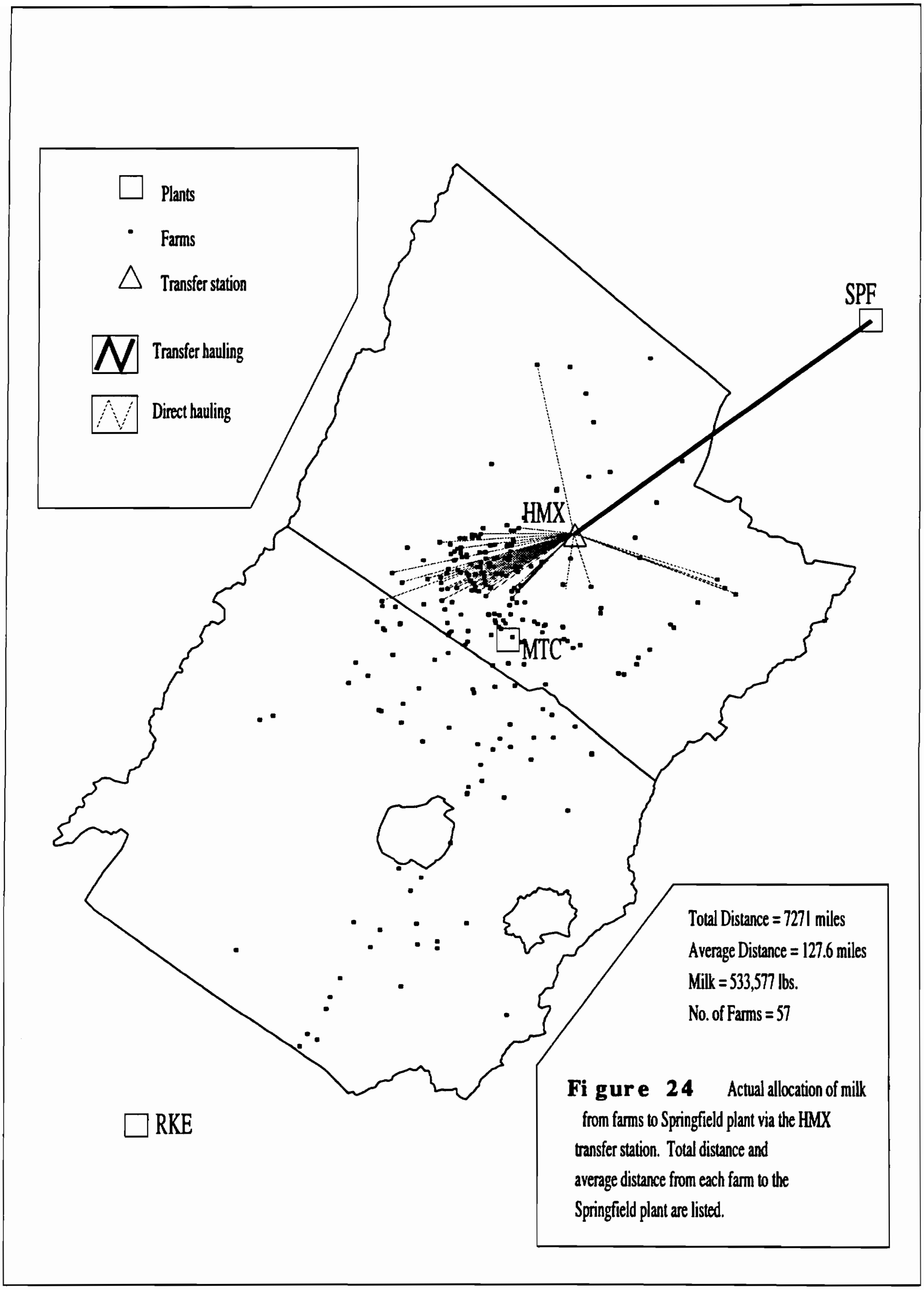


Figure 24 Actual allocation of milk from farms to Springfield plant via the HMX transfer station. Total distance and average distance from each farm to the Springfield plant are listed.

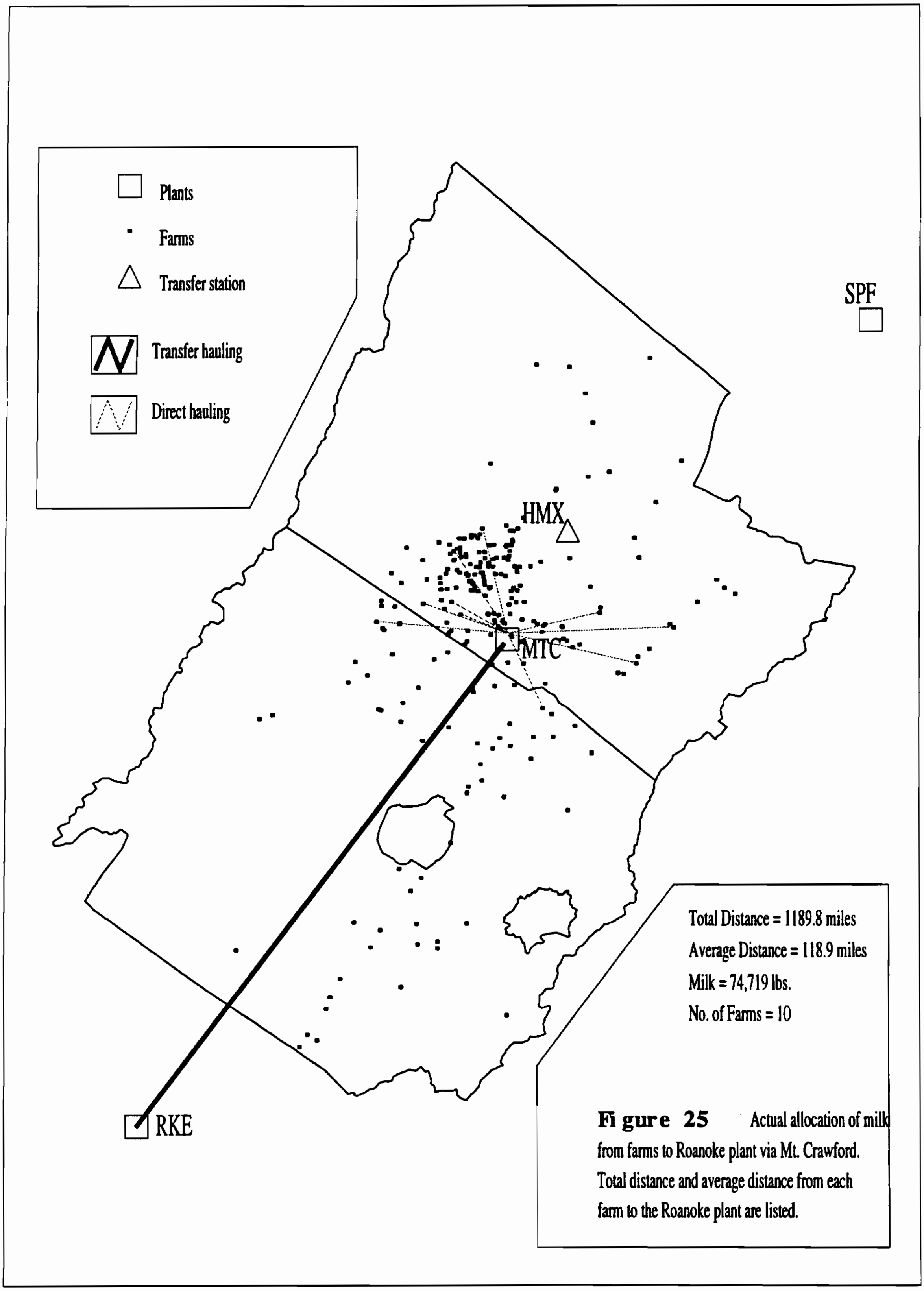


Figure 25 Actual allocation of milk from farms to Roanoke plant via Mt. Crawford. Total distance and average distance from each farm to the Roanoke plant are listed.

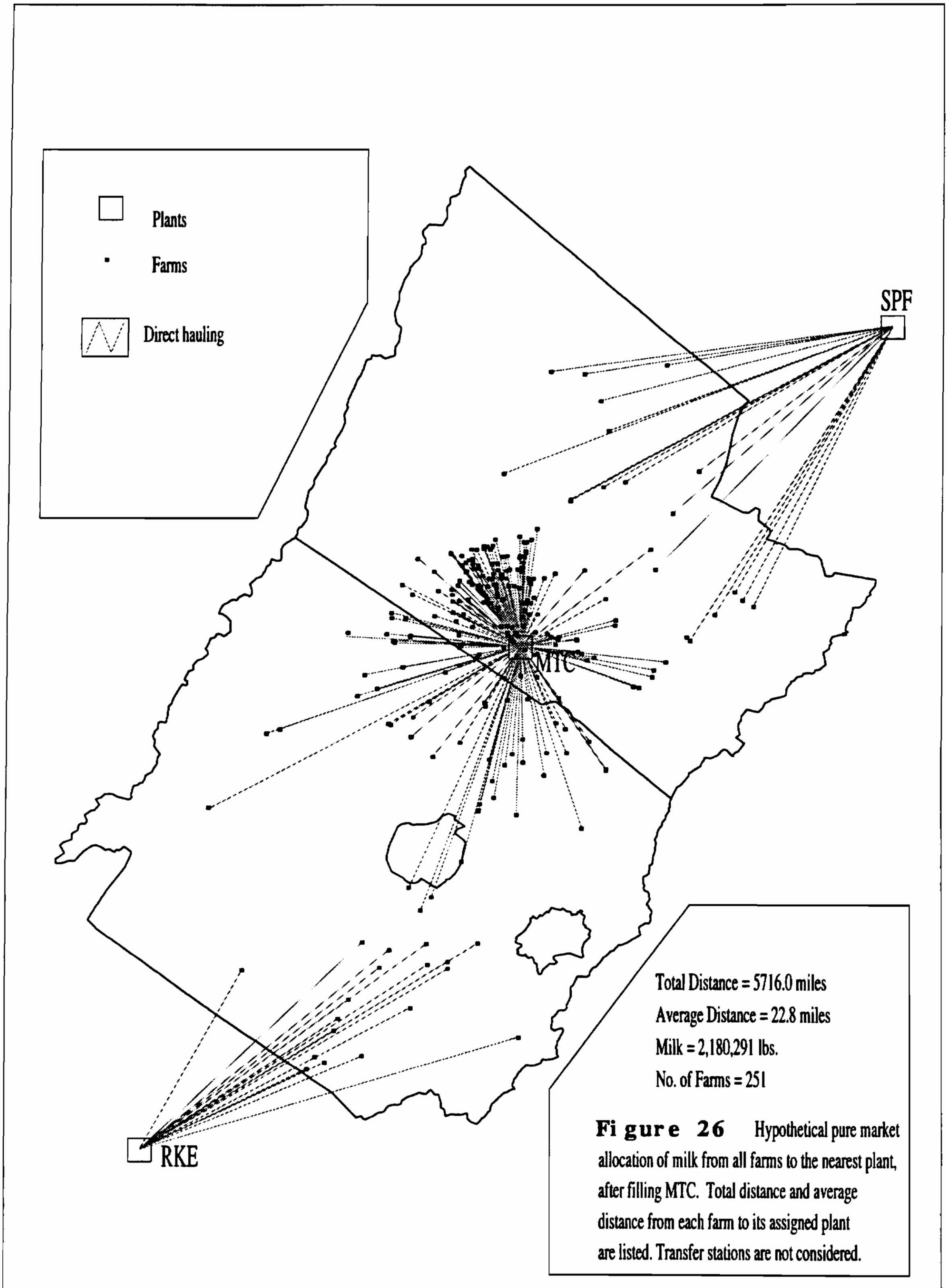


Figure 26 Hypothetical pure market allocation of milk from all farms to the nearest plant, after filling MTC. Total distance and average distance from each farm to its assigned plant are listed. Transfer stations are not considered.

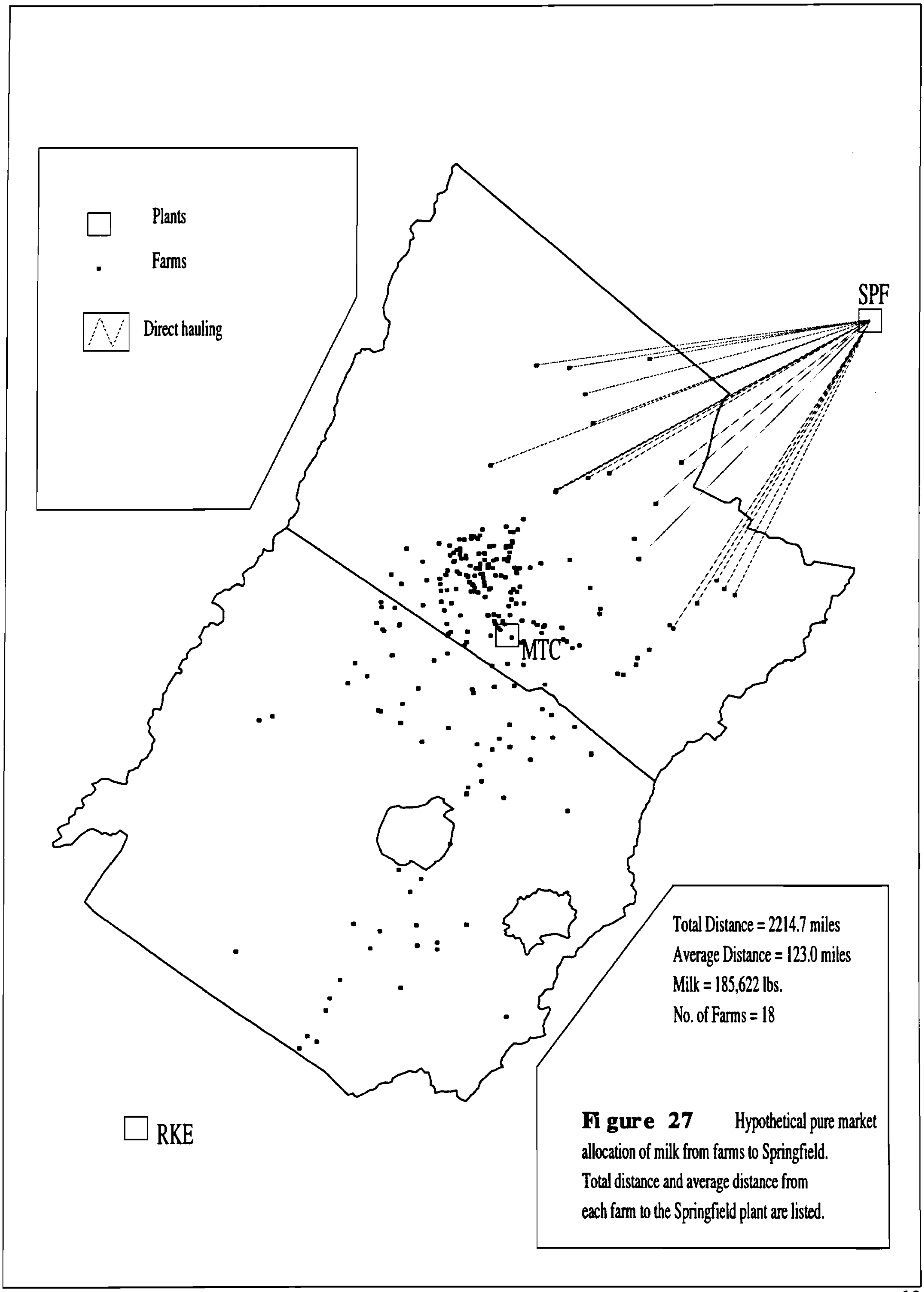


Figure 27 Hypothetical pure market allocation of milk from farms to Springfield. Total distance and average distance from each farm to the Springfield plant are listed.

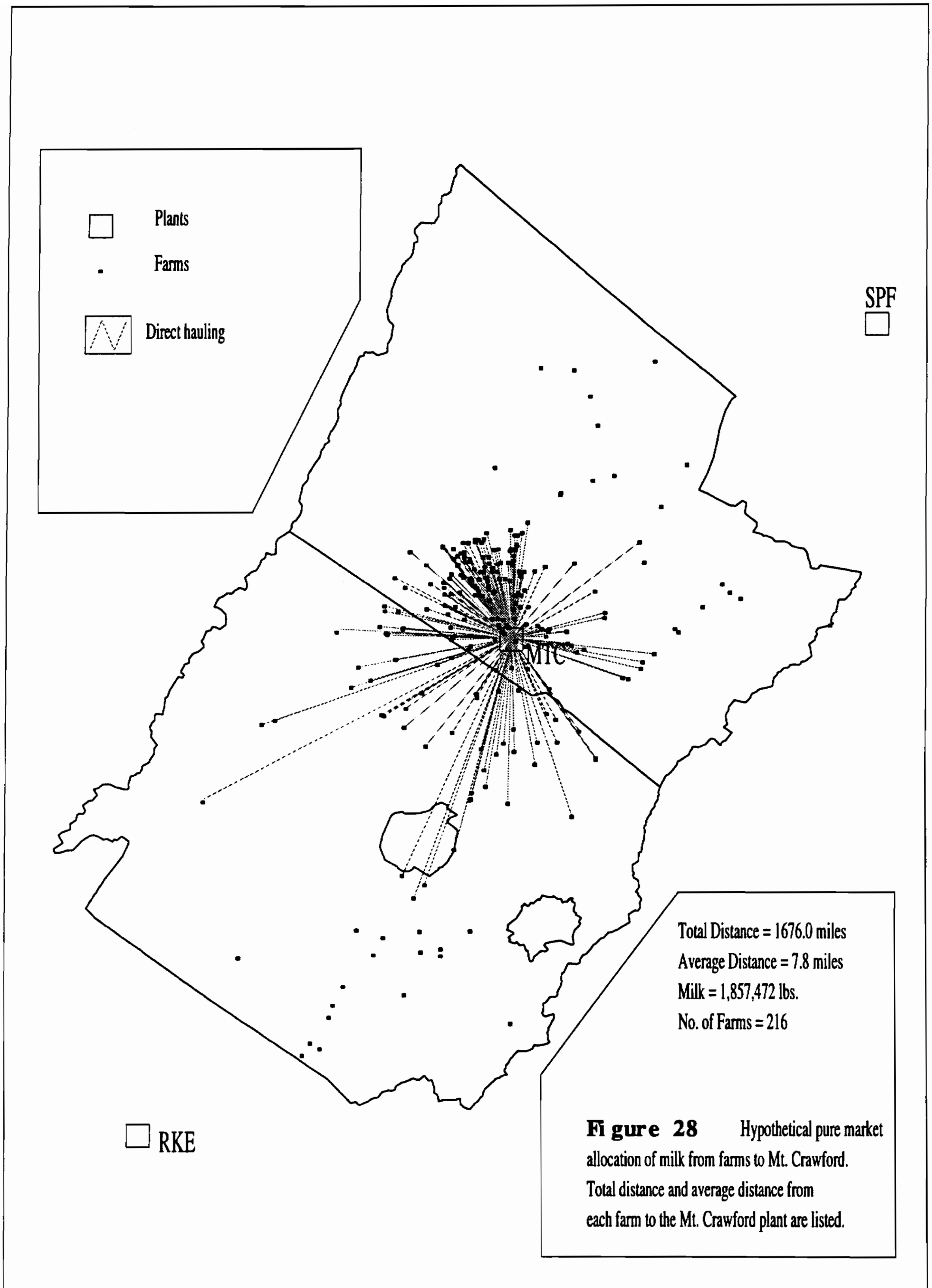
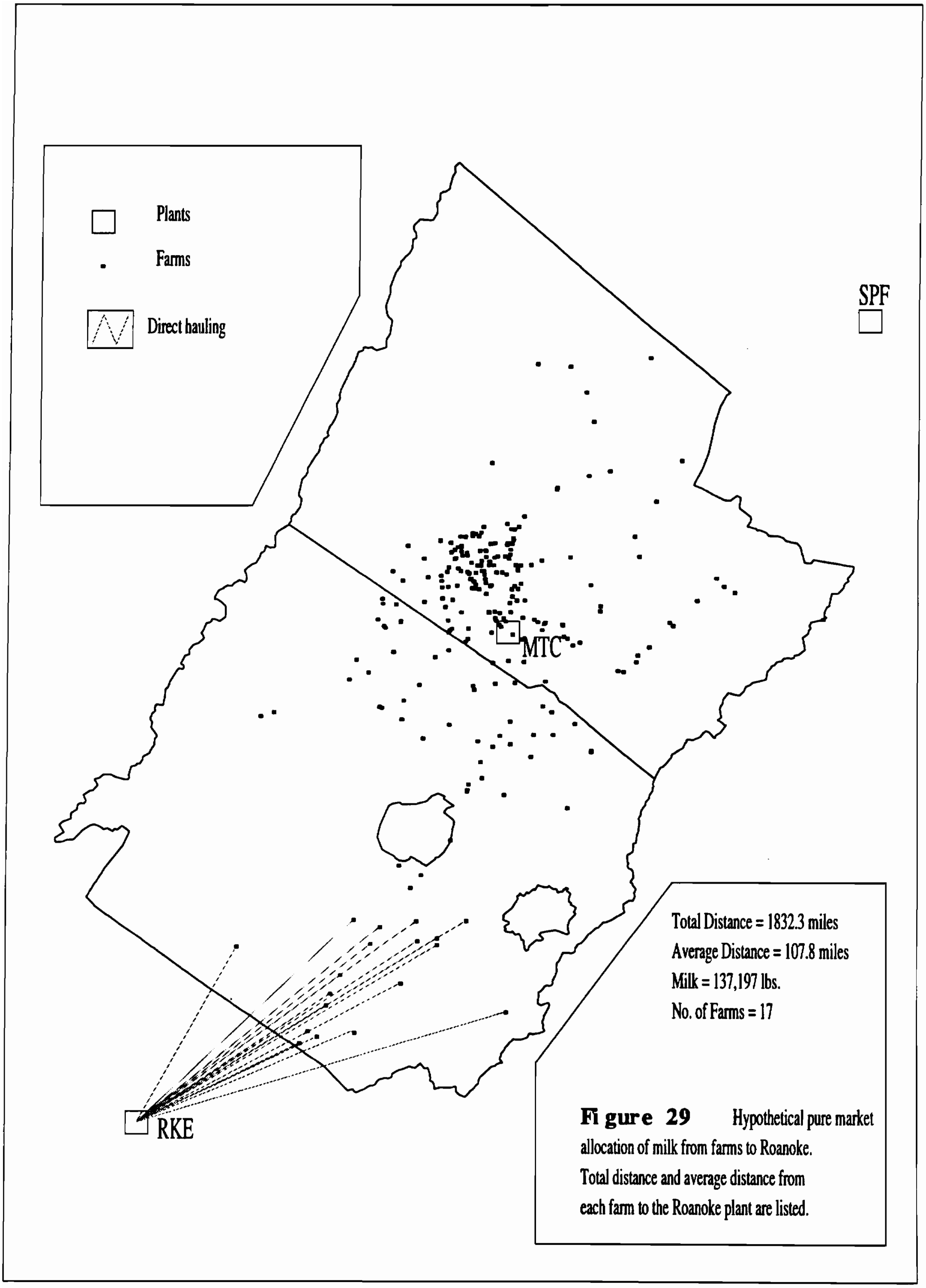


Figure 28 Hypothetical pure market allocation of milk from farms to Mt. Crawford. Total distance and average distance from each farm to the Mt. Crawford plant are listed.



Total Distance = 1832.3 miles
Average Distance = 107.8 miles
Milk = 137,197 lbs.
No. of Farms = 17

Figure 29 Hypothetical pure market allocation of milk from farms to Roanoke. Total distance and average distance from each farm to the Roanoke plant are listed.

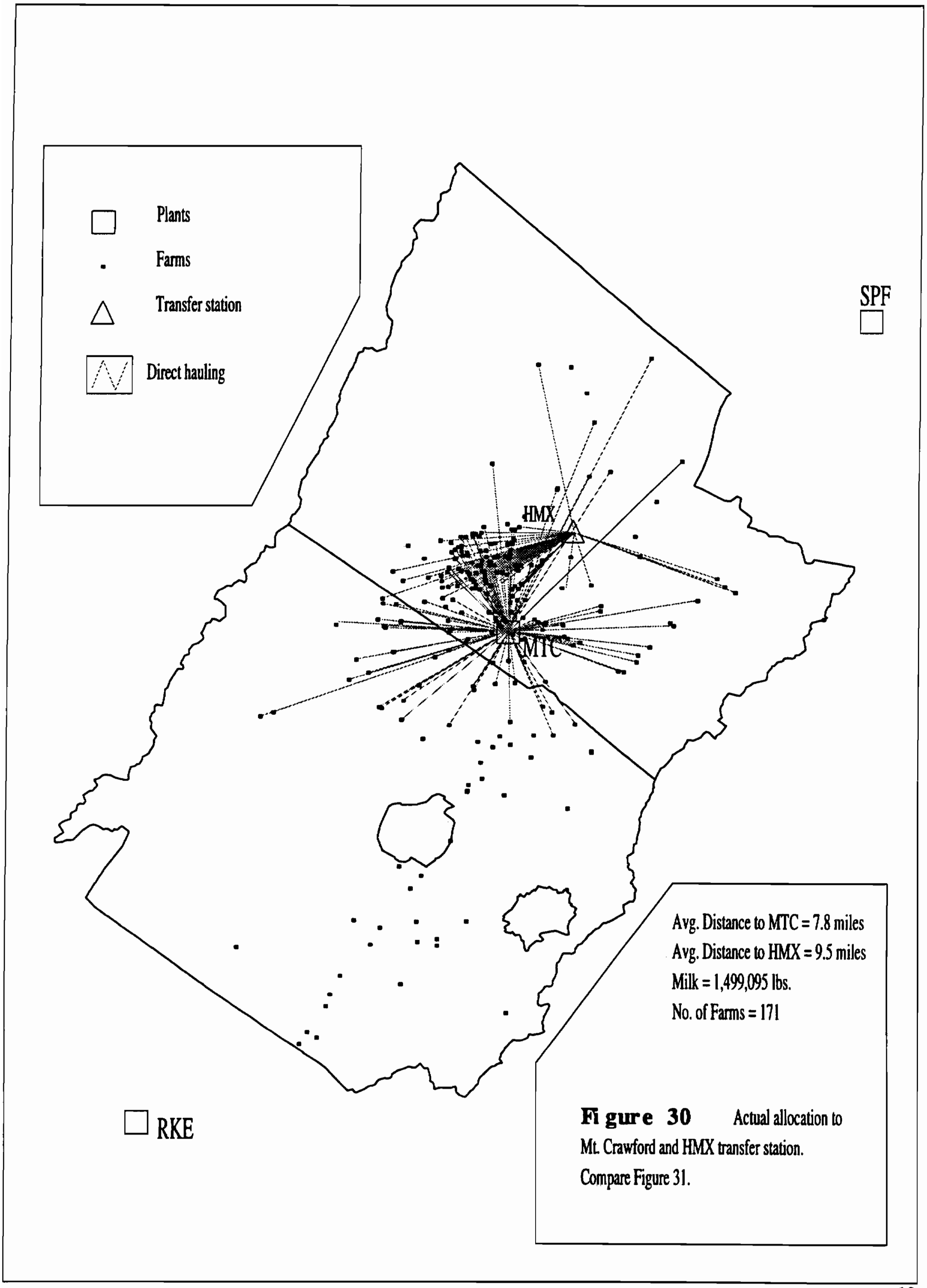


Figure 30 Actual allocation to Mt. Crawford and HMX transfer station. Compare Figure 31.

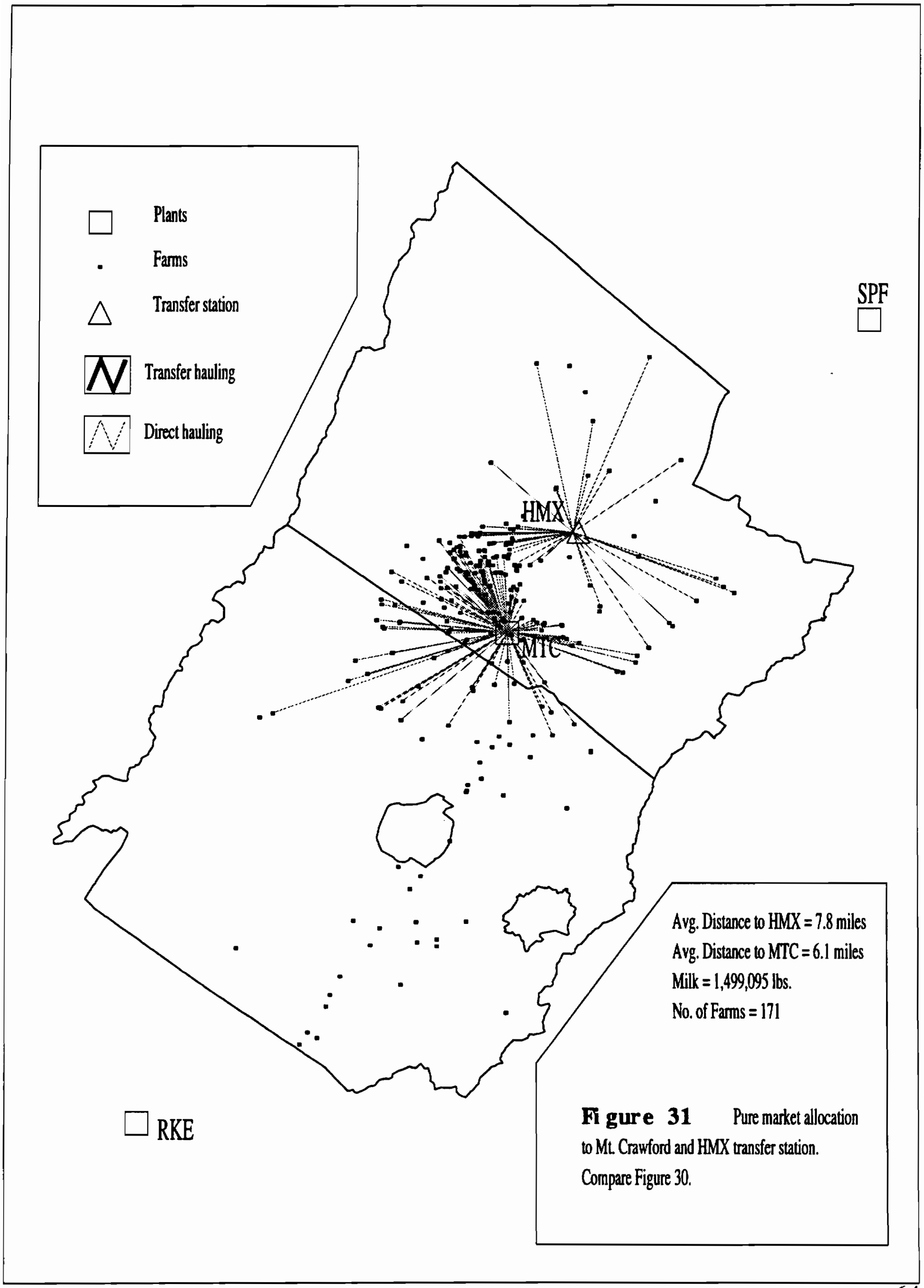


Figure 31 Pure market allocation to Mt. Crawford and HMX transfer station. Compare Figure 30.

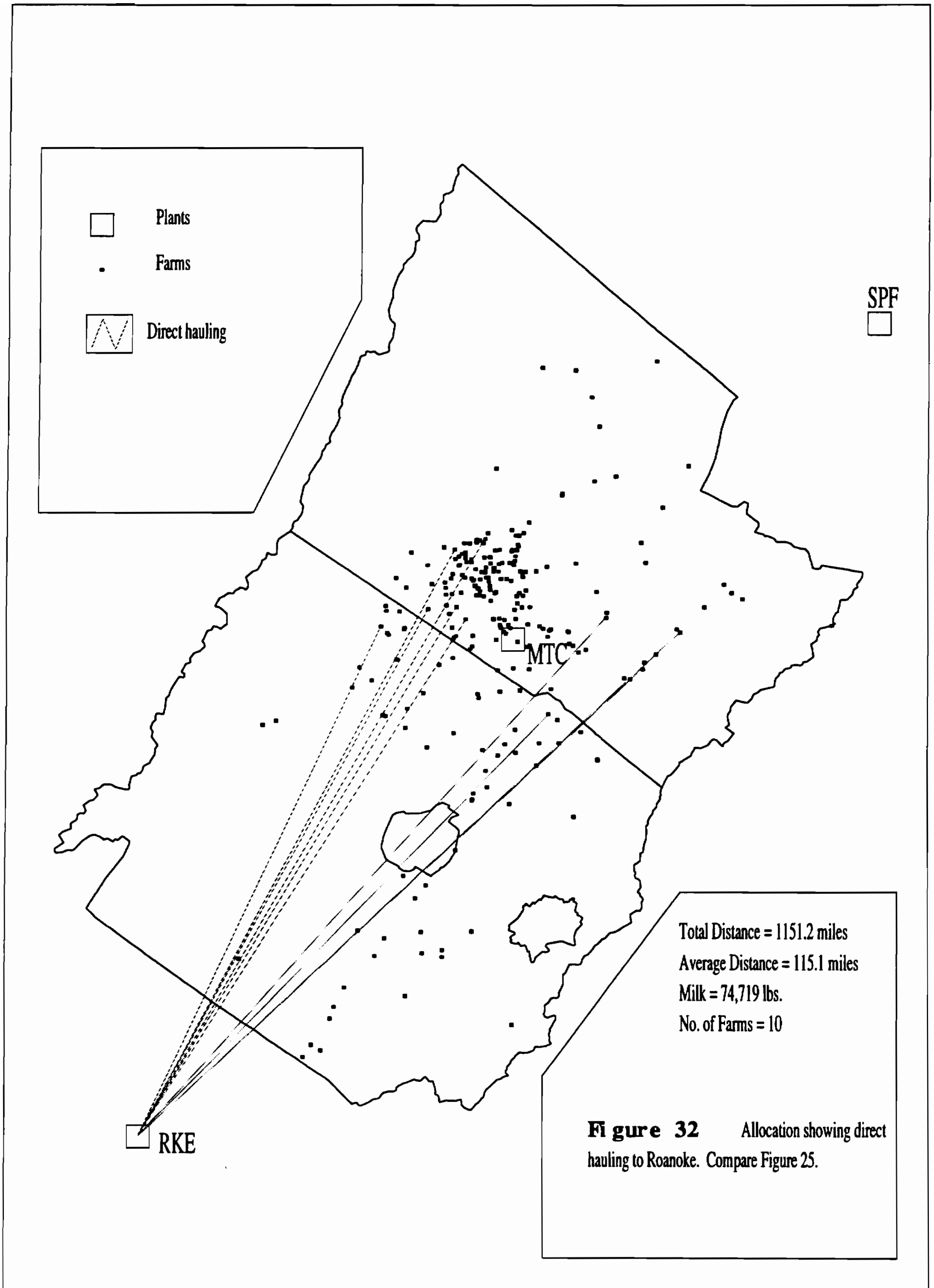


Figure 32 Allocation showing direct hauling to Roanoke. Compare Figure 25.

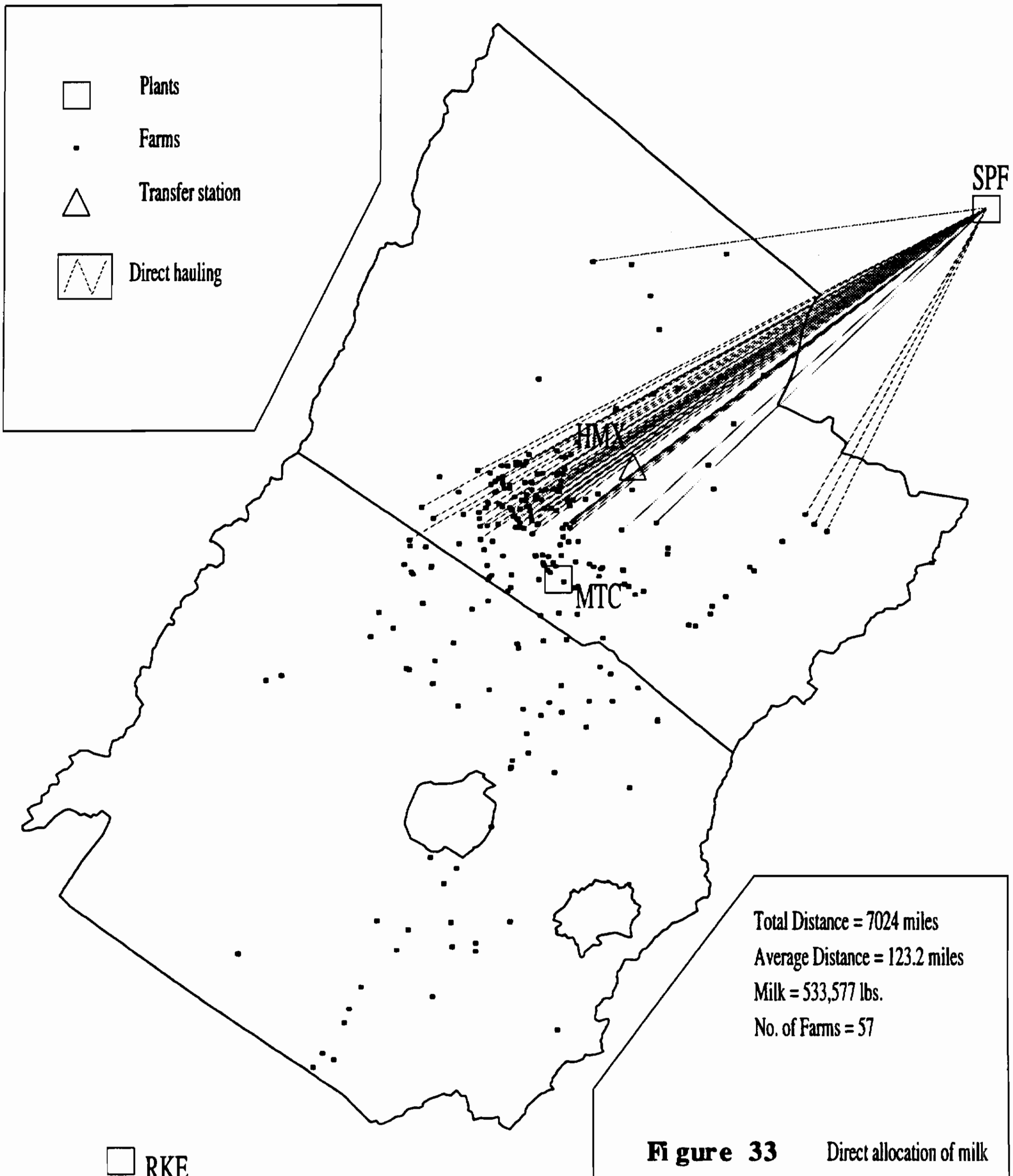


Figure 33 Direct allocation of milk to Springfield. Shows effect of eliminating HMX transfer station. Compare Figure 24.

to Roanoke, (Figure 32). This scenario reduces average travel distance to Roanoke from 118 miles (Figure 25) to 115 miles. By reassigning State Milk Commission base to farms closest to Roanoke, Valley of Virginia could reduce the distance of shipments to Roanoke to 107 miles (Figure 29).

Another scenario depicted by GIS involved mapping the effect of eliminating the Harrisonburg Express transfer station from the hauling strategy. Direct hauling from farms to Springfield by Loudon truck hypothetically replaces the present strategy of hauling through Harrisonburg Express. Cost benefits are obvious. Hauling to Springfield through Harrisonburg Express requires \$0.95 per hundred weight (0.33 + 0.62), compared to only \$0.76 cwt. charged by Loudon (refer to Figure 19). Although average farm to plant distance would drop only 4.4 miles (Figure 33), the lower freight costs charged by Loudon would produce monthly savings in excess of \$15,000 (Table 7).

Table 7. Economic impact of eliminating HMX transfer station (refer to Figures 24 and 33).

	To Springfield via HMX	To Springfield via Loudon Direct hauling
Avg. Distance (mi.)	127.6	123.2
Milk (lbs.)	533,577	533,577
Hauling cost ($ cwt.)	0.95	0.76
Every other day cost ($)	5069	4055
Monthly cost ($)	76,035	60,828

CHAPTER 7: SURVEY OF DAIRY COOPERATIVES

A mail survey of dairy cooperatives was conducted with the objective of determining current methods used by cooperatives to plan milk hauling and to survey market attitudes towards the implementation of GIS within the dairy industry. 30 dairy cooperatives from several regions of the country were selected from Directory of Farmer Cooperatives, (Wells, 1995). Of the thirty cooperatives selected, thirteen responded. Average membership of responding cooperatives was 1854. Responding cooperatives participate in twenty-one of the thirty-three current federal orders.

The survey questions and results are as follows:

Name of Cooperative:
Name of Transportation Officer:
Number of Cooperative Members: **Ranged from 68 to 9500 ; Average = 1854**
Present Federal Milk Marketing Order(s): **#'s 1,2,4,5,6,7,11,12,13,30,36,33,46,49,68,70,75,79, 126, 106, and 138 (see Figure 8).**

or

State Milking Marketing Order(s): **Virginia, Vermont, Western New York**

1. Mark one of the following that best describes your present strategy for assigning trucks to farms.

◊ Manually done with paper map and push-pins..............**(9)**

◊ Some degree of automation is involved and computers are used for part of the process..........**(4)**
◊ Fully automated..............**(0)**

2. Would you be interested in implementing an automated system to help determine milk truck route if it was shown to be efficient and economical?

◊ Yes..........................**(10)**
◊ No............................**(1)**
◊ Maybe......................**(2)**
Why or why not?

Yes:

1. We have looked into some systems, and feel it would save money in cutting miles and time. We also think it will help us plan for future routing changes.
2. We recently purchased a software program to automate the dispatching of already assembled loads...We plan on proceeding to the next step of having the computer assign farms to trucks, but at present this is done manually.
3. We are currently exploring some computer mapping programs and have considered the possibilities of a satellite mapping program.

Maybe:

1. I have looked at a mapping system and it seemed like a lot of work to set it up.
2. Have reviewed automated systems in past without much success.

3. Briefly describe your method of planning milk truck route assignment.

1. We have all independent haulers and they are assigned producers. New producers are assigned to a hauler by location, history of the farm, where we need the milk, and producer preference.
2. Currently we use Rand-McNally for routes from farm to market and also when we import milk for routing trucks [to pick up this milk].
3. Done manually based on load size.
4. We are using a computer program called "Truck Stops", this system is now outdated. We currently rely on the haulers to set up their own routes & they actually do a very good job.
5. We use contract milk haulers in our Eastern Fluid Group of Mid-American. We do our best to assign our routes to their closest markets but this does not always work out for us.
6. Milk haulers have assigned territory. These boundaries are set up when the route is developed or remains the same if a new hauler is hired. If there are conflicts, the haulers must resolve.
7. Each truck has an assigned route, adjustments are made as production changes.
8. We have found that to keep our hauling rates as low as possible, we need to haul as large as possible, and to keep them as full as possible on a year round basis. We do a lot of balancing between haulers by moving farms from one [hauler] to another as production fluctuates. This is currently being done by using maps & pins, but as noted above, we are looking at a program to automate this process.

9. Each hauler is given a designated area, all producers in that area are assigned to him.
10. All milk truck route assignments are the responsibility of the individual haulers.
11. [Based on]: Volume at farm, storage capacity at farm, required frequency of pickups, proximity to other farms and their volume, size and type of tractor-trailer needed for route, and time constraints for delivery to plant customers.
12. Much of our producer milk goes to the same plant each day. This milk , of course, is delivered to the plant located closest to the milk that is a customer of our cooperative. However, during periods of long supply when we are moving surplus milk out of the market of short supply when we are moving surplus milk into the market, much of the milk is not delivered to the same plant every day. The most "efficient" routing of producer milk is affected by plants needs and specific haulers capabilities.
13. Current route reorganization projects have been done using paper county maps and plotting farms; Haulers are identified by colored hi-liters. Our goals in establishing milk truck routes have been focused on minimizing assembly miles and maximizing payload.

Of the thirteen respondents, only four are presently using some type of computer technology for planning of milk hauling. Only one of these four cooperatives, indicated some degree of success and satisfaction with an automated system. Two cooperatives noted some type of negative experience with such systems.

The other nine survey participants operate in a fashion similar to Valley of Virginia, using a paper wall map and color coded pins to mark farms and plants. Of these cooperatives, three indicated that they were currently investigating the feasibility of using a computer based system for route planning.

Overall, ten of the thirteen responding cooperatives indicated that they would be willing to learn more about GIS and how it could improve their hauling efficiency. Of the three cooperatives responding negatively on Question #2, two noted prior negative experiences with computers as the reason, the other indicated no reason for their apprehension.

CHAPTER 8: OBSERVATIONS AND CONCLUSIONS

Through the use of GIS network and allocation functions, this thesis sought to demonstrate the effect of government regulations and cooperative structure on the movement of fluid milk. The research has also evaluated the feasibility of using GIS in the dairy industry, by testing specific algorithms and by surveying current attitudes and practices of dairy cooperatives. Four basic conclusions are drawn concerning the dairy industry and GIS:

1. Constraints imposed by government and marketing decisions made by dairy cooperatives have created situations in the dairy industry where the movement of milk does not concur with a free market economic model.

Government legislation has affected the distance and direction of fluid milk shipment on both the regional and local scales. As they were intended to do, prices imposed by the Federal Order system have influenced the movement of surplus fluid milk away from the Upper Midwest region. Court decisions have allowed for the shipment of milk to more distant markets (Lough and Fallert, 1977).

On the local scale, cooperatives selling milk in multiple federal or state orders must balance milk shipment among these markets. In the case of Valley of Virginia, milk that would, under a pure market system, be assigned to the Mt. Crawford plant, is shipped instead to the more distant HMX transfer station. The cooperative could reassign this milk to the closest plant, but, by so doing, would receive only 70% of the normal market price for milk from those reassigned farms. This is due to federal order regulations concerning the entry of new farmers into its pool. Present allocation of milk is a result of traditional business decisions made by cooperative leadership. Adjustment of the present allocation scheme to produce a more economical situation is discouraged by government regulations.

The use of the HMX transfer station is a tradition carried on by the cooperative despite its unprofitable nature. Under the present situation it costs Valley of Virginia $76,035 monthly to ship milk through HMX to Springfield. By using Loudon trucks to haul direct to Springfield and eliminating the transfer station, the monthly cost drops to $60,828 , a difference of $15,207, (refer to Table 7).

Despite the potential savings that could generated by elimination of the transfer station, Valley of Virginia will not likely pursue such action in the near future. The scheduling flexibility that HMX trucks provide for Valley of Virginia is an important asset, even though this use requires also the use of the inefficient transfer station. Even without these scheduling flexibility provided by HMX, business between the two companies would likely continue on the basis of tradition and a long standing gentleman's agreement between head executives. Major changes in shipment practices may not occur until the present leadership of Valley of Virginia and HMX changes. Valley of Virginia's situation is similar to a phenomenon recognized by Clark in his work with the New Zealand dairy industry. His study showed that dairy farmers and cooperatives were unwilling to abandon long held traditions of milk marketing even though more lucrative outcomes were available through slight reforms in cooperative structure. The security afforded by maintaining these traditions outweighed the benefits of any restructuring policies. In some cases "profit maximization is not the single or even dominant objective of all business organizations, " (Clark, 1979).

2. Using GIS to plan milk shipment on a local scale may not be as efficient as present methods due to the important role of local knowledge, and because of the iterative nature of the GIS algorithms used in the operation.

Though routes chosen by the GIS were significantly shorter than those presently used by the cooperative (Table 6), field verification is necessary to determine the feasibility of computer generated routes. In this study, route feasibility was affected by the unrealistic representation of real world conditions by the digital data. Maps used for this thesis were based on US Census Tiger files. Local variation in the road surface and conditions, including construction, are not maintained on Tiger files. Some road intersections that are actually not intersections are shown on these maps. In other cases, newer roads have been constructed or bridges may have been built or improved. As a result, path finding algorithms selected routes that may be shorter but not possible. A need to obtain better road coverage and to verify its accuracy would have allowed the GIS to better represent the actual conditions.

Milking times determine when visits can be made for milk pick up. This thesis did not consider milking times of individual farms because these data are highly variable, even though they are recorded by drivers. When analyzing the order of farms produced by pathfinding functions, it was evident that some situations could not be implemented due to discrepancies in milking times.

On the local scale, the drivers' knowledge of the roads and experience were also factors affecting the ability of GIS path finding algorithms to accurately predict routes for milk hauling.

The average tenure of Valley of Virginia drivers is 10 -12 years (Jones, 1996). Over time drivers have learned which routes are feasible and efficient. They have also coordinated with farmers to plan visits around individual milking times. Because of varied milking times and the importance local knowledge, GIS route planning on a local scale may not be a feasible alternative to present methods. Further implementation of GIS for route planning at this scale will need to account for these critical variables.

Another limiting factor in the performance of GIS payload maximization functions, as compared to the cooperative's manual method of truck-to-farm assignment, involves the nature of the algorithms used by the ARC/INFO commands SPATIALORDER and COLLOCATE, and the nature of the problem itself. In essence, GIS payload maximization algorithms seek to solve two problems at once: maximize the payload of trucks and minimize travel distance between farms. SPATIALORDER produces a real number that represents the location of each farm in X,Y space. COLLOCATE must then group the farms so that the distance between farms in a group is minimized and payload is maximized.

A multi-objective problem such as this does not have a computable or absolute solution in the same way that 'two plus two equals four' is a computable solution. For such multi-objective problems, these GIS functions seek solutions through an iterative approach. Iterative algorithms provide a solution that is not absolute, but instead, is one of many possible solutions. In this thesis, the algorithm grouped farms, attempting to optimize the average payload for all groups. At the same time, constraints on the distance between farms in a group also had to be taken into account. For these reasons, the GIS solutions for payload maximization in this thesis were not as efficient as the cooperative's manual method.

3. GIS allocation functions are valuable in portraying regional milk shipment and in generating useful alternatives to current hauling problems.

The smaller a road network is, the fewer possibilities exist for finding routes. On a larger scale more possibilities for routes and for human error in choosing routes would exist. For these reasons, the use of GIS on a larger, regional scale produced more feasible results for milk hauling.

Milk allocation under the pure market scenario was significantly more efficient than the present situation. The effect of both government regulation and business tradition are evident in this analysis.

GIS was successful in modeling the two major concerns expressed by the cooperative: the allocation between Harrisonburg Express and Mt. Crawford; and the issue of direct hauling to Roanoke. In contrast to the localized path finding operations discussed above, these problems are more regional in nature and involve more complex calculations by the GIS. It is here where GIS can make its greatest contribution to the efficient practice of fluid milk hauling.

GIS was used to determine the closest plant among a group of farms. By allowing milk to be shipped to the nearest plant (Harrisonburg Express or Mt. Crawford), instead of continuing the traditional shipment pattern, Valley of Virginia would save significant mileage. Direct hauling to Roanoke would also be more economical if reassignment of the base could be made to those farms nearest the Roanoke plant.

4. There exists a market within the dairy industry for an affordable GIS that deals specifically with those constraints and limitations unique to the dairy industry.

One benefit that GIS provides for dairy cooperatives is that of modeling the feasibility of potential changes in milk shipment without the risks involved in actually implementing such changes. 77% of all cooperatives surveyed market milk in at least two federal orders. The fact that most cooperatives sell milk in multiple federal orders means that the number of possible marketing decisions is greatly increased, in which GIS could prove useful.

In addition to the effect of the federal orders, other factors affect the market for an affordable GIS that would serve the dairy industry. A decline in the number of farms and processing plants has created greater distances over which milk must travel to reach market. A greater distance to market means greater care must be taken in planning milk shipment, such as that provided by GIS. Secondly, the survey indicated that 77% of dairy cooperatives would likely invest in a system that would be affordable and efficient for milk hauling. At present, only 23 % use an automated system for route planning. A specialized GIS for milk hauling must deal specifically with those constraints inherent in such operations. Incorporating local knowledge into the system and effectively dealing with the problem of variable milking times will be essential in a milk hauling GIS. Those most likely to implement GIS for milk marketing are those who deal with shipment on a regional scale, including dairy cooperatives, trucking companies and government officials.

Conclusion

GIS is a valuable tool in modeling the effect of government regulations and dairy cooperatives on fluid milk shipment. On the local scale, GIS generated routes for farm pick up were not significantly shorter than currently traveled routes. In some cases the computer routes were not feasible due to variable milking times and local knowledge. Broader scale transportation problems that cover more complex networks provide better opportunities for the implementation of GIS.

As future legislation again changes the marketing structure of the U.S. dairy industry, cooperatives and milk handlers will be able to turn to GIS as an aid in transportation planning. GIS can be used to model the effects of these regulatory changes, as well as to develop specific hauling scenarios for individual cooperatives. As desktop GIS software becomes more affordable the use of GIS to plan and evaluate milk hauling efficiencies will become a common occurrence.

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