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A cost analysis of anhydrous ammonia fertilizer retailing in North Central Iowa

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A cost analysis of anhydrous ammonia fertilizer

retailing in North Central Iowa

by

Arnold Leo Heubrock

A Thesis Submitted to the

Graduate Faculty in Partial Fulfillment of

The Requirements for the Degree of

MASTER OF SCIENCE

Department: Economics
Major: Agricultural Economics

Signatures have been redacted for privacy

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1. INTRODUCTION AND ORGANIZATION

One of the most striking changes in American agriculture since World War II has been the adoption of fertilizer in crop production. In 1950, Iowa farmers spent 27.6 million dollars for lime and fertilizer. By 1968, they had increased their expenditures to 188.9 million dollars (12, p. 65). One form of fertilizer that has won wide acceptance among farmers is anhydrous ammonia.

It has been estimated that in 1971 Iowa farmers spent 41.8 million dollars for ammonia fertilizer. The estimated wholesale cost of this fertilizer was 30.6 million dollars. The difference between these figures, 11.2 million dollars, is an estimate of the costs and profits involved in the retail distribution of anhydrous ammonia. This study is concerned with the cost of the retail distribution of ammonia fertilizer.

1.1. Scope and objectives

One of the objectives in this study is to present a balanced view of the development of the fertilizer industry. This characterization of the fertilizer industry is an attempt to describe the cost setting of the ammonia retailers. Specifically, the Fort Dodge ammonia retailing market is examined for certain market structure traits. Included in the characterization is the identification of practices and problems of retailing ammonia.

A second objective is to estimate the cost of retailing ammonia and to examine how retailing costs are influenced by changes in season length, market share, and demand density.

A final objective is to use the developed cost estimates to evaluate the relative efficiency of ammonia retailing in the Fort Dodge area. This includes an estimate of the cost of a typical retailer.

1.2. Organization of the study

Chapter 2 examines the historical development of the fertilizer industry and, in particular, the nitrogen sector. Included is an analysis of the ammonia retailing industry in the Fort Dodge Functional Economic Area and an identification of retailing practices and problems in that area.

Chapter 3 deals with the relationship of plant and delivery costs and their combination into retail distribution costs. Included is a review of past ammonia retail cost studies.

Chapter 4 identifies and quantifies the cost coefficients and time parameters discussed in Chapter 3. The particular assumptions made about the coefficients and parameters are presented in this chapter.

Chapter 5 presents the cost results by means of a representative example. Changes in the cost results due to changes in season length, market share, and demand density are examined. The importance of plant size and the possibility of economies of size existing in ammonia retailing is also examined. The relative efficiency of the ammonia retailers is discussed, and an estimate of a typical retailer's costs is given. Finally, the importance of some of the assumptions is examined.

Chapter 6 summarizes the study and discusses implications of the results. Included is a discussion of limitations of this study and possible areas of further study.

2. CHARACTERIZATION OF THE FERTILIZER INDUSTRY AND ANHYDROUS AMMONIA DISTRIBUTION

2.1. Growth of fertilizer usage

The usage of fertilizer increased 230 percent between 1950 and 1970 in the United States. This growth in usage has been even more marked in Iowa and the Corn Belt States since 1960 (12). It is the purpose of this section to examine the increase in usage and the reasons behind it.

Table 2.1 represents the fertilizer consumption by farmers in the United States and Iowa for selected years.

Table 2.1. Consumption of fertilizer for the U.S. and Iowa, for selected years (12)

	1950	1960	1970
United States	18 Million Tons	25 Million Tons	39 Million Tons
Iowa	.3 Million Tons	.7 Million Tons	2.6 Million Tons

In addition to the increase in absolute consumption, there has been an increase in the relative nutrient content of fertilizer. In 1950, 18 million tons of fertilizer were purchased containing 4 million tons of plant nutrients, while in 1970, 39 million tons of fertilizer containing 15.8 million tons of plant nutrients were used. This represents an increase of 10.2 percent in the nutrient content of fertilizer (12). Figure 2.1 depicts the plant nutrient consumption of fertilizer for the United States and Iowa.

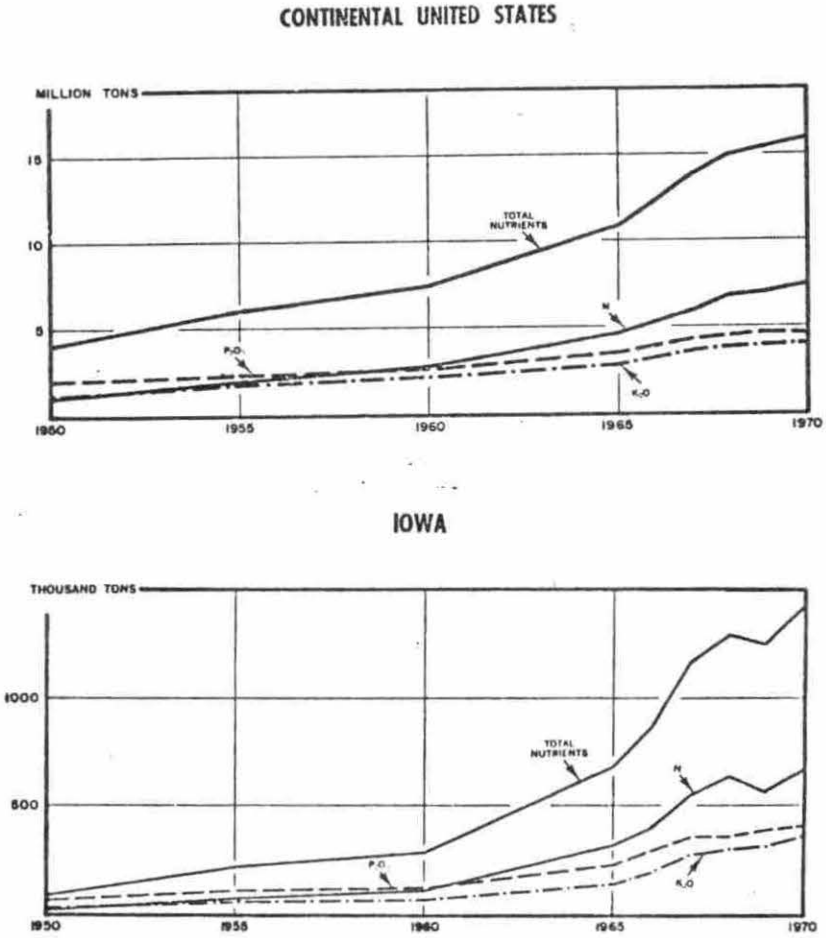

Figure 2.1. Plant nutrient consumption for the U.S. and Iowa, 1950-1970 (12)

2.1.1. Reasons for fertilizer growth

The acceptance of fertilizer by farmers as a profitable input over the past twenty-five years has increased over time. The reasons for this acceptance are: decrease in absolute price, decrease in relative price, increase in knowledge, complementary increase with other technology, and other reasons to be discussed in this section.

2.1.1.1. Decrease in absolute price   Fertilizers are one of the few farm inputs which have actually decreased in price in the past twenty years. The reasons for this reduction in price will become apparent in later sections. Table 2.2 denotes the cost per pound of the three major plant nutrients for selected years.

Table 2.2. Price per pound of nitrogen, P_2O_5, and K_2O, for selected years (5)

	1950			1960			1970		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Nutrient Source	Ammonium Nitrate	Normal Super-phosphate	Muriate of Potash	Anhydrous Ammonia	Concen-trated Super-phosphate	Muriate of Potash	Anhydrous Ammonia	Concen-trated Super phosphate	Muriate of Potash
United States	12.5¢	8.3¢	4.8¢	8.5¢	8.6¢	4.3¢	4.8¢	8.2¢	4.2¢
Iowa	N.A.	13.7¢	N.A.	8.5¢	8.8¢	N.A.	4.8¢	8.2¢	4.3¢

As is apparent from the table, the greatest decrease in price has been in nitrogen fertilizers. Farmers are aware of this reduction in price and have increased their purchases accordingly.

2.1.1.2. Decrease in relative price   Since 1950, prices paid for farm machinery and labor have increased 50 percent while land costs have doubled (19, p. 435). This has provided motivation for the farmer to substitute fertilizer for other farm inputs. It is estimated that a 1 percent increase in land prices will increase fertilizer use by 0.4 percent (18, p. 32). Figure 2.2a depicts a graphic representation of fertilizer prices, index of prices paid by farmers for all goods, and prices received by farmers for their products since 1955.

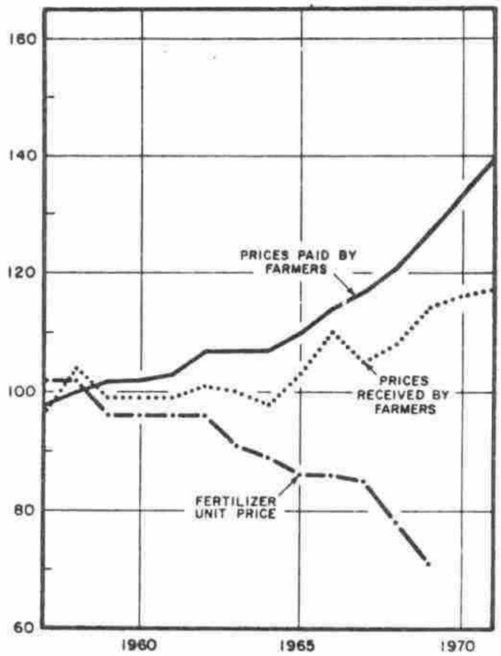

Figure 2.2a. Prices of fertilizer, index of prices paid, and prices received by farmers (18)

Heady, Pesek, and Rau have estimated that one ton of fertilizer will replace 5.7 acres of land in the production of corn on land which previously has received no fertilizer (19, p. 438). In the same study, it was estimated that one ton of fertilizer will replace 600 hours of labor in the production of corn.

A given farmer will probably not farm less land or work fewer hours due to his use of fertilizer. Rather, he will use the fertilizer on a given land area to produce more. But, the substitution of fertilizer for other capital inputs has taken place over the entire farming area of the United States (19, p. 438).

2.1.1.3. The influence of knowledge It has been the trend for fertilizer purchases to increase over time. In an early study of the fertilizer industry, Markham points out the farmers' seemingly irrational habit of not buying the lowest per unit cost plant nutrient (16). This criticism has to be examined in light of the time of Markham's study, 1940-1950's. The lowest per unit cost forms of fertilizer were not always convenient to handle, had undesirable physical properties, and sometimes were not available to the majority of the farmers. But even more important, the farmers of this period were not aware or convinced of the benefits of fertilizer.

From World War II to the present, the USDA, state agricultural experimental stations, extension education services, and private industry have engaged in the dissemination of information to farmers about the profitable benefits derived from fertilizer use. As farmers have learned of these benefits through the institutional sources, through observing their neighbors' success with fertilizers, and through their own experience, their usage has increased.

2.1.1.4. Complementary increase with other technology Growth in the general state of agricultural technology has increased the use of fertilizers in two ways. First, the development of crops which are adapted to higher fertilizer rates, increases in the rates of planting, and improvements in irrigation have increased the need for fertilizer. Second, improvements in cultural practices, insect control, and improved farm machinery have reduced the uncertainty of response to fertilizer use.

2.1.1.5. Other reasons Because of the aforementioned reasons and others, such as larger farms, better informed farmers, and the government price-support program which has intensified the use of fertilizer (19, p. 435), there has been a significant growth in the use of fertilizer. It will be the purpose of the succeeding section to examine the influence this growth has had on the fertilizer industry.

2.2. Changes within the fertilizer industry

To gain an understanding of changes that have taken place in the nitrogen fertilizer sector it is necessary to examine the entire fertilizer industry rather than just the nitrogen sector[1].

Before the 1950's, the traditional pattern of fertilizer marketing was for an individual manufacturer to produce a single plant nutrient and sell it to a regional wholesaler. The wholesaler would mix the various plant nutrients and sell them to an independent dealer who in turn would sell the fertilizer to the farmer. The mixer-wholesaler provided the regional off-season storage and extended credit to the retailer. The fertilizer handled by this marketing system was typically a low analysis, pulverized material.

About 1950, high-analysis fertilizers were being developed. Another phenomenon was taking place on the demand side. In the Midwest, farmers were demanding a prescription type fertilizer for their crops. With this new need and the high-analysis fertilizer available, a new system of

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[1]For a complete review of the fertilizer industry history see Markham (16) and Douglas and Coleman (19).

marketing began evolving. The prescription type fertilizers were provided by bulk blenders who were able to mix the high-analysis fertilizers at the retail level. This system required only a primary producer and retail bulk blender.

Before examining the marketing systems of the 50's and 60's it may be instructive to find what the changes in fertilizers were. The phosphatic fertilizers in the traditional system were a rather low grade (20% P_2O_5) normal superphosphate in a pulverized form. The wet process and the electric furnace enabled the production of concentrated superphosphate (46% P_2O_5) and ammonium phosphates (46-52% P_2O_5) at a lower per unit cost. The production of these materials, for the most part, took place at the major source of phosphorus rock in the southeastern part of the United States.

Granulated fertilizer was also introduced about this time which, because of its better physical properties, was more acceptable to farmers. Granulation also adapted itself well to bulk blending because particle size could be regulated so different nutrients could be blended without fear of separation.

The major change in potash fertilizers was a shift in mining from the New Mexico area to Canada. This extended the transportation requirements and, with the growing demand for fertilizers, the regional storage needs were increased.

During the 50's, different methods of marketing were tried. To assure a market for their product, some manufacturers attempted to sell directly to the farmer. This met with only limited success as the manufacturer had only one of the plant nutrients necessary. They found the sales and credit costs excessively high, and they had only limited regional off-season storage. Another system tried was integration backwards by the mixer-wholesaler. Yet another was an attempt by the primary producers to purchase the mixer-wholesaler's facilities, but the equipment was found to be out-moded for the new fertilizers.

The technological developments had reduced the cost per unit of production, but a large capital investment was required and the traditional manufacturers seemed unwilling to make this investment. At this time, demand estimates for world food needs indicated that there were great potentials in the fertilizer industry (26). Individual companies and entire industries were attracted by the potential profits in fertilizer, and were willing to take the risk on the necessary capital investment. Foremost among these companies were the petroleum companies who had the technically trained personnel to build and operate the new type of plants. The chemical and metal industries were also attracted to fertilizer, either through their trained personnel or through their mining interests.

The marketing of the 1960's was marked by a cumulation of the new technological developments and the entry of new firms into the fertilizer industry. It became apparent to the new members of the fertilizer industry that horizontal integration of fertilizer production facilities was necessary if the farmer market was to be won. This resulted in the acquisition or merger of basic phosphate manufacturing by nitrogen producers and vice-versa. Although integration was not as prevalent in the potash industry, the fertilizer producers were able to assure themselves a source of potash through trade agreements.

Horizontal integration was also taking place at the retail level. Feed and grain dealers took on fertilizer as another product in an attempt to provide their customer a one-stop agricultural service center.

The final integration process taking place was the one already mentioned of combining the fertilizer industry with chemicals, metals, and particularly petroleum.

> The integration program of the 1960's has drastically changed the organization pattern for distribution and marketing fertilizer. Vertical integration came about to secure markets; horizontal integration came about to ensure markets and to obtain maximum use of all the facilities; and overall integration of the fertilizer industry has been accelerated because of the growth potential of the fertilizer industry (19, p. 72).

In the late 50's and early 60's another group of entrants in the fertilizer market was farmer owned cooperatives. Cooperatives found that their owner-patrons were asking that cooperatively owned marketing and manufacturing facilities be provided for serving their fertilizer needs. Regional and national cooperatives entered the fertilizer industry by purchasing existing fertilizer manufacturing plants and by building their own plants. By the mid-sixties, the cooperatives had obtained a significant share of the market (19).

The sixties were characterized by the vertically integrated firms and the regional-national cooperatives supplying the credit and regional storage functions which had been provided by the wholesaler-mixer.

In the latter part of the sixties, the fertilizer industry experienced a large decrease in prices. This was due to overbuilding on behalf of the fertilizer manufacturers. Many of the new entrants to the market made the decision to manufacture fertilizer at about the same time. It is also apparent that the world need for food was not converted into demand for fertilizer. This brought material planned for export into the domestic market, and was an additional cause of depressed prices (6). The low prices of fertilizer drove some of the firms out of the fertilizer industry during the late sixties and early seventies.

2.3. The nitrogen sector of the fertilizer industry

It is the purpose of this section to discuss the development of the nitrogen sector of the fertilizer industry and its products.

As was evident in Figure 2.1, of the three major plant nutrients, nitrogen has experienced the most rapid growth in usage. Since 1950, the use of nitrogen has increased 665 percent. This growth has been due in part to the reasons given in Section 2.2. Also, it is a result of the rapid adaptation of nitrogen in the production of corn. Corn is a heavy user of nitrogen, and accounts for 95 percent of the total nitrogen used in the Midwest (3, p. 13). Furthermore, nitrogen as opposed to potassium or potash fertilizers, must be replaced annually as it is leached from the crop root zone by the movement of soil water. Table 2.3 shows the consumption of nitrogen and selected nitrogen products for the United States and Iowa for selected years.

Table 2.3. Consumption of nitrogen and selected direct application nitrogen products for the U.S. and Iowa (12)

	1950	1960	1970
Nitrogen	Tons	Tons	Tons
U. S.	595,313	2,685,572	7,311,772
Ia.	13,755	103,117	659,435
Anhydrous Ammonia (82.2%N)	Tons	Tons	Tons
U. S.	85,516	708,295	3,491,603
Ia.		31,187	521,588
Nitrogen Solutions (28-41%N)	Tons	Tons	Tons
U. S.	11,108	650,259	3,102,746
Ia.		45,984	220,140
Ammonium Nitrate (33%N)	Tons	Tons	Tons
U. S.	559,584	1,230,732	2,847,334
Ia.	16,782	67,606	133,199
Ammonium Sulfate (20%N)	Tons	Tons	Tons
U. S.	179,420	510,087	771,655
Ia.	252	4,416	1,552
Sodium Nitrate (16%)	Tons	Tons	Tons
U.S.	627,357	454,211	87,128
Ia.			

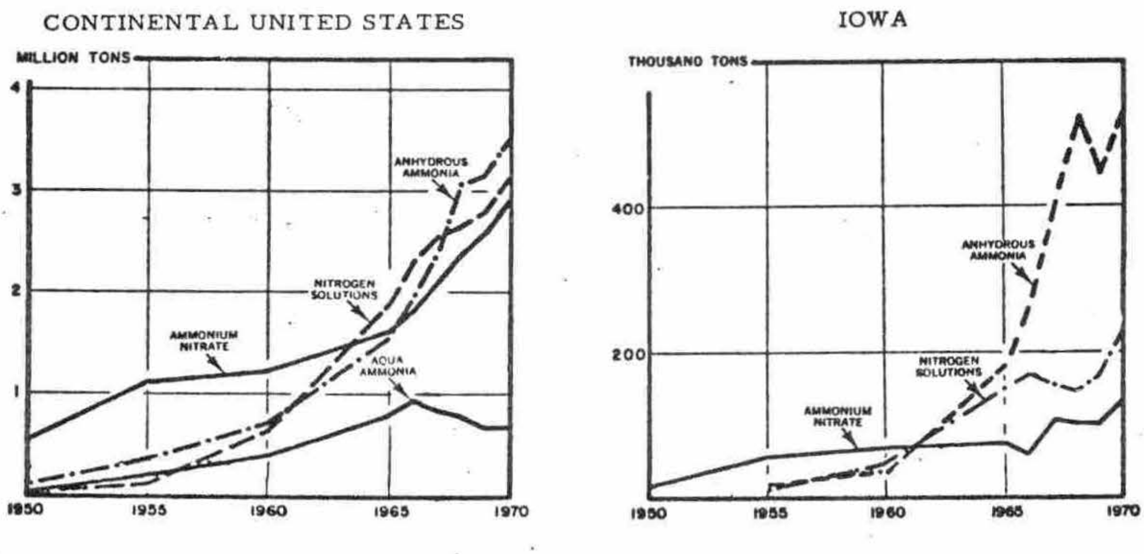

Figure 2.2b. Consumption of selected nitrogen materials for the United States and Iowa (12)

As is apparent from Figure 2.2b and Table 2.3, the largest growth in nitrogen fertilizer has been in anhydrous ammonia. Since 1950, ammonia usage in the U.S. has increased by 3980 percent. An important reason for this growth has been the large decrease in price of anhydrous relative to other forms of nitrogen fertilizers. Table 2.4 gives the comparative cost per pound of nitrogen for selected nitrogen products for selected years.

Table 2.4. Prices of some basic forms of nitrogen in Iowa for selected years (5)

Year	Anhydrous ammonia cost per lb. nitrogen	Ammonium nitrate cost per lb. nitrogen	Ammonium sulfate cost per lb. nitrogen	Urea cost per lb. nitrogen
1951	----	13.0¢	----	----
1956	9.7¢	13.1	18.3¢	----
1961	8.5	12.4	14.6	11.7¢
1966	6.7	11.6	12.9	12.2
1970	4.3	9.4	12.0	9.1

The first major commercial nitrogen fertilizers produced in the United States were nitrate of soda (16%N) and ammonium sulfate (20%N). These forms of nitrogen predominated in use until the 1940's. Ammonium nitrate (33%N) became the leading source of nitrogen in the 1950's and was replaced by anhydrous ammonia (82%N) by 1960.

As the nutrient content of the fertilizers was increasing the concentration of nitrogen manufacturers was decreasing[2]. Before World War II, the synthetic nitrogen industry was a highly oligopolistic industry, with two manufacturers accounting for 86 percent of the market (17, p. 372). During the war, there was a large demand for nitrogen in the production of munitions for which the U.S. government contracted the building of war time plants. After World War II, through the judicious sale of the government plants, the concentration of the four largest producers was reduced to 44.7 percent (17, p. 373). The large demand for nitrogen fertilizer brought more firms into the industry and by 1963 the four largest firms produced only 29.5 percent of the nitrogen (17, p. 374).

> By most standards by which industrial structure is assessed, the structure of the synthetic nitrogen industry has evolved from a highly concentrated oligopoly to one consistent with effective competition... (17, p. 374).

By 1969, the concentration of production had been further reduced. The four largest firms controlled only 15.1 percent of the market (1).

The price decrease for anhydrous ammonia has been a result of technological advances in the production of ammonia. The introduction of the centrifugal compressor in the late fifties, gave rise to significant economies of size in manufacturing. The maximum daily production had been 400 tons of ammonia per day, the advent of the centrifugal

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[2] Concentration, as used here, refers to the percentage of manufacturing production by one or by a group of firms.

compressor increased the range of daily production to 600-3000 tons (19, p. 76).

It was pointed out that the petroleum industry took the lead in vertically integrating the fertilizer industry. Since ammonia is made from water, air, and natural gas, the petroleum companies saw the production of nitrogen fertilizer as a highly profitable way of selling more natural gas or hydrogen feedstocks (19, p. 71). The petroleum industry also had the necessary trained personnel to run the complex plants. It was from the nitrogen sector that these companies began and then integrated horizontally into the rest of the fertilizer industry.

2.4. Manufacturing and transportation of anhydrous ammonia

The purpose of this section is to briefly describe the ammonia manufacturing industry, its structure, and the transportation-storage system used between the manufacturer and retailer.

2.4.1. Manufacturing

In the Haber-Bosch Process, anhydrous is manufactured by combining nitrogen and hydrogen under pressure and heat in the presence of an iron catalyst. The first full-scale snythetic ammonia plant began operation in Germany in 1913 with a capacity of 27 tons per day (24). Currently, there are more than 121 anhydrous ammonia manufacturing facilities that are owned by at least 84 different companies, with no single company having a significant proportion of the capacity (1). Production of anhydrous ammonia was 13.1 million short tons in 1970, and capacity is estimated to be 17.0 million tons for 1972 (13).

The anhydrous ammonia manufacturers experienced the depressed prices prevalent throughout the fertilizer industry during the late sixties. At times, there was more than 30% excess ammonia manufacturing capacity which resulted in the exit of the old style, smaller plants. In 1970, it was estimated that production was 73.2 percent of capacity (13).

The majority of this capacity, especially the large scale plants (1000 tons per day plant and larger) is located on the Gulf of Mexico in order to take advantage of the lower cost of natural gas and the savings encountered by shipping the material to storage facilities located on the waterways (24).

2.4.2. Transportation and storage

A physical characteristic of ammonia needs to be explained; anhydrous ammonia is a gas at room temperature which condenses to a liquid at minus 28 degrees Fahrenheit. Under sufficient pressure it will remain in the liquid state. This characteristic requires special handling techniques in the transportation and storage of ammonia. There are two methods of shipping and storing ammonia; cryogenically (-28°F and no pressure), or under pressure at atmospheric temperatures.

The present methods of transporting the fertilizer from the manufacturer to the retail distributor include: 1) shipment on cryogenic barge or pressurized barge from the manufacturer to cryogenic transhipment facilities on the waterways, 2) shipment by pipeline from the Gulf coast to the Midwest, 3) shipment by rail from the manufacturer or transhipment points to the retailer in tank cars, or 4) shipment by truck transports from the sources of manufacturing or the storage facilities to the retailer.

The obvious advantage of cryogenic storage is its much lower cost. The cost of storage investment is $37 per ton for a 30,000 ton cryogenic unit compared to a $200 or $225 per ton cost for a 30,000 gallon high pressure tank (24).

The lowest per unit cost form of transportation is provided by the cryogenic barges. These units hold about 2,500 tons of material, and shipments as large as 20,100 tons have been moved up the Mississippi.

The most recent innovation in ammonia is the pipeline. There are two different ammonia pipelines leading from the Gulf of Mexico to the Midwest. The spatial advantage enjoyed by the 600 ton per day plants in the Midwest, the center of the present nitrogen demand, has been removed by the pipelines (19, p. 76).

The least cost method over land is rail for distances greater than 40 miles. The ammonia is carried in 11,000 gallon tank cars which hold approximately 25 tons, and in "jumbo" 30,000 gallon tank cars. The use of rail service is rather limited in that the railroads have not been able to respond to the intense seasonal nature of the anhydrous ammonia demand. Rail cars are often used as a form of "mobil storage". The rail cars are delivered to the retailer before the beginning of the ammonia season. The retailer will supplement his normal storage from the rail car.

During the ammonia season, the anhydrous is delivered to the retail dealer by truck transports. The transports hold approximately 18 tons of material, which is pumped into the retailers' pressurized storage.

2.5. Manufacturing, terminal storage, pipeline, and retailing in Iowa

Thus far, the discussion of anhydrous ammonia manufacturing and transportation has been a discussion of the industry in general for the United States. This section will be a brief description of wholesale activity (manufacturing and terminal storage) and retailing in Iowa.

2.5.1. Wholesale activity in Iowa

There is more than 600,000 tons of manufacturing capacity in Iowa and 900,000 tons of cryogenic storage. This compares with a consumption of 521,588 tons in 1970[3]. Figure 2.3 locates the manufacturing points, cryogenic transhipment points, and the ammonia pipelines.

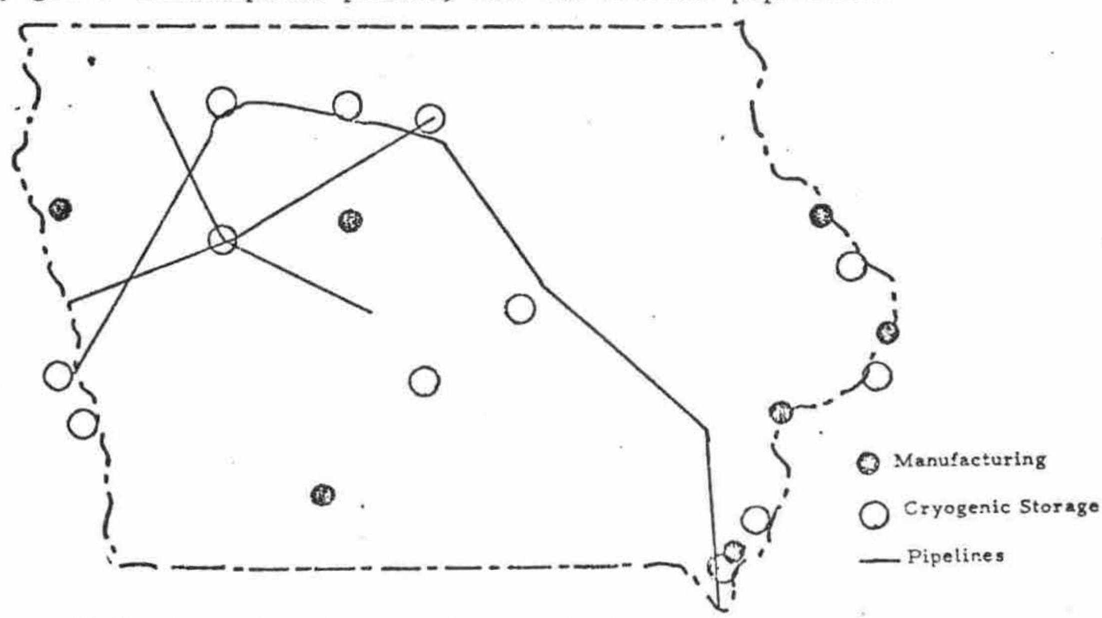

Figure 2.3. Location of ammonia manufacturing plants, croygenic storage points, and ammonia pipelines in Iowa

[3]R. R. Thorsheim, Director, Fertilizer Division, Iowa Department of Agriculture, Des Moines, Iowa, personal communication, 1971.

2.5.2. Ammonia retailing in Iowa

Anhydrous ammonia retailing in Iowa started its growth in the late 50's and matured in the late 60's. In 1965, the first year that records on retail outlets were available, there were 432 retail outlets with average yearly sales of 323 tons per plant. By 1970, this had grown to 1308 retail points, with average yearly sales of 399 tons per retail outlets[4]. The number of retail outlet appears to have stabilized with entrants equalling exits. Because anhydrous and blended fertilizers are highly complementary, they are usually sold in conjunction with each other.

Thus far the discussion has centered on the manufacturing and distribution of fertilizer in Iowa and the United States. The next section will deal with the distribution of ammonia in the Fort Dodge Functional Economic Area. First it is necessary to explain the Functional Economic Area concept and the reasons for choosing this area.

2.6. Functional Economic Areas

The geographic area with which this study deals is the Fort Dodge Functional Economic Area. The purposes of this section are to explain the concept of a Functional Economic Area, and to provide a brief description of some of the salient agronomic facts of the Fort Dodge area.

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[4]Thorsheim, text referral, p. 19.

2.6.1. The Functional Economic Area

Fox, in a number of continuing studies (7, 8, 9), has shown that the county is too small a unit to comprise a self-contained economic area. Fox makes a number of basic assumptions about the consumption habits of people, including the assumption that consumers attempt to organize their time as effectively as possible in order to gain the greatest utility. This means that the basic pattern of travel is temporal. This desire to utilize time efficiently, and the innovation of the automobile, has completely transformed the American society and essentially stripped the counties of their economic usefulness.

In place of the county Fox proposes an economic unit which he calls a Functional Economic Area or a low density city:

> A labor market area[5] is relatively closed or bounded with respect to the income-producing activities of its residents. It is also relatively closed or bounded with respect to a cluster of consumer-oriented or "residentiary" activity. Almost all of the labor resident is sold within it and almost all of the goods consumed in the area are bought within it (7).

From the definition it is evident that there is a *de facto* monopoly on the labor market. Furthermore, the Functional Economic Area is people rather than resource oriented. The Functional Economic Areas located in the Midwest are usually considered to have an agricultural export base.

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[5] Labor market area refers to the low density city.

Conforming to the temporal nature of travel, people have been found to be unwilling to travel more than one hour for purposes of labor or consumption. Since an hour's travel time on the open highway is approximately 50 miles, the distance from the center of the Functional Economic Area to its periphery is about 50 miles. This would mean a circle shaped Functional Economic Area under conditions of no competition, or a hexagon shaped Functional Economic Area under idealized competitive conditions. But, due to the rectangularity of our north-south, east-west highways, the locus of points equidistant from the center which most closely approaches a hexagon is a square with its sides rotated at a 45 degree angle to the road system. The square rotated 45 degrees, then, best describes the shape of a Functional Economic Area. A Functional Economic Area has an area of from 4,000 to 6,000 square miles, and a population of more than 150,000 people.

Figure 2.4. Map of suggested Functional Economic Areas in Iowa

2.6.2. Fort Dodge Functional Economic Area

The Fort Dodge Functional Economic Area is comprised of nine counties located in North-Central Iowa. The area is named after the central city which had a population of 31,263 in 1970. There was a total of 185,701 people in the 5,161 square mile area at the time of the last census (23).

The counties in the Fort Dodge Area are: Boone, Calhoun, Carroll, Greene, Hamilton, Humboldt, Pocahontas, Webster, and Wright. The area is shown below in Figure 2.5.

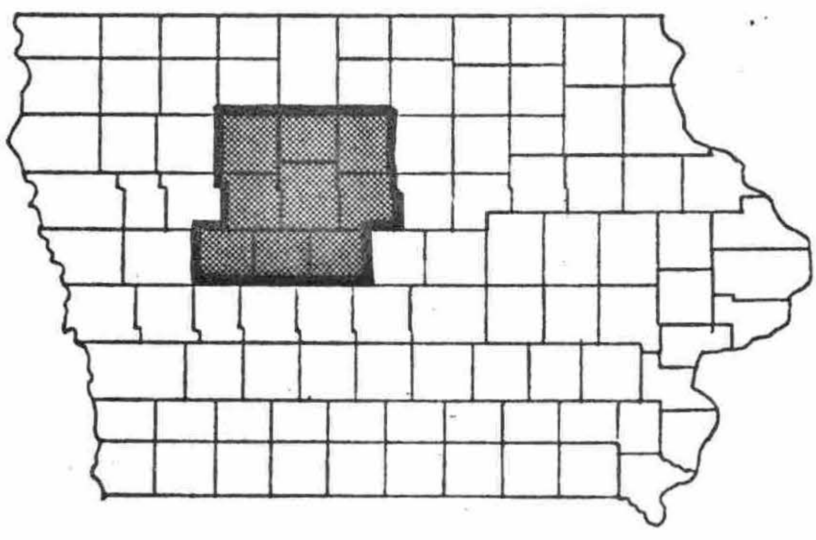

Figure 2.5. Map of Iowa and the Fort Dodge area

As stated earlier, the Functional Economic Area is a self-contained labor unit. The principal product, or the basis for the economy of the Fort Dodge area, is agriculture.

> Nevertheless, agriculture is still the dominant sector of the area when we count both its direct and indirect effects on total employment. The combination of agriculture and manufacturing associated with agriculture is so dominant that it describes almost all the economic base that permits existence of the nine-county area (8).

The Iowa Extension Service, on September 1, 1967, began serving the area from the Fort Dodge University Extension Office. The Extension Service was reorganized in recognition of the change to area problems. The county units have been maintained because of the past economic information and the present governmental organization. The area office employs area specialists who advise and supplement the county extension personnel.

The number of farms and people living on those farms has been steadily decreasing, while the average farm size of the area has been increasing. Table 2.5 indicates some of the current statistics of the area's and the state's agriculture. It is projected that by 1980, the area will have between 8,000 to 10,000 farms with an average size of 320 to 400 acres per farm (14).

The soils of the Fort Dodge area are members of the Clarion-Nicollet-Webster Soil Association Area, except for those in the southwest half of Carroll County. The latter are members of the Marshall Soil Association Area. The area's soils are members of the Brunizim and Humic Gleys great soil group, which are among the most productive in the world. The topography is nearly level to gently sloping. Soils which could be continually row cropped comprise 76.7 percent of the cropland, and soils that would adapt to row crops every two years in a four-year rotation comprise 18.1 percent of the total cropland.

Table 2.5. Farm size and farm population of the Fort Dodge area and Iowa, 1970 (15)

County	Number of Farms	Total Land in Farms	Average Size	Total Square Miles	Number of Persons Living on Farms Jan. 1, 1970
Boone	1,405	346,851	247	573	5,449
Calhoun	1,319	354,788	269	568	4,729
Carroll	1,530	361,719	236	573	6,601
Greene	1,219	354,274	291	574	4,375
Hamilton	1,446	359,747	249	570	5,101
Humboldt	942	271,926	289	438	3,578
Pocahontas	1,285	362,617	282	476	5,055
Webster	1,552	429,412	277	714	5,910
Wright	1,318	363,438	276	575	4,914
Area	12,016	3,204,772	267	5,161	45,703
State	135,264	33,689,873	249	56,045	520,131

The Fort Dodge area is a heavy cash grain production area. The major crops are corn and soybeans. Although comprising only 9.4 percent of the total land in farms of Iowa, this area accounted for 12.6 percent of the total corn production and 17.8 percent of the total soybean production in 1970 (15). Table 2.6 gives the fertilizer usage and acres of corn harvested in the Fort Dodge area.

Table 2.6. Fertilizer usage and corn production in the Fort Dodge area and Iowa for selected years (15,22)

	Fort Dodge Area			Iowa		
Year	Acres of corn	Average bushel per acre	Tons of fertilizer used	Acres of corn	Average bushel per acre	Tons of fertilizer used
1970	1,172,402	91.9	298,360	10,004,162	85.8	2,645,482
1966	1,173,400	91.5	167,346	10,603,400	89.0	1,301,478
1961	1.125,000	77.7	84,661	10,253,900	75.4	638,558
1956	1,074,700	43.3	53,758	10,014,704	53.0	377,037
1951	1,244,800	43.4	31,287	10,131,824	43.0	321,180
1946	1,355,800	60.0	25,419	11,047,203	57.0	182,651

The area is a relatively heavy user of fertilizer. In 1970, the area consumed 13.9 percent of the total plant nutrients used in the state (22). Figure 2.6 gives the primary plant nutrient consumption since 1950.

PLANT NUTRIENT CONSUMPTION

FORT DODGE AREA

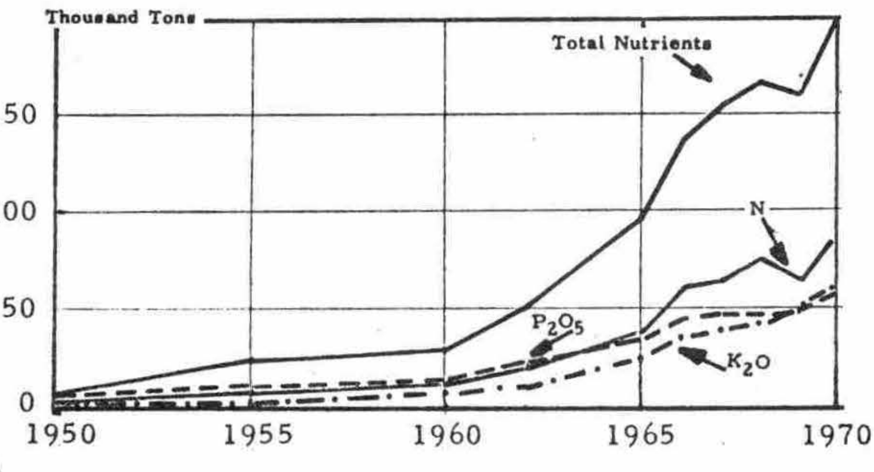

Figure 2.6. Primary plant nutrient consumption for the Fort Dodge area (22)

Of the Functional Economic Areas in the state of Iowa, the Fort Dodge area is probably the heaviest user of anhydrous ammonia. In 1970, the area consumed 15.1 percent of the total anhydrous used in the state (22). The total tonnage used was 78,703 tons, and this accounted for 77.7 percent of the total nitrogen used in the area (22). Table 2.7 gives the ammonia consumption for the Fort Dodge area for selected years, and Figure 2.7 depicts the consumption of selected nitrogen fertilizers since 1962.

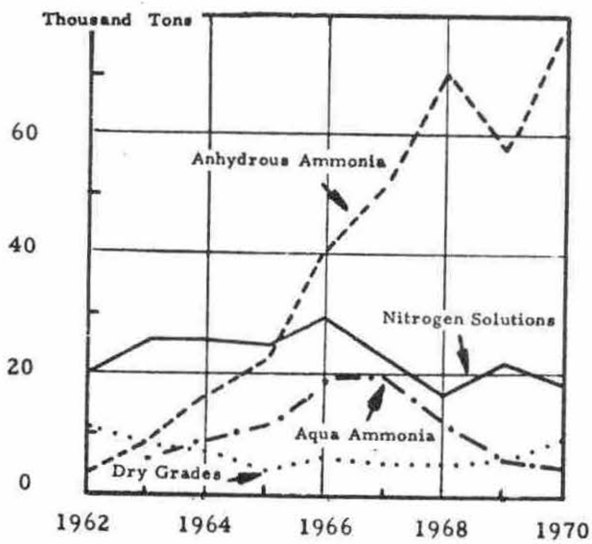

Figure 2.7. Consumption of selected nitrogen products in the Fort Dodge area (22)

Table 2.7. Anhydrous ammonia consumption in the Fort Dodge area, for selected years (22)

	1962	1965	1966	1967	1968	1969	1970
	Tons						
Iowa	55,105	181,573	260,870	404,414	525,256	441,581	521,588
Fort Dodge Area	4,478	22,940	42,373	52,268	70,012	58,475	78,703

2.7. Distribution of anhydrous ammonia in the Fort Dodge area

The purpose of this section is to discuss in some detail ammonia retailing and the market structure of ammonia distribution in the Fort Dodge area.

The characteristics of market structure, set forth by Moore and Walsh (17, p. XIV), that will be examined are the number and size of dealers within the market, the degree of vertical integration within the industry, and the barriers to entry within the market. Since anhydrous is a non-differentiated product, that aspect will not be assumed to have an influence on market structure.

The information concerning tonnages was obtained from the state tax tonnages reported to the Iowa Department of Agriculture--State Chemical Laboratory. The information pertaining to individual companies was considered confidential. The discussion that follows pertains to the 1969-70 crop year.

2.7.1. Wholesalers in the Fort Dodge area

The wholesalers (the vertically integrated firms or regional cooperatives discussed in Section 2.2) provide the off season storage, a portion of the credit needs for the retail dealers, the educational needs of the retail employees, and at times, the pressurized storage vessel.

The wholesale sales by type of firm are: 58.4 percent by corporations and 41.6 percent by regional cooperatives. Although there is a fairly high degree of vertical integration in the Fort Dodge area, there are some independent retailers and some sales of anhydrous to local cooperatives by corporations. The six largest wholesalers sell 64.1 percent of the total ammonia in the area, and there were 28 wholesalers in the area in 1970.

2.7.2. Retail market structure in the Fort Dodge area

2.7.2.1. Number and size In 1969-70, there were 150 retail outlets located in 98 different towns in the Fort Dodge area. The

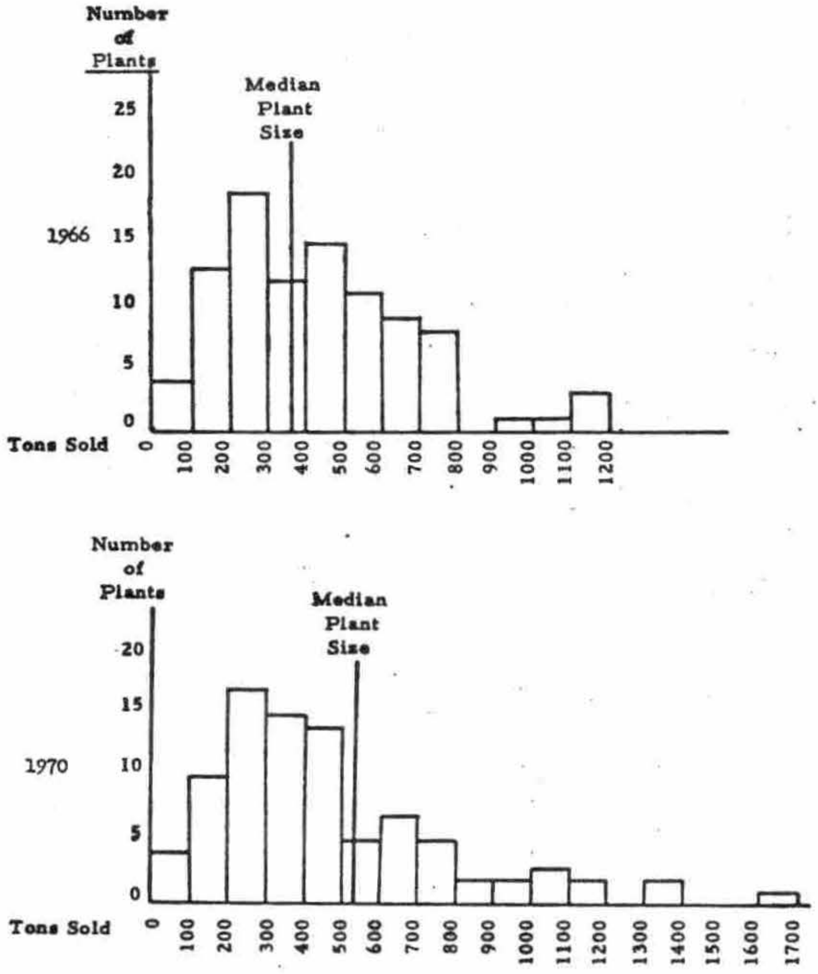

Figure 2.8. Histogram of plant size for selected plants in the Fort Dodge area, 1966 and 1970 (22)

average yearly sales were 521 tons of ammonia per retail plant. Figure 2.8 presents histograms of tonnages sold by some of the retailers in the Fort Dodge area for 1966 and 1970. Due to the method of reporting, tonnage volume on all retail plants was not available.

As is apparent from the histograms there appears to be a fairly large number of small volume plants. The average plant size has increased between the years of 1966 and 1970. There appears to be more plants with significantly larger volumes in 1970.

2.7.2.2. Vertical integration   Table 2.8 designates the degree of vertical integration present in the retailing sector.

Table 2.8. Vertical integration of ammonia retailers in the Fort Dodge area, 1970, as measured by form of ownership (22)

Number	Type of ownership	Percentage of total volume in the area
15	Corporations	49.5
50	Local cooperatives	43.2
11	Independents	7.3

The highest degree of integration in terms of decision making and delegation of responsibility is exercised by the corporations. Because of leasing arrangements between the regional cooperatives and the local cooperatives or between the independent retailers and the wholesalers, there may not be independence of buying decisions by these two types of organizations. In other areas of decision making, the local cooperatives and independent retailers demonstrate autonomy at the retail level.

2.7.2.3. Barriers to entry The only barrier to entry that should be pointed out is that someone wishing to enter the ammonia retailing business would probably also have to supply the other plant nutrients through bulk blending or liquid mix. Even considering this, the capital requirements are not high and there are no predatory practices which would be any more harmful to a new entrant than an established firm. The number of new facilities constructed in the mid-sixties is an indication of the lack of entry barriers.

2.7.3. Phenomena within the retail distributing sector

The purpose of this section is to examine some of the problems and practices in the retail distribution of ammonia and develop guidelines for a cost study.

This information is a result of interviews with over 50 retail ammonia dealers, wholesalers, manufacturers, and control officials in the fertilizer industry; surveys of and by ammonia wholesalers; examination of sales records of ammonia retailers; trade area studies of five retailers; and two years of the author's observations while studying and working in the fertilizer industry. Some of the statements are qualitative but still important to an understanding of ammonia retail distribution.

2.7.3.1. History The first retailers of ammonia in the Fort Dodge area were independents. This was in the mid 1950's when there were substantial profit margins and relatively few distributors. In the latter part of the fifties, the cooperatives replaced some of the independents in the retail marketing of fertilizer, and substantially increased the number of retailers in the market. The cooperatives were multiple product farm suppliers since their product lines included feed, petroleum, LP gas, fertilizer, and grain handling. The vertically integrated corporations started building their crop service centers, which usually were comprised of a bulk blending operation and an ammonia outlet, in the early sixties.

One feature that all retailers have in common, no matter what the organizational type, is that they are multiple product firms. To the author's knowledge there are no firms in the Fort Dodge area which handle only anhydrous - at the very least the retailers sell a full line of fertilizers and chemicals. The apparent reason for the multiple product lines is a better utilization of labor.

2.7.3.2. Season length Any farm supply operation associated with crop growth will be seasonal, but few have the intense seasonality typified by anhydrous ammonia. As one ammonia retailer commented:

> "My ammonia equipment sits rusting in the yard for 50 weeks of the year and the farmer tries to wear it out the other two"[6].

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[6] Raymond Chartier, Manager, Farmer's Co-op Company, Dallas Center, Iowa, personal communication, 1971.

In the early years of ammonia development, most of the anhydrous was applied by sidedressing. Then, to alleviate the short sidedress season, some distributors promoted pre-plant season, with hardly any sidedressing being practiced.

The very limited season has resulted in a larger number of delivery units throughout the industry, a greater off-season storage requirement, and possibly a greater number of retail distributors. The average season length for 37 retail distributors, in the Fort Dodge area, during the 1971 pre-plant season was 15.6 continuous days[7]. During this period, these retailers sold 93 percent of their total ammonia volume.

2.7.3.3. Services The ammonia retailers provide a number of services for their farmer customers. Most have some type of soil sampling program, which ranges from interpretation of the sample's results to collecting and paying for the sample. Applicators are usually provided to the farmer by the retailer. At one time, there was a per acre charge for the use of the applicating machine, but this disappeared during the price depression of the late sixties. Some retailers provide custom application services, or have arrangements with farmers who perform custom application. The credit policies of the ammonia retailers are dependent upon the individual dealer. Some finance the crop to harvest, others have a firm policy of taking a note if payment is not made within thirty days of purchase, and some do not have a policy.

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[7] L. Thayer, Fertilizer Merchandiser, Farmland Industries, Inc., personal communication, 1971.

2.7.3.4. Advertising The burden of radio-television advertising is usually carried by the wholesaler. Advertising in the local paper, and a promotional dinner for his customers is usually the extent of the retailer's advertising. Some of the cooperatives and most of the vertically integrated corporations make off-season contact with farmers to attract new customers.

2.7.3.5. Physical facilities This section will deal with the physical aspects of delivering the ammonia from the retailer to the farmer.

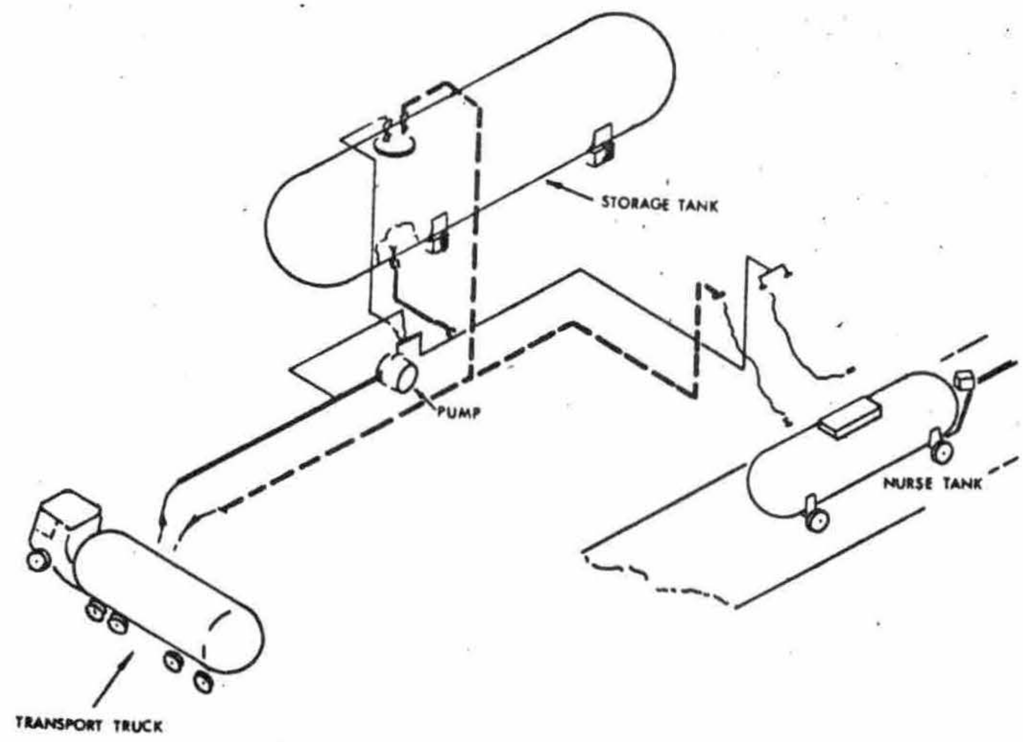

Figure 2.9. Typical anhydrous ammonia retailing outlet

Figure 2.9 depicts a typical retailing outlet. The pressurized storage tank acts as a reserve between transport loads. The ammonia is transferred by means of a pump from the storage tank into a nurse tank, and then delivered to the farm where it is injected into the soil by means of some type of applicating machine.

2.7.3.5.1. Storage vessels The pressurized storage vessels (bulk tank) range in size from 12,000 gallons to 30,000 gallons. The size needed by a retailer will depend on the volume of material sold, the proximity to a terminal storage point, and the ability of the retailer's supplier to deliver the ammonia when needed. Initial investment costs per ton of storage do not decline with larger storage vessels because of the pressurization requirement. Tanks larger than 30,000 gallons are not used, as this is the largest size that can be shipped by rail. As was mentioned earlier, the supplier may provide the bulk tank, or other additional storage for a minimal rental fee.

2.7.3.5.2. Pumps The type and size of transferring unit can change the rate of output for a plant. If the rail car "mobil storage" is used, a vapor compressor is necessary to unload the car. Liquid transfer pumps are frequently used to increase the rate of output, but they may require larger plumbing in the bulk plant (storage vessel and pump).

2.7.3.5.3. Delivery equipment--Trucks A pickup is the vehicle most often used in the delivery of ammonia. The retailer will use a 3/4 ton pickup or a 3/4 ton four wheel drive pickup for delivery. The four wheel drive is most satisfactory in plowed fields and is better for the delivery of the bulk blend fertilizer. Other vehicles, such as feed trucks, are utilized in ammonia delivery, or the farmer may "pickup" the material himself.

Nurse tanks--The nurse tanks are the pressurized tanks used to deliver the ammonia to the farm. A 1000 gallon nurse tank appears to be as large a unit as is practical. A larger unit requires a heavier running gear, and would require brakes which would make the cost prohibitive. The farmer would also object to a larger nurse tank because of the larger power requirement and additional soil compaction that would result.

One of the criteria used by the ammonia retailers as a measure of efficiency is the tons of material delivered per nurse tank per season. In a survey of 28 retailers in the Fort Dodge area, the average efficiency was 35 tons/nurse tank/season with a range of 22 tons/nurse tank/season to 57 tons/nurse tank/season. The average number of nurse tanks per dealer surveyed was 22.

Applicators--Various types of applicating machines are used. Among these are: tool bar applicators, which pull the nurse tanks behind them through the field; and tank mounted applicators, which have a pressurized mounted tank ranging in size from 200 to 500 gallons. This tank is filled from the nurse tank. The tank mounted applicator may be adapted to bypass the mounted tank so it too may be used as a tool bar applicator. Various farm implements have been adapted to apply ammonia while performing their tillage duties. Some of these are: moldboard plows, field cultivators, disks, and chisel plows.

There has been a trend to larger applicating machines. When anhydrous was introduced, three row applicators with a 10 foot swath were used. Now the dealers are providing 30 foot tool bars.

No matter what type of application method is used, there are some peculiarities about the application of anhydrous that should be mentioned. A proper seal must be obtained after the liquid is injected into the soil or the ammonia will escape into the atmosphere. This means that some device on the applicator to seal the injection hole is usually required. Although the expansion radius of the anhydrous is usually not more than three inches, it is desirable to place the ammonia about six inches deep (slightly deeper if the soil is sandy).

The 28 retailers surveyed owned an average of eight tool bar applicators and five tank mounted machines. The average efficiency per applicator per season was: 57 ton/applicator/season with a range of 33.3 ton/applicator/season to 88 ton/applicator/season.

2.7.3.6. Study of five retailers To obtain some idea of the average number of miles a retailer must travel in delivering ammonia to customers (average length of haul) for ammonia retailers, a study of the 1971 ammonia sales of five dealers was made. The trade area for each dealer was marked off in mile increments from the plant, and all customers and their usages were located. Estimates of the demand densities for each retailer's trade territory were made. The retailer's share of each increment mile was measured against total demand in that mile to determine the retailer's market share. Table 2.9 gives the result of this study.

Table 2.9. Average one way haul for 5 retail ammonia dealers and their market share, by increment mile

Mile	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Plant Total Tonnage	Average Haul Distance (One-way)
	% of Total Demand																
Plant 1	100	100	81	49	41	38	50	37	31	32	17	11	9	2	8	1985	6.63
Plant 2	100	100	100	84	31	25	9	7	6	4	1	1	-	-	-	1039	4.10
Plant 3	100	92	78	76	56	47	58	32	23	9	8	-	-	-	-	1547	5.72
Plant 4	100	75	32	26	21	17	9	7	3	3	4	-	-	-	-	531	4.79
Plant 5	-	9	33	29	20	25	15	10	3	1	-	-	-	-	-	441	6.91
Composite	100	92	70	51	37	30	27	19	12	7	5	5	1	-	9	1160	6.37

The composite was adjusted for differences in demand density between trade areas. A rather interesting phenomena was noted--the market share of the firms declined with distance from the plant. This is represented graphically in Figure 2.10.

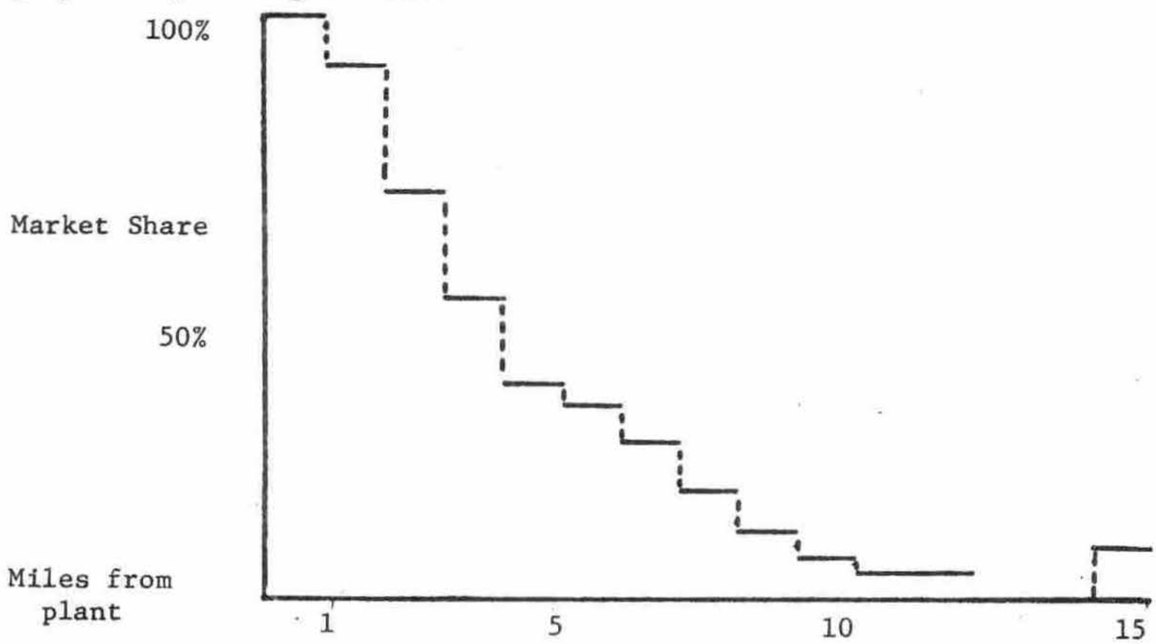

Figure 2.10. Graphic representation of declining market share for five ammonia retailers in the Fort Dodge area

2.8. Summary

The descriptive information in this chapter can be used for purposes other than characterizing the fertilizer industry and ammonia retailing. Much of the information is used in this study as assumptions for developing a cost model for estimating the cost of retailing ammonia.

There are a number of reasons for developing cost estimates of retail ammonia distribution. First, it became apparent during the course of interviewing ammonia retailers that a need exists for a systematic approach to the analysis of retailing costs. Most retailers interviewed had only a vague idea of what the costs of their ammonia operations were, and there were conflicting opinions about whether costs were reduced with increased volume. The cost data available to the retailers is usually combined with other product costs, which makes it difficult for the retailer to determine the cost of retailing ammonia. Second, cost estimates are necessary if comments about the relative efficiency of individual plants and the retailing market structure are to be made.

Once cost estimates are developed it will be of interest to examine certain events or problems: Would retailing costs be influenced by a change in the government price support program? What would happen to costs if there were a longer period of time to make delivery to the farmer? Will increasing application rates have an influence on costs? What is the influence of competition on a retailer's costs?

It will be the purpose of the remainder of this study to develop cost estimates of ammonia retail distribution, and to examine the influence of the factors mentioned in the preceding paragraph on these costs. The next chapter will deal with the theoretical development of cost concepts germane to a firm in a spatial setting.

3. PLANT AND DELIVERY COST RELATIONSHIPS

The purpose of this chapter is to present and examine cost relationships relevant to a spatially oriented firm. The method of development will be to examine plant cost and delivery costs, separately, and then to combine these component costs to arrive at retail distribution costs. This will not be an attempt to explain in detail the theory of the firm, as no reference will be made to revenue maximization. Rather, what follows is a discussion of modifications of conventional cost theory needed in this study to examine costs of retail distribution[1].

3.1. Plant costs

The plant cost sections will deal with the particular assumptions made, and the impact of these assumptions on conventional plant costs in the short and long run.

3.1.1. Modification of production costs

Constant variable plant costs were assumed. The justification for this simplification is drawn from the plant operations study by French, Sammet, and Bressler (11). They define the production process in terms of operating stages. The plant is defined as the integration and aggregation of all plant stages, transferring links, and temporary storage necessary to produce the final product or products. The conventional theory of increasing variable costs has its most direct application to

[1]For a complete examination of the theory of the firm see Cohen and Cyert (4).

the individual stage and is not applicable to the plant because:

> As the various stages becomes more directly connected i.e., as between-stage transportation and the opportunities for temporary storage are reduced, the flow of these materials become highly integrated. Unless rate of output at all stages can be varied simultaneously the impact of such integration is to lessen the possible range of rate variation at any particular stage. In the extreme, this may reduce to virtually a single rate or perhaps several discrete rates (11, p. 547).

If the rate of output is held constant, and total output is varied by varying the hours of production, the uniform level of intensification in the rate sense should produce constant variable costs. Also, since cost and volume are both linear functions of time, they are also linear functions of each other (11, pp. 548-49).

In addition to the integration of plant stages limiting rate variation, technical restraints may have the same effect. The technical requirements of a machine may, in fact, dictate a single rate of output. Even if the individual machine can have different rates, inputs associated with the machine, such as labor, will be added in a fixed proportion no matter what the rate. The technical restraint on rate variation, and the addition of labor in fixed proportions again imply constant variable costs.

If plants of different size are considered, all plants will have constant variable costs. But, the constant variable costs will differ between plants.

These modifications of production theory can be applied to the anhydrous ammonia retail plant. The image of a "plant" in the sense of producing a product, processing a product, or somehow changing the form of a good does not apply at the retail level of ammonia distribution. Rather, the retail plant acts as a transfer unit and a temporary storage point between the wholesaler and the farmer. The technical factor of constant pump speed, and the fact that a laborer must be present whether filling one or two nurse tanks indicate that the assumption of constant variable costs can safely be made.

3.1.2. Plant cost in the short run

The short run is defined, in this discussion, to mean that certain factors of production are fixed. The plant costs may be expressed in the following manner: Let TPC represent total plant costs, PFC plant fixed cost, PVC plant variable cost[2], and D plant volume (tons). Then, total plant costs are the summation of plant fixed cost and plant variable cost.

$$TPC = PFC + PVC \tag{3.1}$$

But, plant variable costs may be expressed as the product of plant volume and constant per unit variable costs APVC,

$$PVC = (D)(APVC) \tag{3.2}$$

substituting

$$TPC = PFC + (D)(APVC) \tag{3.3}$$

which expresses total plant costs as a function of plant fixed costs,

---

[2]Since, in the case of constant variable costs, marginal costs and variable costs will be equal, the above discussion does not include references to marginal costs.

constant per unit variable costs, and volume.

The average plant cost, APC, is TPC divided by volume.

$$\text{APC} = \frac{\text{PFC}}{\text{D}} + \text{APVC} = \text{AFPC} + \text{APVC} \quad [3.4]$$

The relationship between plant volume and total costs and plant average costs are presented graphically in Figure 3.1.

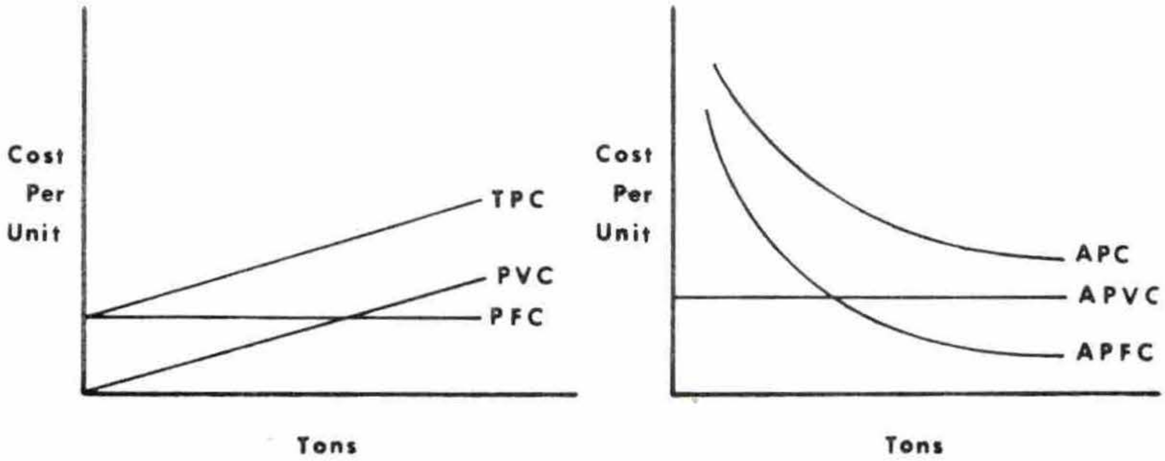

Figure 3.1. Total and average plant cost in the short run

It should be noted that average plant costs are at a minimum at plant capacity. This departs from the usual textbook representation where, because of increasing variable costs, the minimum average plant cost would occur at "less than full plant volume".

3.1.3. Conventional long run plant costs

If all of the factors of production are assumed to be variable, a long run condition exists. Long run costs can be represented graphically (Figure 3.2) as the envelope of a series of short run average cost curves.

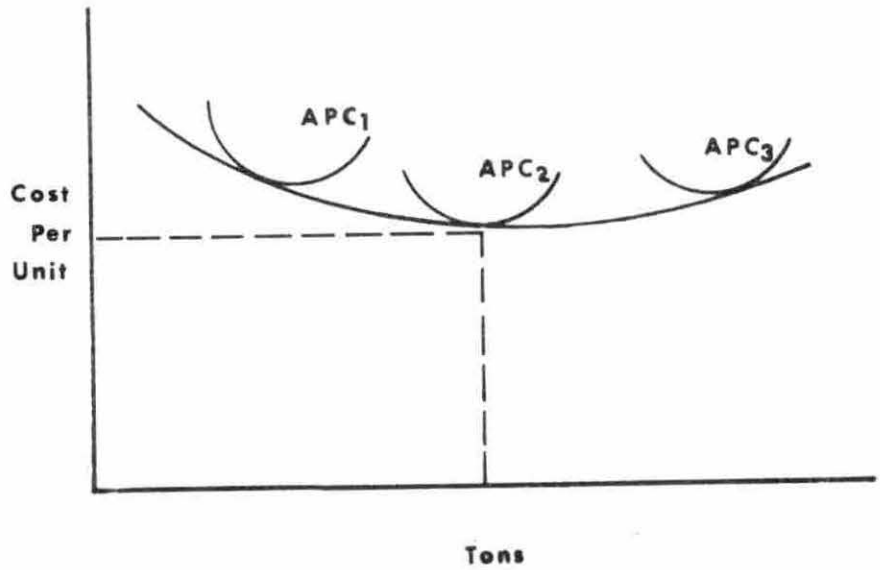

Figure 3.2. Conventional long run average plant cost curve

The long run cost curve, or planning curve, is the locus of production points at which each individual short run plant produces at a lower per unit cost than any other plant. Given the increasing variable cost assumption, there is only one case where the minimum short run cost of a plant is tangent to the minimum point on the long run cost curve. This particular plant size may be termed the optimal or least cost plant. The decreasing portion of the curve is explained by pecuniary (i.e., the larger plants can drive a harder bargain for inputs) or technological factors. The increasing portion of the curve is normally explained by the inability to coordinate the plant operation.

3.1.4. Modification of the long run average cost curve

Given the assumption that variable costs are constant, the short run cost curve for each plant is tangent to the planning curve at a level of output corresponding to the capacity of that plant. No diseconomy plants were budgeted in this study, resulting in the L-shaped long run average cost curve representative of empirical findings (4, p. 144). These cost relationships are represented by Figure 3.3.

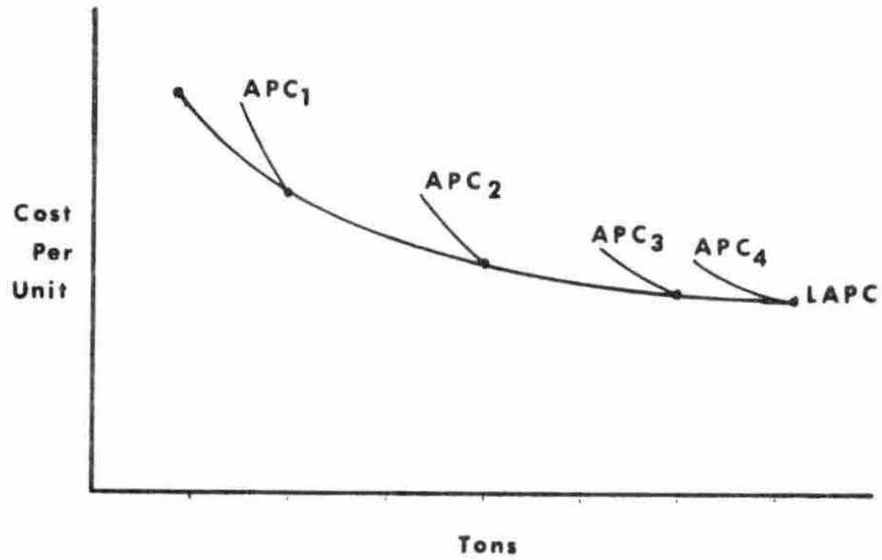

Figure 3.3. Modified long run average cost curve for plants with constant variable costs

3.2. Delivery costs

Plant costs are only a portion of the costs facing a spatially located business. The other portion is the cost of moving the product from the plant to the customer.

The cost of delivering the product depends on the distance it must be hauled, on the hauling cost per mile, and on the number and cost of the delivery units required.

The presentation which follows is an adaptation from French's "Some Considerations in Estimating Assembly Cost Functions for Agricultural

Processing Operations" (10). Whether the problem is one of moving a commodity such as grain from the farm to a central handling point, or one of delivering an input such as fertilizer to the farm, the concepts which French develops are equally valid.

3.2.1. Relating variable delivery costs to plant volume

This section includes a development of the relationship between variable delivery costs and plant volume. First, average length of haul is related to plant volume. Then, variable delivery costs are related to average length of haul. And finally, through average length of haul, variable delivery costs are related to plant volume.

3.2.1.1. Relating average length of haul to plant volume

Figure 3.4 depicts the spatial setting assumed for retail plants in this study. A square grid system of roads is the road pattern normally found throughout much of the central part of the United States.

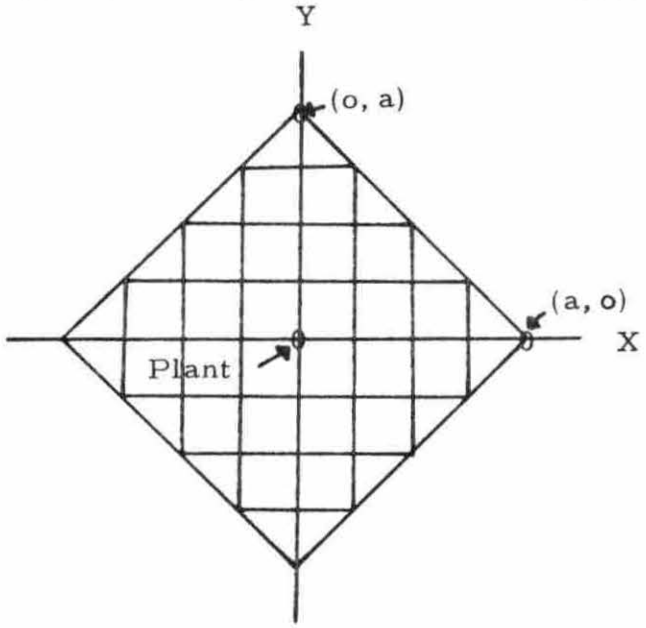

Figure 3.4. Spatial location of plant

Assume that the retailer has a 100 percent market share in his trade area. Let D represent the volume demanded in the trade area, and assume it is the same as plant volume. Further, assume that the customers are spread uniformly across the trade area (demand plane). The uniformity of spacing allows us to use an average density of demand, $\overline{P}$, which yields a continuous approximation to the actual relationship between volume demanded (D) and distance traveled from the plant (a). Then,

[3.5][3] $$D = 2\overline{P}a^2$$

is demand in relation to a.

If density, P, is uniform throughout the trade area, the average travel distance, $\overline{A}$ for a square trade area with a diagonal distance 2a, is

[3.6] $$\overline{A} = \frac{4}{\text{area}} \int_o^a \int_o^{a-x} (x + y) \quad dydx = \frac{2}{3} a$$

and using [3.5]

[3.7] $$\overline{A} = \frac{2}{3} \frac{D^{1/2}}{2^{1/2}\overline{P}^{1/2}} = .4714 \frac{D^{1/2}}{\overline{P}^{1/2}}$$

which expresses the average length of haul in terms of plant volume and demand density.

3.2.1.2. Relating variable delivery cost to average length of haul Next, it is possible to relate variable delivery costs and the average length of haul. French states:

---

[3]Note: Since area = side (x) squared and $4a^2 = 2x^2$, $x^2 = 2a^2$.

> The total cost of transporting the product from the plant to any customer depends on the equipment used, the labor used with each piece of transport equipment, the work methods employed by the labor, the distance from the plant to the customer, the speed of travel, the total volume of product handled per trip and per season, and waiting time at the plant or in the field (10, pp. 769-70).

The cost per load was assumed to be a linear function of distance traveled. Since the load capacity of anhydrous ammonia nurse tanks is strictly limited by the pressurized container requirement, and because volume per trip is near capacity limits, it was assumed these restraints would effectively limit load costs before cost per load increased at an increasing rate. Further, since vehicle speed is restricted by road conditions and legal speed limits, it was assumed that vehicle speed could be averaged.

With these simplifications and given hauling methods, the variable delivery cost per unit of commodity is composed of: (1) a constant cost per unit b_o, associated with loading, unloading and average waiting time, and (2) a constant cost per unit of distance (mile) traveled, b_1, which includes costs of labor, gasoline, maintenance, etc. (10, p. 773). For a single demand point, the variable cost of delivering any given volume D, is:

[3.8] $$VDC = D\ (b_o + b_1 A)$$

where A is the distance traveled to one demand point.

For several discrete demand sources, the variable delivery cost per season is the weighted sum of the delivery costs to each demand source where the weights are volumes transported to each demand source. That is:

[3.9] $$VDC = \Sigma\ (b_o D_i + b_1 D_i A_i)$$

where D and A are defined as above and i refers to a particular demand source.

Using the assumption that demand is uniform in the trade area, total variable cost may be expressed as

[3.10] $$VDC = D\ (b_o + b_1 \overline{A})$$

where $\overline{A}$ is the average length of haul.

3.2.1.3. Relating variable delivery cost to plant volume

Now, by substituting equation 3.7 in equation 3.10, we obtain an approximation to the relation between variable delivery cost and plant volume,

[3.11] $$VDC = D\ (b_o + b_1\ \ .4714\ \ \frac{D^{1/2}}{\overline{P}^{1/2}})$$

This relationship implies that total variable delivery costs increase at an increasing rate. By dividing equation 3.11 by volume, we obtain:

[3.12] $$AVDC = \frac{C}{D} = (b_o + b_1\ \ \frac{.4714 D^{1/2}}{\overline{P}^{1/2}})$$

which implies average variable delivery costs increase at a decreasing rate. Williamson has presented an intuitive explanation of this relationship:

> Since the increase in radius of the supply area associated with a unit increase in the farm commodity [delivered] decreases as total quantity [delivered] increases, the average

> over-the-road haul and [delivery] costs will increase at a decreasing rate as quantity of commodity [delivered] increases (27, p. 954).

The relationships between plant volume and variable delivery costs are presented graphically in Figure 3.5.

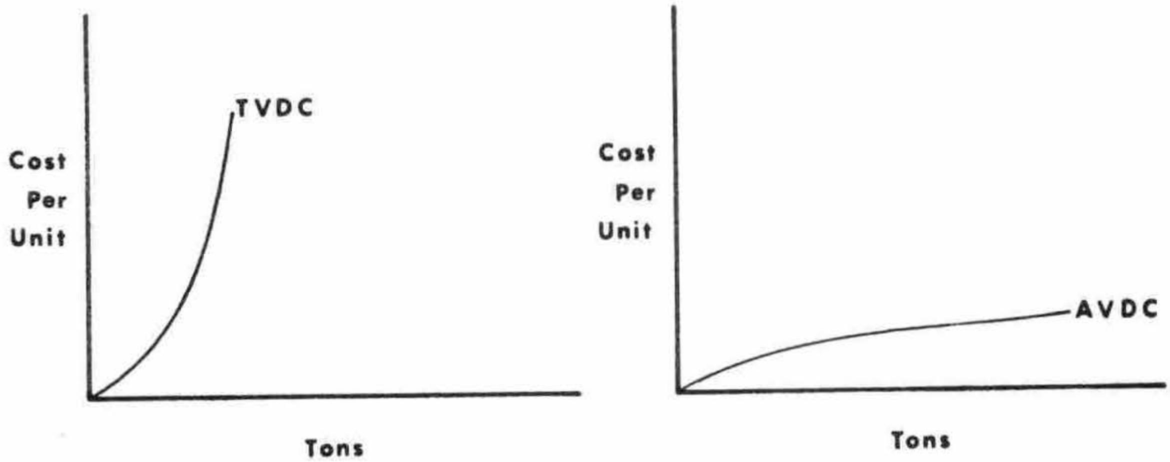

Figure 3.5. Graphic representation of total and average variable delivery costs

3.2.2. Determination of the number of delivery units

Thus far the variable delivery costs have been related to plant volume. Next it is necessary to determine the number of delivery units needed, and the fixed delivery costs for a given technology level. This will be accomplished by first relating the season length to the number of delivery units needed.

Let H represent the working hours effectively available. The expression $g_o + g_1\bar{A}$ is the delivery time per unit of product, where g_o includes loading time, unloading time, and allowances for average time loss due to the impossibility of coordinating plant and delivery operations, and g_1 is the average per unit of volume per unit of distance traveled. Then the number of delivery units, N, is the smallest whole number such that:

$$N \geq \frac{D(g_o + g_1\overline{A})}{H} \qquad [3.13]$$

If there are different types of equipment in the delivery system they may have different effective working hours, H (e.g., applicator working hours would be associated with farmer working hours, while pickup working hours would more likely be associated with plant working hours). Thus, there may be a different value of N for each type of delivery equipment.

Let F represent the yearly fixed cost associated with a single unit of one type of delivery equipment. Then, the yearly fixed cost for that type of delivery equipment is:

$$FDC = FN \qquad [3.14]$$

and

$$AFDC = \frac{FN}{D} \qquad [3.15]$$

is the average yearly fixed delivery cost.

Figure 3.6 depicts relationships between yearly fixed delivery costs and volume for the case involving only one type of delivery equipment. Two points should be noted: (1) the total yearly fixed delivery cost is represented as a discontinuous function, that is a result of an inability to add part of a delivery unit. (The latter occurs because as each successive unit is added, the volume of material it can deliver is reduced due to the additional on the road travel time.) (2) The average fixed total delivery costs are a series of declining curves.

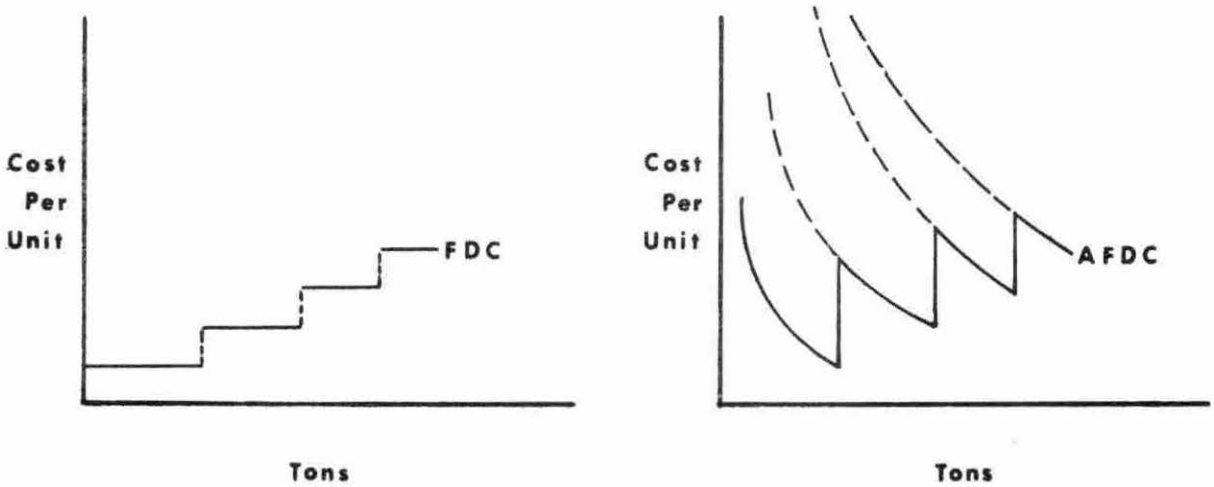

Figure 3.6. Graphic representation of total and average fixed delivery costs

3.2.3. Total delivery costs

When only one type of delivery equipment is used, total delivery costs, TDC, are the combination of [3.11] and [3.14].

[3.16] $$TDC = D\ (b_o + b_1 \quad .4714 \quad \frac{D^{1/2}}{P^{1/2}}) + FN$$

Average total delivery costs, ADC, are the combination of [3.12] and [3.15].

[3.17] $$ADC = b_o + b_1 \quad \frac{.4714D^{1/2}}{B^{1/2}} + \frac{FN}{D}$$

Average total delivery costs are represented in Figure 3.7 for one particular set of delivery units.

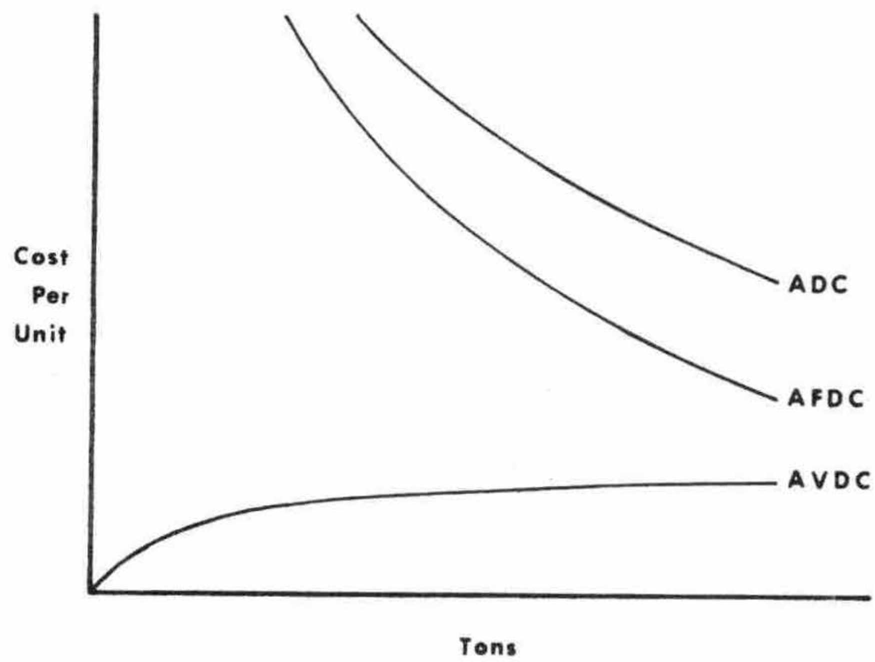

Figure 3.7. Average delivery costs and component costs

3.2.4. True long run delivery costs--a note

This study considered only one assembly technique (pickups and 1000 gallon nurse tanks). For a "true" long run analysis to determine minimum long run delivery costs, it is necessary to consider all labor intensities and assembly techniques:

> Alternatives may be defined in terms of assembly technique (a particular type of equipment combined with efficiently organized labor) and the level of labor intensity (the quantity of labor used in relation to the quantity of equipment). These different techniques and levels of labor intensity are associated with different values of the coefficients for cost (b_o,b_1) and time (g_o,g_1), then allowing D and H to take on all possible values defines the volume-distance-hours areas for which particular techniques and labor intensities give least cost and, correspondingly, defines the long-run transportation cost surface for efficient operation under these conditions (10, pp. 74-75).

By restricting technology to one level, the long run retail distribution costs can be obtained when the delivery costs are combined with long run plant costs, but only for that technology level.

3.3. Retail distribution costs

The costs which are of interest to the ammonia retailer are the combination of plant and delivery costs. This combination will be referred to as the retail distribution cost. If the plant cost curve and delivery cost curve are not dependent upon one another in any way, it is permissible to add these cost curves (27, p. 954).

3.3.1. Individual plant retail distribution costs

By setting demand, D, equal to plant capacity it is possible to solve equations [3.16] and [3.17] to determine the delivery cost for a plant at its capacity. Retail distribution costs, RDC_p, for an individual plant, p, then are the combination of [3.3] and [3.16].

$$[3.18] \qquad RDC_p = PFC_p + PVC + D(b_o + b_1 \; .4714 \; \frac{D^{1/2}}{B^{1/2}}) + FN$$

and average retail distribution costs are the combination of [3.4] and [3.5]

$$[3.19] \qquad ARDC_p = PFC_p + APVC + (b_o + b_1 \; .4714 \; \frac{D^{1/2}}{\bar{P}^{1/2}}) + FN$$

The average retail distribution cost and its component costs for a given plant and set of delivery equipment are depicted in Figure 3.8.

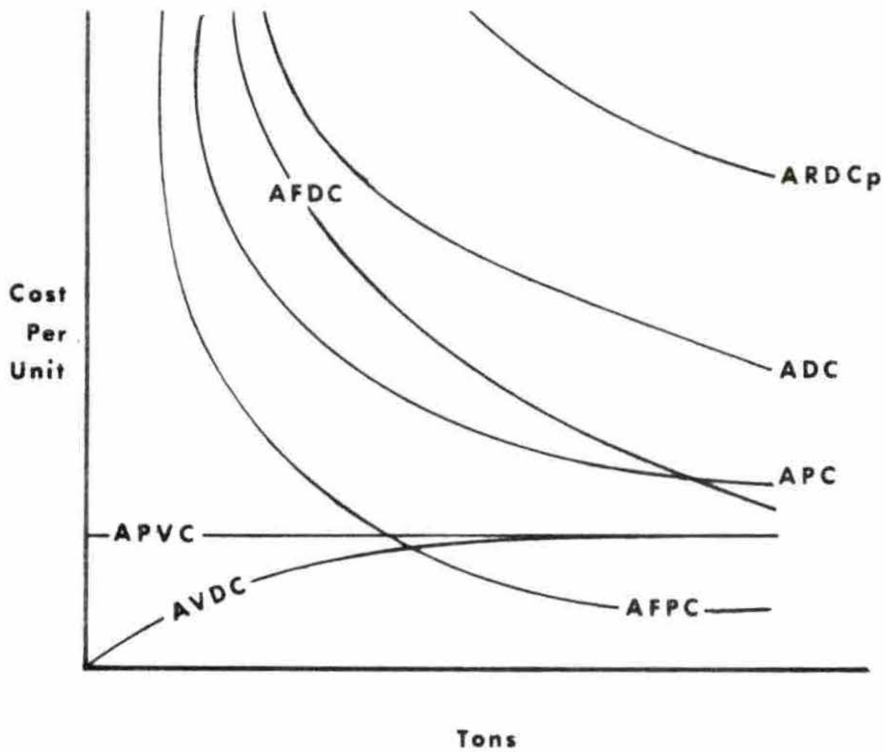

Figure 3.8. Average retail distribution cost and its component cost curves for an individual plant

There is a special case which will be noted in the empirical discussion, that of a plant not having enough delivery equipment. This condition may be a result of: a limited labor supply, not being able to capture enough market to justify the addition of more equipment, etc. Whatever the reason, this shortrun possibility does exist and is presented in Figure 3.9.

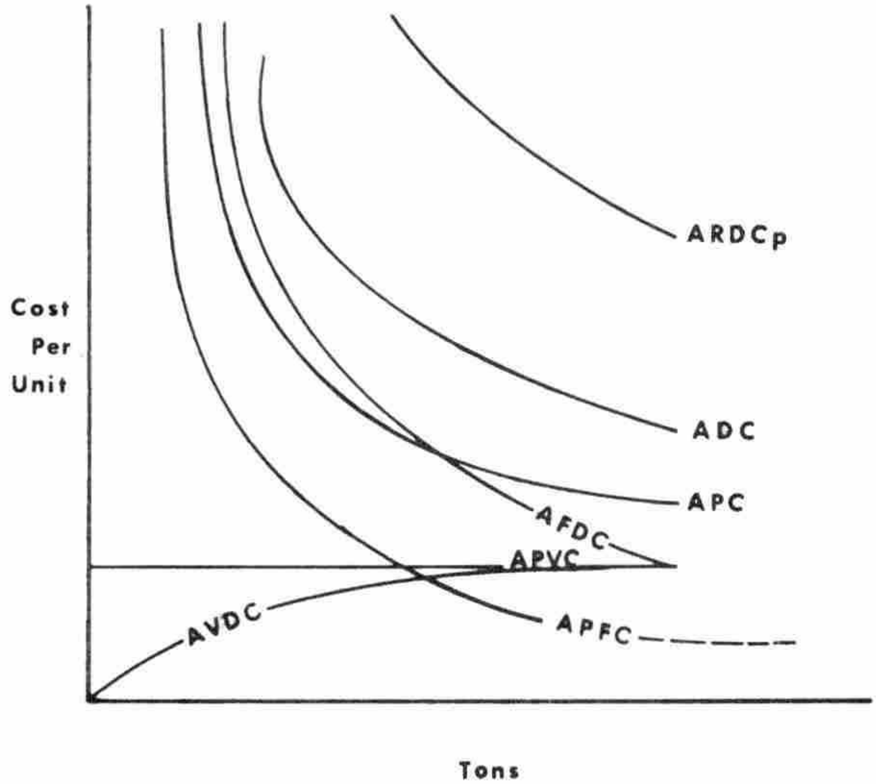

Figure 3.9. Average retail distribution cost for a plant with limited delivery equipment

3.3.2. Long run retail distribution costs

If the factors of production and delivery are allowed to vary, it is possible to determine the average long run retail distribution costs, LARD. The average long run retail distribution cost curve is the combination of the average long run plant cost curve and the average long run delivery cost curve. Figure 3.10 depicts these cost relationships.

A few things should be noted about the long run average delivery cost relationships. First, the downward sloping portion of LARC represents the minimum equipment requirement possible. (In the case of anhydrous retailing the firm must purchase one pickup.) Second, the LADC is represented as a continuous curve. This implies that the problem of discrete delivery units is ignored. The estimate of LADC used in this study is the ADC for each plant at its capacity[4].

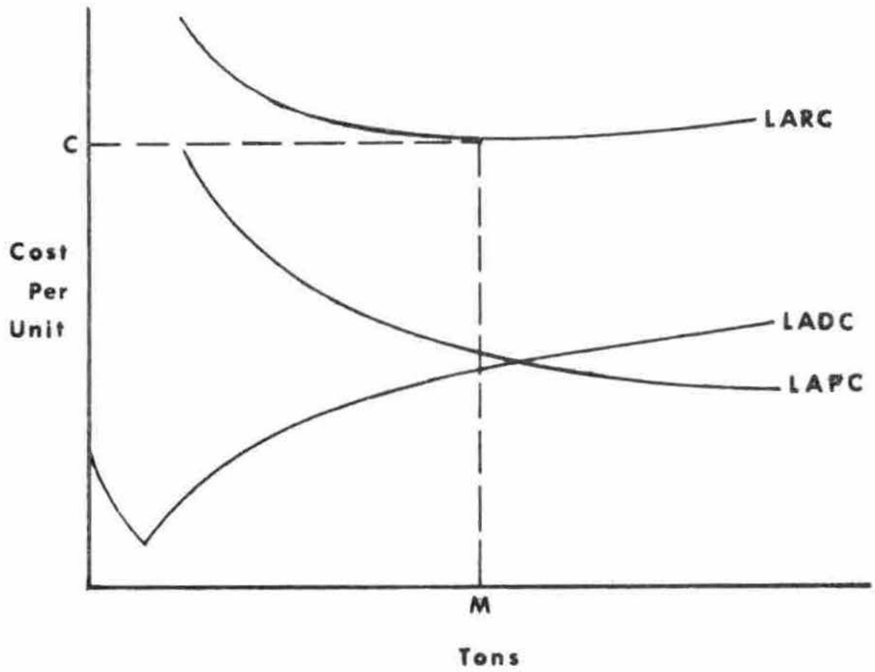

Figure 3.10. Graphic representation of the long run average retail distribution cost and the component costs of long run plant cost and delivery costs

It is apparent that there is a plant size, M, that when combined with delivery costs will yield a minimum long run average retailing cost, C. This will be the optimum plant size-delivery cost combination that this study will try to ascertain.

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[4]There is a possibility of a special case existing where retail distribution costs would be at a minimum at less than plant capacity. This possibility was checked empirically and found not to be a factor.

3.4. Influence of season length, market share, etc. on retailing cost

It is possible to determine the influence of different season lengths, market shares, government price-support programs, and rates of application on retail costs.

An increase in the effective working hours, H, is most comparable to a shift in technology. An increase in the season length will result in the long run average cost curve shifting downward.

A longer season should reduce the number of delivery units, and thus the yearly fixed delivery cost. It should be noted that due to the expansion in working hours each unit will handle more volume, as more time is allowed to handle a given volume.

Figure 3.11 represents the cost change due to a longer season for the long run average plant curve and a single delivery unit.

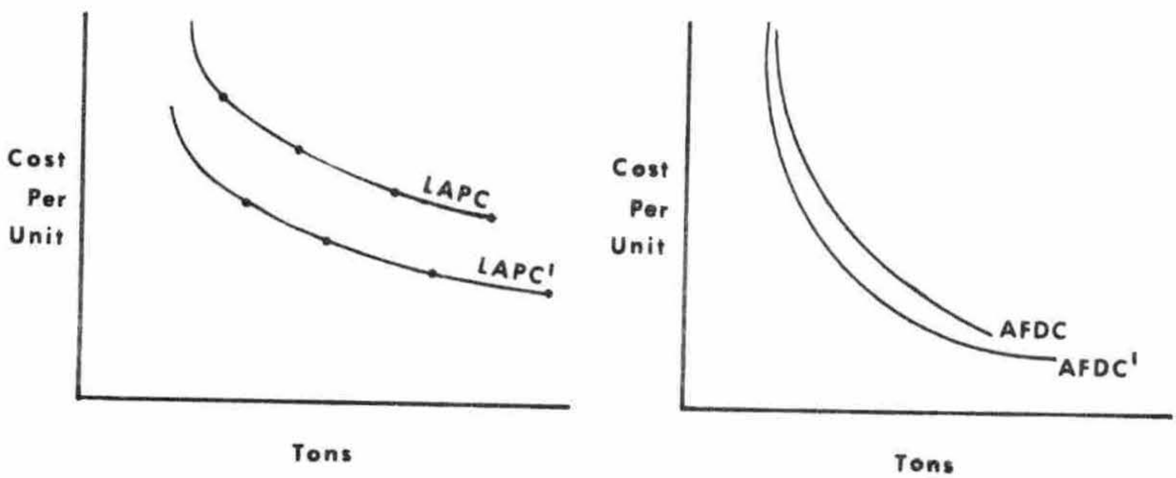

Figure 3.11. Influence of a change in season length on long run plant costs and yearly fixed delivery cost of an individual delivery unit

It is not readily apparent what influence a change in season length would have on variable delivery costs as there would most likely be changes in work methods also.

Demand density, $\overline{P}$, is measured in units of tons per square mile, in this study. Demand density is a function of the number of pounds of ammonia used per acre and the number of acres of corn. If either the rate or the number of acres are increased, $\overline{P}$, will also increase. The influence of an increase in demand density would be to reduce variable delivery costs through a reduction in average haul distance.

Also the demand density affects the average fixed delivery costs through $\overline{A}$, average travel distance. Fewer delivery units would be needed as average travel distance is reduced due to the increased demand density.

One of the restrictive assumptions used in relating plant volume to delivery cost was that the retailer obtains 100 percent of the demand in his trade area. This assumption becomes important if determinant solutions to optimum size of plant, location of plant, and optimum number of firms in an industry are desired for spatially located firms in long run equilibrium[5]. If the market share is less than 100 percent the variable delivery costs would be increased through an increase in average length of haul. Again fixed delivery costs are also affected by the change in average length of haul.

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[5]For a full development of these concepts see Williamson (27).

3.5. Past studies of ammonia retailing

There have been only a limited number of studies dealing with ammonia retail costs. Rathjen analyzed the current retail cost structure of anhydrous ammonia and bulk blending in Minnesota (20). Table 3.1 presents the comparative costs of different outputs for ammonia from this study.

Table 3.1. Cost estimates for ammonia retailing in Minnesota for specialized product firms (20)

Output-Tons	211	534	882	1800	2224	2432
Firm Type	Estimated Cost/Ton					
Specialized	$87.38	$37.24	$24.60	$16.00	$14.42	$12.85
Multi-product	37.23	18.52	13.54	10.50	16.09	9.68

From this information, Rathjen concludes that there are significantly lower costs due to increased size. For the specialized firm, comparable to the vertically integrated firms in this study, the decrease in cost due to increased output was $74.53 per ton. For the multiple-product firm, comparable to a cooperative or independent retailer in this study, the decrease in cost due to increased output was $27.64 per ton. Since over half of the firms delivering ammonia in Minnesota have tonnage volumes of less than 400 tons and the retail margin is about 20 dollars per ton, Rathjen concludes there are a large number of firms losing money at the retail level. The major reason retail firms did not exit from the ammonia industry, according to Rathjen, is that the manufacturers are assuming some of the retail cost to assure sale of production capacity.

Rathjen's conclusion regarding reductions in cost due to economies of size is subject to question because some of his analytical procedures are questionable. Rathjen states that the economies of size between plants would result from technical economies (20, p. 33), but he only considers one plant. Table 3.1 actually represents cost points for succeedingly larger level of output on a single short run cost curve for a single plant.

Another questionable procedure involved merging plant fixed costs and delivery fixed costs. Handling the fixed costs in this manner results in a loss of the relationship between increasing delivery cost and decreasing plant cost.

A few technical mistakes should also be pointed out. The particular pump-motor combination Rathjen chose has a theoretical capacity of 2400 tons for the 300 hour season he uses, and a practical capacity of 1500 tons. Yet in his analysis a capacity of 6000 tons per season is included. No time allowances were made for the farmer using the nurse tank to apply the anhydrous. Applicator costs were not included. Finally, Rathjen points out the farmers desire for increased services in the form of delivery to the farm, yet he includes the cost of only one pickup.

Rathjen adopted the cost data from the study of ammonia and nitrogen solution retailers in Nebraska by Rudel and Walsh (21). The Nebraska study was a short-run break-even analysis based on economic engineering data and survey data gathered in Nebraska. Rudel and Walsh state that the retail market in Nebraska has been characterized by the following factors in recent years: 1) the entry of an excessive number of small retail plants due to manufacturers attempting to market their excess manufacturing capacity, 2) much of the cost of retailing has been shifted to the wholesalers, 3) the established plants have been prevented from growing in size by the entry of many new small retail plants, and 4) the entry of the new plants was in the face of decreasing retail margins.

The authors explain the rather contradictory actions of the retailers in the following manner: 1) many of the retailers have been following a short run policy of selling below full cost to recover some of their fixed investment, 2) the firms that sell ammonia are multiple product firms and have been covering their losses in ammonia with revenue from other products, and 3) some of the costs have been passed along to the manufacturer through vertical integration.

Table 3.2 presents the cost information Rudel and Walsh base their conclusions on. In 1967, 43 percent of the ammonia retailed in Nebraska came from plants with annual volumes of less than 400 tons (21, p. 12).

Table 3.2. Ammonia retailing costs for Nebraska ammonia distributors (21)

Output Ton	207	574	943	1,571	2,658
Cost	$39.36	$18.45	$13.78	$10.97	$9.20

Again, the cost information is subject to some criticism: 1) the particular plant that was used is not practically capable of more than

1500 tons in the 300 hour season used, 2) there is no distinction made between plant costs and delivery costs, 3) no applicator costs were included, 4) from the information available it appears that no variable operating costs for the pickup were included, and 5) only one pickup was included for the entire tonnage range considered.

These past studies of ammonia retailing suggest that there is a need for a full identification of costs associated with ammonia retailing. It will be the purpose of the next chapter to do so.

4. IDENTIFICATION OF COMPONENT COSTS FOR AMMONIA RETAILERS

The purpose of this chapter is to specify the cost coefficients and time parameters for the relationships discussed in Chapter 3.

4.1. Cost model overview

As the discussion which follows is rather detailed, a general description of the cost model will be given here. The cost model is designed to incorporate many of the practices observed in the preliminary surveys of retailers.

Because anhydrous ammonia is sold from multiple product firms, obtaining statistical cost data on retailing is quite difficult. The phenomenon of multiple product sales results in accounting costs for anhydrous being merged with other product costs. For this reason, a modified engineering cost approach is the method of cost determination used in this study. When possible the technical input-output relationships (true engineering costs) for ammonia retailing operations are used. But, for some operations the engineering cost method yields information that is not descriptive of the observed retailing activities. In these cases, other means of cost determination are used.

Six different plants are budgeted, four farm supply unit plants representative of full farm suppliers, and two specialized plants characteristic of the vertically integrated fertilizer dealers. The major difference between the two firm types is that plant labor for the specialized plants is fixed while it is variable for the farm supply unit plants. All plants are budgeted with constant variable costs.

The delivery costs are comprised of driver labor, and pickup, nurse tanks, and applicator costs. To reflect the various types of applicating equipment a composite applicating machine is developed. Adjustments for different rate levels (number of pounds of ammonia used per acre) and changes in season length are made for this composite machine.

Time parameters to reflect loading, unloading, waiting in the field, etc. are developed to determine the number of pickups, nurse tanks, and applicators needed. Adjustments in the time parameters are made for different rate levels and the two season lengths. The cost model is designed to select the number of pickups, nurse tanks, and applicators needed for different volumes of ammonia for a particular combination of season length, market share, and demand density.

An attempt is made to reflect costs of firms with multiple product sales. The criterion used in this determination is the proportion of ammonia sales to total sales of the firm. The author admits this is an arbitrary allocation, but one that does allow a measurement of otherwise indeterminate costs.

4.2. Demand density, market share, and season length

In Chapter 2 and 3 it was suggested that demand density, market share, and season length would have an effect upon retailing costs. It is the purpose of this section to explain the specific assumptions used in this study concerning these factors.

4.2.1. Demand density

The purpose of this section is to explain the assumptions used in this study regarding demand density. In order to determine the average length of haul it is necessary to define the demand in terms of the number of tons of ammonia per square mile, this will be referred to as the demand density. Demand density is a function of the number of pounds of nitrogen used per acre, the number of corn acres in a square mile, and the percentage of nitrogen supplied by anhydrous ammonia. What follows are the particular assumptions made about these factors comprising demand density.

The number of pounds of ammonia per acre will be referred to as a rate level. The objectives were two-fold in choosing rate levels: First, rate levels were chosen that are representative of present and expected future usage. Second, rate levels were used that would definitely show differences in retailing costs, if such differences exist. The three rate levels used are: 130 lbs. of nitrogen or 160 lbs. of ammonia per acre; 160 lbs. of nitrogen or 195 lbs. of ammonia per acre; and 200 lbs. of nitrogen or 245 lbs. of ammonia per acre.

The first rate level is representative of current consumption. The determination of the current consumption is made on the assumption that corn accounts for 95 percent of the total nitrogen used in the area. This means that 79,254 tons of nitrogen were used on the 1,219,298 acres planted in 1970, or an average of 130 lbs. of nitrogen per acre (22, 15). This is in agreement with views of authorities[1] about nitrogen usage in

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[1]Richard Gray, Area Economist, Fort Dodge, Iowa, personal communication, 1971 and Regis Voss, Extension Agronomist, Iowa State University, Ames, Iowa, personal communication, 1972.

the Fort Dodge area. The current usage closely approaches the recommended levels for the highest return per dollar invested in fertilizer (25).

The second rate level, 160 lbs. of nitrogen per acre, is representative of a rate which would return the highest net return per acre (25). The 200 lb. per acre rate level might best be thought of as representative of a technological shift in the production of corn.

The number of acres of corn grown per section is dependent upon the demand for corn, the relative price of soybeans and other crops with respect to corn, government price-support programs, etc. Rather than develop an independent demand for corn in the Fort Dodge area the author chose to use the 1966-70 corn production acreage to represent one level of corn production in the area. The 1966-70 average corn acres per section is 227 acres. To reflect either a change in the government price-support program due to crop disease, war, etc., or to reflect a significant rise in the relative price of corn, a 275 acres of corn per square mile level of corn production was included.

The percentage of nitrogen supplied by anhydrous ammonia is dependent upon the price relationships of ammonia and other sources of nitrogen, and on the preferences of farmers for particular types of nitrogen fertilizers. It was assumed that in the Fort Dodge area ammonia is used only on corn. The 1968-70 average ratio of ammonia to nitrogen used on corn indicates that ammonia comprises 76 percent of the total nitrogen used on corn (22). Because anhydrous ammonia is the raw material used in the production of other nitrogen fertilizers it was assumed that there would continue to be substitution of ammonia for these other sources of nitrogen. Table 4.1 presents the demand densities used.

Table 4.1. Demand density of ammonia for different acre and rate levels

		% N supplied by NH_3	227 acres of corn/ sq. mile	275 acres of corn/ sq. mile
#'s N/acre	Equivalent #'s NH_3/ acre		Demand density	tons/sq. mile
130#'s	160#'s	76	13.84	16.67
160#'s	196#'s	85	18.45	22.23
200#'s	245#'s	90	23.06	27.79

4.2.2. Market share

One of the questions raised in Chapter 2 was: What is the influence of competition on costs? The purpose of this section is to explain the reasons for choosing the three market shares used in this study. The three market shares used are: a 100 percent market share, a declining market share, and a constant market share of 33 percent.

As was explained in Chapter 3 the perfectly competitive model yields some logically satisfying solutions and makes possible determinant solutions to long run equilibrium plant size and location problems. One market share is included to represent this condition. This particular market share assumes that the retailer obtains 100 percent of the demand in his trade area.

Although the 100 percent market share model answers some important questions, it is not very representative of the competitive conditions actually facing the retailer. One method sometimes used in spatial studies is to assume a constant market share for the entire trade area which is less than 100 percent of the market. The constant market share used in this study assumes that the retailer obtains 33 percent of the total demand in each increment mile. Figure 4.1 depicts a constant market share of this nature.

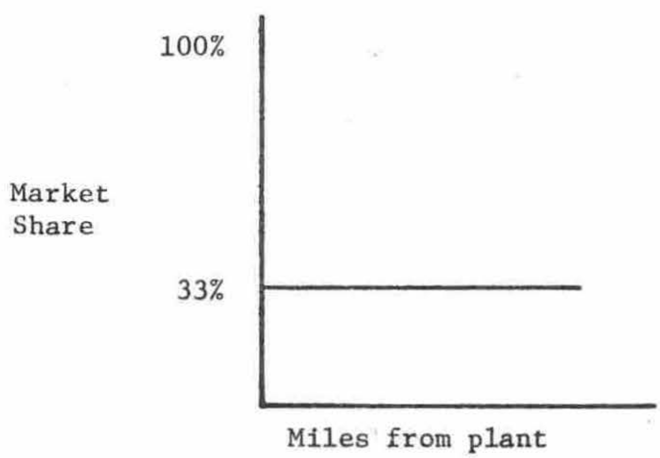

Figure 4.1. Constant market share of 33 percent

A declining market share was included to reflect the preliminary study of average travel distance. Figure 4.2 depicts a (discontinuously) declining market share.

For the first rate level (160 lbs. NH_3/acre) the constant market share of 33 percent and the declining market share have the same total demand in a 15 mile trade area. Comparisons of retail distribution costs for these two market share assumptions will be made.

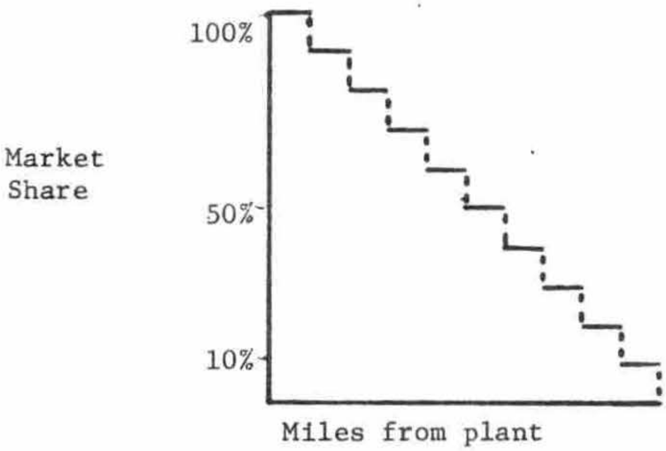

Figure 4.2. Declining market share

4.2.3. Season length

The highly intensive nature of the present day retail marketing of ammonia suggests that costs might be reduced if there is more time available to deliver the fertilizer. The season length which represents the present day season was determined through interviews with retailers and manufacturers, and from the survey of 37 retailers in the Fort Dodge area mentioned earlier.

The season length used to represent the present day season or what will be referred to as the regular season, is 15, 10 hour applicating days. To examine what affect more applicating time would have on costs a 20 percent increase in applicating time is used. This additional time would be gained through increased sidedressing and fall application.

The three market shares, the six demand densities; and the two season lengths will be used to examine how these factors will change costs. A particular combination of market share, demand density, and season length will be referred to as the "market environment" the retailer is facing.

4.3. Interest, taxes, depreciation and firm types

An interest charge of 6.5 percent is used for all plant and delivery equipment. The interest charge represents both borrowed funds and a return on investment for the retailer. Property taxes for plant equipment, nurse tanks, and applicators were calculated on the basis of 27 percent of the market value times a mileage rate of 92.753[2]. Depreciation was calculated on the basis of a straight line depreciation schedule.

Two basic types of firms are considered. The first type, which will be referred to as a farm supply unit, handles a complete product line of farm supplies, including bulk fertilizer and ammonia. This firm type is representative of cooperatives and independent retailers. The second firm type, a specialized integrated fertilizer distributor handling bulk fertilizers, agricultural chemicals, and anhydrous ammonia, is characteristic of the corporate firms retailing anhydrous in the Fort Dodge area.

These two firm types are included in an attempt to represent firms handling multiple products. Multiple products introduce a problem of arbitrary allocation of fixed costs for multiple use facilities.

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[2]Average mileage rate of 21 towns and cities in the Fort Dodge area.

> Any allocation of fixed costs (to a multiple use facility) is purely arbitrary, although as a practical matter, some such allocation may be necessary in specific cases (10, p. 774).

Ammonia sales as a percentage of total firm sales are the criterion used in this study to determine what cost would be charged against anhydrous for the use of a multiple use facility. Table 4.2 denotes the total and component sales used for the farm supply units. Sales information was acquired from a survey of 14 farm supply cooperatives in the Fort Dodge area.

Table 4.2. Average of total and component sales for 14 farm supply cooperatives, 1970

Farm Supply Units	
Product	Sales
Grain Sales	$1,966,301
Feed	264,144
Fertilizer	119,089
Ammonia	52,275
Scale Related Sales	$2,401,809
Seed	19,494
Petroleum	149,342
Farm supplies	80,202
Total	**$2,650,847**

This information is then used to estimate the fixed cost of a multiple use facility that is allocated against ammonia for each individual farm supply unit. Since no relationship was found between total sales and ammonia sales, total sales are held constant at 2.6 million dollars for all farm supply units considered. This assumption is important because it results in different fixed costs for a multiple use facility being allocated against the individual farm supply unit plants.

A similar method of handling multiple use facility fixed costs is used for the specialized plants. But, total sales of the two specialized plants are not the same. The smaller specialized firm is assumed to employ one full time man while the larger employs two. To justify the employment of two full time men, it was assumed that the larger firm had sales twice as large as the first. The sales for the specialized fertilizer dealers are presented in Table 4.3.

Table 4.3. Estimated total and component sales for specialized fertilizer dealers

Product	Specialized Firm 1	Specialized Firm 2
Bulk Fertilizer	$162,000	$324,000
Ammonia	67,500	135,000
Scale Related Sales	229,500	459,000
Agricultural Chemicals	40,500	81,000
Total Sales	$270,000	$540,000

4.4. Plant costs

The basic ammonia retail outlet was described in Chapter 2. The plant consists of the bulk tank and pump, a scale for weighing the nurse tank, and some type of office building for handling the billing and record keeping. The activities involved in the plant operation are: filling the nurse tank, hooking and unhooking the nurse tank to the pickup, weighing the nurse tank, and monitoring the unloading of truck transports and rail cars.

The costs, wear on equipment, labor requirements, and plant capabilities in this section were obtained through interviews with retailers, wholesalers, manufacturers of ammonia equipment, and technically trained personnel in the fertilizer industry. The plant capacities are chosen to typify those currently being used for retailing ammonia except for the largest plant. The largest retail operation the author is aware of is a 2000 ton per year plant.

Six different plants are considered in the study. Table 4.4 designates the plant capacities of the six plants for the regular and expanded seasons. Because it is assumed that the plants would have larger capacities for the expanded season, it is necessary to treat the costs of the two seasons separately. Henceforth, the discussion will center on the regular season plants, and changes for the expanded season plants will be noted. The effective working hours, H, for the plants in the regular season are assumed to be the same as the time allowed for delivery or 180 hours. For the expanded season, the effective working hours for plants are 216 hours.

Table 4.4. Plant capacities for regular and expanded seasons

Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
	..................Tons..................				........Tons.......	
REGULAR SEASON	900	1800	2300	3200	900	1800
EXPANDED SEASON	1100	2100	3200	3800	1100	2100

4.4.1. Fixed plant costs

Those costs which are considered to be fixed are: the bulk plants, risers, scales, office buildings, and fixed labor.

4.4.1.1. Bulk plant The bulk plant is comprised of the pressurized storage vessel and the transfer pump. As was mentioned in Chapter 2, the cost of the pressurized storage vessels is essentially constant. The particular storage tank a given plant will need is determined by the volume assumed for the plant and the size of the rail car which will serve the plant (regular or jumbo car). For plants 2, 3, and 4 of the farm supply unit plants, a 26,000 gallon tank is added at a rental cost of $1 per year. This is included to represent a rather common arrangement between the retailer and supplier.

The difference in plant capacities is gained through different sizes of pumps, motors, and plumbing. All plants are budgeted with a vapor compressor as the compressor is necessary for the unloading of rail cars. Plants 1 and 5 are assumed to use this same vapor pump for the filling of nurse tanks, while the other plants use a liquid pump for this purpose. All plants except 4 are assumed to use two inch plumbing. Plant 4 is budgeted with three inch plumbing to gain additional capacity. Table 4.5 sets forth the budget costs and capacities for the plants.

The site preparation cost is the cost necessary for preparing the site for the bulk tank. The rated capacity is the manufacturer's suggested rate, while the regular and expanded season capacities are the rates assumed for actual operating conditions. The expanded season rates are reduced to reflect additional start up time as the expanded season is assumed to be a less intensive operation. A 20 year depreciation schedule, with no salvage value, is used.

Table 4.5. Bulk plant costs and capacities, regular and expanded season

Type Firm	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Storage Vessel	1-12,000 Gal. Tank	1-12,000 1-26,000 Gal. Tank	1-18,000 1-26,000 Gal. Tank	2-26,000 Gal. Tank	1-12,000 Gal. Tank	1-18,000 Gal. Tank
Type Rail Car	Regular	Jumbo	Jumbo	Jumbo	Regular	Jumbo
Loading Pump Size Motor	Vapor 5 H.P.	Liquid 5 H.P.	Liquid 7.5 H.P.	Liquid 10 H.P.	Vapor 5 H.P.	Liquid 5 H.P.
Cost	$7,210	$9,339	$13,026	$16,665	$7,210	$12,839
Site Preparation Cost	$ 500	$ 550	$ 600	$ 700	$ 500	$ 500
Rated Capacity	8 Ton/Hr	12 Ton/Hr	14 Ton/Hr	20 Ton/Hr	8 Ton/Hr	12 Ton/Hr
Capacity, Regular Season	5 Ton/Hr	10 Ton/Hr	12.8 Ton/Hr	17.8 Ton/Hr	5 Ton/Hr	10 Ton/Hr
Capacity, Expanded Season	4.9 Ton/Hr	9.7 Ton/Hr	12.5 Ton/Hr	17.6 Ton/Hr	4.9 Ton/Hr	9.7 Ton/Hr

4.4.1.2. Risers The nurse tank risers are stanchion-like devices which are the loading points for nurse tanks and hold the filling hose when not in use. Each riser is capable of filling two nurse tanks at one time. Plant 4 is budgeted with two risers while the rest of the plants have only one.

4.4.1.3. Scales The farm supply units are budgeted with a 70 foot grain scale, at a cost of $15,000, while the specialized fertilizer dealers are budgeted with a 20 ton scale at a cost of $5400 (20). The scale costs introduce the first arbitrary allocation of fixed costs. It is assumed that the farm supply units will use their scale for grain, feed, bulk fertilizer, and ammonia while the cost of the scale for the specialized dealer is allocated between bulk fertilizer and ammonia. In Tables 4.2 and 4.3, the total sales of the commodities using the scale were referred to as scale related sales. Table 4.6 gives the percentage of ammonia sales to scale related sales, based on a $75.00 per ton price of ammonia. A 20 year depreciation schedule with no salvage value is used.

Table 4.6. Percentage of ammonia sales to scale related sales and scale cost allocated to ammonia, for regular and expanded season

REGULAR SEASON Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
NH_3 Sales as % of Scale Related Sales	2.9%	5.5%	6.7%	8.8%	30%	30%
Cost Allocated to NH_3	$435	$825	$1,005	$1,320	$1,620	$1,620
EXPANDED SEASON						
NH_3 Sales as % of Scale Related Sales	3.5%	6.1%	7.7%	10.5%	35.9%	35.9%
Cost Allocated to NH_3	$525	$915	$1,155	$1,575	$1,798	$1,798

4.4.1.4. Office building The function of the office building is to house the records, files, phone, and to act as the central control point for the retail operation. The farm supply units are assumed to work from a central administration building costing $35,000 which is depreciated over 20 years with a $10,000 residual value. The specialized fertilizer dealers work from a 16X16 foot building costing $3530 which is depreciated over 20 years with no residual value (20).

Table 4.7 gives the percentage of ammonia sales to total firm sales used in this study. Total firm sales are those found in Tables 4.2 and 4.3.

Table 4.7. Percentage of ammonia sales to total firm sales and cost of office building allocated to ammonia, for regular and expanded season

REGULAR SEASON Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
NH_3 Sales as % of Total Firm Sales	2.6%	4.9%	6.0%	7.7%	25%	25%
Cost Allocated to NH_3	$910	$1,715	$2,100	$2,695	$883	$883
EXPANDED SEASON						
NH_3 Sales as % of Total Firm Sales	3.1%	5.4%	6.7%	9.3%	30.6%	30.6%
Cost Allocated to NH_3	$1,085	$1,890	$2,345	$3,255	$1,060	$1,060

4.4.1.5. Land The land is needed for the bulk plant and storage of the delivery equipment in the off-season. It is assumed that land is available for purchase next to a rail siding. Table 4.8 shows the amount of land and its budgeted cost. It is assumed that land retains its value, so the only costs allocated for land are interest and property taxes. It is assumed that land needs will not differ for the two seasons considered.

Table 4.8. Land requirements and costs for the plants

Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Land Requirement	1 Acre	1-1½ Acres	1-1½ Acres	2 Acres	1 Acre	1½ Acres
Cost	$1,000	$1,500	$1,500	$2,000	$1,000	$1,500

4.4.1.6. Fixed labor The handling of the fixed labor costs is a major difference between the specialized fertilizer dealers and the farm supply units. It is assumed that the labor cost for operating the specialized fertilizer firms is fixed. The only fixed labor for the farm supply units is managerial. The justification for this assumption is that labor for the farm supply unit can be diverted to another product (feed, petroleum, etc.) while this opportunity does not exist for the specialized dealer.

The arbitrary allocation of these costs is based on the percentage of ammonia sales to total sales found in Table 4.7. A base salary plus allowances for social security and employee benefits is included in this cost. The yearly base salary for the farm supply unit manager is $14,000, the smaller specialized firm is assumed to need one man at a yearly base salary of $9,000, while the larger specialized firm is budgeted on the basis of two men with combined yearly base salaries of $16,000. The reason for doubling the sales of the larger specialized firm, as explained in section 4.3, is based on the assumption that it would take substantially greater sales to justify the employment of two men. Table 4.9 gives the fixed labor costs for the six plants for the regular and expanded seasons.

Table 4.9. Fixed labor costs for plants, for regular and expanded season

REGULAR SEASON						
Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Allocated Labor Fixed Cost	$404	$762	$933	$1,198	$2,500	$4,444
EXPANDED SEASON						
Allocated Labor Fixed Cost	$482	$840	$1,042	$1,447	$3,000	$4,944

4.4.1.7. Other fixed costs Other costs which are assumed to be fixed are: office equipment, fixed insurance cost, track leasing, and safety equipment.

The office equipment costs for the farm supply units are based upon a survey of three farm supply cooperatives whose average equipment costs were $6200. The fixed cost of the office equipment is arbitrarily allocated on the basis of the percentage of ammonia sales to total firm sales found in Table 4.7. The fixed office equipment costs for the specialized fertilizer dealer are based on an estimate of the minimum equipment necessary for equipping a small office. This cost of $1030 again is arbitrarily allocated on the percentage basis given in Table 4.7. The office equipment is depreciated on a ten year no salvage value basis.

An umbrella insurance policy to guard against the possibility of an ammonia accident is included. The $540 yearly cost is allocated on the basis of the percentages given in Table 4.7.

Track leasing is assumed to be a yearly fixed cost. The amount of track needed for each plant is based on rail car size and volume of ammonia sales.

Miscellaneous fixed cost includes: safety equipment such as gas masks, gloves, and a water tank; plus mobil gasoline driven transfer pumps for transferring ammonia from the nurse tank into the tank mounted applicators. The miscellaneous costs are depreciated on the basis of three years with no residual value.

The fixed costs for these other items are presented in Table 4.10.

It should be noted that no seasonal adjustment is made for track leasing or miscellaneous costs.

Table 4.10. Other fixed costs for plants, regular and expanded season

REGULAR SEASON						
Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Fixed Insurance Cost	$15.08	$28.42	$34.80	$44.66	$145	$145
Office Equipment Costs	$162	$306	$375	$481	$310	$310
EXPANDED SEASON						
Fixed Insurance Cost	$17.98	$31.32	$38.86	$53.94	$174	$174
Office Equipment Costs	$194	$338	$419	$581	$320	$320
Track Leasing	$500	$900	$1,150	$1,600	$500	$900
Miscellaneous	$174	$255	$260	$406	$174	$255

4.4.1.8. Total fixed costs Tables 4.11 and 4.12 show the total fixed costs and the plant capacities for the regular and expanded seasons, respectively. A few points on the table should be noted. The storage reserve is calculated on the combination of the pressurized tank and the mobil storage provided by the rail cars. The adjusted total is the total cost minus the cost of land as interest and property taxes are the only true cost due to land. The miscellaneous costs include fixed insurance cost, safety equipment, and mobil transfer equipment.

Table 4.11. Total and component fixed cost for plants, regular season

Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Storage Reserve	7 Hours	11.6 Hours	11.7 Hours	12.1 Hours	7 Hours	8.5 Hours
Pumping Capacity	5 Ton/Hr	10 Ton/Hr	12.8 Ton/Hr	17.8 Ton/Hr	5 Ton/Hr	10 Ton/Hr
Bulk Plant Cost	$7,210	$9,339	$13,026	$16,665	$7,210	$12,839
Site Preparation Cost	$500	$550	$600	$700	$500	$500
Scale	$435	$825	$1,005	$1,320	$1,620	$1,620
Office Building	$910	$1,715	$2,100	$2,695	$883	$883
Land	$1000	$1500	$1500	$2000	$1000	$1500
Office Equipment	$162	$306	$375	$481	$310	$310
Total	$10,217	$14,185	$18,606	$23,861	$11,523	$17,652
Adjusted Total	$8,944	$12,188	$16,497	$21,079	$10,523	$16,152
Yearly Depreciation	$447	$609	$825	$1,054	$526	$802
Property Tax	$148	$358	$430	$491	$185	$268
Interest	$332	$461	$605	$788	$385	$574
Track Leasing	$500	$900	$1,150	$1,600	$500	$900
Miscellaneous	$189	$283	$295	$451	$319	$400
Tank Rental	----	$1	$1	$1	----	----
Fixed Labor	$404	$762	$933	$1,198	$2,500	$4,444
Yearly Fixed Cost	$2,020	$3,374	$4,239	$5,583	$4,415	$7,388

Table 4.12. Total and component fixed cost for plants, expanded season

Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Storage Reserve	7.0 Hours	11.8 Hours	12.0 Hours	12.4 Hours	7.0 Hours	7.4 Hours
Pumping Capacity	4.9 Ton/Hr	9.7 Ton/Hr	12.5 Ton/Hr	17.6 Ton/Hr	4.9 Ton/Hr	9.7 Ton/Hr
Bulk Plant Cost	$7,210	$9,339	$13,026	$16,665	$7,210	$12,839
Site Preparation Cost	$500	$550	$600	$700	$500	$500
Scale	$525	$915	$1,155	$1,575	$1,798	$1,798
Office Building	$1,085	$1,890	$2,345	$3,255	$1,060	$1,060
Land	$1,000	$1,500	$1,500	$2,000	$1,000	$1,500
Office Equipment	$194	$338	$419	$581	$320	$320
Total	$10,514	$14,532	$19,045	$24,776	$11,888	$18,017
Adjusted Total	$9,189	$12,465	$16,842	$21,800	$10,888	$16,517
Yearly Depreciation	$459	$623	$842	$1,090	$545	$821
Property Taxes	$150	$362	$422	$506	$171	$248
Interest	$342	$472	$608	$802	$397	$583
Track Leasing	$500	$900	$1,150	$1,600	$500	$900
Miscellaneous	$192	$286	$299	$460	$348	$429
Tank Rental	----	$1	$1	$1	----	----
Fixed Labor	$482	$840	$1,042	$1,447	$3,000	$4,944
Yearly Fixed Cost	$2,125	$3,484	$4,364	$5,906	$4,961	$7,925

4.4.2. Variable plant costs

As was pointed out in Chapter 3, Section 1 constant variable costs were a simplifying assumption made for this study. The variable costs included are bulk plant maintenance, overhead costs, shrink, operating capital, variable labor for the farm supply units, and others.

4.4.2.1. Bulk plant maintenance   The information in this section was gained through interviews of retailers and ammonia equipment dealers. The life expectancy assumed on the equipment is: vapor pumps - six years, liquid pump - three years, electric motors - ten years and, hoses and valves - four years. It is assumed that the pressurized tank

Table 4.13. Bulk plant maintenance cost, regular and expanded season

REGULAR SEASON Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
	$/ton				$/ton	
Vapor Pump	$.557	$.259	$.218	$.157	$.557	$.259
Liquid Pump	----	.380	.329	.372	----	.380
Motor	.142	.142	.138	.134	.142	.142
Hoses and Valves	.572	.354	.332	.370	.572	.374
Painting and Maintenance	.429	.399	.375	.316	.429	.349
Total	$1.700	$1.534	$1.392	$1.349	$1.700	$1.414
EXPANDED SEASON						
Vapor Pump	$.493	.219	$.186	$.132	$.493	.219
Liquid Pump	----	.320	.280	.323	----	.320
Motor	.116	.122	.118	.113	.116	.122
Hoses and Valves	.468	.294	.283	.311	.468	.274
Painting and Maintenance	.372	.335	.317	.268	.372	.285
Total	$1.449	$1.290	$1.184	$1.147	$1.449	$1.150

will be painted every fourth year. In addition, a cost for ground maintenance around the bulk plant is included. Table 4.13 gives these costs for the plants.

4.4.2.2. Overhead costs The overhead costs are comprised of electricity and heating for the office building, general advertising for the firm, legal and auditing services, telephone, office supplies, and bad debt. The cost information was acquired through the survey of the 14 farm supply cooperatives in the Fort Dodge area mentioned earlier. These costs are given in Table 4.14.

Table 4.14. Average of total and component overhead costs for 14 farm supply cooperatives

Electricity and Heat for Office Building	$ 960
Director Fees, Travel and Meetings	$2,933
General Advertising	$4,160
Dues, Subscriptions and Donations	$ 560
Legal, Audit, and Bank Services	$2,147
Telephone	$1,480
Office Supplies	$2,618
Bad Debt	$1,758
Office Maintenance	$ 705
Total Overhead Cost	$17,321

The method of determining the overhead costs that would be charged against anhydrous is the same as that used for estimating the fixed cost of a multiple use facility. The overhead costs of Table 4.14 are arbitrarily allocated on the basis of ammonia sales as a percentage of total firm sales from Table 4.7. These same costs are used in the determination of the specialized firms' overhead costs with the exception that the director fees were eliminated.

Table 4.15. Variable overhead costs for plants, regular and expanded season

REGULAR SEASON						
Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
	--cost/ton--					
Allocated Overhead Costs	$.50	$.47	$.45	$.42	$.47	$.47
EXPANDED SEASON						
Allocated Overhead Costs	$.49	$.45	$.43	$.39	$.46	$.46

4.4.2.3. Shrink Shrink is calculated on the basis of 1 percent of a wholesale cost of $55.00 per ton. The shrink is a result of the inability to completely unload the rail cars and transports, and loss of material through leakage.

4.4.2.4. Operating capital An operating capital interest charge of 6.5 percent, based on a retail price of $75.00/ton for a two month period is used.

4.4.2.5. Variable labor for farm supply units Variable labor costs for the farm supply units include: time for loading nurse tanks, unhooking and hooking the nurse tanks to the pickups, monitoring the unloading of truck transports and rail cars, and weighing the nurse tanks. The labor cost is based on a cost of $2.50 per hour plus adjustment for social security, employee benefits, overtime, and a variable insurance cost. The total hourly charge is $3.19.

Table 4.16 denotes the number of full time equivalent men assumed to be needed to perform these functions for each plant. Included in the table are the labor costs on a per ton basis for the regular and expanded season. Differences between seasons are due to different hourly plant rates and overtime payment. The off season labor is included to represent maintenance on the bulk plant.

Table 4.16. Variable labor costs for the farm supply units, regular and expanded seasons

	PLANT 1		PLANT 2		PLANT 3		PLANT 4	
	Season		Season		Season		Season	
	Reg.	Exp.	Reg.	Exp.	Reg.	Exp.	Reg.	Exp.
	$/Ton							
In Season	$.53	$.44	$.40	$ $.35	$.39	$.34	$.27	$.25
Off Season	.05	.05	.05	.05	.04	.04	.03	.03
Total	$.58	$.49	$.45	$.40	$.43	$.38	$.30	$.28
Number of fulltime equivalent men	3/4		1		1-1/4		1-1/2	

4.4.2.6. Other variable overhead costs Other variable overhead costs includes promotion, soil testing, employee education, and billing. These costs are considered to be the same for each plant except as noted below.

Promotion--It is assumed that some type of appreciation dinner will be held for the retailer's customers. This cost of $.05 per ton is the same for all plants.

Soil testing--It is assumed that the retailers provide a soil sampling service for their customers. The cost includes labor and pickup charges for the farm supply unit while only the cost of operating a pickup for the specialized fertilizer firms is included. The cost is allocated between bulk fertilizer and ammonia, and it is assumed that land will be sampled every three years.

Employee education--Education of employees in handling and promoting ammonia is based on a cost of one day per man per year for the farm supply units. Because of the fixed cost of labor for the specialized firms this cost is not included for the specialized plants.

Billing--Billing of customers for the farm supply units includes bookkeeping labor, letters, and postage. Only the cost of letters and postage is included for the specialized fertilizer firms.

4.4.2.7. Total variable costs Table 4.17 presents the total and component variable costs for the regular and expanded season, respectively. The differences between the farm supply unit plants and the specialized plants should be noted. The differences in costs between firm type can be explained by the assumptions concerning plant labor.

4.4.3. Summary of plant costs

The preceding has been an explanation of the assumptions concerning plant costs used in this study and the cost coefficients that are used in this study. It should be pointed out that the depreciation schedule used for both plant and delivery equipment is based on those normally used by accountants for ammonia retailers.

Table 4.17. Total and component variable costs for plants, regular and expanded seasons

	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
	$/Ton					
REGULAR SEASON						
Maintenance	$1.70	$1.53	$1.39	$1.35	$1.70	$1.41
Overhead	.50	.47	.45	.42	.47	.47
Electricity	.02	.03	.03	.03	.02	.03
Promotion	.05	.05	.05	.05	.05	.05
Soil Testing	.07	.07	.07	.07	.03	.03
Shrink	.55	.55	.55	.55	.55	.55
Operating Capital	.81	.81	.81	.81	.81	.81
Employee Education	.07	.07	.07	.07	-----	-----
Billing	.15	.15	.15	.15	.04	.04
Labor	.58	.45	.43	.30	-----	-----
Total	$4.50	$4.18	$4.00	$3.80	$3.67	$3.39
EXPANDED SEASON						
Maintenance	$1.45	$1.29	$1.18	$1.15	$1.45	$1.15
Overhead	.49	.45	.43	.39	.46	.46
Electricity	.02	.03	.03	.03	.02	.03
Promotion	.05	.05	.05	.05	.05	.05
Soil Testing	.07	.07	.07	.07	.03	.03
Shrink	.55	.55	.55	.55	.55	.55
Operating Capital	.81	.81	.81	.81	.81	.81
Employee Education	.07	.07	.07	.07	-----	-----
Billing	.15	.15	.15	.15	.04	.04
Labor	.49	.40	.38	.28	-----	-----
Total	$4.15	$3.87	$3.72	$3.55	$3.41	$3.12

4.5. Delivery costs

The purpose of this section will be to determine the cost coefficients and time parameters for

[3.16] $$TDC = D(b_o + b_1 \frac{.4714D^{1/2}}{\bar{P}^{1/2}}) + FN \ .$$

and

[3.17] $$ADC = (b_o + b_1 \frac{.4714D^{1/2}}{\bar{P}^{1/2}}) + \frac{FN}{D} \ .$$

In the plant cost section the method of development was to determine the fixed cost and then the constant variable costs. The method in this section will be to discuss the peculiarities, the constant variable costs per ton, the time parameters, and finally the yearly fixed cost for each delivery unit type.

4.5.1. Applicator costs

Five different applicating machines are considered in this study: a 5 row tank mounted applicator which can be converted to a tool bar for preplant application, a 7 row tool bar, a 30 foot tool bar, and a 10 foot chisel plow.

4.5.1.1. Constant variable costs for applicators Table 4.18 gives constant variable costs per ton, b_o, for the applicators. It should be noted that in addition to seasonal differentiation, costs are also calculated for different rate levels.

Table 4.18. Constant variable costs of applicators for different rate levels and different seasons

	REGULAR SEASON			EXPANDED SEASON		
	Lbs. NH_3/Acre			Lbs. NH_3/Acre		
	160	195	245	160	195	245
	$/Ton					
Knives	$.73	$.69	$.63	$.73	$.67	$.63
Shanks	.12	.11	.09	.12	.10	.09
Bearings	.79	.73	.67	.79	.72	.66
Hose	.10	.08	.06	.10	.08	.06
Valves	.07	.06	.05	.07	.06	.05
Total	$1.81	$1.67	$1.50	$1.81	$1.63	$1.49

The constant variable costs for applicators are maintenance on the machine. The injector knife wear for the 5 row mounted applicator and the 7 row tool bar is based on 800 acres of application per knife. The shaker knife used on the 30 foot tool bar is based on a life of 2000 acres per knife.

The shanks (mechanical devices to which the knives are mounted) are budgeted on the basis of one shank breaking per five machines per year. The valve replacement is an estimate made from the wear on nurse tank valves. It is assumed that hoses will be replaced every three years for safety purposes. The basis for these costs is interviews with retail dealers and ammonia equipment dealers.

4.5.1.2. Determination of time parameters for applicators

Application activities include: applicating time, waiting in the field for exchange of nurse tanks, moving from field to field, start up time, breakdown time, and coordination time.

Rather than try to determine how many individual 5 row mounted applicators, 7 row tool bars, etc., will be needed, a composite applicating machine is developed. The composite machine is made up of varying percentages of individual applicating machines depending upon the season and rate level.

The reasons for changing the composite are: First, to reflect increasing applicator size, a greater proportion of the application is done by larger machines as rate level increases (i.e. the 30 foot tool bar comprises a greater proportion of the composite as rate level increases). Second, the composite is changed to represent a change to more sidedressing and the inclusion of fall application (represented by the chisel plow) for the expanded season. The above reasons and the increased efficiency due to a higher rate level explain the changes in constant variable costs per ton given in Table 4.18.

Table 4.19. Percentage of individual applicating machines for different season and different rate levels

	REGULAR SEASON			EXPANDED SEASON		
	Lbs. NH_3/Acre			Lbs. NH_3/Acre		
	160	195	245	165	195	245
5 Row Applicator	.4	.4	.4	.46	.46	.46
7 Row Tool Bar	.6	.4	.3	.48	.28	.27
30 Foot Tool Bar	--	.2	.3	--	.15	.16
Chisel Plow	--	--	--	.06	.09	.09

The determination of the constant time per ton for applicators, g_o, is the first deviation from the true engineering cost approach. Using time parameter estimates for waiting in the field to exchange nurse tanks, moving from field to field, start up time for each farmer, breakdown time, coordination time, etc. was found to result in too few applicators as compared to actual retailing operations.

It was then decided to use the industry measurement of applicator efficiency; the tons of ammonia/applicator/year. The efficiency chosen (75 tons/applicator/season) for the current 160 lbs. NH_3/acre, rate level is representative of well organized present day retailers. Efficiencies of 95 and 115 tons/applicator/year were used for the higher rate levels.

One time parameter estimate was retained, the time needed for applying the ammonia. The method of how this portion of g_o is determined is demonstrated by means of an example:

An example for determination of constant applicating time requirement, for a 7 row tool bar:

1) Swath X machine speed/square feet/acre = acres/hr.
   23.33 X 4.5MPH/43,560 sq.ft/acre = 12.72 acres/hr.

2) $$\frac{1}{\text{acres/hr. X rate/acre/\# in a ton}} = \text{hrs./ton}$$

3) $$\frac{1}{\text{12.72 acres/hr. X 160\# } NH_3\text{/2000\#}} = .98 \text{ hrs./ton}$$

Table 4.20 shows the speed and constant time requirement for the individual applicating machines.

Table 4.20. Constant time requirements for individual applicating machines for different rate levels

	M.P.H.	Acres/Hr	---------Lbs. NH_3/Acre-------		
			160	195	245
			-----------Hrs/Ton-----------		
5 Row Mounted Applicator	5.5	11.11	1.41	1.09	.90
*Used as a Tool Bar	5.0	10.10	1.24	1.01	.81
7 Row Tool Bar	4.5	12.72	.98	.81	.64
30 Foot Tool Bar	5.5	20.00	--	--	.41
Chisel Plow	3.5	6.36	1.96	1.62	1.28

* The 5 row machine may be used for either sidedressing or preplant application.

This information is then utilized in the computation of the composite machine time requirements represented in Table 4.21 for the regular and expanded seasons.

Table 4.21. Composite applicating machine constant time requirements for different rate levels and different seasons

REGULAR SEASON	Lbs. NH_3/Acre: 160							195							245						
	% of Comp.	X	Hrs/Ton		Comp. Hrs/Ton			% of Comp.	X	Hrs/Ton		Comp.			% of Comp.	X	Hrs/Ton		Comp.		
5 Row Applicator	.1	X	1.41	=	.14			.1	X	1.09	=	.11			.1	X	.90	=	.09		
Used as a Tool Bar	.3	X	1.24	=	.37			.3	X	1.01	=	.30			.3	X	.81	=	.24		
7 Row Tool Bar	.6	X	.98	=	.59			.4	X	.81	=	.32			.3	X	.64	=	.19		
30 Foot Tool Bar	--		--		--			.2	X	.51	=	.10			.3	X	.41	=	.12		
Total					1.10							.82							.64		
EXPANDED SEASON																					
5 Row Applicator	.20	X	1.41	=	.28			.20	X	1.09	=	.22			.20	X	.90	=	.18		
Used as a Tool Bar	.26	X	1.24	=	.32			.26	X	1.01	=	.26			.26	X	.81	=	.21		
7 Row Tool Bar	.48	X	.98	=	.47			.47	X	.81	=	.23			.27	X	.64	=	.17		
30 Foot Tool Bar	--		--		--			.15	X	.51	=	.08			.16	X	.41	=	.07		
Chisel Plow	.06	X	1.96	=	.12			.09	X	1.62	=	.15			.09	X	1.28	=	.11		
Total					1.19							.94							.74		

The composite constant time per ton for different rate levels and seasons is given in Table 4.22, the total constant time g_o for applicators.

Table 4.22. Total constant time, g_o, for applicators determined by applicator efficiency parameters for different rate levels and different seasons

Efficiency Parameter	REGULAR SEASON			EXPANDED SEASON		
	Tons/Applicator/Season			Tons/Applicator/Season		
	75	95	115	75	95	115
	----Lbs. NH_3/Acre---			----Lbs. NH_3/Acre---		
	160	195	245	160	195	245
	------Hrs/Ton--------			------Hrs/Ton--------		
Applicating Time	1.10	.82	.64	1.19	.94	.74
Other	.80	.68	.71	.73	.79	.79
Total g_o applicators	1.90	1.50	1.35	1.92	1.73	1.53

The constant time per unit of volume, per unit of distance traveled, g_1, is calculated for moving the applicators from one customer to another. The parameter, g_1, for applicators was calculated on the basis of one minute per ton per one way mile or .017 hrs./ton.

The effective working hours per season, H, for applicators is based on 15, 10 hours applicating days for the regular season, as explained in section 4.2. The effective working hours are increased by 20 percent to 180 hours for the expanded season.

4.5.1.3. Determination of fixed cost for applicators The individual applicating machine proportions from Table 4.19 are used in the determination of the composite machine fixed cost. Table 4.23 presents the fixed cost for the composite machine.

Table 4.23. Fixed cost for composite machine for different rate levels and different seasons

REGULAR SEASON	Lbs. NH_3/Acre 160			195			245		
	% of Composite	Machine Cost	$ Cost	% of Composite	Machine Cost	$ Cost	% of Composite	Machine Cost	$ Cost
5 Row Mounted Applicator	.4	X $1581 =	$632	.4	X $1641 =	$656	.4	X $1705 =	$682
7 Row Tool Bar	.6	X $1071 =	$611	.4	X $1058 =	$1058	.3	X $1120 =	$336
30 Foot Tool Bar	--	--	--	.2	X $2158 =	$2158	.3	X $2158 =	$647
Composite Machine Cost			$1243			$1511			$1665
EXPANDED SEASON									
5 Row Mounted Applicator	.46	X $1581 =	$727	.46	X $1641 =	$755	.46	X $1705 =	$784
7 Row Tool Bar	.48	X $1071 =	$488	.28	X $1058 =	$296	.27	X $1120 =	$302
30 Foot Tool Bar	--	--	--	.15	X $2158 =	$324	.16	X $2158 =	$345
Chisel Plow	.06	X $826 =	$50	.09	X $860 =	$77	.09	X $890 =	$80
Composite Machine Cost			$1265			$1452			$1511

It should be noted that the individual machine cost increases with rate. This is a result of additional knives and shanks on the machines. As the rate per hose is increased a physical limit on flow is reached so it is necessary to add additional hoses, knives, and shanks to obtain the desired rate per acre.

Yearly fixed cost--The yearly fixed depreciation costs are determined on a five year depreciation schedule with a 10 percent salvage value. Additional yearly fixed costs are interest, property taxes, agricultural use license ($3), insurance ($4), and safety equipment ($3). These costs are given in Table 4.24.

Table 4.24. Yearly fixed costs of composite applicating machines for different rate levels and different seasons

	REGULAR SEASON			EXPANDED SEASON		
	-Lbs. NH_3/Acre-					
	160	195	245	160	195	245
Composite Machine Cost	$1243	$1511	$1665	$1265	$1452	$1511
Depreciation	$224	$272	$299	$228	$262	$272
Interest	42	49	53	42	46	50
Property Tax	16	19	21	16	18	20
Other Yearly Costs	10	10	10	10	10	10
Yearly Fixed Cost	$284	$350	$383	$296	$336	$352

4.5.2. Nurse tank costs

The nurse tank considered is a 1,000 gallon pressurized tank with a 5th wheel running gear. The costs of other modes of moving the anhydrous from the plant to the farm appear to be prohibitive.

4.5.2.1. Constant variable nurse tank costs The constant variable costs per ton, b_o, for nurse tanks are maintenance. The maintenance cost consists of hose, valve, and gauge replacements; wagon tongue breakage due to the farmer turning too short; wheel packing; painting the pressurized tank every three years; and tire repair and replacement. These costs are presented in Table 4.25. There are no adjustments made for season or rate level. These costs were obtained through interviews of retailers.

Table 4.25. Constant variable costs for nurse tanks

Component cost	\$1/Ton
Hoses	.12
Valves and gauges	.22
Wagon tongues	.26
Wheel packing	.07
Painting	.27
Tires	.18
Total cost	\$1.11/Ton

4.5.2.2. Determination of time parameters for nurse tanks

The activities associated with nurse tanks are applicating time, waiting at the plant, filling, weighing, and breakdown. Again the industry measurement of efficiency, tons/nurse tank/year, is used to determine the constant time requirement, g_o. The three efficiencies used are 55, 70, and 90/tons/nurse tank/season. Table 4.26 gives the constant time associated with each ton, g_o, for nurse tanks.

The constant time per unit of volume, per unit of distance traveled, g_1, is calculated at the rate of two minutes per ton per one way mile or 30 miles per hour.

Table 4.26. Constant time requirement, g_o, of nurse tanks for different seasons and different rate levels

	REGULAR SEASON			EXPANDED SEASON		
	Lbs. NH_3/Acre					
	160	195	245	160	195	245
	Hrs/Ton			Hrs/Ton		
Time Associated With Applicator	1.90	1.50	1.35	1.92	1.73	1.53
Other	.74	.73	.63	.75	.74	.72
Constant Time, g_o	2.64	2.23	1.98	2.67	2.47	2.25

The effective working hours, H, for nurse tanks is a weighted average of the time spent with applicators and that spent with pickups.

4.5.2.3. Yearly fixed cost for nurse tanks   The cost of the nurse tank is $1027. A 10 year depreciation schedule is used with a 10 percent salvage value. Other costs include interest, property tax, agricultural use, license ($5), insurance ($4), and safety equipment ($5).

Table 4.27 presents the yearly fixed cost for nurse tanks.

Table 4.27. Yearly fixed cost for nurse tanks

Nurse tank cost	$1,027
Depreciation	$92.40
Interest	33.38
Property tax	12.84
Other	14.00
Total yearly fixed cost	$153.00

4.5.3. Pickup costs

The pickup budgeted in this study is a 3/4 ton 4 wheel drive unit which was chosen because of its better reliability in plowed fields.

And, it is assumed that the retailer handled bulk fertilizer in which case a 4 wheel drive pickup is almost a necessity.

4.5.3.1. Constant variable pickup cost The only constant variable cost per ton, b_o, for pickups is for the trip through the farmer's field. This is calculated at \$.03/ton.

4.5.3.2. Determination of time parameters for pickups The activities associated with the pickup are waiting at the plant, weighing, and waiting in the field for exchange of nurse tanks. Table 4.28 gives the constant time requirement, g_o, of pickups for different rate levels.

Table 4.28. Constant time requirement, g_o, of pickups for different rate levels

		-------Lbs. NH_3/Acre-------		
		160	195	245
Activity	Time	----------Hrs/Ton----------		
Waiting at Plant	5 Min/Ton	.083	.083	.083
Weighing	1 Min/Ton	.017	.017	.017
Waiting in Field	5 Min/Ton	.083	.083	.083
Start Up Time	20 Min/Farm	.052	.039	.031
Constant Time g_o		.235	.222	.214

The constant time per unit of volume, per unit of distance traveled, g_1, is calculated at the rate of two minutes per ton per one way mile or 30 miles per hour.

The effective working hours, H, for pickups are based on 15, 12 hours delivery days. This is increased by 20 percent to 216 hours for the expanded season.

4.5.3.3. Yearly fixed cost for pickups The cost of the pickup is \$4,770. A five year depreciation schedule was used with a

25 percent salvage value. Other costs which are presented in Table 4.29 are interest, license, and insurance.

Table 4.29. Yearly fixed cost for pickups

Pickup cost		\$4,770
Depreciation		\$ 715
Interest		156
License		35
Insurance		130
	\$1036 X 30%	\$ 311 yearly fixed cost allocated to NH_3

As is apparent from the above table, there was an arbitrary allocation of fixed cost to anhydrous. The basis of this arbitrary allocation is the percentage of ammonia sales to combined ammonia and fertilizer sales from Table 4.3.

4.5.3.4. Constant per unit of volume per unit of distance traveled cost, b_1, for pickups

Table 4.30. Component and total b_1 cost for pickups

Gas	2.76¢/gal X 6 MPG	4.25¢/mile
Oil		.2
Maintenance		1.0
Repair		1.0
Total		6.45¢/1 way mile

The cost associated with travel, b_1, and its component costs are given in Table 4.30.

4.5.4. Labor cost

The driver labor cost is assumed to be independent of plant type or size. Further, driver labor is assumed to be variable (i.e. each plant has enough drivers to deliver the complete output of that plant). The time requirements are the same as for the pickups. The cost is based on the $3.19/hourly wage used for the variable labor of the farm supply unit plants. Off season labor is included for the repair work on nurse tanks and applicators. Table 4.31 illustrates the constant per unit of volume cost, b_o, for labor.

Table 4.31. Total constant unit volume labor cost, b_o, and component costs for different rate levels

	Lbs/acre		
	160#'s	195#'s	245#'s
In season	$.76/ton	$.72/ton	$.69/ton
Off season	.20	.15	.11
Total constant unit volume labor cost, b_o	$.96/ton	$.87/ton	$.80/ton

4.5.5. Component delivery costs

At the beginning of the delivery section the stated purpose was to determine the cost coefficients and time parameters for [3.15] and [3.16], Table 4.32 presents the component costs and time parameters.

Table 4.32. Component delivery costs and time parameters

	REGULAR SEASON			EXPANDED SEASON		
	Lbs. NH_3/Acre					
	160	195	245	160	195	245
b_c	\$1/Ton					
Applicator	\$1.81	\$1.67	\$1.50	\$1.81	\$1.63	\$1.49
Nurse tank	1.11	1.11	1.11	1.11	1.11	1.11
Pickup	.03	.03	.03	.03	.03	.03
Labor	.96	.87	.80	.96	.87	.80
Tobal b_o Cost	\$3.91	\$3.68	\$3.44	\$3.91	\$3.64	\$3.43
b_o	\$/1 way Mile					
Labor	.107	.107	.107	.107	.107	.107
Pickup	.064	.064	.064	.064	.064	.064
Total b_1 Cost	\$.171	\$.171	\$.171	\$.171	\$.171	\$.171
Time						
Effective working hours, H						
H App	150	150	150	180	180	180
H Pickup	180	180	180	216	216	217
H Nurse tank	160	162	164	193	194	197
	Hrs/Ton					
g_o App	1.90	1.50	1.35	1.92	1.73	1.53
g_o Nurse tanks	2.64	2.33	1.98	2.67	2.47	2.25
g_o Pickup	.235	.222	.214	.235	.222	.214
g_o	Hrs/1 Way Mile					
g_1 App	.017	.017	.017	.017	.017	.017
g_1 Nurse tansk	.033	.033	.033	.033	.033	.033
g_1 Pickups	.033	.033	.033	.033	.033	.033
Yearly Fixed Cost						
Composite Applicators	\$284	\$350	\$383	\$297	\$356	\$352
Nurse tanks	153	153	153	153	153	153
Pickups	311	311	311	311	311	311

5. PRESENTATION OF COST RESULTS

The purpose of this chapter is to present the findings of this study and evaluate the efficiency of ammonia retailing.

This chapter is organized in the following manner: 1) an overview of how the costs are determined, 2) presentation of short and long run plant costs, 3) examples of how delivery costs are determined, 4) an example of how short run retail distribution costs are determined, 5) presentation of the representative long run retail distribution costs, 6) comparison of current and expanded season's costs, 7) comparison of different market share's costs, 8) comparison of different demand densities' costs, 9) an analysis of the importance of plant size, and 10) a discussion of the efficiencies of retailers.

Three different methods are used to present the cost data. First, cost tables are used to show both short and long run costs. Second, regression is used to present the short and long run plant costs in a concise manner. Finally, graphs are used to depict the cost findings.

5.1. Cost model overview

In Chapter 4 an overview of the cost model was given to provide a framework for discussion of the cost coefficients and time parameters. The purpose of this overview is to provide a similar framework to describe how the cost model was used in determining retail distribution costs.

Equation [3.3] $TPC = FPC + D \cdot APVC$ is the basis for the determination of the plant costs[1]. Plant costs were calculated for the 6 plants. Because plant capacity is changed for the expanded season there are a total of 12 short run plant costs.

Equation [3.13] and [3.16] provide the basis for calculation of delivery costs. The number of delivery units are determined by

$$[3.13] \qquad N \geq \frac{D(g_o + g_1 \bar{A})}{H}$$

Then, the total delivery cost is resolved by

$$[3.16] \qquad TDC = D(b_o + b_1 \ .4714 \ \frac{D^{1/2}}{\bar{P}^{1/2}}) + FN \ .$$

Because each market environment (a particular season, market share, rate level, and corn acreage) is considered to be a unique cost situation it is necessary to calculate delivery costs for each market environment. A total of 36 separate delivery costs were determined (the total combinations of the 2 seasons, 3 market shares, and 2 corn acreages).

The fixed delivery cost corresponding to each plants capacity output (volume) is determined. Then short run retail distribution costs are calculated for each plant. The 36 separate delivery costs, when combined with the six plant costs, result in 216 unique short run retail distribution cost cases. The 216 short run costs, at each plant's capacity, are given in the Appendix. Also included in the Appendix are the plant

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[1]Note: Plant costs, delivery costs, and short run retail distribution costs were calculated with the aid of the computer. All three of these costs were calculated in 100 ton intervals.

costs, delivery costs, and the numbers of pickups, nurse tanks, and applicators for each case.

The short run retail distribution costs, at each plant's capacity of the 4 farm supply plants are used to estimate the long run average retail distribution costs. Changes in the long run retail distribution costs are examined for different seasons, market shares, and demand densities.

5.2. Plant costs

This section will deal with the determination of the individual plant costs, and the use of the individual plant costs in estimating the long run plant costs.

5.2.1. Short run plant costs

Table 5.1 denotes the plant capacities for the regular and expanded seasons for the six plants considered.

Table 5.1. Plant capacities for the regular and expanded season

	Farm Supply Units				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
	tons					
Regular Season	900	1800	2300	3200	900	1800
Expanded Season	1100	2100	2700	3800	1100	2100

It was possible to formulate the cost data from Chapter 4 into a regression equation. Regression is used here as a means of presentation of information rather than as a tool of analysis. Table 5.2 presents the regression results of the 12 short run plant costs (because of the 2 season lengths there were 12 rather than six short run costs).

Table 5.2. Results of short run plant analysis: Equation for total yearly plant cost

Category of Variable	Variable	Notation	Coefficient
Dependent			
	Total Plant Cost	TPC	
Independent			
	Fixed Plant Cost		
	Intercept	B_o	$2020.00
	Dummy for plant size 2	CAP2	1354.00
	Dummy for plant size 3	CAP3	2219.00
	Dummy for plant size 4	CAP4	3563.00
	Dummy for specialized plant	PT	2395.00
	Dummy for expanded season	S	105.00
	Interaction for specialized plant, size 2	PTXCAP2	1619.00
	Interaction for expanded season, plant size 2	SXCAP2	5.00
	Interaction for expanded season, plant size 3	SXCAP3	20.00
	Interaction for expanded season, plant size 4	SXCAP4	218.00
	Interaction for specialized plant, expanded season	PTXS	441.00
	Interaction for specialized plant, expanded season, size 2	PTXSXCAP2	-14.00
	Constant Variable Plant Cost		
	Yearly Tonnage (tons)	Q	4.50
	Interaction for tonnage, size 2	QXCAP2	-0.32
	Interaction for tonnage, size 3	QXCAP3	-0.50
	Interaction for tonnage, size 4	QXCAP4	-0.70
	Interaction for specialized plant, tonnage	PTXQ	-0.83
	Interaction for specialized plant, tonnage size 2	PTXQXCAP2	0.04
	Interaction for expanded season, tonnage	SXQ	-0.35
	Interaction for expanded season, tonnage, size 2	SXQXCAP2	0.04
	Interaction for expanded season, tonnage, size 3	SXQXCAP3	0.07
	Interaction for extended season, tonnage, size 4	SXQXCAP4	0.10
	Interaction for extended season, specialized plant, tonnage	SXPTXQ	0.09
	Interaction for extended season, specialized plant, size 2, tonnage	SXPTXQXCAP2	-0.01

A series of examples will be given to demonstrate the use of the regression equation.

Problem: What is the short run plant cost for 100 tons of output for Plant 1 in the regular season?

$TP_1C_{100\ tons} = B_o + 100Q$

$2020.00 + 100 ($4.50)

$TP_1C_{100\ tons}$ = $2470.00

Problem: What is the short run plant cost for 2700 tons of output for Plant 3 in the expanded season?

$TP_3C_{2700\ tons} = B_o$ + CAP3 + S + SXCAP3 + 2700 (Q +

$2020.00 + $2219.00 + #105.00 + $20.00 + 2700 ($4.50-

QXCAP3 + SXQ + SXQXCAP3)

0.50 -0.35 + 0.07)

$TP_3C_{2700\ tons}$ = $14,408

Problem: What is the short run plant cost for 1425 tons of output for the specialized plant, size 2 in the expanded season?

$TP_{s2}C_{1425\ tons} = B_o$ + CAP2 + PT + S + PTXCAP2 + SXCAP2

$2020.00 + $1354.00 + $2395.00 + $105.00 + $1619.00 + $5.00

PTXS + PTXSXCAP2 + 1425(Q + QXCAP2 + PTXQ + PTXWXCAP2

\+ $441.00 - $14000 1425(4.50 - 0.32 0.83 0.04

SXQ + SXQXCAP2 + SXPTXQ + SXPTXQXCAP2)

\- 0.35 + 0.04 + 0.09 - 0.01)

$TP_{s2}C_{1425\ tons}$ = $12,542

The average plant cost is the total plant cost divided by output.

Figure 5.1 presents the plant costs for the 4 farm supply units for the regular season. As is apparent from the graph, economies of size do

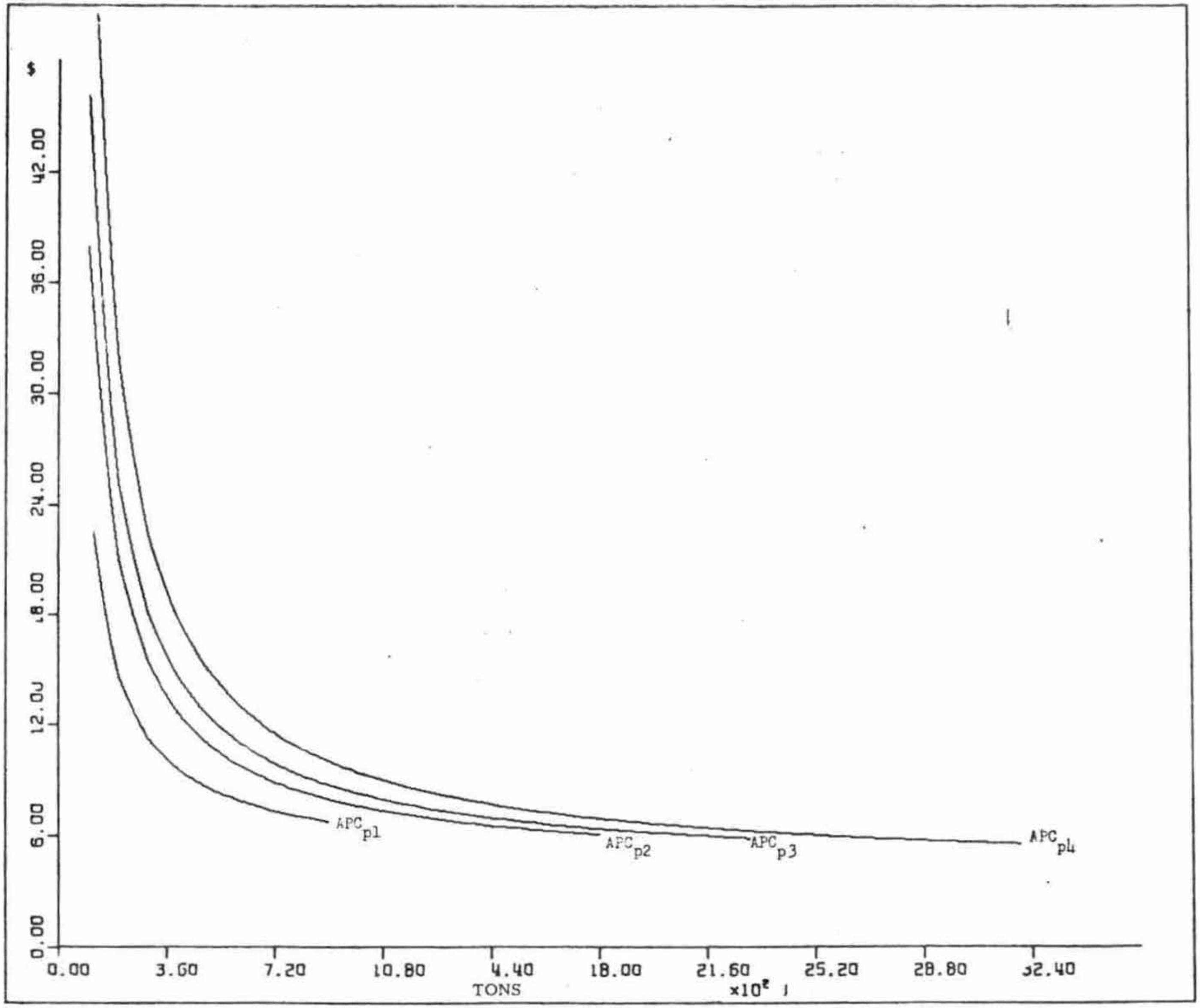

Figure 5.1. Average plant costs for the four farm supply unit plants, regular season

exist for plants. Although not represented graphically the specialized plants have greater costs for all ranges of volume as compared to Plants 1 and 2 of the farm supply units. The difference in plant costs between plant 1 and plant 2 of the farm supply unit firm type and the specialized firms' plant S1 and S2 lies in the higher fixed costs (primary fixed labor cost).

5.2.2. Long run plant costs

The individual plant costs, at their capacities, can be considered point estimates of the long run plant costs. Table 5.2 was used to calculate the capacity costs for each plant for both seasons. The cost information is given in Table 5.3. Also, included in Table 5.3 is the regression estimate of the long run plant costs. The reader is cautioned that the range of interpolation for the specialized plants is 900 to 1800 tons.

Table 5.3. Total plant cost, all plants at capacity, regular and expanded season
Regression equations for long run plant costs

Firm type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
Regular	$6066	$10,890	$13,432	$18,728	$7722	$13,482
Expanded	6688	11,613	14,418	19,380	8712	15,939
Regular LTPC	=	$e^{2.956}Q^{.846}$			$e^{2.798}Q^{.859}$	
Expanded LTPC	=	$e^{3.471}Q^{.842}$			$e^{3.572}Q^{.822}$	

Legend: LTPC = Long run total plant cost, e base of natural log, Q = tonnage.

Figure 5.2 presents graphically the long run plant costs for the farm supply units in the regular season.

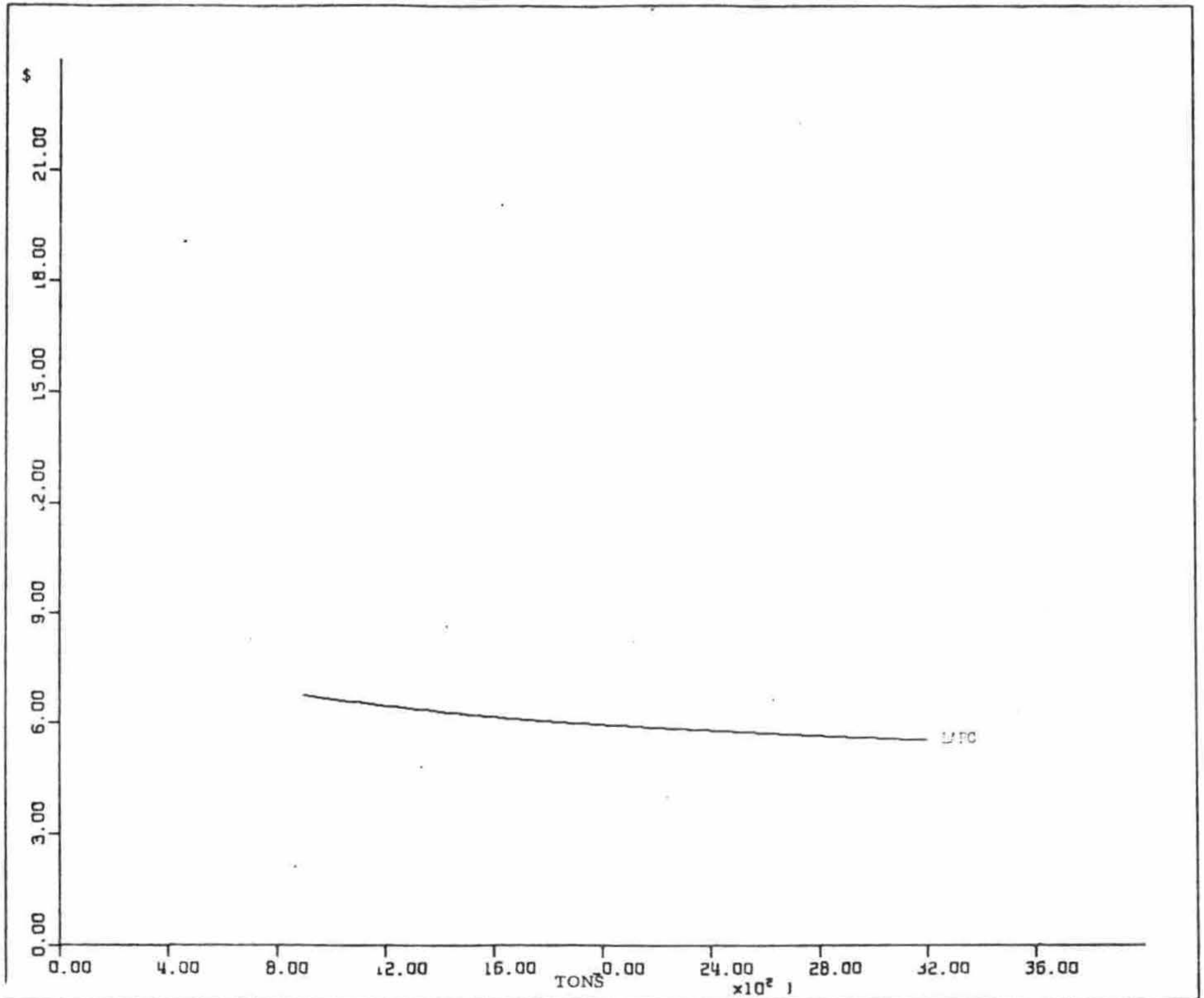

Figure 5.2. Long run average plant costs for the farm supply unit firms, regular season

5.3. Delivery costs

This section will deal with the determination of delivery costs. The method used was to calculate variable and fixed yearly delivery costs for 100 ton intervals with the use of equations [3.11] and [3.13][2]. Two examples will follow to demonstrate how delivery costs were determined. Table 5.4 is a summation of costs and coefficients from Table 4.32 needed for the cost determination.

Table 5.4. Selected cost coefficients and time parameters for delivery costs

Demand Density = 13.84 ton/sq. mile, regular season	b_o	b_1	H	Yearly Fixed Cost	g_o	g_1
Type delivery unit	----cost/ton---		Hours		----hrs/ton-----	
Applicator	$1.81	----	150	$284	1.90	.017
Nurse tank	1.11	----	160	153	2.64	.033
Pickups	.03	0.107	180	311	0.235	.033
Labor	.96	0.064				
	$3.91	$0.171				

To determine the variable delivery cost of 100 tons of ammonia for a 100 percent market share, the appropriate coefficients can be substituted into equation [3.11].

$$\text{Variable delivery costs} = D(b_o = b_1 \ .4714 \ \frac{D^{1/2}}{P^{1/2}});$$

$$VDC_{100\ tons} = 100\ \text{tons}\ (\$3.91/\text{ton} + (\$0.171/\text{ton/mi})(.4714\ \frac{100\ \text{tons}}{13.84\ \text{ton/sq.mile}}^{1/2})$$

$$= \$414.37.$$

[2]An attempt was made to use regression to present delivery costs but it was not possible to specify the cost-volume-distance relationships with the degree of accuracy desired.

To resolve the fixed delivery costs for 100 tons of ammonia, it is first necessary to determine the number of delivery units, N, from equation [3.13],[3] $N = \frac{D(g_o + g_1\bar{A})}{H}$.

Number of:

Applicators; $N \geq \frac{100 \text{ tons } (1.90 \text{ hrs.} + (0.017 \text{ ton/hr/mi})(1.27 \text{ mi})}{150 \text{ hrs}}$,

$N \geq 1.28 = 2$ applicators

Nurse tanks; $N \geq \frac{100 \text{ tons } (2.64 \text{ hrs.} + (0.033 \text{ ton/hr/mi})(1.27 \text{ mi})}{160 \text{ hrs}}$,

$N \geq 1.67 = 2$ nurse tanks

Pickups; $N \geq \frac{100 \text{ tons } (0.235 \text{ hrs.} + (0.033 \text{ ton/hr/mi})(1.27 \text{ mi})}{180 \text{ hrs}}$,

$N \geq 0.13 = 1$ pickup.

The fixed delivery cost, FDC, then, is the sum of the individual units.

$$FDC_{100 \text{ tons}} = FN = 2\ (\$284) + 2\ (\$153) + \$311$$

$$FDC_{100 \text{ tons}} = \$1185.$$

Total delivery cost, TDC, then is the sum of VDC + FDC

$$TDC_{100 \text{ tons}} = \$414.37 + \$1185 = \$1599.37$$

The average delivery cost, ADC, for 100 tons of ammonia is

$$ADC_{100 \text{ tons}} = \frac{TDC_{100 \text{ tons}}}{D} = \frac{\$1599.37}{100 \text{ tons}} = \$15.99/\text{ton}.$$

A slightly different method is used for determining the delivery cost for the declining market share. For this market share condition it is

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[3] $A = .4714 \frac{D^{1/2}}{P^{1/2}}$, average travel distance, and average one way travel distance will be used interchangeably throughout the rest of this chapter.

necessary to resolve the demand for the retailer in each increment mile. Then the ton-miles can be stipulated and thus the average one way travel distance. Table 5.5 gives the determination of ton-miles for the declining market share for 900 tons of ammonia.

Table 5.5. Determination of ton-miles, an example

Demand Density = $\bar{F}$ = 13.84 ton/sq. mile							
Miles from plant	1	2	3	4	5	6	7
Total demand in i^{th} mile*(tons)	27.68	83.04	138.40	193.76	249.12	304.48	359.84
Market share in i^{th} mile (%)	100	93	86	79	72	65	58
Plant's demand in i^{th} mile (tons)	27.68	86.53	119.02	153.07	179.37	197.91	136.42
Ton miles	27.7	173.1	357.1	612.3	896.8	1187.5	954.9

*Total demand = $2\,(i)^2\,\bar{F}$ and demand in i^{th} mile = $2\,(i)^2\,\bar{F} - 2(i-1)^2\,\bar{F}$.

The average travel distance, then, is the ton-miles divided by tons

$$\text{Average one way travel distance}_{900\ \text{tons}} = \frac{4209.4\ \text{ton-miles}}{900\ \text{ton}} = 4.68\ \text{miles}^4.$$

Using equation [3.10] for variable delivery costs

$$VDC = D\ (b_o + b_1\ ATD),$$

the delivery cost for 900 tons of ammonia under conditions of declining market share is:

$$VDC_{900\ \text{tons}} = 900\ \text{tons}\ (\$3.91/\text{ton} + (\$0.171/\text{ton/mi})(4.68\ \text{mi}))$$

$$VDC_{900\ \text{tons}} = \$4239.00$$

The number of delivery units,

$$\text{Applicators;}\ N \geq \frac{900\ \text{ton}\ (1.90\ \text{hrs.} + (0.017\ \text{ton/hr/mile})(4.68\ \text{mi}))}{150\ \text{hrs}}$$

$$N \geq 11.88 = 12$$

[4]In the computer program an iterative process was used which yields a slightly different average travel distance.

$$\text{Nurse tanks; } N \geq \frac{900 \text{ ton } (2.64 \text{ hrs.} + (0.033 \text{ ton/hr/mile})(4.68 \text{ mi}))}{160 \text{ hrs}}$$

$$N \geq 15.72 + 16$$

$$\text{Pickups; } N \geq \frac{900 \text{ tons } (0.235 \text{ hrs} + (0.033 \text{ ton/hr/mile})(4.68 \text{ mi}))}{180 \text{ hrs}}$$

$$N \geq 1.94 = 2$$

$$FDC_{900 \text{ tons}} = 12\ (\$284) + 16\ (\$153) + 2\ (\$311) = \$6478.00$$

Then the total delivery cost for 900 tons of ammonia is

$$TDC_{900 \text{ tons}} = \$4239.00 + \$6478.00 = \$10,717.00$$

and the average delivery cost for 900 tons of ammonia,

$$ADC_{900 \text{ tons}} = \frac{\$10,717}{900 \text{ ton}} = \$11.91/\text{ton}.$$

A few comments need to be made on the use of this method. First, it is necessary to calculate the delivery costs for each market environment combination, this is why the demand density, market share, and season length were specified in Table 5.4. Second, it should be apparent from the examples that the 100 ton intervals are an arbitrary break which results in excess capacity of the delivery units. The alternative is to calculate the individual incremental capacities for the three different types of delivery equipment which becomes rather unmanageable.

Table 5.6 presents the delivery costs for the following market environment: regular season, declining market share, 160 lbs. of ammonia per acre on 173 acres of corn per section or a demand density of 13.84 ton/sq. mile.

Table 5.6 represents an estimate of the long run delivery costs for the specified market environment. The long run delivery costs are defined here to mean the minimum delivery costs for delivering a given volume of ammonia. It should be apparent from Table 5.6 that the average delivery cost is not a smooth curve. This is due to the excess capacity of the delivery units. Similar calculations were made for all 36 different market environments.

Table 5.6. Delivery costs for regular season, declining market share, and demand density of 13.84 ton/sq. mile, in 100 ton intervals

Output	ATD	Number of Pick-ups	Number of N.T.	Number of Apps.	Variable Del. Cost	Yearly Fixed Cost	Total Del. Cost	Average Var. Del. Cost	Average Yearly Fixed Cost	Average Del. Cost
								--------$1 ton	-----------	-----
100	1.37	1	2	2	$414.37	$1185	$1599.37	$4.14	$11.85	$15.99
200	1.95	1	4	3	848.66	1775	2623.66	4.24	8.88	13.21
300	2.40	1	6	4	1296.07	2365	3661.09	4.32	7.88	12.20
400	2.80	1	7	6	1755.53	3086	4841.53	4.39	7.71	12.10
500	3.15	1	9	7	2224.51	3676	5900.51	4.45	7.35	11.80
600	3.48	2	11	8	2703.07	4577	7280.07	4.56	7.63	12.13
700	3.79	2	13	10	3190.57	5451	8641.57	4.61	7.79	12.35
800	4.08	2	15	11	3686.50	6041	9727.50	4.66	7.55	12.16
900*	4.36	2	16	12	4190.77	6478	10,668.77	4.70	7.20	11.85
1000	4.64	3	18	14	4703.41	7663	12,366.41	4.75	7.66	12.37
1100	4.91	3	20	15	5223.70	8253	13,476.70	4.79	7.50	12.25

5.4. Short run retail distribution costs - an example

Thus far plant costs and delivery costs have been treated separately. It is the purpose of this section to show how they are combined into short run retail distribution costs. With the aid of the regression equation, Table 5.2, it is possible to determine short run plant costs for a given plant. Short run total and average plant costs for plant 1 of the farm supply unit firm type are given in Table 5.7.

The market environment that is defined for this example is the one previously specified for determining the delivery cost of the declining market share. The fixed delivery cost chosen from Table 5.6 is the equipment necessary to delivery the plant's total volume of 900 tons. The reason for choosing this particular equipment combination is that when combined with variable delivery costs, and plant cost, it yields the lowest retail distribution cost for that plant.

Table 5.7. Plant cost for plant 1, farm supply unit type, regular season

Output (Tons)	Plant Fixed Cost	Plant Variable Cost	Total Plant Cost	Average Plant Fixed Cost	Average Plant Variable Cost	Average Total Plant Cost
				--------------$1/Ton--------------		
100	$2020	$450	$2470	$20.20	$4.50	$24.70
200	2020	900	2920	10.10	4.50	14.60
300	2020	1350	3370	6.73	4.50	11.23
400	2020	1800	3820	5.05	4.50	9.55
500	2020	2250	4270	4.04	4.50	8.54
600	2020	2700	4720	3.36	4.50	7.86
700	2020	3150	5170	2.88	4.50	7.38
800	2020	3600	5620	2.52	4.50	7.02
900	2020	4050	6070	2.24	4.50	6.74

Equations [3.18] and [3.19] are used to combine the short run plant costs and short run delivery costs to determine short run retail distribution costs. The total and average short run retail distribution costs and the component costs are given in Table 5.8. These same costs are depicted graphically in Figure 5.3. Apparent from the graph and the table, delivery costs make up a large proportion of the retail distribution costs.

Table 5.8. **Short run retail distribution cost and component costs, regular season**

The firm has 2 pickups, 16 nurse tanks, and 12 applicators								
Output (Tons)	RDC	TPC	TDC	VPC	VDC	FPC	FDC	ATD (mi's)
100	$9362.37	$2,470	$6892.37	$445	$414.37	$2020	$6478	1.37
200	10,246.66	2,920	7326.66	900	848.66	2020	6478	1.95
300	11,144.09	3,370	7774.09	1350	1296.09	2020	6478	2.40
400	12,053 51	3,820	8233.51	1800	1755.51	2020	6478	2.80
500	12,972.51	4,270	8702.51	2250	2224.51	2020	6478	3.15
600	13,901.07	4,720	9181.07	2700	2703.07	2020	6478	3.48
700	14,838.57	5,170	9666.57	3150	3190.57	2020	6478	3.79
800	15,784.50	5,620	10,164.50	3600	3686.50	2020	6478	4.08
900	16,738.77	6,070	10,668.77	4050	4190.77	2020	6478	4.36
	ARDC	APC	ADC	AVPC	AVDC	AFPC	AFDC	
	-----	-----	-----	-----	cost/ton	-----	-----	
100	$93.62	$24.70	$68.92	$4.50	$4.14	$20.20	$64.78	
200	51.23	14.60	36.63	4.50	4.24	10.10	32.39	
300	37.15	11.23	25.08	4.50	4.32	6.73	21.59	
400	30.13	9.55	20.58	4.50	4.38	5.04	16.19	
500	25.94	8.54	17.40	4.50	4.45	4.03	12.96	
600	23.17	7.86	15.30	4.50	4.50	3.36	10.80	
700	21.20	7.38	13.81	4.50	4.56	2.88	9.25	
800	19.73	7.02	12.71	4.50	4.61	2.52	8.10	
900	18.60	6.74	11.85	4.50	4.66	2.24	7.20	

Legend: RDC-Retail distribution cost, TPC-Total plant cost, TDC-Total delivery cost, VPC-Variable plant cost, VDC-Variable delivery cost, FPC-Fixed plant cost, FDC-Fixed delivery cost, ATD-Average one way travel distance, ARDC-Average retail distribution cost, APC-Average plant cost, ADC-Average delivery cost, AVPC-Average variable plant cost, AVDC-Average variable delivery cost, AFPC-Average fixed plant cost, AFDC-Average fixed delivery cost

This has been one example of short run retail distribution costs. There were 216 similar such determinations made. The Appendix presents the costs of the 216 cases at each plants' capacity.

5.5. Long run retail distribution cost

To make comments on the importance of plant size and to make generalizations about season length, market share, and demand density it is necessary to develop long run costs. The 4 farm supply plant's short run retail distribution costs, at capacity, will be used as estimates of the long run costs.

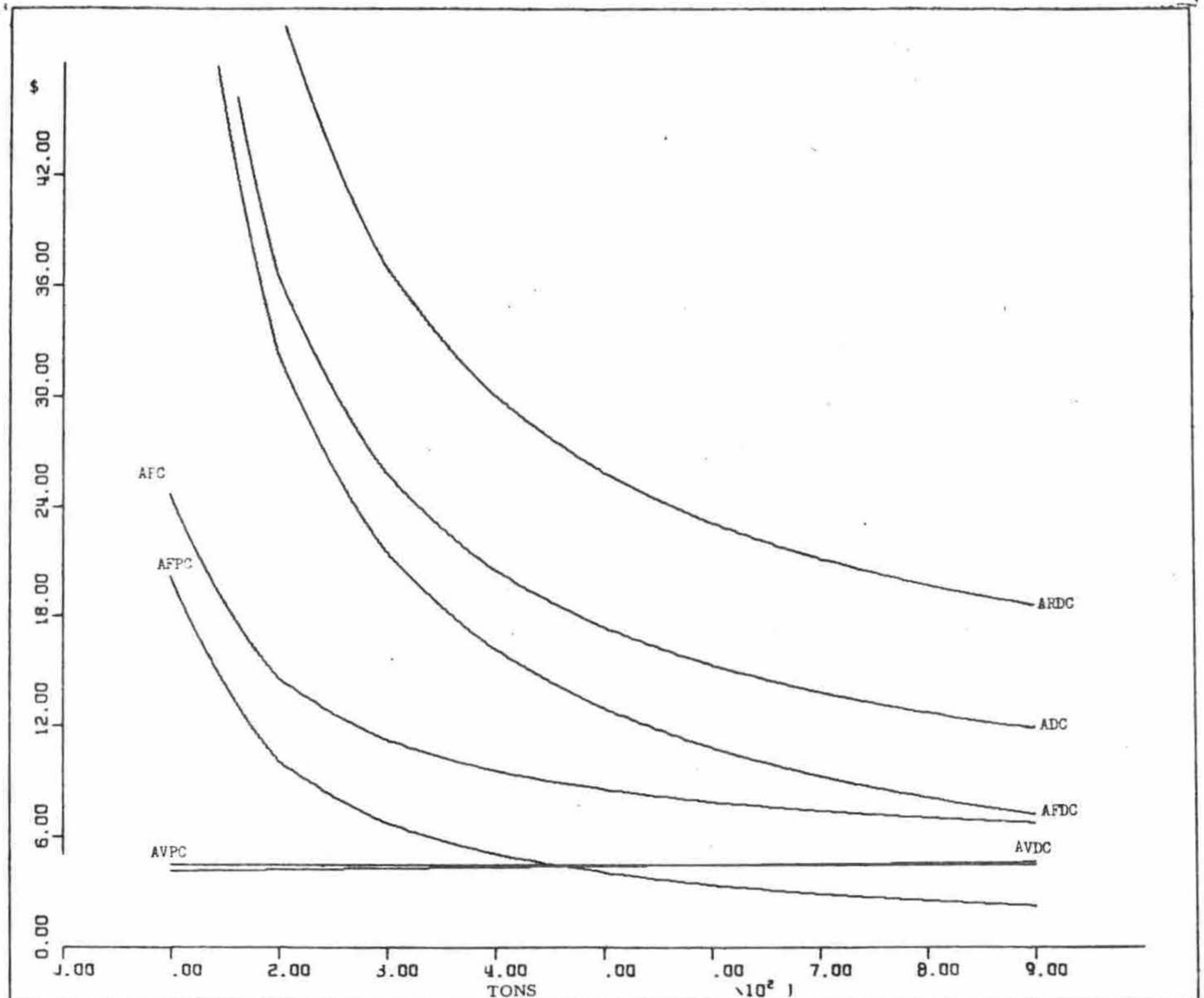

Figure 5.3. Short run average retail distribution costs and component costs for plant 1 of farm supply unit type firms

5.5.1. The representative market environment

Space does not allow for the presentation of all 36 market environments' long run distribution costs. Discussion will focus on the current market environment and changes in cost due to changes in season length, market share, and demand density.

The market environment that will be considered representative of the current market situation is: the regular season, a declining market share, 160 lbs. of ammonia per acre on 173 acres of corn per section or a demand density of 13.84 tons/sq. mile.

Table 5.9 presents the average retail distribution costs for the plants under the representative market environment. Included are the component plant and delivery costs, the number of each type of delivery units, and the average one way travel distance for each plant. The delivery costs are those necessary to deliver the volume of anhydrous at each plant's capacity. Figure 5.4 depicts these costs graphically.

Table 5.9. Average retail distribution costs for the current market environment in the Fort Dodge area

Dec. Mar. Share, Regular Season, 160# NH_3/acre, 173 acres per section, Demand Density = 13.84 ton/section.

Firm Type	Farm Supply Units				Specialized	
	*Plant 1	Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
ARDC	$18.60	$18.73	$19.00	$20.96	$20.43	$20.17
APC	6.74	6.05	5.84	5.54	8.58	7.49
ADC	11.85	12.67	13.16	15.41	11.85	12.67
Number of						
Pickups	2	5	7	14	2	5
Nurse Tanks	16	33	43	65	16	33
Applicators	12	25	32	47	12	24
ATD (mi)	4.36	6.72	8.72	16.74	4.36	6.72

Legend: ARDC = Average retail distribution cost; APC = Average plant cost; ADC = Average delivery cost; ATD = Average one way travel distance; *Least cost plant.

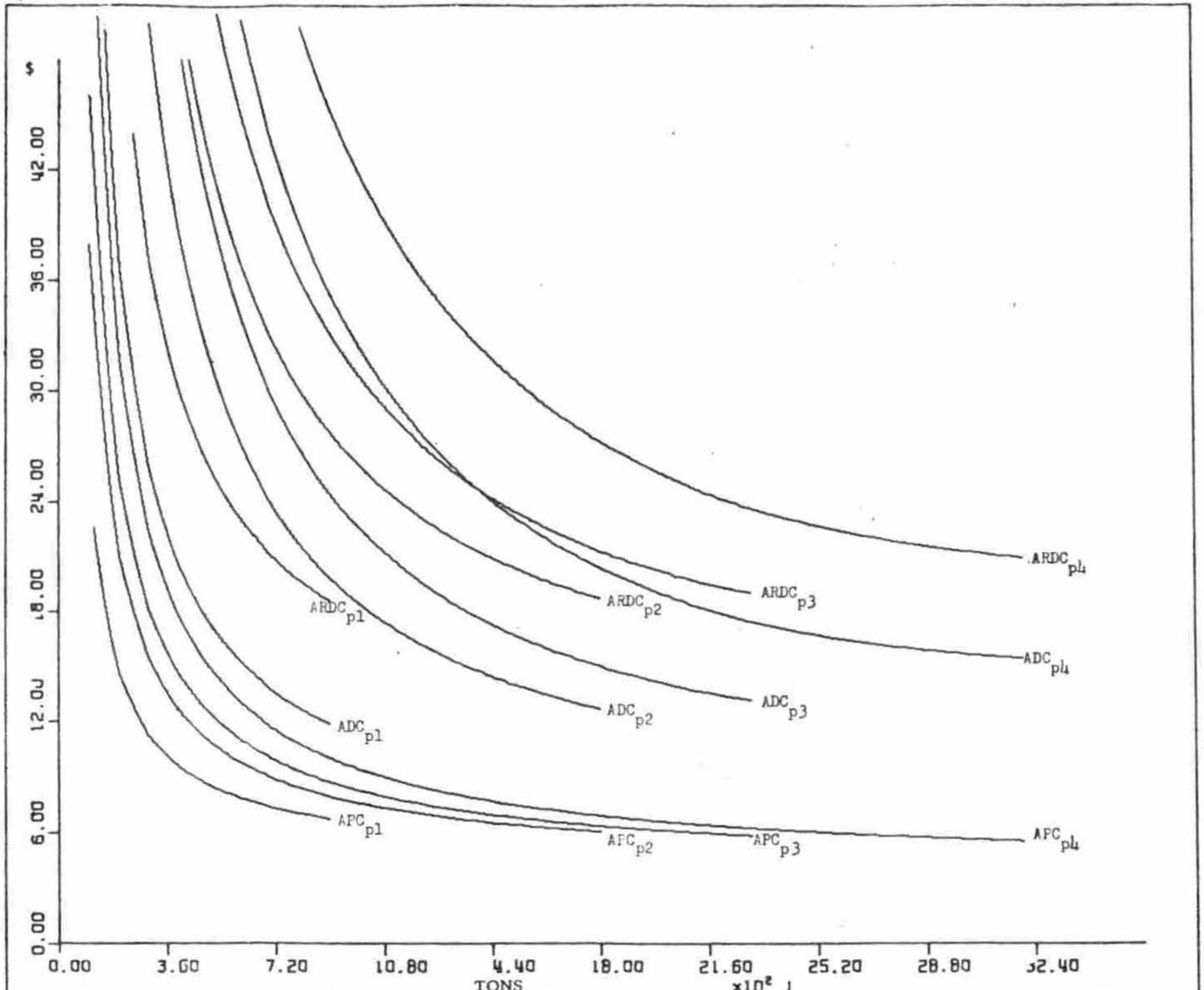

Figure 5.4. Average retail distribution costs for the four farm supply unit plants under the current market environment

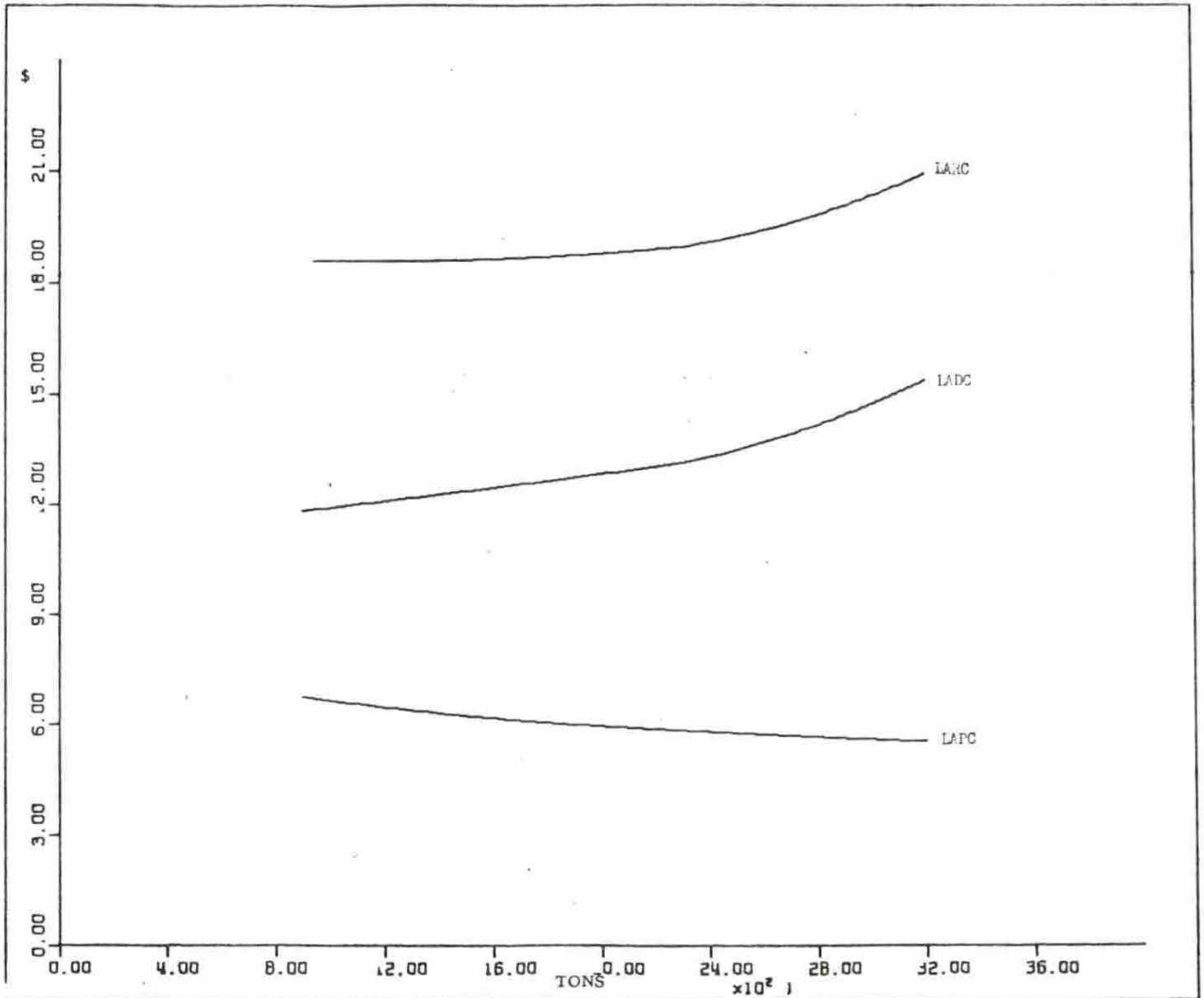

Figure 5.5. Estimated long run average retail distribution costs for the farm supply unit firms under the current market environment conditions

From the table it is apparent that the plant delivery unit combination that yields the lowest average retail distribution cost for the farm supply units is Plant 1 while the specialized plant S2 is the lower cost plant for the specialized firms. In all cases considered in this study, plant S2 was the lowest cost of the specialized plants. As would be expected average delivery costs increase as plant size increases. The increase in pickup numbers between Plant 1 (2) and Plant 4 (14) represents the most dramatic change in equipment units and can be explained by the much greater travel distance necessary to obtain the needed volume for Plant 4.

The individual retail distribution costs and the component costs for each plant at capacity can be assumed to be observations along the long run retail distribution cost curve. Figure 5.5 represents the estimated long run average retail distribution costs for the farm supply unit firms under the current market environment. As is apparent from the graph there are slight diseconomies for this market environment. It is against this cost estimate that cost comparisons for changes in season length, market share, and demand density will be made.

5.5.2. Change in season length

It was proposed in Chapter 2 that possible cost savings could be realized if there were more time available to distribute the ammonia. This section will examine how retailing costs will change with additional distribution time.

In Table 5.10 the costs for a market environment are given which has a 20 percent increase in distribution time (application and delivery time). This market environment differs from the representative market environment only in the time available for distribution. The optimum plant-delivery combination has shifted from plant 1 to plant 2 for the farm supply units. There has been a reduction of $1.18 per ton in average retail distribution cost between the optimal plants for the two different market environments. (In other words, the minimum average retail distribution costs has been reduced $1.18 per ton while there has been an increase of 1400 tons of ammonia distributed.)

This cost savings is realized for all plants and for increased tonnages. An increase in season length then would result in cost savings to retailers and also in increased plant capacities.

Table 5.10. Average retail distribution costs for plants with an expanded season

Expanded Season						
Firm Type	Farm Supply Unit				Specialized	
	Plant 1	*Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
ARDC	$17.55	$17.42	$18.34	$20.93	$19.39	$18.78
APC	6.08	5.53	5.34	5.10	7.92	6.89
ADC	11.47	11.89	13.01	15.82	11.47	11.89
Number of						
Pickups	3	5	8	18	3	5
Nurse Tanks	17	33	44	69	17	33
Applicators	13	25	33	49	13	25
ATD (mi)	4.91	7.59	12.02	22.42	4.91	7.59

Legend: ARDC = Average retail distribution cost; APC = Average plant cost; ADC = Average delivery cost; ATD = Average one way travel distance; *Least cost plant.

The amount of delivery equipment has increased for all plants but this should be viewed with the reminder that there has been an increase in the annual tonnage for each plant. In other words, if, for plant 1,

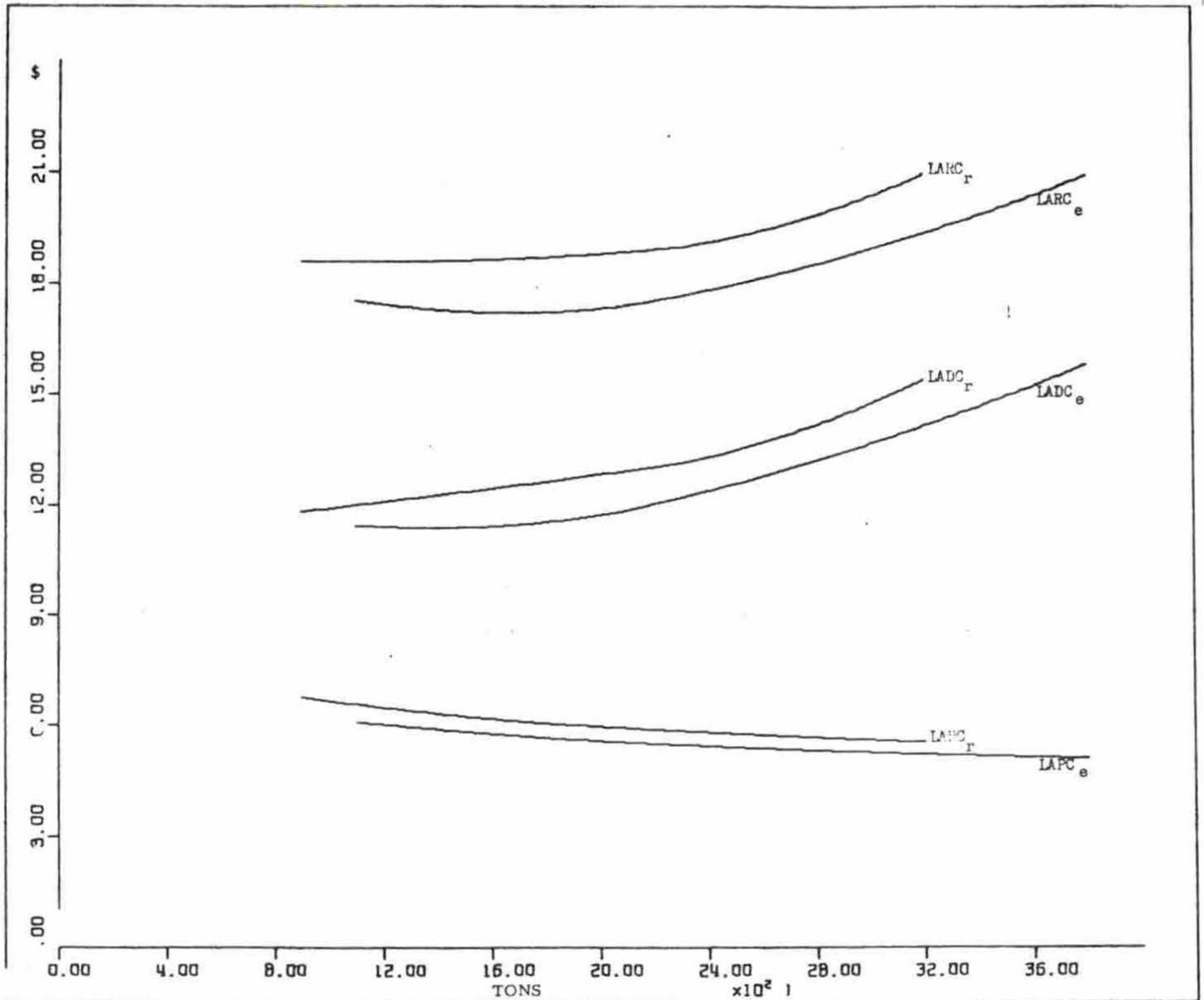

Figure 5.6. Comparative long run average retail distribution costs for the regular and expanded season

plant capacity had remained at 900 tons per season the number of delivery units needed would have been reduced to 14 nurse tanks, 10 applicators, and the number of pickups needed would have remained at 2 for the expanded season. Average delivery costs would have been $11.02/ton or a reduction of $.83/ton. Again the greatest change in delivery units is in pickups, plant 1 (3) to plant 4 (18).

Figure 5.6 depicts the long run average cost curves for the regular and expanded seasons. It should be noted that there is a general shift downward for all costs in the expanded season.

5.5.3. Changes in market share

Another objective of this study was to examine the effect of different estimate of the market share assumptions on retailing costs. This section will deal with these considerations.

Table 5.11 gives the average retail distribution costs for the market environment described in section 5.4.1 with the exception that the market share assumption has been changed. If the retailer could obtain all of the demand in his trade area it is apparent that costs would be reduced. What is even more significant is that the optimum plant-delivery unit combination has shifted from plant 1 with a 900 ton capacity for declining market share to the 3200 ton plant for the 100 percent market share. Or, average retail distribution costs have been reduced $.41/ton with a 2300 ton increase in volume. As plant costs are the same for both market environments all of the difference can be explained in terms of average travel distance. For the most extreme comparison, a retailer owning plant 4 facing a declining market share environment would have an average travel distance of 16.74 miles. While this same retailer when having a 100 percent market share would have an average travel distance of 7.17 miles, or a difference of 9.57 miles. This would indicate that retailing costs are increased by competitive market factors.

Table 5.11. Average retail distribution costs for plants, different market shares

100% Market Share						
Firm Type	Farm Supply Units				Specialized	
	Plant 1	Plant 2	Plant 3	*Plant 4	Plant 1	Plant 2
ARDC	$18.50	$18.34	$18.23	$18.19	$20.33	$19.78
APC	6.74	6.05	5.84	5.54	8.58	7.49
ADC	11.76	12.28	12.38	12.65	11.76	12.28
Number of						
Pickups	2	5	6	9	2	5
Nurse Tanks	16	33	42	59	16	33
Applicators	12	24	31	43	12	24
ATD (mi)	3.80	5.38	6.08	7.17	3.80	5.38
33% Market Share						
	Plant 1	*Plant 2	Plant 3	Plant 4	Plant 1	Plant 2
ARDC	$19.81	$19.43	$19.51	$19.70	$21.64	$20.87
APC	6.74	6.05	5.84	5.54	8.58	7.49
ADC	13.06	13.37	13.67	14.16	13.06	13.37
Number of						
Pickups	3	6	8	12	3	6
Nurse Tanks	17	34	44	62	17	34
Applicators	13	25	32	45	13	25
ATD (mi)	6.58	9.31	10.53	12.42	6.58	9.31

Legend: ARDC = Average retail distribution cost; APC = Average plant cost; ADC = Average delivery cost; ATD = Average one way travel distance; *Least cost plant.

The market environment including the constant market share of 33 percent has generally higher costs for the small plants as compared to the declining market share. The optimum plant-delivery unit combination shifts from plant 1 to plant 2. There is an increase of $.83 per ton in the minimum average retail distribution cost for the constant 33 percent market share. Again this difference in costs can be explained in terms of differences in average travel distance.

The trade area was specified for the representative market environment and the constant market share environment in such a manner that in a 15 mile radius of the plant, the total demand obtainable by the plants (2074 tons) was the same. In this case, it can be concluded that the constant market share assumption results in higher delivery costs for plants with smaller volumes.

Figure 5.7 depicts the comparative long run average retail distribution costs for 100 percent market share, $LARC_1$, declining market share $LARC_{dms}$, and constant market share of 33 percent, $LARC_{.33}$. The most striking comparison is between $LARC_1$, and $LARC_{dms}$ where the cost curve changes from continuous diseconomies to continuous economies over the volume range considered.

The influence of market share has a similar effect on the retail distribution costs of the specialized plants. The difference again can be explained by the change in average travel distance. The 33 percent market share assumption results in a cost difference of $.77/ton between plants S1 and S2 while the declining market share would result in a $.26/ton difference.

5.5.4. Changes in demand density

As discussed in Chapter 4 demand density is comprised of the pounds of ammonia used per acre (rate level) and the number of acres using

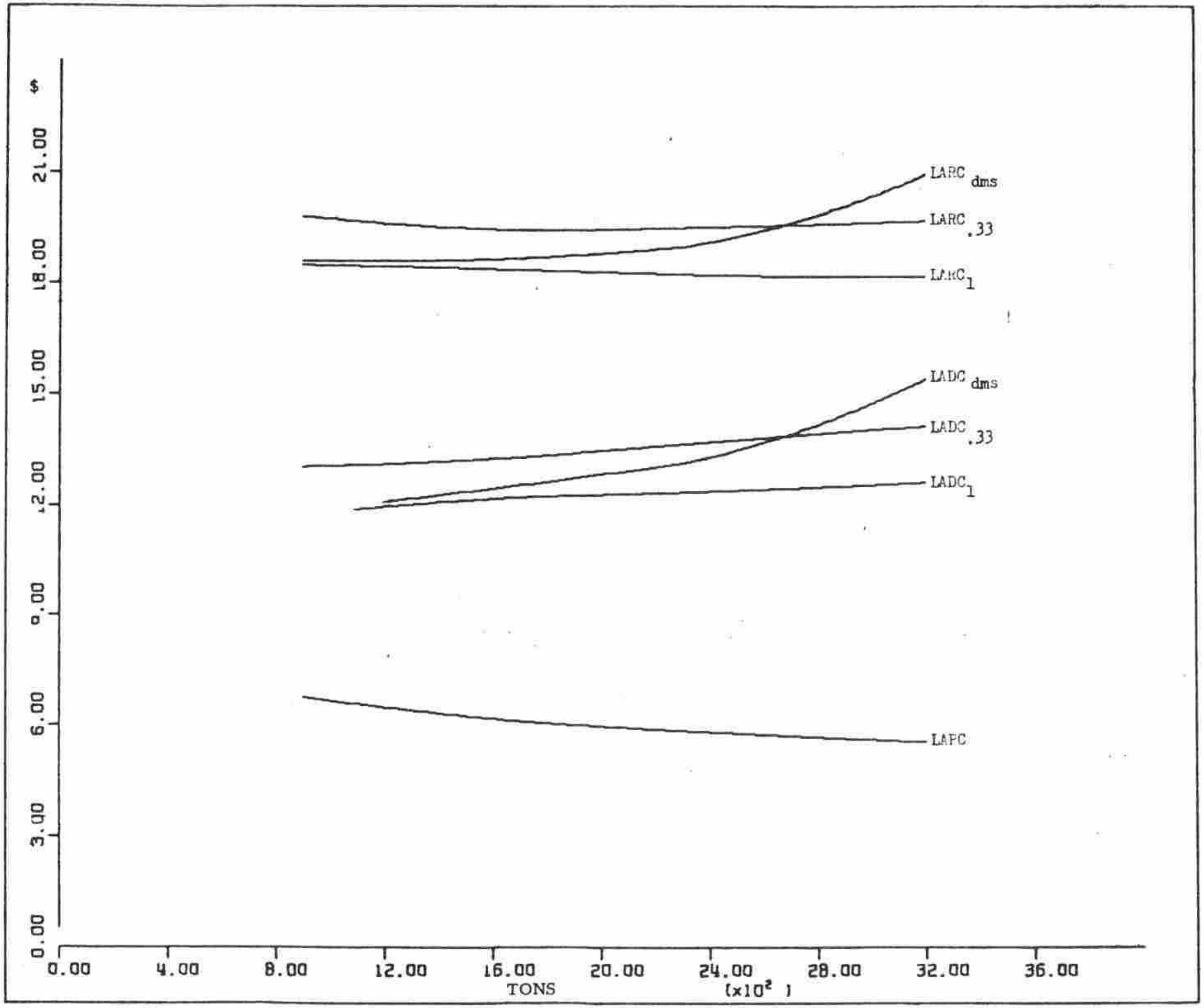

Figure 5.7. Comparative long run average retail distribution costs for different market shares

ammonia per square mile. This section will deal with changes in these two factors.

5.5.4.1. <u>Change in rate used per acre</u> The question to be examined here is: What can the retailer expect to be the effect on costs as per acre usage increases? Table 5.12 presents the retail distribution costs for plants under the current market environment except for rate levels.

Table 5.12. Average retail distribution costs for plants, different rate levels

195# NH_3/acre, 193 acres/section, Demand Density = 18.45 ton/section						
Firm Type	Farm Supply Unit				Specialized	
	Plant 1	Plant 2	*Plant 3	Plant 4	Plant 1	Plant 2
ARDC	$17.74	$17.26	$17.19	$17.78	$19.57	$18.70
APC	6.74	6.05	5.84	5.54	8.58	7.49
ADC	10.99	11.21	11.35	12.23	10.99	11.21
Number of						
Pickups	2	5	6	10	2	5
Nurse Tanks	13	25	33	47	13	25
Applicators	10	19	24	35	10	19
ATD (mi)	3.71	5.56	6.52	9.46	3.71	5.56
245# NH_3/acre, 204 acres/section, Demand Density = 23.06 ton/section						
	Plant 1	Plant 2	Plant 3	*Plant 4	Plant 1	Plant 2
ARDC	$17.05	$16.42	$16.50	$16.39	$18.88	$17.86
APC	6.74	6.05	5.84	5.54	8.58	7.49
ADC	10.30	10.36	10.66	10.84	10.30	10.36
Number of						
Pickups	2	4	6	8	2	4
Nurse Tanks	11	22	28	40	11	22
Applicators	9	17	22	30	9	17
ATD (mi)	3.29	4.85	5.64	7.04	3.29	4.85

Legend: ARDC = Average retail distribution cost; APC = Average plant cost; ADC = Average delivery cost; ATD = Average one way travel distance; *Least cost plant.

As demand density increases from 13.84 ton/sq. mile to 18.45 ton/square mile (rate level increases from 160 lb/acre to 195 lb/acre) the optimum plant-delivery unit combination shifts from plant 1 to plant 3. This is a decrease of \$1.41/per ton associated with an increase in tonnage of 1400 tons.

As demand density increases from 13.84 ton/sq. mile to 23.06 ton/sq. mile (rate level increases from 160 lb/acre to 245 lb/acre) the optimum plant-delivery unit combination shifts from plant 1 to plant 4. This is a decrease of \$2.21 per ton associated with an increase in tonnage of 2300 tons.

Again the change in delivery cost can be explained by the change in average travel distance. It is interesting to note that the 23.06 ton/sq. mile demand density results in 6 fewer pickups, 25 fewer nurse tanks, and 17 fewer applicators than the representative market environment.

The difference in long run distribution costs due to differences in rate are depicted in Figure 5.8. $LARC_{160}$ represents the current demand density, $LARC_{195}$ represents demand density for 18.45 ton/sq. mile, and $LARC_{245}$ demand density for 23.06 ton/sq. mile. The cost curve changes from continuous diseconomies to continuous economies over the volume range considered from the lowest to highest demand densities.

5.5.4.2. <u>Change in acres per sq.mile</u> The final factor to be examined is a change in the number of corn acres grown per section. Table 5.13 presents the average retail distribution costs for plants under the current market environment except for the number of acres. As demand density increases from 13.84 ton/sq. mile to 16.67 ton/sq. mile the optimum plant-delivery unit combination shifts from plant 1 to plant 3.

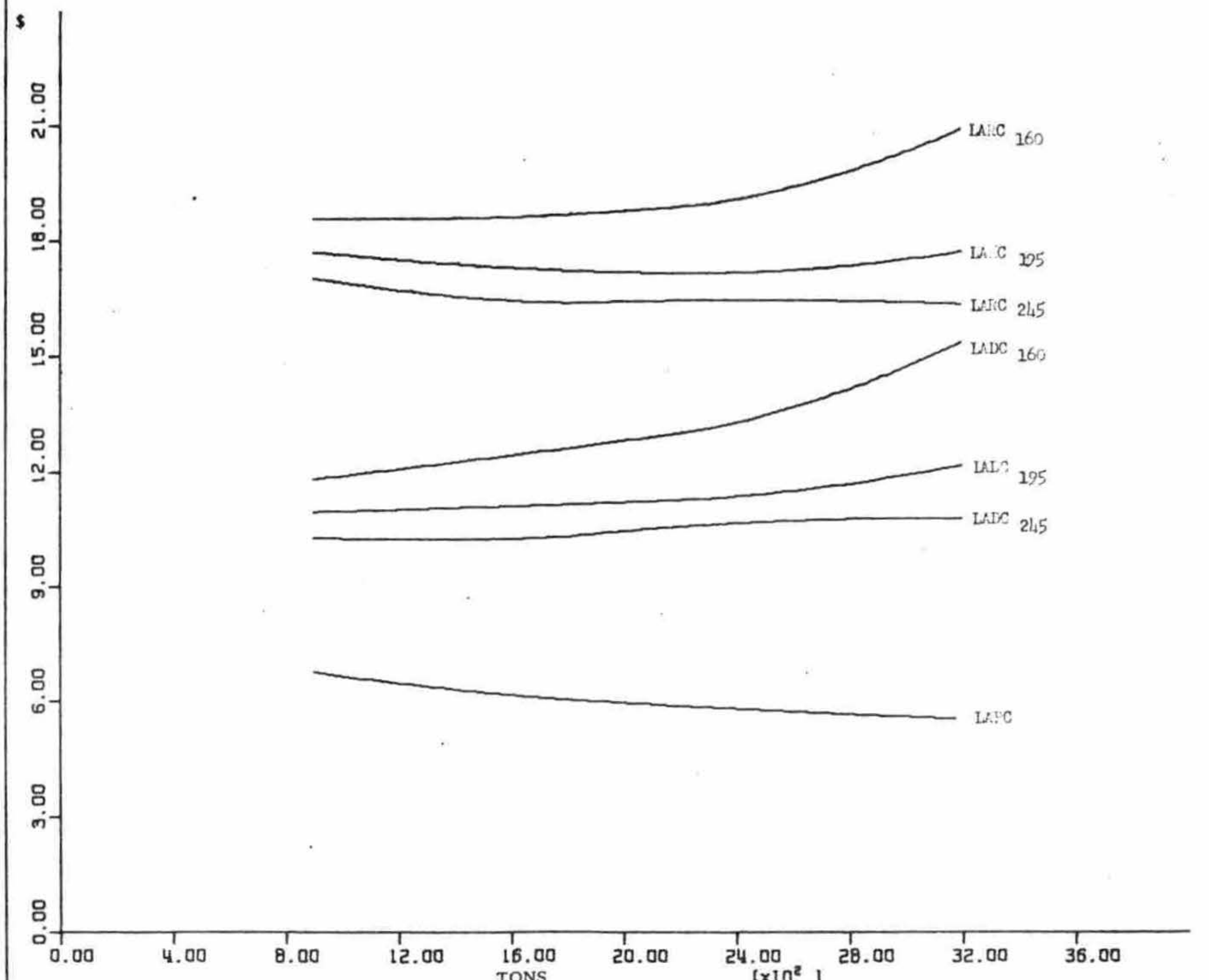

Figure 5.8. Comparative long run average retail distribution costs for different per acre rate levels of ammonia

This is a decrease of \$.21/ton associated with an increase in tonnage of 1400 tons. This change can again be explained by the reduction in average travel distance. Again there is a rather large increase in pickup numbers between plant 1 (2) and plant 4 (11).

Table 5.13. Average retail distribution costs for plants, different acreage levels

209 acres per section, Demand Density = 16.67 ton/section						
Firm Type	Farm Supply Units				Specialized	
	Plant 1	Plant 2	*Plant 3	Plant 4	Plant 1	Plant 2
ARDC	\$18.53	\$18.43	\$18.39	\$19.47	\$20.36	\$19.87
APC	6.74	6.05	5.84	5.54	8.58	7.49
ADC	11.78	12.38	12.54	13.92	11.78	12.38
Number of						
Pickups	2	5	6	11	2	5
Nurse Tanks	16	33	42	62	16	33
Applicators	12	24	31	45	12	24
ATD (mi)	3.93	5.92	7.01	11.62	3.93	5.92

Legend: ARDC = Average retail distribution cost; APC = Average plant cost; ADC = Average delivery cost; ATD = Average one way travel distance; *Least cost plant.

Figure 5.9 presents the long run average distribution cost comparisons between the increased acreage level, $LARC_{2a}$, and the current acreage level, $LARC_{1a}$.

Changes in demand density has the same characteristic effect on the specialized plants as it does on the farm supply unit plants. As demand density increases the average retail distribution cost is reduced as is average travel distance.

As was discussed in Chapter 3, the influence due to changes in season length, market share, and demand densities can be predicted on an <u>a priori</u> basis. The importance of the foregoing examination of these factors was to determine the relative importance of each individual

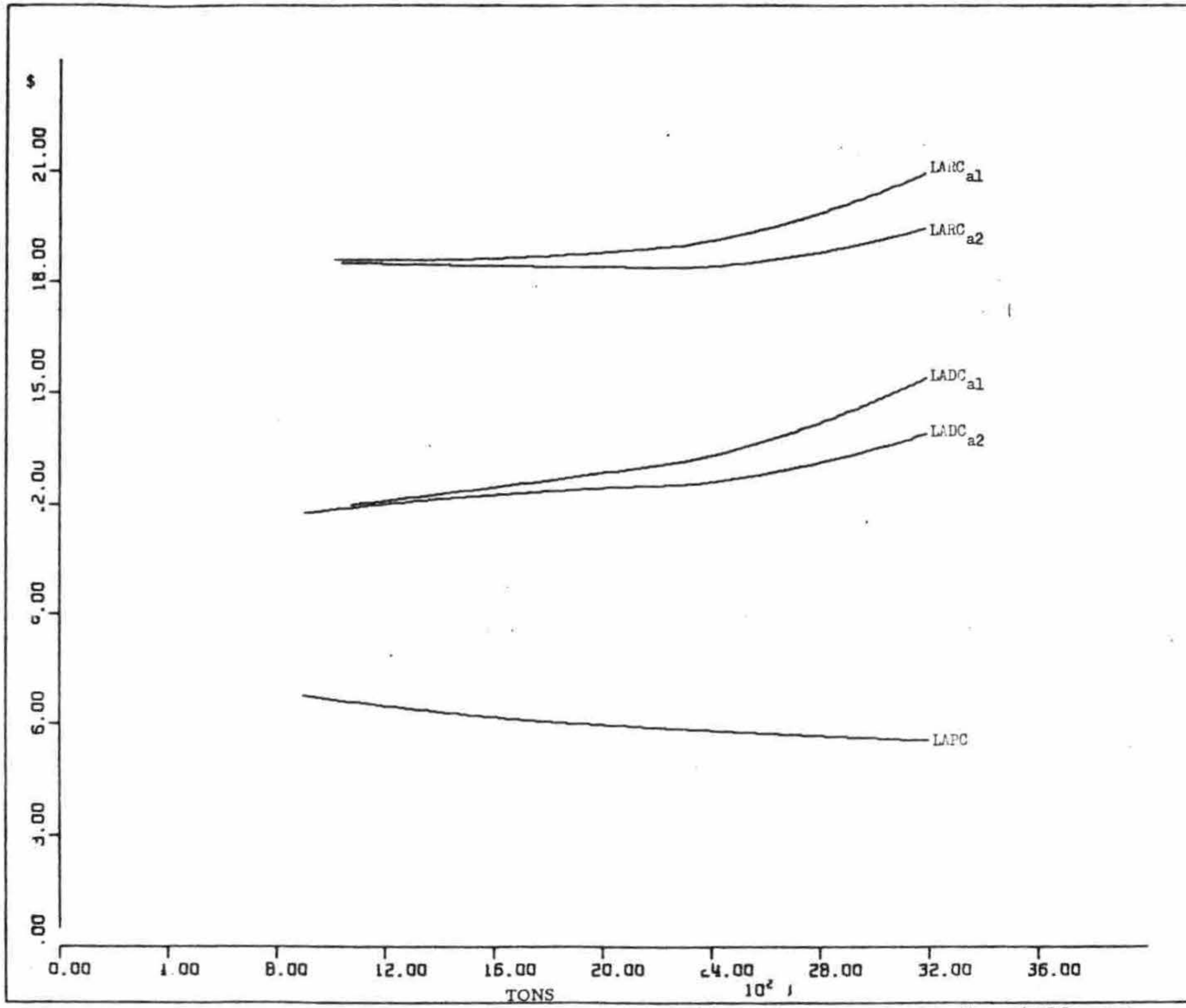

Figure 5.9. Comparative long run average retail distribution costs for different acreage levels

factor with the other factors held constant. The next section will be a summary of the 36 market environment optimal solutions.

5.5.5. Summary of cost model results - farm supply units

Table 5.14 gives the optimum plant size and the minimum average retail distribution costs for the 36 market environments considered for the farm supply units. The mean cost for all of the optimum solutions is \$16.85/ton and the mean plant size is 2.65 (the mean plant size here is used as an index of plant size and the problem of having a fraction of a plant is ignored).

Table 5.14. Optimum plant size-delivery equipment combinations for the 36 market environments considered and associated average retail distribution costs

		Demand Densities (Tons/sq. mi.)					
Market Share	Season	13.84	16.67	18.45	22.23	23.06	27.79
100 percent	Regular	4 \$18.19	2 \$18.00	4 \$16.72	4 \$16.63	3 \$16.04	4 \$15.90
	Expanded	3 16.85	4 15.80	4 15.07	2 16.66	3 15.66	4 14.90
Declining	Regular	1 18.62	3 18.39	3 17.17	2 16.99	2 16.39	3 16.10
	Expanded	2 17.42	2 17.10	2 16.16	2 or 3 15.89	4 15.41	2 15.15
33 percent	Regular	2 19.43	2 19.29	3 17.99	2 17.65	2 17.08	3 16.87
	Expanded	1 17.96	2 17.83	2 16.82	2 16.69	2 16.06	3 15.79

Note: The top number indicates optimum plant size and the bottom number the average retail distribution cost for the plant-delivery equipment for each market environment.

The information in Table 5.14 was cross tabulated to obtain the mean plant sizes and the average retail distribution costs, ARDC, for different seasons, market shares, rate levels, and corn acreages. This information is presented in Table 5.15.

Table 5.15. Cross tabulation of average retail distribution cost and plant size for the 36 market environments, for farm supply unit type firms

FACTOR	SEASON		MARKET SHARE			RATE LBS. NH_3/ACRES			ACRES	
	Reg.	Exp.	33%	D.M.S.	100%	160	195	245	227	275
ARDC	$17.41	$16.29	$17.45	$16.73	$15.12	$17.41	$16.92	$16.22	$17.48	$16.21
Plant size	2.72	2.58	2.17	2.37	3.42	2.29	2.58	3.08	2.55	2.75
ATD Mi	6.76	6.82	8.30	5.89	5.86	7.20	6.58	6.16	6.98	6.32

Legend: ARDC - Average retail distribution cost, ATD - Average one way travel distance.

Some generalizations can be made about the influence of the factors. As the time allowed for ammonia delivery is increased, the average retail distribution cost is reduced as is optimum plant size. The reduction in plant size is not unreasonable as the capacity of each plant is increased for the expanded season. As the market share that a retailer obtains increases, average retail distribution cost is reduced and optimum plant size is increased. Both changes can be explained by the reduction in average travel distance. As the per acre usage of ammonia increases, the average retail distribution cost decreases and the optimum plant size increases. As the number of acres devoted to corn increases, the average retail distribution cost is reduced and optimum plant size increases. Both demand density factors, rate level and acreage can be explained by the reduction in average travel distance.

5.5.6. Summary of cost model results - specialized plants

To this point the discussion of average retail distribution costs has centered on the farm supply unit type firms. The primary reason is that only two specialized plants were budgeted and it is difficult to make generalizations about the long run distribution costs with only two point estimates. Table 5.16 presents the cost information for the 36 market environments.

Table 5.16. Average retail distribution costs for the 2 specialized plants for the 36 market environments.

Market Share	Season	Plant	Demand Densities (Tons/sq. mi.) 13.84	16.67	18.45	22.28	23.06	27.79
100 Percent	Regular	1	$20.35	$20.29	$19.13	$18.91	$18.41	$18.38
		2	19.78	19.44	18.38	18.30	17.74	17.63
	Expanded	1	18.99	18.92	17.93	17.87	17.50	17.31
		2	18.26	18.03	17.18	17.11	16.47	16.40
Declining	Regular	1	20.44	20.36	19.58	19.15	18.89	18.42
		2	20.17	19.87	18.70	18.43	17.86	17.77
	Expanded	1	19.39	19.02	18.01	17.94	17.57	17.51
		2	18.78	18.46	17.52	17.25	16.78	16.51
33 Percent	Regular	1	21.65	21.24	20.27	19.84	19.20	19.31
		2	20.87	20.73	19.22	19.09	18.52	18.41
	Expanded	1	19.65	19.68	18.80	18.71	18.19	17.82
		2	19.42	19.20	18.19	18.06	17.42	17.30

The mean average retail distribution cost (for the 36 market environments) for the specialized plant 1 is $19.18/ton and is $18.46/ton for specialized plant 2. Specialized plant 2 was the optimum plant for all market environments. The generalizations made about season, market share, and demand density for the farm supply units also apply to the specialized firms.

As was pointed out in the discussion of plant costs, the specialized firm type has higher plant costs. The higher plant costs explain why specialized firms have higher distribution costs than the farm supply unit's plants 1 and 2 as delivery costs are independent of firm type. Whether the farm supply units have an actual cost advantage is subject to question, a vertically integrated firm may more than overcome these

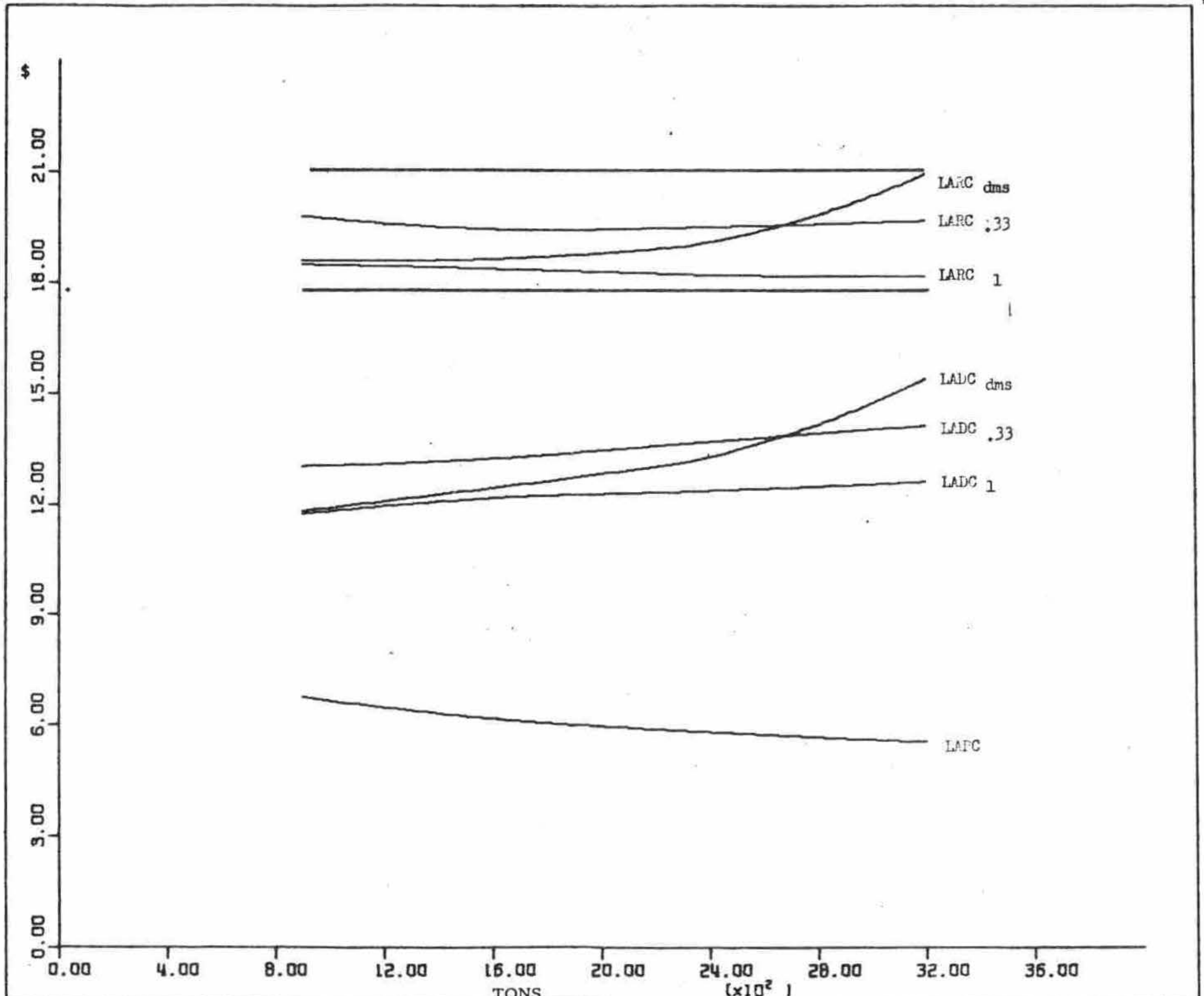

Figure 5.10. Cost range of different market shares

costs through savings on sales cost and better control of distribution from manufacturer to retailer.

5.5.7. Importance of plant size

Rathjen (20) and Rudel and Walsh (21) state that there are cost savings to be enjoyed from increased plant size. It is the purpose of this section to explore this contention. Table 5.17 presents the mean average retail distribution costs and average one way travel distance of the four farm supply unit plants for the 36 market environments.

Table 5.17. Mean average retail distribution cost of the four farm supply unit plants for the 36 market environments

	Plant 1	Plant 2	Plant 3	Plant 4
ARDC	$17.18	$16.91	$16.95	$17.29
ATD (mi)	4.32	6.18	7.16	9.49

The author would contend that a cost difference of $.38/ton (difference of mean average retail distribution cost between plant 2 and plant 4) over a range of 2700 tons (900 tons for plant 1 in the regular season to 3800 tons for plant 4 in the expanded season) and more than doubling of average travel distance should be considered constant costs. Figure 5.10 depicts the comparative market shares again. The long run average distribution curve is changed from a diseconomies curve, to an economies curve, to a traditional envelope curve depending on what market share is assumed. The sensitivity of the long run average distribution curve to changes in the market environment can be viewed in a broader range of costs that are essentially constant. The retailer would have a better chance of reducing costs by attempting to interest some of his customers in applying ammonia at a different time or in gaining a larger market share through better service than through trying to select the optimum plant size.

5.6. Retailing efficiency

The foregoing discussion has centered on the influence of various factors which will affect the plant size - delivery equipment selection of an individual firm. This section will deal with the relative efficiency of the industry in the Fort Dodge area and the ammonia distribution costs of a "typical retailer". The importance of the assumption about driver labor will be examined and what effect the assumption has upon the practicality of some of the cost model solutions.

5.6.1. Number of retailers

In the discussion of market structure in Chapter 2, it was learned that there are 150 ammonia retailers in the Fort Dodge area. If the market can be viewed to be in long run equilibrium, how many retailers should there be? The 100 percent market share discussed in section 5.5.3 may be viewed as representative of a long run equilibrium solution. This would mean that in a perfectly competitive market, no more than 25 equidistantly spaced retail plants would be needed to distribute the 78,703 tons of ammonia fertilizer. Why is there such a large difference between the optimal and actual?

Part of the question can be answered by the cost model, if costs are essentially constant (the difference between plant 1 and plant 4 is

$.31/ton) then plant 1 might safely be assumed to be representative of an optimal plant. This would increase the number of retailers to 88. Even with this modification, there appears to be an excessive number of retailers.

Another partial answer is an implicit assumption that was made about the wholesalers; that they could deliver all of the ammonia a retailer might need. For an individual retailer this is not an unrealistic assumption, but for a wholesaler with a large number of retailers to supply, or the entire ammonia retail industry the assumption is subject to question. Time did not allow for a complete analytical examination of ammonia distribution from manufacturer to farmer but this generalization will be made: Some of the small volume size of the retailers can be explained by the inability of the wholesalers to deliver the material in the short time available. It may be possible that an increase in available application time would result in greater cost savings at the manufacturing and croyogenic storage levels than in retail distribution costs. The cost savings at the manufacturing level should result from better utilization of plant capacity and the increased time should result in a reduction of the off-season storage (the reader is reminded that there is 900,000 tons of terminal storage in Iowa and a usage of 521,588 tons in 1970).

The large growth in ammonia usage in the past ten years indicates the industry is not in long run equilibrium. The early and mid-sixties were characterized by entry of first the cooperatives and then the vertically integrated firms to take advantage of manufacturing economies of size and the increase demand for fertilizer. The late sixties and early seventies have witnessed the exit of some retailers in the Fort Dodge area: In 1969, there were 164 active retailing sites, 1970 there were 150 and 1971 there were 144[5]. If retail margins continue at their present levels (about $20/ton) more firms can be expected to leave the industry.

A final reason can be given for choosing a smaller plant size as being a more realistic plant selection: the assumption of having unlimited driver labor. To examine the possibility of economies existing in retail distribution, it was assumed that the number of pickup drivers was variable. In Section 5.5, it was pointed out that the number of pickups increased from 2 to 14 for the representative market environment, this would necessitate a corresponding increase in the number of drivers. The largest number of pickup drivers working from a single site that the author is aware of is five. Although the farm supply unit type firms have a labor pool to draw from, it is not unlimited. This problem is even more critical for the specialized firms if they are to obtain volumes much beyond 500 tons (the approximate limit for a driver and pickup). One solution to the problem of limited drivers that one retailer uses is to hire farmers and their pickups to make custom deliveries on a per load basis.

The question of the efficiency of the typical retailer has yet to be examined. The average yearly sales in the Fort Dodge area were 521 tons in 1970. How does this compare with the costs of plant 1 and what are the retailing costs of a "typical retailer".

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[5]Thorsheim, text referral, p. 19.

5.6.2. Retailing costs of a typical retailer

In Chapter 3 a situation was presented where a retailer might have efficient utilization of delivery equipment but is unable to obtain plant capacity (perhaps due to the local competitive condition or his wholesaler's inability to supply enough ammonia). The costs of a retailer with limited plant volume will be compared with the cost of a typical retailer.

The average retailer will be defined as a full farm supply firm (farm supply unit) with plant 1 being representative of his bulk plant. The additional cost due to under utilization of the plant can be found with the use of Table 5.2.

$$TP_1\ C_{521\ tons} = \underset{\$2020}{B_o} + \underset{521\ tons\ (\$4.50)}{521Q} = \$4364.50$$

and $AP_1\ C_{521\ tons} = \$8.38/ton$. The average cost of plant 1 at its capacity is \$6.74, so there is an increase of \$1.64 per ton due to under utilization of the plant. Both the efficient retailer with limited plant volume and the typical retailer experience these increased plant costs.

The efficiencies from the survey of the 28 retailers on the nurse tanks and applicators (Chapter 2, pp. 35, 36) will be those used as being representative of a typical retailer (35 tons/nurse tank/season and 57 tons/applicator/season). While the method used in section 5.2 is used to determine the equipment cost of the efficient retailer with limited plant volume, the representative market environment discussed in 5.5.1 is the one assumed for this discussion. Table 5.18 presents a cost comparison for a typical retailer and the efficient retailer.

Table 5.18. Average retailing costs for a typical retailer and an efficient retailer with limited plant volume

	Typical retailer	Efficient retailer with limited plant volume	Difference
Plant cost/ ton	$8.37	$8.37	-
Nurse tanks	15	9	6
Cost/ton	$4.40	$2.64	$1.76
Applicators	10	7	3
Cost	$5.45	$3.81	$1.64
Pickups	1	1	-
Cost	$ .60	$ .60	-
Variable delivery costs	$4.47	$4.47	-
Total	$23.29	$19.89	$3.40

Average travel distance 3.30 miles.

It is apparent then that the average retailer has additional costs of $3.40/ton due to the under utilization of nurse tanks and applicators. In fact, there are greater cost inefficiencies due to excessive numbers of nurse tanks and applicators ($3.40/ton) than there are due to under utilization of plant capacity ($1.64/ton).

There are a number of possible explanations for the excessive number of nurse tanks and applicators. First, the farmer often demands back up nurse tanks which will sit in the field waiting to be used. Second, the farmer often "picks up" ammonia, at a discounted price, himself. This often results in the delivery equipment sitting on the farm waiting the farmer's convenience. Finally, the retailers limited number of pickups may result in an under utilization of the nurse tanks and applicators.

5.6.3. Summary comments on the efficiency of ammonia retailers

Past studies (20, 21) have depicted the ammonia retail market as: having an excessive number of firms; the manufacturer's accepting a portion of the retailing costs; following a short run practice of selling below full costs; economies of size in retailing not being taken advantage of; and the retail industry as a whole being rather inefficient.

One shortcoming of these past studies is that there was not a complete identification of the costs of ammonia retailing. These studies understated nurse tank and pickup costs and excluded applicator costs. This study has shown that these costs are an important component of retail distribution costs, accounting for 63 to 75 percent of total retail distribution cost depending upon the particular market environment.

Losses have been incurred at the retail level of ammonia distribution[6]. But to attribute these to small plant size is subject to question. First, the entire ammonia industry and the fertilizer industry in general have experienced losses due to excess capacity and there have been reductions in profits throughout the distribution chain from manufacturer to and including the retailer. Second, it is conceivable that a retailer

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[6]For a review of ammonia retail prices and margins see Rudel and Walsh (21).

with limited volume and efficient utilization of delivery equipment would realize lower per unit cost than one with larger volume and under utilization of delivery equipment.

Finally, there are some inefficiencies in retailing which appear to arise from under utilization of the delivery equipment. But, when the restraints of the intense season, the wholesalers limited ability to serve, and the limited amount of driver labor are considered, it appears the retailers are performing effectively.

6. SUMMARY

6.1. Summary and conclusions

There has been a large and rapid growth in the usage of fertilizer in the United States and in Iowa since 1950. In Iowa alone, the consumption has increased from .3 million tons to 2.6 million tons of fertilizer. The reasons for this growth include: 1) the reduction in relative price of fertilizer to other crop production inputs and the corresponding substitution of fertilizers for these factors of production, 2) the increased acceptance of fertilizer as a profitable resource by farmers through the educational efforts of various governmental agencies and private industry, and 3) the general growth of technology in crop production.

The fertilizer industry's response to the large increase in demand has been characterized by technological advances and a high degree of integration throughout all sectors of the industry. Retail distribution of fertilizer has seen the advent of bulk blending and anhydrous ammonia as the primary means of providing the plant nutrients to the farmers.

One form of fertilizer that has enjoyed wide acceptance by farmers is anhydrous ammonia. In Iowa, it has become the primary nitrogen source. One of the main reasons for the acceptance of ammonia is that it is the lowest cost per unit form of nitrogen.

The introduction of the centrifugal compressor enabled the ammonia manufacturers to take advantage of economies of size in production. The ammonia industry has been characterized by the building of large manufacturing plants near the supply of natural gas on the coast of the Gulf of Mexico. The distribution system has been built around these plants with pipelines and cryogenic barges transporting the material to the Midwest where it is stored at cryogenic terminals. In the late sixties, the ammonia sector, as well as the entire fertilizer industry, experienced depressed prices due to the overbuilding of plants and the entrance of many new firms.

The purpose of this study was to examine the retail distribution costs of ammonia retailers in a nine county area in North Central Iowa, the Fort Dodge Functional Economic Area. In 1970, there were 150 ammonia retailers with average yearly sales of 521 tons per retail outlet in the Fort Dodge area. It was found that there was a fairly high degree of vertical integration among retailers, with vertically integrated firms having 49.5 percent of the sales in the area, cooperatives 43.2 percent, and independent retailers 7.3 percent. The rapid growth in the number of retailers during the early and mid-sixties indicated the lack of barriers to entry in ammonia retailing. One characteristic of all firms retailing ammonia was multiple product sales. The degree of multiple product sales varies from a complete line of crop production chemicals to a full line of farm supplies.

A series of interviews and surveys were undertaken to ascertain the problems and practices of ammonia retailing. The most prominent feature of ammonia retailing is the highly intense seasonality of demand, with most dealers having only a ten day to three week period to make delivery of almost all material. In a survey designed to learn the average travel distance and trade territories of retailers, an interesting phenomena was observed - the percentage of the market a retailer obtained declined with distance from the plant. In a third survey, the average efficiencies of nurse tank and applicators were obtained.

To evaluate the relative efficiency of the retailing industry and to estimate the costs of a typical retailer, a modified synthetic cost model was developed. The basis for the cost model was the development of the relationship between plant volume and delivery costs through average travel distance. Plant costs and delivery costs were then combined to form retail distribution costs.

The cost model incorporated many of the practices observed in the preliminary surveys of retailers. An arbitrary method of handling multiple-use facilities was developed. Six different plants were budgeted, four farm supply unit plants representative of full farm suppliers and two specialized plants representing the vertically integrated fertilizer dealers. The major difference between the two firm types was that plant labor was fixed for the specialized plants and variable for farm supply units. The plant volumes ranged from 900 tons per year for the present intense season to 3800 tons per year for an expanded season. The plant costs, as were all component retailing costs, were obtained through interviews and surveys of ammonia retailers and ammonia equipment dealers.

The delivery costs were comprised of driver labor, pickup, nurse tank, and applicator costs. To reflect the various types of applicating equipment a composite applicating machine was developed, with adjustments made for different rate levels (lbs. of ammonia per acre) and changes in season length. Time parameters to reflect loading, unloading, waiting in the field, travel, etc. were developed to determine the number of pickups, nurse tanks, and applicators needed. Adjustments in the time parameters were made for different rate levels of ammonia and for the two season lengths. The cost model selected the number of individual delivery units needed for different volumes, season lengths, market shares, and demand densities.

The plant costs were examined for cost differences. A difference of $1.20 per ton was found to exist between the smallest and largest plants for the present intense delivery season. It was concluded that there are slight economies to be gained from the larger plant size.

The various combinations of the 2 season lengths, 3 market shares, 3 rate levels, and 2 acreage levels considered, resulted in 36 different market environments. When the delivery costs of each market environment were combined with the individual plant costs of the six plants there were a resultant 216 short run retail distribution cost cases.

A market environment representative of the current season, competitive condition, and ammonia usage was defined. The short run retail distribution costs of plant 1 of the farm supply unit type were examined in detail. It was found that delivery costs comprised a large portion of the retailing costs. Of the $18.60 per ton average retail distribution costs, delivery costs made up $11.85 per ton while plant costs comprised $6.74 per ton.

The average retail distribution costs of the four farm supply unit plants were examined for changes when each one of the components of the representative market environment was changed. This was done to examine the influence on long run retailing costs due to changes in season length, market share, and demand density.

It was found that optimal average retail distribution costs could be reduced by $1.18 per ton if the delivery season was expanded 20 percent. There was also a shift in the optimum plant-delivery equipment combination from plant 1 to plant 3, or an increase in volume distributed of 1400 tons of ammonia.

Three different competitive situations were examined: a market share of 100 percent, the representative declining market share, and a constant market share of 33 percent. It was found that the 100 percent market share situation has a $.41/ton reduction in retailing costs as compared to the declining market share. A shift in the optimum plant-delivery equipment combination occurred from plant 1 to plant 4. The difference in the two market shares can be explained by the difference in average travel distance. The constant market share of 33 percent has the effect of raising the delivery costs for the plants with smaller volume, when compared to the declining market share. This again can be explained by the difference in average travel distance.

Different demand densities due to an increase in either the rate of ammonia used per acre or the number of acres of corn grown were compared with the current demand density of 13.84 ton/sq.mi. It was found in all cases that costs were reduced due to reductions in average travel distance.

Due to the higher fixed cost of the specialized plants the retailing costs were found to be greater than the farm supply unit plants. It is not known whether the cost savings from vertical integration would overcome these higher retailing costs.

The costs and plant size of the optimum plant size delivery equipment combinations for the 36 market environments were cross tabulated with these findings: 1) as time for ammonia retail delivery is increased, retail distribution costs are reduced as is the size of the plant, 2) as the market share a retailer obtains increases, the retail distribution cost is reduced and optimum plant size is increased, 3) as the demand density (either rate level or number of corn acres) increases, retailing costs decrease and optimum plant size increases.

The possibility of economies of plant size existing in retail distribution of ammonia was examined. The retail distribution costs of the four supply unit plants were averaged for the 36 different market environments and a cost difference of $.38/ton in retailing cost existed between the four plants. It was concluded from this that retail distribution costs were essentially constant. In other words, plant size has only a minor influence on retailing costs.

The constant cost finding was used to explain the sensitivity of the long run retail distribution cost curve to changes in market environment. The constant retail distribution costs can be explained in this manner: the rising delivery cost offsets the slight cost savings enjoyed by the larger plants.

The costs developed in this study were used to evaluate the retailing efficiency in the Fort Dodge area. The 150 retailers appear to be excessive when measured against the 88 suggested by the cost model. Two short comings of the cost model were pointed out that might explain some of the differences: 1) the wholesaler's inability to service the demand in the short time allowed and 2) the limited amount of driver labor available to make deliveries. When these factors are considered the retailers appear to be doing a fairly effective job of marketing.

The costs of a typical ammonia retailing operation were estimated. These costs were \$23.29 per ton. Some inefficiencies were found in the typical retailing operation measured against the cost model results. Additional plant costs of \$1.64 per ton and additional delivery costs of \$3.40 per ton were estimated for the typical retailer. The plant costs arise from an inability to realize plant capacity. The additional delivery costs are due to under utilization of nurse tanks and applicators.

6.2. Limitations of the study and areas for further examination

There were a number of factors that were not considered (due to the limits of time). It is the purpose of this section to point out those factors and suggest their importance.

6.2.1. Location

No reference was made to the location or relocation of distributors. Currently, the pattern of location in the Fort Dodge area appears to follow the railroad lines. As the railroads continue the abandonment of their feeder lines, the pattern of location should shift to the major highways in the area. The decline in rail service will also have the influence of necessitating additional bulk tank storage.

6.2.2. Rental tanks

It was assumed that additional bulk storage was rented by the retailer at a minimal fee from his supplier. If the retailer must purchase the additional storage himself the influence would be to raise his fixed costs and make the smaller plant the optimal plant in almost all the situations considered.

6.2.3. Market share

As already pointed out, the particular market share assumed can have an influence on distribution costs and optimal plant size. In developing the cost model, it was found that the particular specification of the declining market share also had a significant influence on optimal plant selection. The declining market share is a behavioral characteristic of farmers and additional study is needed to learn what prompts farmers to prefer the closer retailer.

6.2.4. Season length

The cost model suggests that there are cost savings to be realized if more time is allowed for delivery. Whether this additional time is actually available is subject to question. The farmers have adapted to the preplant season because it is a convenient time for their operation. A discount program to encourage usage at other times deserves investigation.

6.2.5. Multiple products

The concept of multiple product sales is not new. The author admits that there are limitations in the method used in this study to determine the cost of a multiple use facility allocated against a single product. Since a large proportion of farm supplies are sold through multiple product firms a need exists for the examination of differences in costs, optimum plant sizes, and investment decisions between multiple product firms and single product firms. Criteria need to be developed for the allocation of cost of a multiple use facility. It is the author's belief that a better description of the two factors of market share and multiple product firms would result in greater reliability in cost estimates and measurements of marketing efficiency.

7. LITERATURE CITED

1. Ammonia Plant Capacity. Agricultural Nitrogen News 6: 6-12. November-December, 1968.

2. Anhydrous Prices Expected to Climb. Des Moines [Iowa] Sunday Register, Vol. 123: No. 233; Section F, page 1. February 13, 1972.

3. Beaton, J. D. and Tisdale, S. L. Potential Plant Nutrient Consumption in North America. The Sulfur Institute Bulletin 16. 1969.

4. Cohen, Kalman J. and Cyert, Richard M. Theory of the Firm: Resource Allocation in a Market Economy. Englewood Cliffs, New Jersey, Prentice-Hall, Inc. 1965.

5. Crop Reporting Board. Agricultural Prices. United States Department of Agriculture Statistical Reporting Service Bulletin PR 4. Various issues.

6. Fertilizer Marketing in a Changing Agriculture. Fertilizer Production and Marketing Conference, Memphis, Tennessee, October 1-3, 1969.

7. Fox, Karl A. Strategies for Area Delimitation in a National System of Regional Accountants. Unpublished mimeographed paper prepared for the Institute for Urban and Regional Studies, St. Louis, Missouri. ca. 1966.

8. Fox, Karl A. The New Synthesis of Rural and Urban Society. Unpublished mimeographed paper presented at Conference on the Economic Problems of Agriculture, Rome, Italy, September 1-8, 1965. Ames, Iowa, Economics Department, Iowa State University. ca. 1966.

9. Fox, Karl A. Use of Regional Accounts in the Development of Programs for Economic Growth: Programs for Economic Growth in Non-Metropolitan Areas. Unpublished mimeographed paper presented at the Third Conference on Regional Accounts, Miami Beach, Florida, November 19-21, 1964. Ames, Iowa, Economics Department, Iowa State University. ca. 1965.

10. French, Ben C. Some Considerations in Estimating Assembly Cost Functions for Agricultural Processing Operations. Journal of Farm Economics 4: 767-778. 1960.

11. French, B. C., Sammet, L. L., and Bressler, R. G. Economic Efficiency in Plant Operations with Special Reference to the Marketing of California Pears. Hilgardia 19: 543-713. 1956.

12. Hargett, Norman L. 1970 Fertilizer Summary Data. National Fertilizer Development Center, Tennessee Valley Authority Bulletin Y-164M. 1971.

13. Houston, E. C. The Nitrogen Industry in the United States. Office of Agricultural and Chemical Development, Tennessee Valley Authority Bulletin. May, 1971.

14. Howell, H. B. Agricultural Projections--1980. Fort Dodge Extension Programming Area, Iowa State University, Cooperative Extension Service Bulletin FM-1514. 1966.

15. Iowa Department of Agriculture, Agricultural Statistics Bulletin 92. Various issues.

16. Markham, Jesse W. The Fertilizer Industry: Study of an Imperfect Market. Nashville, Tennessee, Vanderbilt University Press. 1958.

17. Moore, John R. and Walsh, Richard G. Market Structure of the Agricultural Industries. Ames, Iowa, The Iowa State University Press. 1966.

18. National Fertilizer Development Center. Searching the Seventies. Tennessee Valley Authority Bulletin Y-34. 1971.

19. Nelson, L. B. and others. Changing Patterns in Fertilizer Use. Chicago, Illinois, Soil Science Society of America Symposium. February 14-15, 1968.

20. Rathjen, Robert A. An Economic Analysis of Fertilizer Retailing in Minnesota. Unpublished Ph.D. Thesis. Minneapolis, Minnesota, Library, University of Minnesota. 1970.

21. Rudel, R. K. and Walsh, R. G. Effects of Vertical Integration on Profitability of Ammonia and Solution Fertilizer Retailing by Cooperatives. University of Nebraska College of Agriculture Experiment Station Bulletin S. B. 512. 1970.

22. State of Iowa, Department of Agriculture. Distribution of Fertilizer Tonnage by Grades and Material. Iowa Department of Agriculture State Chemical Laboratory Bulletins. July 1, 1962-June 30, 1963 through July 1, 1969-June 30, 1970.

23. U. S. Census Bureau. 37th Census, 1970. Population, PC (VI)-17-Iowa. 1970.

24. Vickor, Malcolm H. and others. Agricultural Anhydrous Ammonia Technology and Use. Madison, Wisconsin, American Society of Agronomy. 1966.

25. Voss, Regis D. Guide to Efficient Fertilizer Use, Clarion-Webster-Nicollet Area. Iowa State University Cooperative Extension Service Bulletin PM-471-1. 1969.

26. Wellman-Lord, Inc. World Fertilizer Forecast 1965-1980. Jacksonville, Florida, Paramount Press, Inc. 1965.

27. Williamson, J. C., Jr. The Equilibrium Size of Marketing Plants in a Spatial Market. Journal of Farm Economics 4: 953-967. 1962.

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9. APPENDIX

As was mentioned in Chapter 5 there were a total of 216 different short run retail distribution cost cases. This appendix will present these costs for each plant at its capacity.

The appendix is organized in the following manner: Tables A.1, A.2, and A.3 contain cost information pertaining to the smaller acreage levels, while A.4, A.5, and A.6 pertains to the greater corn acreages. Table A.1 and A.4 contain cost information on the 160 lbs. of NH_3/acre rate level; Table A.2 and A.5 contain information on the 195 lbs. of NH_3/acre rate level. Contained within each table are the costs for each market share and the 2 seasons.

Included in the appendix are the graphs depicting differences in the long run average costs for market share (comparable to Figure 5.7).

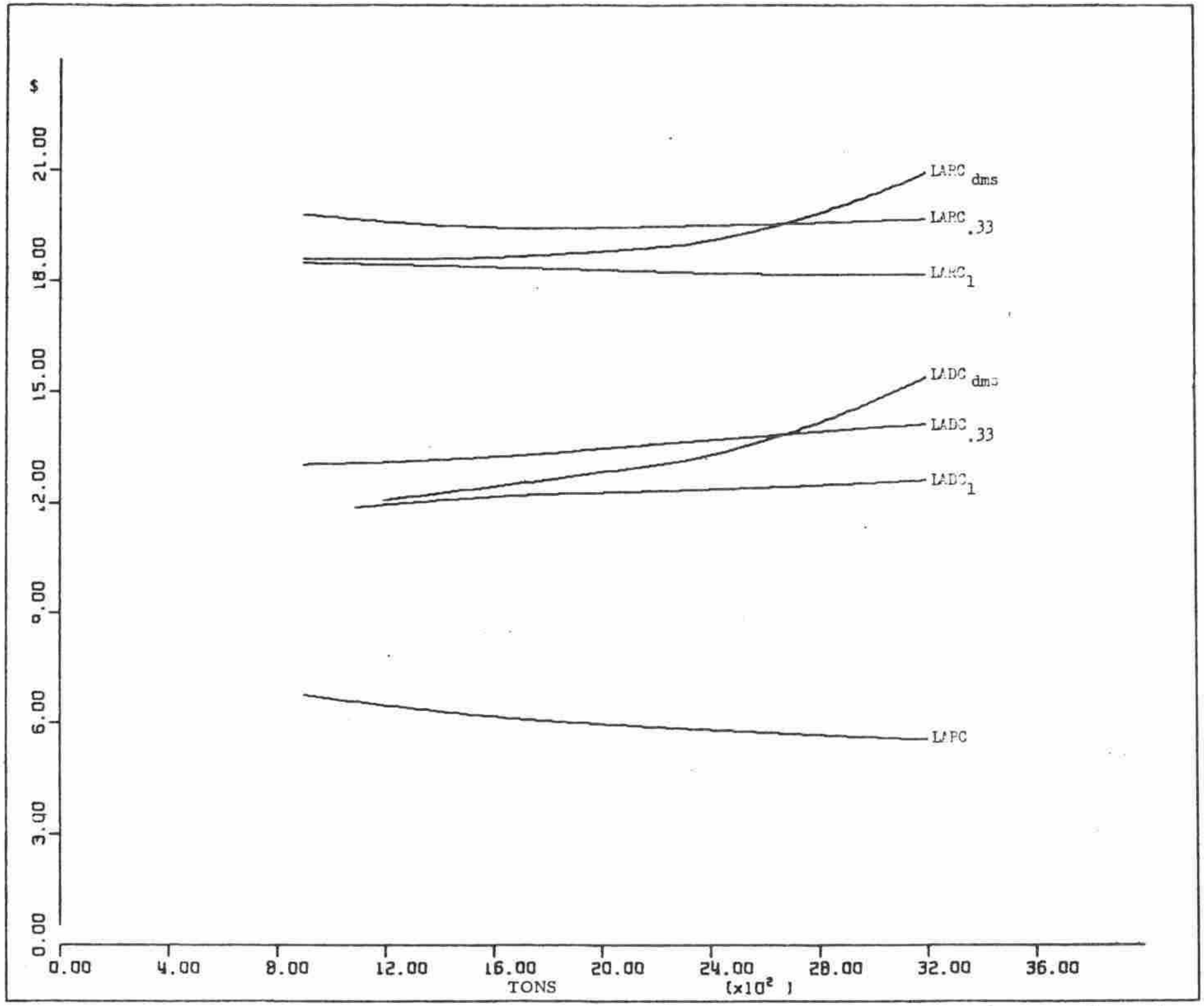

Figure A.1. Comparative long run average costs for different market shares, demand density = 13.84 ton/sq. mi.

Table A.1. Short run retail distribution costs, for all plants, demand density = 13.84 ton/sq.mi.

Market Share = 100% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	3.80	2	12	16	$18.50	$6.74	$7.20	$11.76
2-1800	5.38	5	24	33	18.33	6.05	7.46	12.28
3-2300	6.08	6	31	42	18.23	5.84	7.43	12.38
4-3200	7.17	9	43	59	*18.19	5.54	7.51	12.65
S1-900	3.80	2	12	16	20.35	8.59	7.20	11.76
S2-1800	5.38	5	24	33	19.78	7.49	7.46	12.28

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	4.20	2	12	15	$17.15	$6.08	$6.47	$11.07
2-2100	5.81	5	24	32	16.90	5.53	6.45	11.37
3-2700	6.58	6	31	42	*16.85	5.34	6.47	11.52
4-3800	7.81	9	44	59	16.90	5.10	6.54	11.80
S1-1100	4.20	2	12	15	18.99	7.92	6.47	11.07
S2-2100	5.81	5	24	32	18.26	6.89	6.45	11.37

Market Share = Declining Demand - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	4.36	2	12	15	*$18.59	$6.74	$7.20	$11.85
2-1800	6.72	5	25	33	18.72	6.05	7.61	12.67
3-2300	8.72	7	32	43	19.00	5.84	7.76	13.16
4-3200	16.74	14	47	65	20.96	5.54	8.64	15.41
S1-900	4.36	2	12	15	20.44	8.59	7.20	11.85
S2-1800	6.72	5	25	33	20.17	7.49	7.61	12.67

Legend: P-T = Plant number - tons at capacity; S - Specialized plant; ATD = Average one way travel distance, in miles; Number of: P = Pickups, APP = Applicators, and NT = Nurse tanks; ARDC = Average retail distribution cost; * Indicates the least cost plant; APC = Average plant cost; AFDC = Average fixed delivery cost; ADC = Average delivery cost.

Table A.1. Continued

Market Share = Declining Demand - Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	4.91	3	13	17	$17.55	$6.08	$6.71	$11.47
2-2100	7.59	5	25	33	*17.42	5.53	6.67	11.89
3-2700	12.02	8	33	44	18.34	5.34	7.03	13.01
4-3800	22.42	18	49	69	20.93	5.10	8.07	15.82
S1-1100	4.91	3	13	17	19.39	7.92	6.71	11.47
S2-2100	7.59	5	25	33	18.78	6.89	6.67	11.89

Market Share = 33% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	6.58	3	13	17	$19.80	$6.74	$8.03	$13.06
2-1800	9.31	6	25	34	*19.42	6.05	7.87	13.37
3-2300	10.53	8	32	44	19.51	5.84	7.96	13.67
4-3200	12.42	12	45	62	19.70	5.54	8.96	14.90
S1-900	6.58	3	13	17	21.65	8.59	8.03	13.06
S2-1800	9.31	6	25	34	20.87	7.49	7.87	13.37

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	7.28	2	11	14	$18.42	$6.08	$6.69	$11.73
2-2100	10.06	6	25	34	*18.06	5.53	6.89	12.53
3-2700	11.41	8	32	44	18.13	5.34	6.92	12.79
4-3800	13.53	112	46	63	18.44	5.10	7.10	13.34
S1-1100	7.28	2	11	14	19.65	7.92	6.69	11.73
S2-2100	10.06	6	25	34	19.42	6.89	6.89	12.53

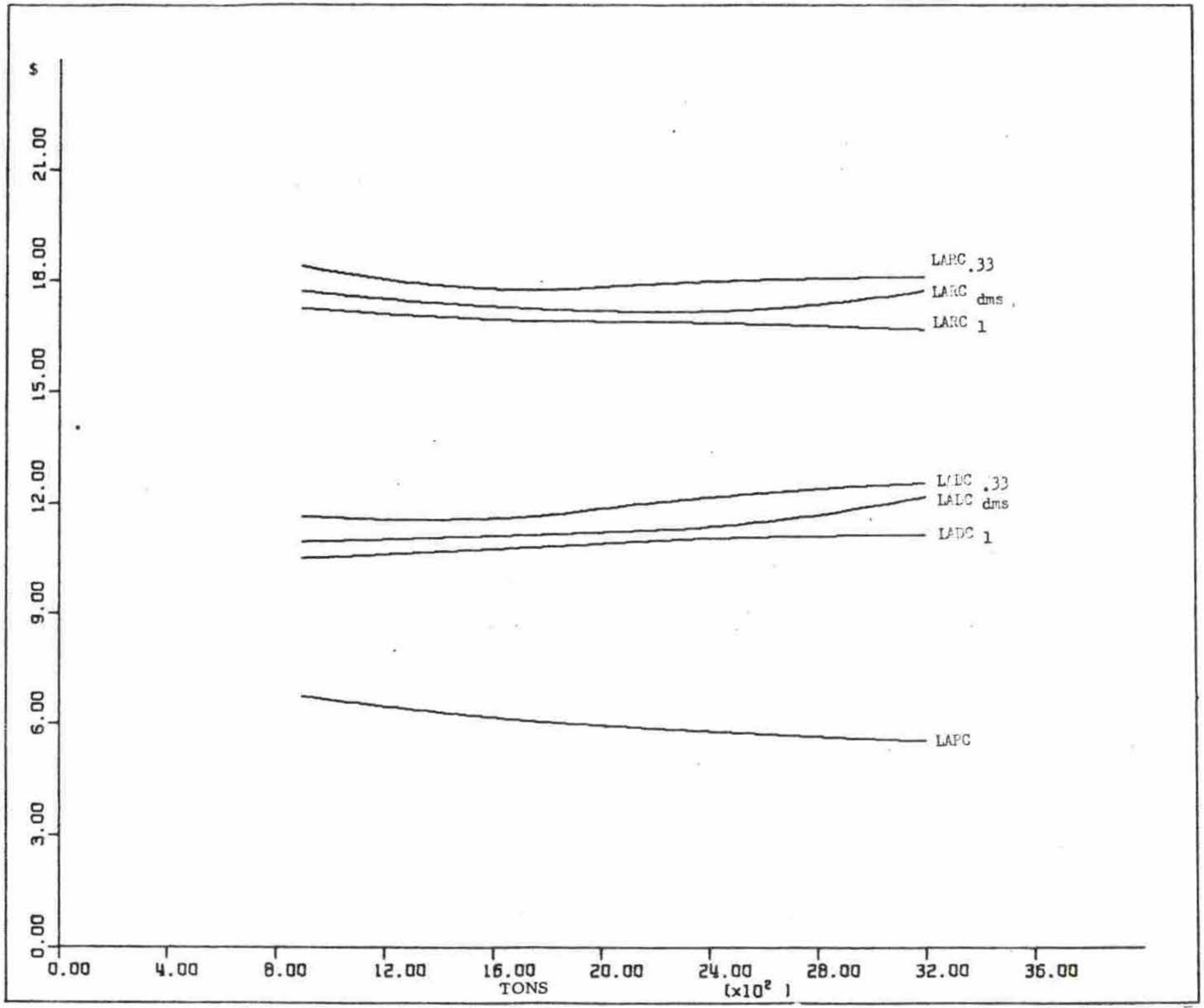

Figure A.2. Comparative long run average costs for different market shares, demand density = 18.45 ton/sq. mi.

Table A.2. Short run retail distribution costs, for all plants, demand density = 18.45 ton/sq.mi.

Market Share = 100% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	3.29	2	9	13	$17.28	$6.74	$6.30	$10.54
2-1800	4.66	4	19	25	16.93	6.05	6.40	10.88
3-2300	5.26	6	24	32	16.91	5.84	6.49	11.07
4-3200	6.21	8	33	45	*16.72	5.54	6.44	16.72
S1-900	3.29	2	9	13	19.13	8.59	6.30	10.54
S2-1800	4.66	4	19	25	18.38	7.49	6.40	10.88

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	3.64	2	11	14	$16.09	$6.08	$5.74	$10.01
2-2100	5.03	4	21	27	15.82	5.53	5.79	10.29
3-2900	5.70	6	27	35	15.86	5.34	5.90	10.52
4-3800	6.77	8	38	50	*15.80	5.10	5.90	10.69
S1-1100	3.64	2	11	14	17.93	7.92	5.74	10.01
S2-2100	5.03	4	21	27	17.18	6.89	5.79	10.29

Market Share = Declining Demand - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	3.71	2	10	13	$17.73	$6.74	$6.68	$10.99
2-1800	5.56	5	19	25	17.26	6.05	6.58	11.21
3-2300	6.52	6	24	33	*17.19	5.84	6.55	11.35
4-3200	9.46	10	35	47	17.78	5.54	6.94	12.23
S1-900	3.71	2	10	13	19.58	8.59	6.68	10.99
S2-1800	5.56	5	19	25	18.70	7.49	6.58	11.21

Legend: P-T = Plant number - tons at capacity; S = Specialized plant; ATD = Average one way travel distance, in miles; Number of: P = Pickups, APP = Applicators, and NT = Nurse tanks; ARDC = Average retail distribution cost; *Indicates the least cost plant; APC = Average plant cost; AFDC = Average fixed delivery cost; ADC = Average delivery cost.

Table A.2. Continued

Market Share = Declining Demand - Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	4.15	2	11	14	$16.17	$6.08	$5.74	$10.09
2-2100	6.13	5	21	27	*16.16	5.53	5.94	10.63
3-2700	7.34	6	27	36	16.19	5.34	5.96	10.86
4-3800	13.41	12	41	54	17.68	5.10	6.64	12.57
S1-1100	4.15	2	11	14	18.01	7.92	5.74	10.09
S2-2100	6.13	5	21	27	17.52	6.89	5.94	10.63

Market Share = 33% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	5.70	3	10	13	$18.42	$6.74	$7.02	$11.68
2-1800	8.06	5	19	26	*17.77	6.05	6.66	11.72
3-2300	9.12	7	25	34	17.99	5.84	6.90	12.14
4-3200	10.75	11	35	48	18.15	5.54	7.08	12.60
S1-900	5.70	3	10	13	20.27	8.59	7.02	11.68
S2-1800	8.06	5	19	26	19.22	7.49	6.66	11.72

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	6.08	3	11	15	$16.96	$6.08	$6.16	$10.88
2-2100	8.71	5	22	28	*16.82	5.53	6.16	11.29
3-2700	9.88	7	28	37	16.92	5.34	6.25	11.58
4-3800	11.72	11	40	53	17.18	5.10	6.43	12.08
S1-1100	6.08	3	11	15	18.80	7.92	6.16	10.88
S2-2100	8.71	5	22	28	18.19	6.89	6.16	11.29

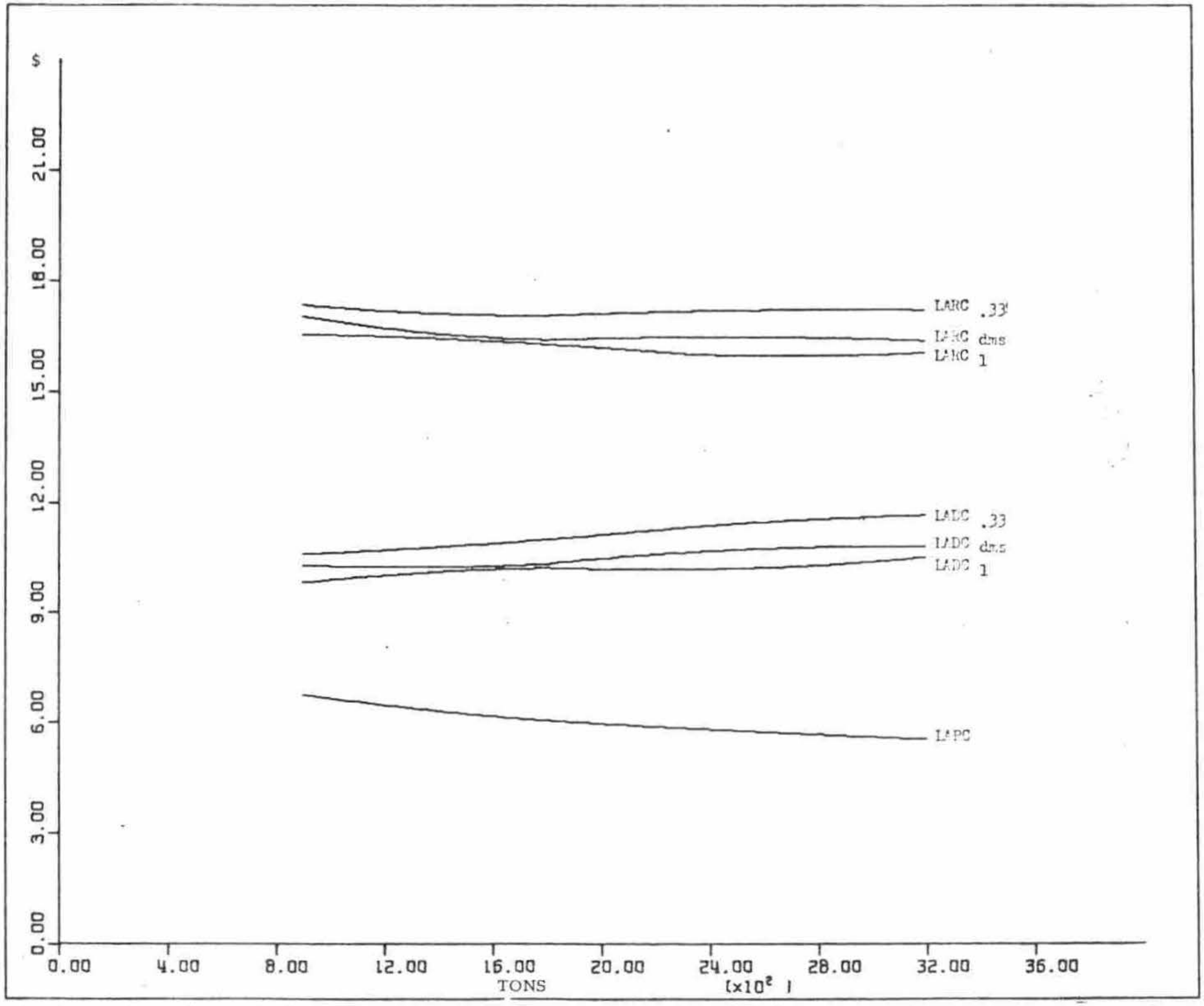

Figure A.3. Comparative long run average costs for different market shares, demand density = 23.06 ton/sq. mi.

Table A.3. Short run retail distribution costs, for all plants, demand density = 23.06 ton/sq.mi.

Market Share = 100% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	2.94	2	8	11	$16.57	$6.74	$5.88	$ 9.83
2-1800	4.16	4	17	22	16.30	6.05	6.08	10.25
3-2300	4.71	5	21	28	*16.04	5.84	5.94	10.20
4-3200	5.55	8	30	39	16.08	5.54	6.14	10.54
S1-900	2.94	2	8	11	18.41	8.59	5.88	9.83
S2-1800	4.16	4	17	22	17.74	7.49	6.08	10.25

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	3.26	2	10	13	$15.66	$6.08	$5.59	$9.58
2-2100	4.50	4	18	24	15.10	5.53	5.38	9.57
3-2300	5.10	5	24	31	15.12	5.34	5.48	9.78
4-3800	6.05	8	33	44	*15.07	5.10	5.50	9.97
S1-1100	3.26	2	10	13	17.50	7.92	5.59	9.58
S2-2100	4.50	4	18	24	16.47	6.89	5.38	9.57

Market Share = Declining Demand - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	3.29	2	9	11	$17.04	$6.74	$6.29	$10.30
2-1800	4.85	4	17	22	16.41	6.05	6.08	10.36
3-2300	5.64	6	22	28	16.50	5.84	6.24	10.66
4-3200	7.04	8	30	40	*16.39	5.54	6.19	10.84
S1-900	3.29	2	9	11	18.89	8.59	6.29	10.30
S2-1800	5.64	4	17	22	17.86	7.49	6.08	10.36

Legend: P-T = Plant number - tons at capacity; S = Specialized plant; ATD = Average one way travel distance, in miles; Number of: P = Pickups, APP = Applicators, and NT = Nurse tanks; ARDC = Average retail distribution cost; *Indicates the least cost plant; APC = Average plant cost; AFDC = Average fixed delivery cost; ADC = Average delivery cost.

Table A.3. Continued

Market Share = Declining Demand - Expanded Season

P - T	ATD (mi)	Number of P	APP	NT	ARDC	APC	AFDC	ADC
1-1100	3.67	2	10	13	$15.73	$6.08	$5.59	$9.65
2-2100	5.32	4	19	24	*15.41	5.53	5.54	9.88
3-2700	6.25	6	24	31	15.43	5.34	5.59	10.09
4-3800	8.58	9	34	46	15.76	5.10	5.76	10.65
S1-1100	3.67	2	10	13	17.57	7.92	5.59	9.65
S2-2100	5.32	4	19	24	16.78	6.89	5.54	9.88

Market Share = 33% - Regular Season

P - T	ATD (mi)	Number of P	APP	NT	ARDC	APC	AFDC	ADC
1- 900	5.10	3	9	11	$17.35	$6.74	$6.29	$10.61
2-1800	7.21	5	17	23	*17.08	6.05	6.34	11.03
3-2300	8.15	7	22	30	17.20	5.84	6.51	11.35
4-3200	9.62	10	31	42	17.23	5.54	6.59	11.69
S1-900	5.10	3	9	11	19.20	8.59	6.29	10.61
S2-1800	7.21	5	17	23	18.52	7.49	6.34	11.03

Expanded Season

P - T	ATD (mi)	Number of P	APP	NT	ARDC	APC	AFDC	ADC
1-1100	5.64	3	10	13	$16.35	$6.08	$5.87	$10.27
2-2100	7.79	5	19	25	*16.06	5.53	5.76	10.53
3-2700	8.83	7	25	33	16.23	5.34	5.95	10.89
4-3800	10.48	10	35	47	16.30	5.10	5.97	11.19
S1-1100	5.64	3	10	13	18.19	7.92	5.87	10.27
S2-2100	7.79	5	19	25	17.42	6.89	5.76	10.53

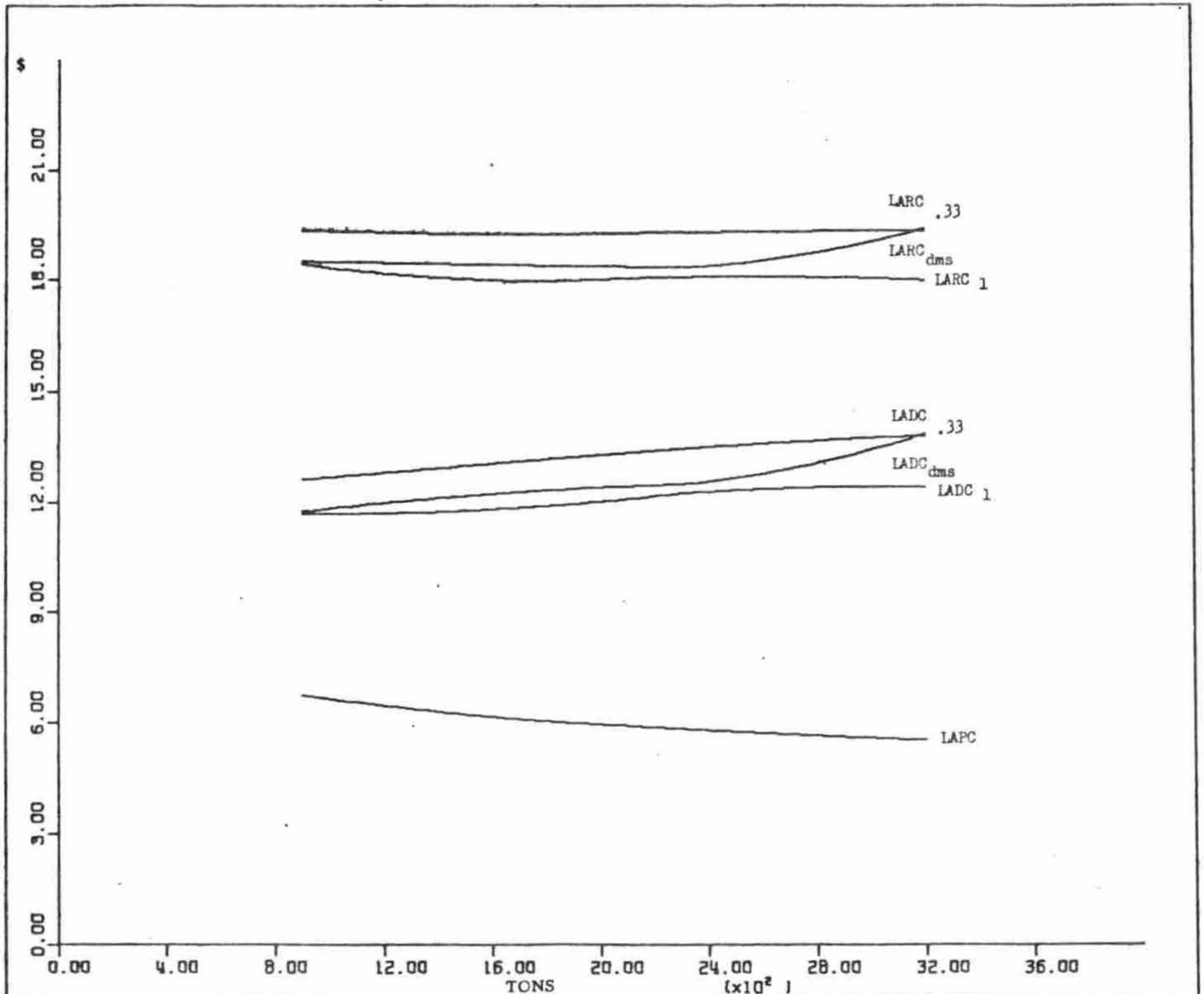

Figure A.4. Comparative long run average costs for different market shares, demand density = 16.67 ton/sq. mi.

Table A.4. Short run retail distribution costs, for all plants, demand density = 16.67 ton/sq.mi.

Market Share = 100% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	3.46	2	12	16	$18.44	$6.74	$7.20	$11.70
2-1800	4.90	4	24	32	*18.00	6.05	7.20	11.95
3-2300	5.54	6	31	42	18.13	5.84	7.43	12.29
4-3200	6.53	9	43	58	18.04	5.54	7.46	12.49
S1-900	3.46	2	12	16	20.29	8.59	7.20	11.70
S2-1800	4.90	4	24	32	19.44	7.49	7.20	11.95

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	3.83	2	13	17	$17.08	$6.08	$6.43	$11.00
2-2100	5.29	4	24	32	*16.66	5.53	6.31	11.13
3-2700	6.00	6	31	41	16.70	5.34	6.41	11.36
4-3800	7.12	9	44	59	16.78	5.10	6.54	11.68
S1-1100	3.83	2	13	17	18.92	7.92	6.43	11.00
S2-2100	5.29	4	24	32	18.03	6.89	6.31	11.13

Market Share = Declining Demand - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	3.93	2	11	15	$18.53	$6.74	$7.20	$11.78
2-1800	5.92	5	24	33	18.43	6.05	7.46	12.38
3-2300	7.01	6	31	42	*18.39	5.84	7.43	12.54
4-3200	11.62	11	45	62	19.47	5.54	8.03	13.92
S1-900	3.93	2	11	15	20.36	8.59	7.20	11.78
S2-1800	5.92	5	24	33	19.87	7.49	7.46	12.38

Legend: P-T = Plant number - tons at capacity; S = Specialized plant; ATD = Average one way travel distance, in miles; Number of: P = Pickups, APP = Applicators, and NT = Nurse tanks; ARDC = Average retail distribution cost; *Indicates the least cost plant; APC = Average Plant cost; AFDC = Average fixed delivery cost; ADC = Average delivery cost.

Table A.4. Continued

Market Share = Declining Demand - Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	4.40	2	13	17	$17.18	$6.08	$6.43	$11.10
2-2100	6.57	5	24	33	*17.10	5.53	6.53	11.57
3-2700	8.32	7	32	43	17.43	5.34	6.75	12.09
4-3800	16.30	14	47	65	19.23	5.10	7.42	14.13
S1-1100	4.40	2	13	17	19.02	7.92	6.43	11.10
S2-2100	6.57	5	24	33	18.46	6.89	6.53	11.57

Market Share = 33% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	6.00	3	12	17	$19.39	$6.74	$7.71	$12.65
2-1800	8.48	6	25	34	*19.31	6.05	7.87	13.23
3-2300	9.59	8	32	44	19.35	5.84	7.96	13.51
4-3200	11.31	11	45	62	19.42	5.54	8.03	13.87
S1-900	6.00	3	12	17	21.24	8.59	7.71	12.65
S2-1800	8.48	6	25	34	20.73	7.49	7.87	13.23

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	6.63	3	13	17	$17.84	$6.08	$6.71	$11.76
2-2100	9.16	6	25	33	*17.83	5.53	6.82	12.30
3-2700	10.39	8	32	43	17.90	5.34	6.87	12.56
4-3800	12.33	12	46	62	18.19	5.10	7.06	13.09
S1-1100	6.63	3	13	17	19.68	7.92	6.71	11.76
S2-2100	9.16	6	25	33	19.20	6.89	6.82	12.30

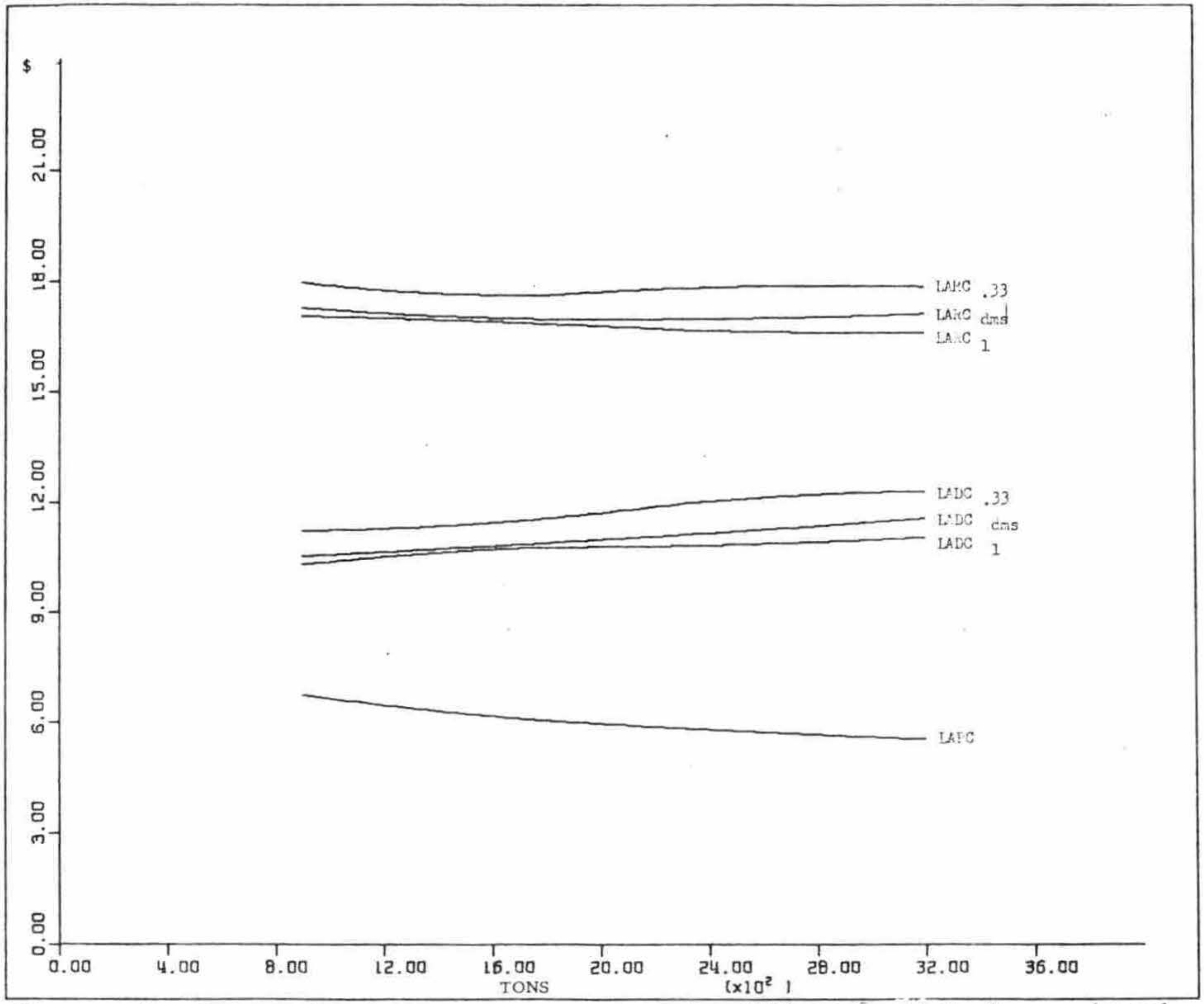

Figure A.5. Comparative long run average costs for different market shares, demand density = 22.23 ton/sq. mi.

Table A.5. Short run retail distribution costs, for all plants, demand density = 22.23 ton/sq.mi.

Market Share = 100% - Regular Season

P - T	ATD (mi)	Number of P	APP	NT	ARDC	APC	AFDC	ADC
1- 900	3.00	2	9	12	$17.06	$6.74	$6.13	$10.32
2-1800	4.24	4	19	25	16.86	6.05	6.40	10.81
3-2300	4.79	5	24	32	16.70	5.84	6.35	10.85
4-3200	5.66	8	33	45	*16.63	5.54	6.44	11.08
S1-900	3.00	2	9	12	18.91	8.59	6.13	10.32
S2-1800	4.24	4	19	25	18.30	7.49	6.40	10.81

Expanded Season

P - T	ATD (mi)	Number of P	APP	NT	ARDC	APC	AFDC	ADC
1-1100	3.32	2	11	14	$16.03	$6.08	$5.74	$9.95
2-2100	4.58	4	21	27	15.74	5.53	5.79	10.21
3-2700	5.20	5	27	35	*15.65	5.34	5.79	10.32
4-3800	6.16	8	38	49	15.66	5.10	5.86	10.55
S1-1100	3.32	2	11	14	17.87	7.92	5.74	9.95
S2-2100	4.58	4	21	27	17.11	6.89	5.79	10.21

Market Share = Declining Demand - Regular Season

P - T	ATD (mi)	Number of P	APP	NT	ARDC	APC	AFDC	ADC
1- 900	3.36	2	9	13	$17.27	$6.74	$6.30	$10.56
2-1800	4.96	4	19	25	*16.98	6.05	6.40	10.93
3-2300	5.76	6	24	32	17.00	5.84	6.49	11.15
4-3200	7.25	9	34	46	17.15	5.54	6.69	11.61
S1-900	3.36	2	9	13	19.15	8.59	6.30	10.56
S2-1800	4.96	4	19	25	18.43	7.49	6.40	10.93

Legend: P-T = Plant number - tons at capacity; S = Specialized plant; ATD = Average one way travel distance, in miles; Number of: P = Pickups, APP = Applicators, and NT = Nurse tanks; ARDC = Average retail distribution cost; *Indicates the least cost plant; APC = Average plant cost; AFDC = Average fixed delivery cost; ADC = Average delivery cost.

Table A.5. Continued

Market Share = Declining Demand - Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	3.74	2	11	14	$16.10	$6.08	$5.74	$10.02
2-2100	5.44	4	21	27	*15.89	5.53	5.79	10.36
3-2700	6.40	6	27	35	15.98	5.34	5.90	10.64
4-3800	9.19	10	39	51	16.50	5.10	6.19	11.40
S1-1100	3.74	2	11	14	17.94	7.92	5.74	10.02
S2-2100	5.44	4	21	27	17.25	6.89	5.79	10.36

Market Share = 33% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	5.20	2	10	13	$17.99	$6.74	$6.68	$11.25
2-1800	7.35	5	19	26	*17.65	6.05	6.66	11.60
3-2300	8.31	7	25	34	17.85	5.84	6.90	12.00
4-3200	9.80	10	35	48	17.89	5.54	6.99	12.34
S1-900	5.20	2	10	13	19.84	8.59	6.68	11.25
S2-1800	7.35	5	19	26	19.09	7.49	6.66	11.60

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	5.74	3	11	15	$16.87	$6.08	$6.16	$10.79
2-2100	7.94	5	22	28	*16.69	5.53	6.16	11.16
3-2700	9.00	7	28	37	16.77	5.34	6.25	11.43
4-3800	10.68	11	40	52	16.96	5.10	6.39	11.86
S1-1100	5.74	3	11	15	18.71	7.92	6.16	10.79
S2-2100	7.94	5	22	28	18.06	6.89	6.16	11.16

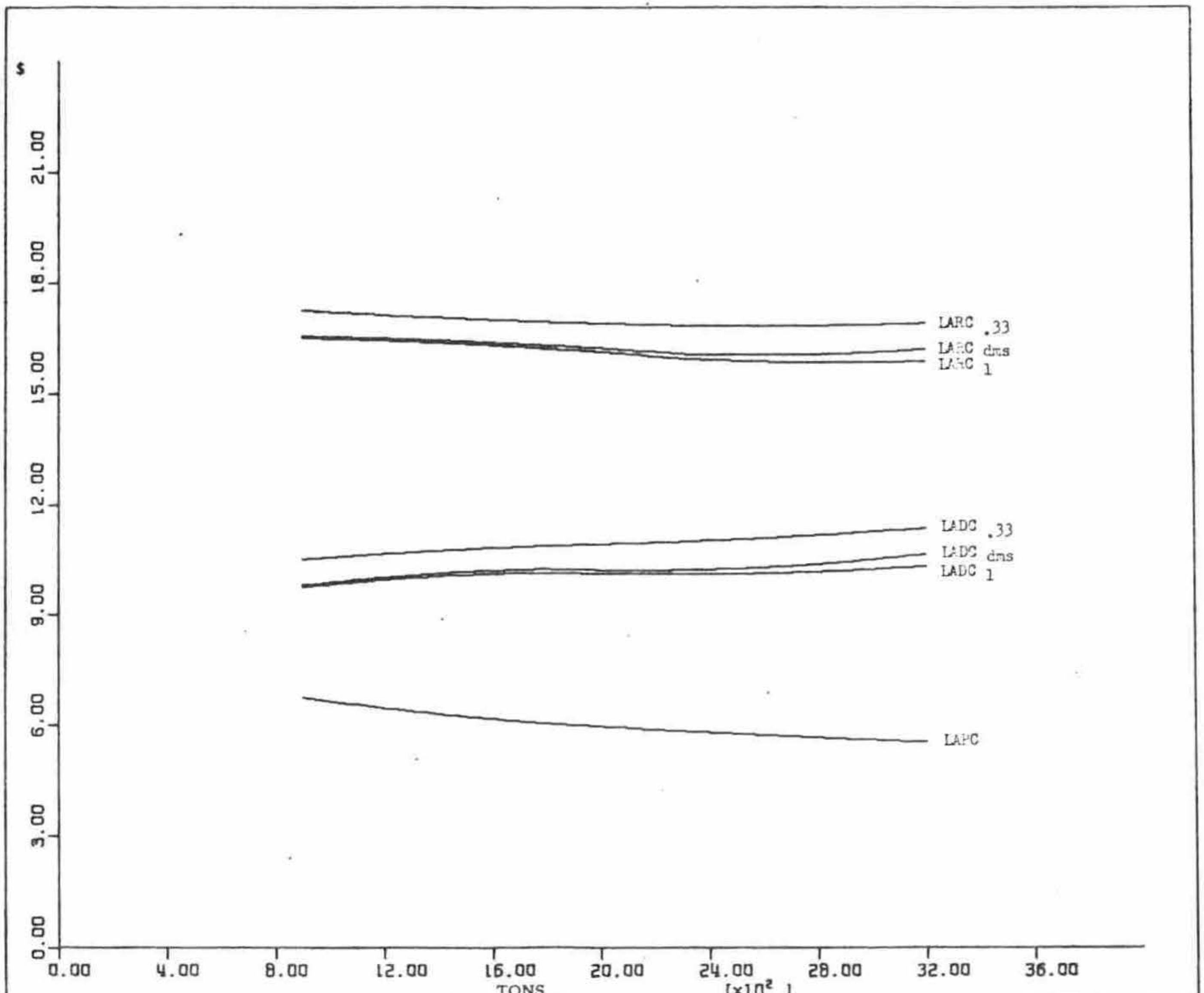

Figure A.6. Comparative long run average costs for different market shares, demand density = 27.79 ton/sq. mi.

Table 4.6. Short run retail distribution costs, for all plants, demand density = 27.79 ton/sq.mi.

Market Share = 100% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	2.24	2	8	11	$16.53	$6.74	$5.88	$9.79
2-1800	3.79	4	17	22	16.27	6.05	6.08	10.18
3-2300	4.29	5	21	28	15.97	5.84	5.94	10.13
4-3200	5.06	7	30	39	*15.90	5.54	6.04	10.36
S1-900	2.24	2	8	11	18.38	8.59	5.88	9.79
S2-1800	3.79	4	17	22	17.68	7.49	6.08	10.18

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	2.97	2	10	12	$15.47	$6.08	$5.45	$9.39
2-2100	4.10	4		24	15.06	5.53	5.38	9.51
3-2700	4.65	5	24	31	15.04	5.34	5.48	9.70
4-3800	5.51	7	33	44	*14.90	5.10	5.42	9.79
S1-1100	2.97	2	10	12	17.31	7.92	5.45	9.39
S2-2100	4.10	4	18	24	16.40	6.89	5.38	9.51

Market Share = Declining Demand - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	2.97	2	8	11	$16.57	$6.74	$5.88	$9.83
2-1800	4.35	4	17	22	16.33	6.05	6.08	10.28
3-2300	5.03	5	21	28	*16.10	5.84	5.94	10.25
4-3200	6.18	8	30	40	16.24	5.54	6.19	10.69
S1-900	2.97	2	9	11	18.42	8.59	5.88	9.83
S2-1800	4.35	4	17	22	17.77	7.49	6.08	10.28

Legend: P-T = Plant number - tons at capacity; S = Specialized plant; ATD = Average one way travel distance, in miles; Number of: P = Pickups, APP = Applicators, and NT = Nurse tanks; ARDC = Average retail distribution cost; *Indicates the least cost plant; APC = Average plant cost; AFDC = Average fixed delivery cost; ADC = Average delivery cost.

Table A.6. Continued

Market Share = Declining Demand - Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	3.32	2	10	13	$15.67	$6.08	$5.59	$9.59
2-2100	4.76	4	18	24	*15.15	5.53	5.38	9.62
3-2700	5.54	5	24	31	15.19	5.34	5.48	9.86
4-3800	6.97	8	34	44	15.32	5.10	5.59	10.22
S1-1100	3.32	2	10	13	17.51	7.92	5.59	9.59
S2-2100	4.76	4	18	24	16.51	6.89	5.38	9.62

Market Share = 33% - Regular Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1- 900	4.65	2	9	11	$17.24	$6.74	$6.29	$10.54
2-1800	6.57	5	17	23	16.97	6.05	6.34	10.92
3-2300	7.43	6	22	29	*16.87	5.84	6.31	11.03
4-3200	8.76	9	31	41	16.94	5.54	6.45	11.40
S1-900	4.65	2	9	11	19.13	8.59	6.29	10.54
S2-1800	6.57	5	17	23	18.41	7.49	6.34	10.92

Expanded Season

P - T	ATD (mi)	Number of P	Number of APP	Number of NT	ARDC	APC	AFDC	ADC
1-1100	5.14	2	10	13	$15.98	$6.08	$5.59	$9.90
2-2100	7.10	5	19	25	15.94	5.71	5.76	10.41
3-2700	8.05	6	24	32	*15.79	5.34	5.65	10.46
4-3800	9.55	10	35	46	16.10	5.10	5.93	10.99
S1-1100	5.14	2	10	13	17.82	7.92	5.59	9.90
S2-2100	7.10	5	19	25	17.30	6.89	5.76	10.41