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Marketing New England Poultry

7. Economics of Broiler Feed Mixing and Distribution

By CLARK R. BURBEE, EDWIN T. BARDWELL
and ALFRED A. BROWN

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
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Preface and Acknowledgements

This bulletin is the seventh in a series being issued by the Agricultural Experiment Station, University of New Hampshire, in cooperation with the Agricultural Experiment Station, University of Massachusetts, and the Economic Research Service, United States Department of Agriculture.

The series is concerned with various aspects of poultry marketing in New England. Previous publications in the series with their New Hampshire Experiment Station Bulletin numbers are: 1. *Characteristics of the Processing Industry (444)*, 2. *Economies of Scale in Chicken Processing (450)*, 3. *Capital Accumulation Potential of Broiler Growers (475)*, 4. *Structure and Performance of the Assembly System (476)*, 5. *Effects of Firm Size and Production Density on Assembly Costs (482)*, 6. *Economies of Scale in Hatching and Cost of Distributing Broiler Chicks (483)*, and 8. *Effects of Firm Size and Production Density on Spatial Costs for an Integrated Broiler Marketing Firm (485)*. Two companion reports published by the Agricultural Experiment Station, University of Massachusetts, are *Freight Rates on Feed, Central Territory Origins to New England and Middle Atlantic States (508)* and *Freight Rates and the Eastern Poultry Industry (533)*.

The objectives of this study are to determine the costs of mixing broiler feed and economies associated with size of feed mixing firms. Also determined are the costs of delivering the feed and how these costs are affected by changing 1) firm size (volume), 2) delivery density (tons per square mile), and 3) distance.

The authors appreciate the cooperation of the mill operators who provided information and data on input-output relationships and costs: also those manufacturers and suppliers of milling equipment who furnished data on specifications, capacities and costs. The authors acknowledge the assistance received from William F. Henry and other members of the Resource Economics Department, University of New Hampshire, and George B. Rogers, Marketing Economics Division, Economic Research Service, United States Department of Agriculture.

TABLE OF CONTENTS

		Page
	SUMMARY AND CONCLUSIONS	3
I.	INTRODUCTION	5
II.	OBJECTIVES	6
III.	METHOD AND PROCEDURE	6
	Method	6
	Procedure	7
IV.	ECONOMIES OF SIZE IN FEED MANUFACTURING	8
	Feed Manufacturing Process	8
	Labor Inputs and Costs	11
	Investment and Costs for Feed Manufacturing Facilities	15
	Ownership Costs	19
	Administrative and Supervisory Personnel Costs	22
	Utility Costs	22
	Other Costs	26
	Economies of Size	30
	Short-Run Average Costs	31
V.	COST OF BULK FEED DISTRIBUTION	31
	Procedure	31
	Bulk Feed Distribution Operation	35
	Feed Distribution Model	35
	Investment	38
	Feed Distribution Costs	41
VI.	TOTAL COST FOR FEED MANUFACTURING AND DISTRIBUTION	48
	Effect of Density Level	49
	APPENDIX	52
	A. Determination of Feed Mill Capacities and Outputs	52
	B. Poultry Feed Formulations	55
	C. Major Equipment Items for Eight Model Mills	56
	D. Short-Run Average Costs	57

Summary and Conclusions

The highly competitive nature of the broiler industry is forcing New England firms to place increased attention on adjustments to reduce unit broiler feed costs. Two possibilities for unit cost reductions are available. They are: (1) to increase the scale of the feed manufacturing plant to obtain any economies of size that may exist and (2) to increase the density of poultry production around the feed mixing plant to reduce unit distribution costs.

Economies of size are determined by using economic-engineering procedures. This method was used in a study of eight mills varying in capacity from 20.9 tons to 348.4 tons per eight-hour day (5,434 to 90,577 tons annually). Of the total tonnage, 85 percent is broiler feed. Each mill was restricted, moreover, to the manufacturing of five basic formulations: two in crumble form for broilers and three in mash and pellet form for birds in breeding flocks.

Substantial economies of size exist in feed manufacturing. With the model mills operating at their designed capacities, average cost decreases from $8.59 a ton for the smallest mill to $4.01 a ton for the largest mill. Most of the economies accrue from unit reductions in labor costs, building and equipment ownership costs, and administrative personnel costs.

There is evidence that further economies of size exist since average cost is still decreasing for the larger capacity mill models. Furthermore, the model mills are not of sufficient capacity to utilize certain types of existing equipment which would provide additional reductions in unit cost.

Distribution costs for direct delivery of bulk feed from mill to farm using 12-ton capacity trucks are determined for six of the eight model mills. Poultry production density is assumed at three different levels which are equivalent to distributing feed at the rate of 1.31, 6.55, and 32.73 tons per square mile per year. A model was developed and with various assumptions, conditions, and relationships, the physical inputs were determined. Standardized costs were applied to the input quantities to determine the distribution cost for each firm at each density level.

With poultry production density at the 6.55-ton level, an increase from 5,434 to 90,577 tons per year in the volume distributed increases the average cost from $2.44 to $3.98 a ton. At lower density levels, the average cost increases rapidly, while at higher levels it increases at a slower rate.

Increasing density for any of the six firms reduces distribution costs substantially. For any given increase in density, the absolute value of the reduction in cost increases with firm size and volume. Increasing density from 6.55 to 32.73 tons per square mile per year reduces the average distribution cost $.53 a ton for the smallest firm and $1.76 a ton for the largest firm.

Increasing the distance between the mill and a poultry production unit location, with other variables constant, increases the distribution cost. For each added road mile between the two locations, the estimated distribution costs increases 4.89 cents a ton.

Combining feed manufacturing and distribution costs provides information on the least-cost size operation for various levels of density.

At the lowest density level (1.31 tons per square mile), the least-cost operation is a mill manufacturing 32,609 tons a year and distributing into an area with a radius of 89 miles. The total average cost is $10.46 a ton. Increasing density to the 6.55-ton level shifts the least-cost operation to a mill manufacturing 45,287 tons a year and distributing into an area with a radius of 46.9 miles. The total average cost is reduced to $7.82 a ton. Increasing density to the 32.73-ton level shifts the least-cost operation to the largest firm size considered. This mill produces 90,577 tons a year and distributes into an area with a radius of 29.7 miles for a total average cost of $6.23 a ton. Most of the reductions in cost from adjustments in mill size and density are a result of lower distribution costs, not economies of size in feed manufacturing.

At a given density level, there is very little difference in average cost of the combined milling and distribution operations between the large size firms. This situation arises from the fact that as firm size is increased, the economies of size in manufacturing are largely or entirely offset by higher feed distribution costs.

Marketing New England Poultry

7. Economics of Broiler Feed Mixing and Distribution

By Clark R. Burbee, Edwin T. Bardwell and Alfred A. Brown[1]

I. Introduction

Substantial changes have taken place in the technology available to feed manufacturing firms and in the structure of firms in the broiler industry during the last fifteen years. The advancement in technology and competitive pressure has caused a shift in the location of feed manufacturing facilities from distant large-scale mills with their extensive distribution organizations to local specialized mills distributing directly to broiler production units.

Relocating feed manufacturing facilities into major broiler producing areas offers potential cost reductions from (1) operating a modern specialized mill, (2) direct distribution of feed to the producing units by truck, and (3) lower rail freight rates in some areas on ingredients not transhipped by rail as finished feed.[2]

A primary question facing firms in the industry is the optimum sized manufacturing facility and distribution operation needed to minimize the total feed cost per ton at the farm. However, the optimum size is dependent on economies of size in manufacturing and the spatial costs of distributing feed. If economies of size exist (decreasing unit cost with increasing size of mills) increasing capacity may require a firm to enlarge its distribution area. Enlargement of the distribution area increases the average length of haul per ton and consequently the unit distribution cost, providing production density remains constant. The increase in unit distribution cost may partially or totally offset the reductions in unit cost resulting from economics of size in manufacturing. Management must consider manufacturing and distribution costs simultaneously to determine the least cost size operation.

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Mr. Bardwell is Cooperative Agent, Agricultural Experiment Station, University of New Hampshire and Economic Research Service, U.S.D.A.

Mr. Brown is Professor of Marketing and Transportation, Department of Agricultural and Food Economics, University of Massachusetts.

[2] The introduction on July 15, 1964 of mileage, non-transit rates on shelled corn between points in the East is an additional change of potential significance. They are temporary rates due to expire midnight July 14, 1966. Should the rates become a permanent part of the structure, they will add to the cost advantages of mills located in feed-consuming areas that can utilize direct mill-to-farm distribution by truck.

This report does not consider the optimum size and output for a vertically coordinated broiler producing and marketing firm. Such firms perform a number of other activities such as processing, hatching, broiler assembling, and chick distribution. That analysis is the subject of a future report in this series. The present study, however, relates the size of feed mills to the size of growing operations specified for processing plants of stated capacity.

II. Objectives

The purpose of this report is to provide information for planning adjustments that will reduce feed costs for feed-mixing firms with particular reference to the New England broiler industry. Specifically, this report has four objectives, which are:

1. To determine the economies of size in the manufacture of broiler and breeder feeds by feed-mixing plants.

2. To determine the cost of bulk-feed distribution at three levels of broiler and breeder flock production density.

3. To determine the optimum size of combined manufacturing and distributing operations for each production density level.

4. To determine the potential reductions in distribution costs from increases in production density.

In addition, data on input requirements for labor, building, equipment, management, utilities, and other resources of lesser importance are provided for the several sizes of manufacturing and distributing operations. These data along with costs applicable to the New England region are used to develop a short-run average cost curve for each firm to illustrate cost variation with short-run changes in output.

III. Method and Procedure

Method

The economic-engineering method is used to develop the costs in feed manufacturing and feed distributing under several levels of broiler and breeder production density. This approach requires the determination of the various physical input-output relationships for each of the steps in the process. Standardized costs are applied to the physical relationships to derive the cost functions. These relationships are used in "constructing" and "operating" the several model plants and distribution operations.

Several sources were used in obtaining information and data for the manufacturing and distributing phases of this report. Time studies and interviews with mill personnel were made to obtain data on labor requirements. Mill personnel also provided information on managerial inputs, technical data on equipment, and accounting and cost data. Building and equipment specifications and costs were obtained from engineering and equipment manufacturers.

Procedure

Eight model plants are developed and short-run average cost curves determined for comparisons to illustrate the economies of size in feed manufacturing. The volumes of these plants are based on the total feed requirements of eight coordinated firms that produce broilers and hatching eggs under contract along with such other activities as processing and hatching (see Appendix A). The capacity of the final activity stage in the firm, processing, establishes the capacities and volumes for all other activities. Processing capacities considered for this analysis are: 600, 1,200, 1,800, 2,400, 3,600, 5,000, 7,500 and 10,000 of 3.5 pound live birds per hour for eight hours a day, 260 days a year.[1]

The feed volume required of each mill is derived from several input-output relationships and accepted feeding practices.[2] Each mill manufactures a total of five basic formulations, two for broilers and three for breeders producing hatching eggs.[3] It is assumed that each mill produces a given quantity of each formulation each day. The total daily tonnage is manufactured in an eight-hour day and operations are conducted 260 days a year. Table 1 gives the tonnages manufactured per day by formulation and form.

Table 1. Volumes of Feed Manufactured per Day by Formulation and Form for Eight Model Mills

Formulation	Form	Mills							
		A	A′	B	B′	C	D	E	F
		(tons)							
Broiler									
Starter*	Crumbles	6.90	13.79	20.70	27.58	41.40	57.48	86.21	114.94
Finisher**	Crumbles	10.74	21.48	32.22	42.97	64.44	89.52	134.29	179.06
Breeder									
Starter†	Mash	.24	.48	.72	.96	1.44	1.99	2.99	3.99
Grower‡	Pellets	.56	1.12	1.67	2.24	3.35	4.65	6.98	9.30
Breeder§	Mash	2.46	4.93	7.39	9.86	14.79	20.54	30.81	41.08
Total tons per day		20.9	41.8	62.7	83.6	125.4	174.2	261.3	348.4
Total tons per year ‖		5,434	10,868	16,302	21,739	32,609	45,287	67,933	90,577

Coefficients Used
* 2.87 pounds per finished broiler
** 4.48 ponnds per finished broiler
† 6.0 pounds per breeder started
‡ 14.0 pounds per breeder started
§ 8.5 pounds per dozen hatching eggs needed.
‖ 260 day year

[1] These processing firm capacities were developed in G. B. Rogers and E. T. Bardwell's *Marketing New England Poultry: 2. Economies of Scale in Chicken Processing*, University of New Hampshire, Agricultural Experiment Station Bulletin 459, April 1959. However, in that report the processing firms were operated only 247 days per year.

[2] See Appendix A for the coefficients and method used in developing feed volumes manufactured by each model.

[3] See Appendix B for feed formulations.

The ingredients for the formulations are purchased separately by each mill from various sources. The only ingredients purchased as a premix are the drugs and some minerals used in minute quantities which are mixed with a carrier such as corn meal.

In the analysis of short-run average costs for each mill, the outputs of breeder feeds are held constant while broiler feed outputs are varied. The analysis is made in this manner since the production cycle of broilers is substantially shorter than for breeders.

Feed distribution costs are developed for six of the eight mills with operations at their specified capacities. These mills: A, B, C, D, E, and F distribute their total feed production in bulk form by truck direct to broiler and hatching egg-producing units in the surrounding area. The analysis of the distribution operation is based on a method developed in a previous report in this series.[4]

IV. Economies of Size in Feed Manufacturing

Feed Manufacturing Process

The feed manufacturing process of the model mills consists of several stages: receiving and storing ingredients, grinding, mixing, pelleting, and storing finished feeds. Figure 1 illustrates the flow of ingredients and feed through the stages for manufacturing broiler and breeder feeds.

1. *Receiving and Storing Ingredients* — The model mills rely exclusively on rail and truck delivery of ingredients. All grain and grain products originating in the Midwest and some minerals from other regions are delivered by railroad. Other ingredients such as meat and bone scrap, fishmeal, limestone, fat, and premixes are delivered by truck.

Dry ingredients are purchased in bulk or bags. Bulk ingredients are delivered by rail in either hopper or boxcars. Delivery by hopper cars which empty directly into a receiving sink is usually more efficient than box car delivery which requires more time and manual labor to unload. Bagged ingredients are delivered by truck or rail. In either method, the ingredients are unloaded by hand bag truck and stored in a warehouse.

Fat is delivered by heated tank truck in a liquid state and is pumped from the truck directly into heated storage tanks.

Bulk ingredients are conveyed from the receiving sink by a series of screw conveyors to a bucket elevator. The ingredients are elevated and gravity-fed through a turnhead into pipes leading directly to storage silos or bins or to horizontal screw conveyors that convey the ingredients to bins. In the receiving system there is a cleaning shoe to remove foreign material and magnets to remove tramp metal.

Shelled corn is stored in silos located adjacent to the mill building and rail siding. All other dry bulk ingredients are stored in a cluster of bins located in the mill building above the first floor. The capacity of the silos and bins is sufficient for ten days of mill operation at its designed capacity.

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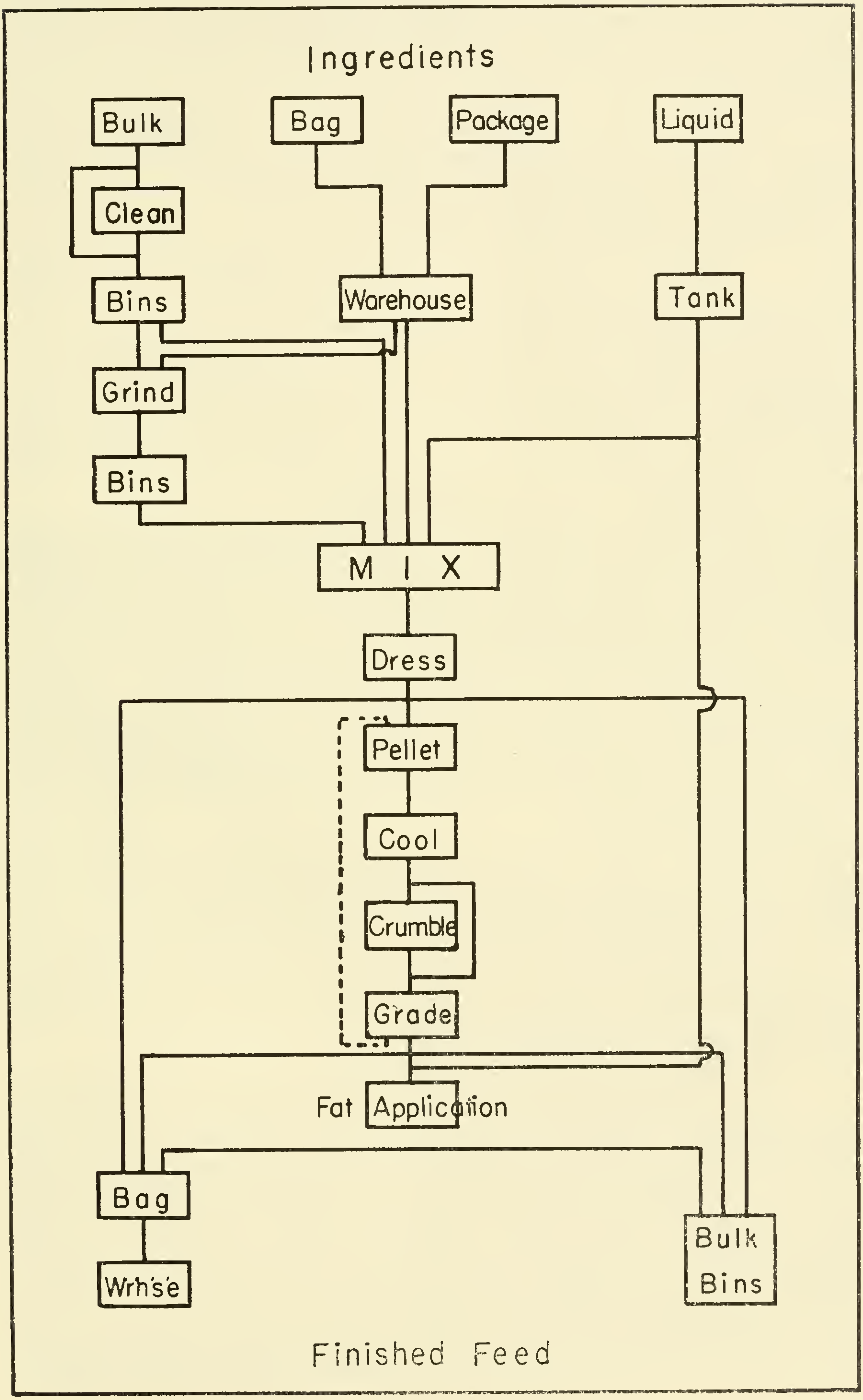
[4] W. F. Henry and C. R. Burbee, *Marketing New England Poultry: 5. Effects of Firm Size and Production Density on Broiler Assembly Costs*, University of New Hampshire Agricultural Experiment Station Bulletin 482, April 1964.

Figure 1. Schematic Flow of Ingredients from Receiving to Finished Mixed Feed



2. *Grinding* — Shelled corn and alfalfa pellets must be ground before being mixed with other ingredients. They are moved by screw conveyor or gravity to the feeders on the hammermills which are used in the model mills. The ground ingredients are then elevated into bins by a pneumatic system.

3. *Mixing* — The mixing stage consists of the following sequence of steps: moving ingredients to the mixing center, weighing, mixing, conditioning and conveying the batch to the next stage. A number of techniques exist for performing each step.

Bulk ingredients are moved from bins to the mixer by "weigh buggies" or conveyors. Weigh buggies are used in conjunction with vertical mixers in small size mills. The ingredients are weighed into the buggy and pushed to and dumped into the mixer sink.

The movement of bulk ingredients by conveyors is the practice in the large size mills since large quantities must be moved in short periods of time to keep mixers operating at capacity. Feeder screws move ingredients into a weigh hopper over the mixer. The quantities of the different ingredients fed into the hopper are controlled from a central panel either by an operator or by automatic devices.

The bagged ingredients are brought from the warehouse periodically. For each batch the bags are opened, weighed, and dumped into the mixer. Fat is pumped directly into the mixer, the amount being controlled manually or automatically. However, if the batch is to be pelleted, the full amount is not generally added at this stage, since a high proportion of fat in the mix makes pelleting extremely difficult.

A batch is mixed for a predetermined length of time to obtain a thorough blend of ingredients. The specific time required depends on the formulation and characteristics of the mixer. Generally, the mixing time is between eight and ten minutes in a vertical mixer and three and five minutes in a horizontal. The time is controlled manually or by an automatic timing device.

The mixed batch is moved from the vertical mixer by conveyor to a bucket elevator. Batches mixed in a horizontal mixer are dumped into a surge bin from which they are moved by conveyor to a bucket elevator. The use of a surge bin results in a substantial increase in mixer capacity.

The mixed batch is elevated and passed through a conditioner to remove any foreign material and to break up lumps. The conditioned batch is moved by self-cleaning chain drag conveyors to the finished mash bins or to holding bins for pelleting.

4. *Pelleting or Crumbling* — This stage consists of several different series of steps depending on the desired finished form of the feed and the formulation. These steps include pelleting, crumbling, and fat application. The pelleting stage starts with mash being fed into the pellet mill where it is conditioned by steam and forced through the pellet die. The continuous flow of hot pellets is gravity fed into a vertical cooler, and then conveyed directly to the grading shoe. If the desired output is crumbles, the cooled pellets are fed into a crumbler and then conveyed to the grading shoe. Fines and oversizes are screened off on the shoe and conveyed back to the pellet mill. Formulations in pellet or crumble form that require additional fat are routed through a fat applicator

where the fat is sprayed on. The finished pellets and crumbles are then conveyed to the holding bins.

5. *Storing Finished Feed* — The finished feeds are elevated to holding bins adjacent to the mill from which they are loaded into bulk trucks. Each model mill has storage capacity for one day's output of each formulation.

Special orders may be bagged. For this purpose, a small bagging scale and portable sewing head are included in each mill. Also, any of the ingredients in the bins may be drawn off and bagged individually.

Labor Inputs and Costs

The labor force consists of production workers who perform the several manufacturing processes and maintenance and repair personnel who are responsible for periodic maintenance and repairs on the equipment and other mill facilities. The man-equivalent estimates given include sufficient time for personal needs as well as limited housekeeping in the respective work areas.

1. *Receiving* — The labor input for receiving a given quantity of ingredients depends on a number of variables such as receiving technology, the form of the ingredients, the flowability of bulk ingredients, the inbound transportation and means of delivery. It is assumed that each mill purchases as many of the ingredients and as large a portion of its requirements in bulk as is possible within the limits of its storage capacity and the established minima required for bulk shipment. In addition, dry bulk ingredients shipped by rail are received in hopper cars if the model mill can regularly order amounts equal to or greater than the carload minimum. Other bulk ingredients are received in boxcars. The percentage of ingredients received, their form, and mode of transportation — including kind of car for rail movements — is given in Table 2.

Table 2. Form Specifications and Mode of Transportation for Ingredients Receipts of Eight Model Feed Mills

Mode and Form	Mills							
	A	A′	B	B′	C	D	E	F
	5,434*	10,868	16,302	21,739	32,609	45,287	67,933	90,577
	(percentage distribution)							
Rail:								
Hopper car — Bulk	78.5	78.5	78.5	88.8	88.8	88.8	88.8	88.8
Boxcar — Bulk		10.3	10.3	. .	...	. .		. .
Boxcar — Bagged	10.2	.	...	...	.	.3	.3	.3
Truck:								
Bulk	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Bagged	3.0	2.9	2.9	2.9	2.9	2.6	2.6	2.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

* Figures across are the tons manufactured annually.

Each mill is equipped with one or more bulk receiving systems rated at 2,000 bushel-per-hour. Hopper cars are unloaded at two different rates depending on the weight per cubic foot of the ingredients and flowability. The rate for corn and pellets is 60 tons per hour and for the soft or lighter ingredients 42 tons per hour. Boxcars are unloaded with a power shovel, also at two different rates: corn and pellets at 42 tons per hour and soft goods at 15 tons per hour. Bagged ingredients are unloaded from boxcars or trucks at a rate of six tons per man-hour.

The receiving crew sets the gates and controls but does not unload bulk ingredients, dry or liquid, when delivered by truck. The truck driver performs the unloading.

In addition to their unloading function, the receiving labor must position and open cars and clean them out after they are emptied. The crew must also clean up around the receiving sink. In the three larger mills which are equipped with automatic control devices for mixing, the receiving crew must move and dump bagged ingredients into small overhead working bins.

The labor requirements for receiving, reduced to a man-equivalent basis, vary from 0.2 in Mill A to 2.1 in Mill F. and are given in Table 3.

Table 3. Daily Labor Requirements and Labor Productivity for Production, Maintenance and Repair of Eight Model Feed Mills*

Operation	Mills							
	A 20.9**	A′ 41.8	B 62.7	B′ 83.6	C 125.4	D 174.2	E 261.3	F 348.4
	(man-equivalents)							
Labor Requirements								
Production								
Receiving	.2	.3	.4	.4	.6	1.2	1.6	2.1
Grinding	.2	.1	.1			...		
Mixing	1.0	2.0	2.6	2.0	2.0	1.0	1.0	1.0
Pelleting and Crumbling	.4	.6	1.0	1.0	1.0	1.0	1.0	1.0
Miscellaneous	.5	.7	.9	.6	.8	.6	.7	.9
Production Total	2.3	3.7	5.0	4.0	4.4	3.8	4.3	5.0
Maintenance and Repair Total	.3	.5	.7	.9	1.0	1.2	1.5	2.0
Total Labor Requirements	2.6	4.2	5.7	4.9	5.4	5.0	5.8	7.0
	(tons per man-hour)							
Labor Productivity								
Production Labor	1.1	1.4	1.6	2.6	3.6	5.7	7.6	8.7
Maintenance and Repair Labor	7.9	10.5	11.7	12.3	15.7	18.1	21.8	21.8
Combined	1.0	1.2	1.4	2.2	2.9	4.4	5.6	6.2
	(man-hours per ton)							
Combined	1.00	.80	.72	.46	.34	.23	.18	.16

* Per eight hour day.
** Figures across are tons manufactured daily.

2. *Grinding* — Generally, very little labor is needed for the grinding of ingredients, except to set the proper conveyors and gates, adjust the feeder control, change a screen, and clean the magnets occasionally.

Corn and alfalfa pellets, the two ingredients that require grinding before mixing, are in bulk form in all the model mills except A where alfalfa pellets are in bags. In this mill the operator must move, open. and dump the bagged pellets into a sink located above the hammermill.

A visual check of the grinding equipment when operating is required only in Mills A, A′ and B. The other mills have remote indicating devices to eliminate the periodic checks at the machines so no labor requirements are shown in Table 3 for them. Responsibility for performing this operation is generally given to the receiving or mixing stage personnel.

3. *Mixing* — The labor requirements for mixing depend upon the kind of mixer, materials-handling equipment, and the degree of automation used to control the process. Three equipment combinations are considered: (1) the vertical mixer with weigh buggies for weighing and moving bulk ingredients, (2) the horizontal mixer with feeder screws. weigh hopper, surge bin, and semi-automatic controls, and (3) the same equipment combination as (2) but with automatic controls.

The first equipment combination requires a substantial amount of labor since the ingredients are handled manually. Buggies are loaded with the required amount of each bulk ingredient, moved, and dumped into the empty vertical mixer. Bagged ingredients are moved from the warehouse. opened, weighed out, and dumped into the mixer sink. As the batch is mixed, the buggies are reloaded. The mixer operator adds any pre-mixes and controls the mix time. This equipment combination is used in model Mills A, A′ and B and the man-equivalents vary from 1.0 to 2.6.

The second equipment combination requires a two-man crew. The mixer operator controls the conveyors moving ingredients to the weigh hopper. the weighing, mix time, and the gates in the weigh hopper and mixer from a control panel. An assistant weighs out and adds bagged ingredients to each batch and performs other minor tasks such as cleaning up around the mixer sink. This equipment combination is utilized in model Mills B′ and C.

The third equipment combination is almost completely automated. The material handling, weighing, mix time, operation of gates, and number of batches are automatically controlled. The mixer operator sets the proper controls for each formulation run, adds premixes, and oversees the operation. With a motor control panel for operating equipment in other manufacturing stages, the mixer operator coordinates the manufacturing stages in the mill. This type of system is used in Mills D, E, and F.

The automatic system has two characteristics not found in the other systems: (1) only one operator is required over a relatively wide range of mixer capacities, and (2) all batches of a given formulation are practically identical because possibilities of human error are largely eliminated.

4. *Pelleting and Crumbling* — The labor requirements for the pelleting stage are essentially those needed for overseeing the operation.

The operator sets up the various pieces of equipment in the stage for each run and clears the system at the end of the run. During the run, the operator makes certain that there is sufficient steam pressure to condition the mash and that the pellet mill motors are operating at or close to their rated capacity. Occasionally, a plug-up occurs in a pellet mill which the operator must clear. Frequent checks of the finished pellets and crumbles are made to assure proper hardness and size, since the oversizes and fines must be recycled through the pellet mill. Excessive recycling can reduce the finished feed output per unit of time.

Table 3 gives the man-equivalents required for this stage which increase from 0.4 for Mill A, to 1.0 for Mills B through F.

5. *Miscellaneous* — There are a number of minor needs for labor in a mill. These include such jobs as bin supervision, housekeeping chores not performed by the other personnel, running errands, and filling in for other personnel that are absent. Man-equivalents needed for these activities are given in Table 3.

6. *Total Labor Inputs* — Table 3 gives the total man-equivalents for production labor and they range from 2.3 for Mill A to 5.0 for Mill F. However, the number of man-equivalents for production labor does not increase continuously with mill size and output because of major changes in manufacturing technology. In Mills A, A′ and B with their large labor input in the mixing stage, the total man-equivalents increase from 2.3 to 5.0. Mills B′ and C have fewer man-equivalents than B, 4.0 and 4.4, and the man-equivalents for Mills D, E, and F vary from 3.8 to 5.0. Labor productivity in production increases continuously over the range in mill sizes from 1.1 to 8.7 tons per man-hour.[5]

Man-equivalents for maintenance and repair, shown in Table 3. vary from 0.3 for Mill A to 2.0 for Mill F.

The total man-equivalents for production and maintenance increase from 2.6 for Mill A to 7.0 for Mill F. Productivity increases from 1.0 ton per man-hour to 6.2 for Mill F.

7. *Total Labor Costs* — Wages for production and maintenance labor vary considerably in New England. The wage rate adopted for production labor is $1.85 an hour plus 37 cents an hour in fringe benefits. Maintenance personnel receive a base wage of $2.00 an hour plus 40 cents an hour in fringe benefits.

Table 4 gives the annual dollar cost and the average labor cost per ton. As mill size and output are increased, the average cost per ton falls rapidly from Mill A through Mill D. Over the range of sizes considered, average cost for labor decreases from $2.26 to $.36 a ton. Decreases in production labor costs account for the greater share of the cost reduction. The average production labor cost decreases from $1.96 to $.26 a ton while the average maintenance labor cost decreases from $.30 to $.11 a ton.

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[5] Mills generally measure productivity in terms of man-hours per ton. For production labor, man-hours per ton decrease from 0.93 for Mill A to 0.11 for Mill F.

Table 4. Annual Production and Maintenance Labor Costs for Eight Model Feed Mills

Mill	Output per Year	Production		Maintenance		Total	
		Annual	Per Ton	Annual	Per Ton	Annual	Per Ton
	(tons)			(dollars)			
A	5,434	10,621	1.96	1,648	.30	12,269	2.26
A′	10,868	17,085	1.57	2,496	.23	19,581	1.80
B	16,302	23,088	1.42	3,344	.20	26,432	1.62
B′	21,739	18,470	.85	4,243	.20	22,713	1.04
C	32,609	20,316	.62	4,992	.15	25,308	.78
D	45,287	17,389	.38	5,715	.13	23,104	.51
E	67,933	19,856	.29	7,488	.11	27,344	.40
F	90,577	23,088	.26	9,984	.11	33,072	.36

Investment and Costs for Feed Manufacturing Facilities

Feed mill investment is the initial dollar purchase price of the durable inputs plus their installation costs. The durable inputs include such items as equipment, buildings and land.

1. *Equipment* — The kind, type and number of equipment items required for the model mills are synthesized from input-output relationships and manufacturer's equipment specifications.[6] Each mill has only the manufacturing equipment capacity to produce the five formulations in the specified forms and quantities within an eight-hour day.

Equipment is divided into seven categories, four of which are concerned with the primary manufacturing stages. The equipment cost presented in Table 5 is the delivered price with the equipment ready for installation. The total installation cost for each model is given in the second part of the table.

Equipment for receiving ingredients consists primarily of screw conveyors and bucket elevators for conveying ingredients from receiving points to storage bins in the mill. Mills A through D have a single bulk receiving system, and Mills E and F have two bulk receiving systems.

Grinding equipment includes screw conveyors to move shelled corn to the hammermills, and pneumatic conveyors for moving the ground materials into working bins.

The mixing equipment consists of conveyors, weigh buggies or hoppers, mixers, conditioners, and weighing and mixing control devices. A substantial change in this equipment is required with the shift from vertical mixers and weigh buggies in Mill B to mechanized conveyors, horizontal mixers, and simple weighing controls in Mill B′.

The pelleting and fat application stage requires the largest purchase price for equipment. This stage includes pellet mills, vertical coolers, crumblers, graders, fat application equipment, and conveyors. This stage accounts for approximately 45 percent of the total purchase price of equipment for each mill.

[6] See Appendix C for list of major equipment items for each model mill.

Table 5. Investment in Equipment by Mill Size for Eight Model Feed Mills

Item	A	A′	B	B′	C	D	E	F
	Mill Investment							
	5,434*	10,868	16,302	21,739	32,609	45,287	67,933	90,577
				(dollars)				
Equipment Purchase Price								
Receiving	4,110	4,468	6,177	8,514	10,365	10,651	30,340	37,031
Grinding	3,341	7,489	8,500	9,900	11,018	20,756	32,302	42,550
Mixing	8,084	10,561	12,576	34,445	35,302	46,544	50,142	60,136
Pelleting and Fat Application	15,969	27,728	38,699	57,624	62,092	82,071	124,836	158,283
Boiler	2,800	6,542	6,944	7,502	10,237	12,930	15,421	16,846
Office	440	592	708	1,020	1,280	1,444	1,708	2,156
Miscellaneous**	2,558	2,807	2,948	11,903	14,336	21,886	25,549	29,896
Total	37,302	60,187	76,552	130,908	144,630	196,282	280,298	346,898
Installation Cost†	15,325	25,430	33,325	56,146	71,515	96,531	133,713	161,558
Total Equipment Investment	52,627	85,617	109,877	187,054	216,145	292,813	414,011	508,456
Investment per ton of Annual Capacity	9.68	7.88	6.74	8.60	6.63	6.47	6.09	5.61

* Figures across are tons manufactured annually.

** Miscellaneous includes equipment not assignable to other categories such as a motor control panel, air compressor, fat pumping and straining equipment, and so on.

† Installation consists of wiring, mechanical installation, plumbing, and contingencies.

Boiler sizes for the model mills are based on estimated steam requirements, most of which are for pelleting, and vary from 20 h.p. for Mill A to 300 h.p. for Mill F.

Miscellaneous equipment includes items not assignable to any of the other categories, such as fat pumping and straining equipment, fat tanks, air compressors, remote motor control equipment, indicators for bins, and so on.

The investment in equipment includes not only the purchase price, but the installation charges for placing the equipment in operational status. These charges include costs for wiring, mechanical installation, and plumbing of fat, steam, and air lines throughout the mill. Installation costs are equivalent to between 40 and 50 percent of the equipment purchase price.

The total investment for equipment — purchase price plus installation — varies from $52,627 for Mill A to $508,456 for Mill F. Total investment, however, does not increase in proportion to increases in capacity. Investment per ton of annual capacity decreases from $9.68 for Mill A to $5.61 for Mill F.

2. *Mill Building* — A number of variables determine the construction cost of buildings. The major ones are: location with reference to transportation, topography and soil conditions of the site, type and size of building constructed, building materials used, and building code requirements. All model mills are assumed to be located on level sites in close proximity to a railroad and highway, with soil conditions satisfactory to support buildings with concrete footings, thus eliminating the need and expense of piling. All buildings are constructed with a steel frame and metal sheathing with no consideration given for future expansion.

The mill building is high in relation to its width and length. This type of construction permits use of gravity as much as possible to move materials. Much of the cubic volume of the mill building above the first floor consists of working bins for storage of ingredients.

The basement of each mill contains the receiving cleaning shoe, hammermills, fat tanks and pumps. In Mills B′ through F, the horizontal mixers, surge bins, vertical pellet coolers, and necessary conveyors are also located in the basement.

The first floor area holds various kinds of equipment depending on the size of the mill, technology adopted, and physical layout. For Mill A the vertical mixer, a unit that contains the pellet mill, cooler, crumbilizer, and grading shoe, and the fat application equipment are located on the first floor. In Mills A′ and B, only the vertical mixers, pellet coolers, and fat application equipment are located on the first floor. The first floor in Mills B′ through F holds the weighing and proportioning equipment, control centers, and pellet mills.

The upper floors of each mill are constructed next to the ingredient holding bin cluster. On these floors are located the mash feed conditioners for all mills, the pellet mills for Mills A′ and B, the crumbilizers and grading shoes for Mills A′ through F, and the fat application equipment for Mills B′ through F. Also on these floors are the bins for holding mash feed for pelleting and for holding pellets or crumbles for fat application.

The investment for the mill buildings complete with bins and fixtures installed ranges from $27,083 for Mill A to $272,091 for Mill F as shown in Table 6.

3. *Warehouse* — Each mill has a warehouse adjoining the mill building and adjacent to rail siding for receiving and storing bagged ingredients. Warehouses have a capacity equivalent to a ten-day requirement for bagged ingredients. Such buildings are steel framed with metal sheathing, constructed on a concrete pad. A cost rate of $6.00 per square foot was used to estimate the warehouse investment for each model mill.

4. *Office* — Each mill has office space for its administrative personnel and staff. The space required for each model is primarily a function of the number of personnel. Square footage requirements were estimated and a cost rate of $10.00 per square foot was used to determine the investment.

5. *Boiler House* — Substantial quantities of steam are required in feed manufacturing for making pellets, heating fat, and heating various sections of the mill. Each mill has one boiler to supply steam, and the boiler is located in a boiler house near the mill. The size of the boiler house is based on the dimensions of the boiler. A cost rate of $12.00 per square foot was used and includes building construction, accessories, and the stack.

6. *Grain Storage* — Each mill has capacity to store a ten-day requirement of shelled corn. The storage facilities range in capacity from 4,400 bushels to74,000 bushels, and consist of two or more round bolted steel tanks located next to the mill building and siding. The investment includes the tanks, fabricated steel supports, concrete pad and footings, ladders, walkways, and erection labor costs.

7. *Rail Siding* — Each mill requires a rail siding to spot and hold loaded cars of ingredients and empty cars waiting to be picked up. Since the railroads in New England generally do not provide private sidings at their expense, the cost is borne by the firm requiring the siding. The linear feet of siding was derived by estimating the likely maximum number of cars to be on track daily and assumed only one switch per day by the railroad. Mills A through D have a one-track siding while Mills E and F have a two-track siding. A rate of $11.00 per linear foot of track was used to derive the siding cost.

8. *Finished Feed Holding* — Each mill has a finished feed holding capacity equivalent to the daily output of each formulation in bulk form. This facility consists of square bolted steel bins erected on a steel frame over a weighing unit and is located next to the mill building. The investment for finished feed storage includes the cost of the bins, fabricated steel, erection, concrete supports, and the weighing unit. A platform motor truck scale to weigh the feed is used for Mills A through C, while a traveling weigh hopper over the trucks is used in Mills D, E, and F.

9. *Land* — Acreage requirements for the several mills were determined from physical layout drawings. The land requirement ranges from

.69 acres for Mill A to 2.68 acres for Mill F. Land was assigned a cost of $5.000 an acre.

10. *Total Investment* — Total investment for the mill sizes considered varies from $105,718 for Mill A to $923,397 for Mill F and are shown in Table 6. Approximately half of the investment is for equipment, and another quarter of it is for the mill building. The other categories account for the remaining quarter of the total investment.

The investment per ton of annual capacity decreases discontinuously over the range of mill sizes considered from a high of $19.46 for Mill A to a low of $10.20 for Mill F. A discontinuity occurs at Mill B′ where substantial changes in manufacturing technology are incorporated.

Ownership Costs

The initial cost of the durable input is spread over its productive life as depreciation. In addition, there are several other costs such as insurance, taxes, maintenance, and interest on investment. In the short run. these costs are fixed, since they do not vary with output. The level of ownership costs for each firm and each item is given in Table 7.

1. *Depreciation* — Depreciation is the cost of time, wear, and obsolescence. Rates for determining annual depreciation costs for the model firms were developed from information provided by mills and equipment manufacturers.

Obsolescence appeared to be the primary consideration in the establishment of the equipment depreciation rate. Firms indicated that 15 years is the maximum period for depreciating equipment, and most were using a shorter time period. All equipment for the model mills is depreciated by the straight-line method over a ten-year period, except the boiler which is depreciated over a 15-year period.

Firms indicated that mill buildings and other facilities are being depreciated over a longer time period. These facilities have not been rendered obsolete by the numerous technological developments in feed manufacturing equipment, and firms apparently do not expect obsolescence to become an important factor. For the model mills, all buildings, the grain storage, rail siding, and finished feed storage are depreciated by the straight-line method over a 25-year period.

2. *Interest on Investment* — A rate of six percent on the undepreciated balance or three percent on the initial investment in equipment, buildings, and other facilities was used to determine the annual cost for interest. In addition, a rate of six percent was used on the nondepreciating land investment.

3. *Taxes* — Property taxes vary considerably between communities as well as between states. In some New England states taxes may be levied on all property, while in others equipment may be exempted. Furthermore, communities in most states are allowed to establish the percentage of total value to be assessed.

The method of establishing the annual tax cost for the model mills was to apply a charge of $5.00 per hundred dollars on 50 percent of the

Table 6. Total Investment for Equipment, Buildings, and Other Facilities for Eight Model Feed Mills

Item	Mills							
	A	A′	B	B′	C	D	E	F
	5,434*	10,868	16,302	21,739	32,609	45,287	67,933	90,577
	(dollars)							
Equipment	52,627	85,617	109,877	187,054	216,145	292,813	414,011	508,456
Mill Building	27,083	48,008	61,942	109,338	132,076	169,650	223,091	272,091
Warehouse	2,520	1,740	2,520	3,300	3,960	5,760	8,200	10,200
Office	1,200	1,800	2,400	2,720	3,000	3,600	4,600	5,600
Boiler House	1,200	1,440	2,898	3,372	4,212	4,680	5,520	6,264
Grain Storage	6,241	8,392	10,165	14,572	20,973	28,103	40,108	52,253
Rail Siding	3,300	3,300	4,620	4,620	5,940	5,940	11,880	14,520
Finished Feed Holding (bulk)	8,103	10,532	15,909	13,868	21,868	29,197	34,877	42,649
Land	3,444	3,444	5,303	5,544	7,128	7,128	9,298	11,364
Total	105,718	164,273	215,634	349,388	416,302	546,876	751,585	923,397
Investment per ton of Annual Capacity	19.46	15.11	13.23	16.07	12.74	12.08	11.06	10.20

* Figures across are tons manufactured annually.

Table 7. Ownership Costs for Eight Model Feed Mills (Annual and Per Ton)

Item	Mills							
	A	A′	B	B′	C	D	E	F
	5,434*	10,868	16,302	21,739	32,609	45,287	67,933	90,577
	(dollars)							
Depreciation								
Equipment	5,169	8,344	10,756	18,455	21,273	28,850	40,887	50,284
Building and Facilities	1,986	3,008	4,018	6,272	7,721	9,877	13,131	16,143
Interest	3,275	5,032	6,628	10,648	12,703	16,620	22,826	28,043
Taxes	2,643	4,107	5,391	8,735	10,408	13,672	18,790	23,085
Insurance	990	1,575	2,057	3,392	4,032	5,338	7,304	8,975
Maintenance	1,023	1,608	2,103	3,438	4,092	5,397	7,423	9,120
Total	15,086	23,674	30,953	50,940	60,229	79,754	110,361	135,650
Cost per Ton	2.78	2.18	1.90	2.34	1.85	1.76	1.62	1.50

* Figures across are tons manufactured annually.

total mill investment. It is assumed that any county taxes incurred are included in the above rate.

4. *Insurance* — A number of factors affect the insurance rate for a feed manufacturing plant. Those having to do with the plant itself include building materials, type of electrical motors and type and quantity of installed fire prevention equipment. The location of the mill in relation to the location of the housing of the community's fire fighting equipment, and the quality and quantity of fire protection services provided by the community also affects the rate.

A rate of $1.00 per $100 of investment in buildings, equipment, and all facilities except the rail siding was used to estimate the annual cost of insurance. The same rate was also used to determine the insurance cost on the average quantity of ingredients being stored by the model mills.

5. *Maintenance* — Maintenance is a fixed cost for keeping buildings, equipment, and facilities in operating condition. An assigned rate of one percent of the initial investment was used to derive the annual maintenance costs.

6. *Total Ownership Costs* — The ownership cost per ton of annual capacity decreases from a high of $2.78 for Mill A to a low of $1.50 for Mill F. The cost per ton decreases with increasing size except at Mill B′ where a major change in manufacturing technology is incorporated.

Administrative and Supervisory Personnel Costs

A number of administrative functions must be performed in a feed mill including management, ingredient purchasing, nutrition and formulation analysis and quality control, typing, bookkeeping, and supervision of personnel. Requirements for these functions were derived from data provided by mills. The man-equivalents required for each function in the model mills are given in Table 8.

Table 8. Personnel Requirements per Day for Various Managerial Functions for Eight Model Feed Mills (Man-Equivalent Basis)

Personnel	Mills							
	A	A′	B	B′	C	D	E	F
	20.9*	41.8	62.7	83.6	125.4	174.2	261.3	348.4
Manager	.20	.35	.45	.55	.80	1.00	1.00	1.00
Assistant Manager	....	.	..	....	...	.	.35	.60
Formulation, Analysis and Quality Control	.10	.15	.15	.20	.25	.30	.35	.40
Foreman	.30	.45	.60	.70	1.00	1.00	1.00	1.00
Assistant Foreman	....	....	..	.	...	.20	.65	1.00
Bookkeeper	.15	.25	.35	.45	.65	.85	1.20	1.60
Typist-Records	.25	.40	.55	.70	.95	1.20	1.65	2.00
Steno-Bookkeeper	.10	.15	.15	.20	.25	.30	.35	.40

* Figures across are tons manufactured daily.

The annual cost increases from $7,800 for Mill A to $54,300 for Mill F. On a per ton basis, the cost decreases from a high of $1.44 for Mill A to $6.00 for Mill F. The administrative personnel costs are summarized in Table 9.

Utility Costs

Utility cost tiems include electricity, water, and fuel. The use data and cost information were obtained from mills, engineering estimates and secondary sources. Costs are shown in Table 10.

1. *Electricity* — Electricity costs for the model mills are determined by estimating the kilowatt hours consumed per day and applying a cost per kilowatt hour. Kilowatt hours are derived by determining the number of horsepower hours per day times a conversion factor of 0.746. Motors under 100 horsepower are further adjusted by a factor of 0.85 because of reduced efficiency in smaller horsepower motors. Pellet mill motors are treated differently since the above method did not provide satisfactory solutions in comparison to available data. These motors consume 70.4 kilowatt hours per machine-hour for each 100 horsepower of rating.

Observed mills in New England paid between 2.8 and 3.0 cents a kilowatt hour. A rate of 2.8 cents per KWH was adopted for the model mills. On a per ton basis, the cost decreases over the range of mill sizes considered from 60.3 cents for Mill A to 49.6 cents for Mill F.

2. *Water* — Water requirements for the model mills are based on boiler and employee consumption. An average of 34.5 pounds of water is used for each boiler horsepower-hour and 100 gallons per day per employee.

Water consumption varies from 29,500 cubic feet per year for Mill A to 341,000 cubic feet for Mill F. The cost, based on a local rate[7], decreases from 1.42 cents per ton of feed for Mill A to 0.67 cents for Mill F.

3. *Fuel* — Fuel requirements for the model mills are based on steam usage for heating certain areas of the mills, the fat, and for pelleting. Fuel consumption for heating space and fat is estimated at from 7.7 to 80.7 gallons per day depending on the mill size. Pelleting requires 1.86 gallons of fuel for each ton of feed pelleted. Total fuel consumption varies from 41.5 to 644.8 gallons per day for the range of mill sizes considered.

Each mill has a fuel storage capacity equivalent to approximately the requirements of ten operating days. On this basis, only Mills D, E, and F are able to receive truck-load quantities of fuel.

All mills use No. 5 fuel oil which is purchased locally. Mills purchasing less than truckload quantities are assumed to pay 10 cents per gallon while other mills receive a truckload quantity discount of one cent per gallon. On a per ton basis, the cost decreases moderately over the range of mill sizes considered from 20 cents a ton for Mill A to 17 cents a ton for Mill F.

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[7] $30.60 first 10,000 cu. ft. plus 17c/100 cu. ft. for all additional, semiannually.

Table 9. Administrative Personnel Costs for Eight Model Feed Mills (Annual and Per Ton)

Personnel	Mills							
	A	A′	B	B′	C	D	E	F
	5,434*	10,868	16,302	21,739	32,609	45,287	67,933	90,577
	(dollars)							
Manager**	2,500	4,375	5,625	6,875	10,000	12,500	12,500	12,500
Assistant Manager†	......	......	......	......	......	......	3,500	6,000
Formulation, Analysis and Quality Control‡	900	1,350	1,350	1,800	2,250	2,700	3,150	3,600
Foreman§	2,100	3,150	4,200	4,900	7,000	7,000	7,000	7,000
Assistant Foreman‖	......	......	......	......	......	1,200	3,900	6,000
Bookkeeper¶	975	1,625	2,275	2,925	4,225	5,525	7,800	10,400
Typist-Records††	875	1,400	1,925	2,450	3.325	4,200	5,775	7,000
Steno-Bookkeeper‡‡	450	675	675	900	1,125	1,350	1,575	1,800
Total	7,800	12,575	16,050	19,850	27,925	34,475	45,200	54,300
Cost per Ton	1.44	1.16	.98	.91	.86	.76	.66	.60

* Figures across are tons manufactured annually
** Salary rate of $12,500 annually
† Salary rate of $10,000 annually
‡ Salary rate of $ 9,000 annually
§ Salary rate of $ 7,000 annually
‖ Salary rate of $ 6,000 annually
¶ Salary rate of $ 6,500 annually
†† Salary rate of $ 3,500 annually
‡‡ Salary rate of $ 4,500 annually

Table 10. Utility Costs for Eight Model Feed Mills
(Annual and Per Ton)

Item	Mills							
	A	A′	B	B′	C	D	E	F
	5,434*	10,868	16,302	21,739	32,609	45,287	67,933	90,577
	(dollars)							
Electricity	3,276	6,196	9,048	11,487	18,884	23,491	35,474	44,946
Water	77	121	161	187	278	352	483	606
Fuel Oil	1,082	2,088	3,063	4,134	6,094	7,545	11,318	15,088
Total (Annual)	4,435	8,405	12,272	15,808	25,256	31,388	47,275	60,640
Per Ton	.82	.77	.75	.73	.77	.69	.70	.67

* Figures across are tons manufactured annually

Other Costs

In addition to costs for labor, ownership, administration, supervision and utilities, there is a set of other costs. These are discussed below and their levels on an annual and per ton basis are shown in Table 11.

1. *Equipment Repair and Service Costs* — Equipment repairs and services are the cost of replacement parts for equipment that has failed because of wear, and services hired by the mill to make certain repairs. Examples are the purchase of pellet mill dies and rolls, hammermill hammers, and the ribbon for a mixer. Services hired by a mill may be for rewinding a burned-out motor or making other repairs that mill personnel are not qualified to make.

Equipment repairs and services are a variable cost since they are a result of wear or use. Data for deriving an estimate of this cost for the model mills were obtained from the observed mills accounting records.

Figure 2 shows the relationship used to estimate repair and service costs. The relationship is between the percent of new equipment investment and the percent of capacity under which the mill is operated. At 100 percent of capacity, the annual repair cost is equivalent to 6.5 percent of the equipment investment.

Figure 2. Relationship between Percent of Mill Capacity Utilized and Percent of New Equipment Investment for Estimating the Annual Variable Equipment Repair Cost

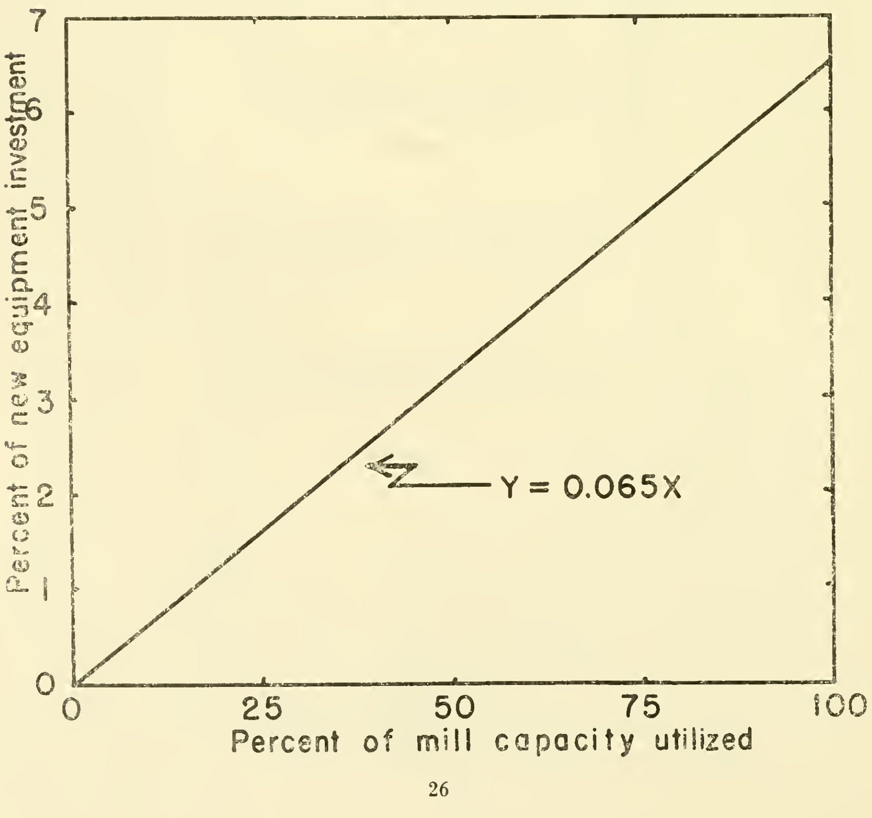


Table 11. Other Costs for Eight Model Feed Mills*
(Annual and Per Ton)

Mill	Output per Year	Equipment Repairs and Services		Mill Supplies		Miscellaneous Costs		Inventory Costs		Shrink	
		Annual	Per Ton	Annual	Per Ton	Annual	Per Ton	Annual	Per Ton	Annual	Per Ton
	(tons)					(dollars)					
A	5,434	3,421	.63	489	.09	1,822	.34	448	.08	907	.17
A′	10,868	5,565	.51	978	.09	3,110	.29	891	.08	1,810	.17
B	16,302	7,142	.44	1,467	.09	4,212	.26	1,336	.08	2,714	.17
B′	21,739	12,159	.56	1,957	.09	5,250	.24	1,781	.08	3,617	.17
C	32,609	14,049	.43	2,935	.09	6,829	.21	2,673	.08	5,429	.17
D	45,287	19,033	.42	4,076	.09	8,711	.19	3,712	.08	7,537	.17
E	67,933	26,911	.40	6,114	.09	12,017	.18	5,569	.08	11,310	.17
F	90,577	33,050	.36	8,152	.09	15,473	.17	7,425	.08	15,088	.17

* When operated at 100 percent of capacity

2. *Mill Supplies Costs* — Mill supplies include lubricants, housekeeping materials, and a number of other miscellaneous items and materials used in the mill. The cost of this category is based on accounting information provided by the observed mills.

3. *Miscellaneous Costs* — Miscellaneous costs include feed registration and analysis fees, audit and legal fees, travel expenses for managerial personnel, dues and subscription costs for various trade magazines and journals, office supplies, telephone, and other minor costs. Accounting data from the observed mills were used to develop estimates of these costs for the model mills.

4. *Inventory Costs* — Sufficient ingredients storage capacity has been built into each model mill to meet capacity needs for ten-day's operation. However, mills generally have smaller volumes of ingredients on hand. For purposes of this analysis, the average quantity of ingredients on hand was assumed to be equivalent to five days of capacity operation.

Two costs are associated with the ingredient inventory, insurance and interest on the investment. Insurance is generally purchased quarterly and the cost approximates $1.00 per $100 of ingredients. Interest on investment is a cost since mills must either use their own or borrow working capital to purchase ingredients. An interest rate of five percent is assumed for capital invested in the five-day supply of ingredients.

The inventory value is established by using the average 1963 delivered price of feed ingredients to New England points. Quantities of ingredients stored are derived from formulations and quantities of each formulation produced per day.

5. *Shrinkage Costs* — Mills experience some loss of ingredients during the handling, storing, and manufacturing stages. This loss is referred to as shrink. Shrink may be caused by loss of moisture in some ingredients which reduces their weight. Other losses occur during the unloading and handling in the mill.

Observed mills did not have precise data on shrink. Most indicated that losses probably ranged from one-quarter to three-quarters of one percent by weight.

A shrink rate of one-quarter of one percent is adopted for the model mills. A low rate is assumed since the model mills have equipment to minimize losses. Shrink was determined for all ingredients except fat and the premixes. Prices used are the average delivered ingredient price to New England points.

6. *Summary of Costs* — Table 12 is a summary of the several cost categories for the eight model mills operating at capacity. The costs are classified as either fixed or variable. Fixed costs include ownership, administrative and supervisory, and miscellaneous. All other costs are variable.

Three of the nine major cost categories account for between two-thirds and three-quarters of the total cost per ton. In Mills A through C, these major costs are ownership, labor, and administrative and supervisory. In Mills D, E and F, the three major costs are ownership, utilities, and administrative and supervisory.

Table 12. Summary of Feed Manufacturing Costs for Operating Eight Model Feed Mills at Capacity

Item	Mills							
	A 5,434*	A' 10,868	B 16,302	B' 21,739	C 32,609	D 45,287	E 67,933	F 90,577
				(dollars per ton)				
Labor								
Production	1.96	1.57	1.42	.85	.62	.38	.29	.26
Maintenance	.30	.23	.20	.20	.15	.13	.11	.11
Utilities	.82	.77	.75	.73	.77	.69	.70	.67
Equipment Repairs and Services	.63	.51	.44	.56	.43	.42	.40	.36
Mill Supplies	.09	.09	.09	.09	.09	.09	.09	.09
Inventory Costs	.08	.08	.08	.08	.08	.08	.08	.08
Shrink	.17	.17	.17	.17	.17	.17	.17	.17
Total Variable Cost**	4.04	3.42	3.15	2.67	2.32	1.96	1.83	1.74
Ownership Costs	2.78	2.18	1.90	2.34	1.85	1.76	1.62	1.50
Administrative and Supervisory	1.44	1.16	.98	.91	86	.76	.66	.60
Miscellaneous	.34	.29	.26	.24	.21	.19	.18	.17
Total Fixed Cost**	4.55	3.62	3.14	3.50	2.91	2.71	2.47	2.27
Total Cost	8.59	7.05	6.29	6.17	5.23	4.68	4.30	4.01

* Figures across are tons manufactured annually
** Due to rounding these figures may not add

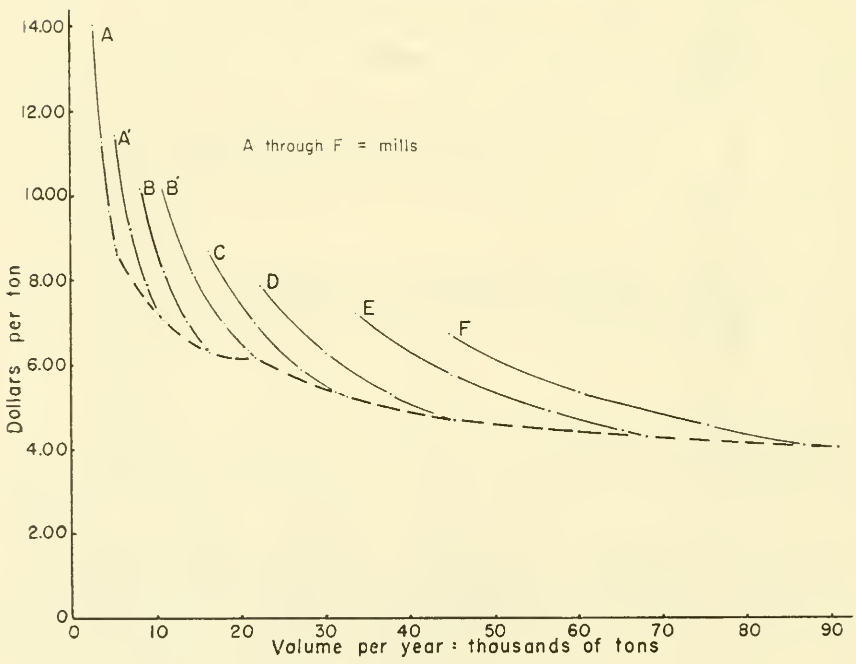
Economies of Size

Two major cost relationships are of concern to feed mill management: one has to do with the relationship of the size of the mill to average cost of manufacturing, the other with the relationship of short-run changes in output to average costs. The first type, often called long-run average cost, is represented by the solid line in Figure 3. That line and Table 12 show that as the size of the mill increases, the average cost per ton at 100 percent of capacity decreases from \$8.59 for Mill A to \$4.01 for Mill F.

Three categories account for 87 percent of the economies. Labor is the most important and accounts for 41 percent of the total economies of size. The ownership and administrative personnel costs are the second and third major source of economies. Ownership accounts for 28 percent and administrative for 18 percent of the total economies. Three other categories, utilities, equipment repairs and services, and miscellaneous, account for the remaining 13 percent of the economies.

Examination of Figure 3 indicates that further economies of size might exist for larger size operations than considered here. The size curve has not become parellel with the output axis since each successively larger mill model has a lower average cost per ton when operated at its designed capacity. Further economies may be possible with equipment possessing greater capacity and by using other technologies.

Figure 3. Short-Run Cost Curves and Economies of Size Curve for Eight Model Feed Manufacturing Mills



Short-Run Average Costs

Output of mills often drops over short periods because of seasonal fluctuations in broiler production. During such periods of reduced output the capacities of mills do not change. However, production costs per ton generally rise because fixed costs of mill ownership and management stay the same, and efficiency in the use of labor is impaired. The effects of such short-run changes in output on average cost for each size of mill are shown by the dotted curves in Figure 3 and are given in Appendix Tables D-1 through D-4. Costs were determined for each mill with output of broiler feed at 40, 60, 80, 95 and 100 percent of capacity. Breeder feed tonnage is held constant because the production cycle for breeders is not affected by short-run changes in broiler production.

V. Cost of Bulk Feed Distribution

New England feed manufacturers have two methods for distributing bulk feed to farms. Mills located in the feed consuming areas rely on direct mill-to-farm shipments by truck. Other firms with mills located substantial distances from feed consuming areas use railroads for the movement of feed to distributing centers. The feed is stored locally and transhipped to farms by truck.

The trend is toward increased direct mill-to-farm distribution. Mills are constructed at strategic locations in major feed consuming areas and bulk distribution is usually confined to a 50 to 70-mile radius.

The purpose of this section is to develop the costs of direct mill-to-farm bulk feed distribution. Costs are determined for six of the eight model feed mills discussed in the previous section for each of three levels of poultry production density.

Procedure

The procedure involves establishing and standardizing a number of different factors which affect distribution costs. These factors include the number and volume of distribution operations, poultry production densities, location and distance from the mill of the poultry production units, technology and technical input-output relationships for determining total inputs by each firm. A schedule of the number and size of daily deliveries is developed from a number of assumptions and conditions pertaining to the conduct of the operation, feeding practices, feed input-output relationships, and flock sizes. The number of trucks and drivers required are calculated for each firm size and density level, and standardized costs are applied to the results. In addition, inputs and costs are estimated for other requirements such as administrative personnel, garage, and so on. With all costs determined, analyses are made to determine how changes in firm size and production density affect feed distribution costs and investment.

1. *Number and Size of Firms, Production Densities, and Location of Poultry Production Units*[1] — Six feed manufacturing mills vary-

[1] This section adapted from W. F. Henry and C. R. Burbee, *op. cit.*

ing in daily output from 20.90 to 348.37 tons establish the respective volumes for the six distribution firms studied. The six mill models are equivalent in output to models A, B, C, D, E, and F in the previous section. These mills supply broiler and breeder feed to coordinated organizations producing from 1.25 to 20.80 million broilers a year.[2] For purposes of identification, each feed distribution firm has the same letter designation as the mill it serves. Table 13 gives the volumes of feed distributed by the six firms.

Three levels of poultry production density are considered.[3] These densities expressed in terms of feed are equivalent to distributing 1.31. 6.55. and 32.73 tons per square mile per year.

The broiler producing area of each firm is a circle with the feed mill located at the center and production units scattered uniformly throughout. The size of the area is a function of firm volume and production density. For each firm, the producing area has a specific number of square miles and radius for each density level. The sizes of the areas and radii are given for each firm in Table 13.

Increasing the volume distributed with density held constant requires a proportionate increase in area. This is illustrated in Figure 4. The circular production area for each of the six firms are superimposed in order of size. The result is a circle enclosed by five bands. The basic or primary circle represents the poultry producing area for Firm A. Moving out from the center, each distribution area in effect adds a band representing the area that must be added with each successive increase in firm size and output. This geometric arrangement provides the framework for investigating feed distribution by the added cost approach. The tons of feed delivered into each band annually are given in Table 13.

Poultry production is assumed to be uniformly scattered throughout the area of each band in producing units. The average of the locations of these units is on a line of determinable radial distance that divides a band into two equal parts with respect to area. The radial or airline distance from the mill location to the line of average location in each band for each density level is derived and given in Table 13.

The relationship between radial distance and road mileage depends on the road net-work concentration in the producing area. For purposes of determining this relationship, Concord, New Hampshire, was selected as the center. The radial distance and road mileage to a number of ran-

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[2] See Appendix Table A-1.

[3] Broiler production densities are 1,052, 5,263, and 26,216 pounds of finished 3.5-pound live broilers produced per square mile per year. Hatching eggs are produced at equivalent density levels. Three such density levels were used in previous reports in this series: for broiler production, *Ibid.*; for hatching eggs, C. R. Burbee and E. T. Bardwell, *Marketing New England Poultry: 6. Economies of Scale in Hatching and Cost of Distributing Broiler Chicks,* University of New Hampshire, Agricultural Experiment Station Bulletin 483, May 1964; and for all spatial activities, C. R. Burbee, E. T. Bardwell, and W. F. Henry, *Marketing New England Poultry: 8. Effects of Firm Size and Production Density on Spatial Costs for an Integrated Broiler Marketing Firm,* University of New Hampshire, Agricultural Experiment Station Bulletin 485, November 1964. However, in those three reports the work year was set at 247 days, rather than the 260 days used in this report, so production density levels were lower on a yearly basis in the previous three reports.

Table 13. Volume, Area, and Distance Specifications and Functions Associated with Three Density Levels of Feed Usage.

Firm	Annual Volume*	Size of Area	Radius of Area	Supply Band	Annual Volume Each Band**	Radial Distance to Average Location	Road Mileage to Average Location†	Travel Time Round Trip to Average Location‡
	(tons)	(thous. sq. mi.)	(miles)		(tons)	(miles)	(miles)	(hours)
1.31 Ton Density Level								
A	5,434	4.2	36.4	I	5,434	25.7	33.2	1.90
B	16,302	12.5	63.0	II	10,868	51.4	67.9	3.44
C	32,609	24.9	89.0	III	16,307	77.1	102.6	4.97
D	45,287	34.6	104.9	IV	12,678	97.3	129.9	6.18
E	67,933	51.9	128.5	V	22,646	117.3	156.9	7.37
F	90,577	69.2	148.4	VI	22,644	138.8	186.0	8.66
6.55 Ton Density Level								
A	5,434	.8	16.3	I	5,434	11.5	14.0	1.05
B	16,302	2.5	28.2	II	10,868	23.0	29.5	1.74
C	32,609	5.0	39.8	III	16,307	34.5	45.1	2.43
D	45,287	6.9	46.9	IV	12,678	43.5	57.2	2.96
E	67,933	10.4	57.5	V	22,646	52.5	69.3	3.50
F	90,577	13.8	66.4	VI	22,644	62.1	83.7	4.13
32.73 Ton Density Level								
A	5,434	.2	7.3	I	5,434	5.1	6.2	.71
B	16,302	.5	12.6	II	10,868	10.3	12.4	.98
C	32,609	1.0	17.8	III	16,307	15.4	19.3	1.29
D	45,287	1.4	21.0	IV	12,678	19.5	24.8	1.53
E	67,933	2.1	25.7	V	22,646	23.5	30.2	1.77
F	90,577	2.8	29.7	VI	22,644	27.7	35.9	2.02

* Annual volume for each firm is the cumulative volume of the last band added to the supply area and the volumes of all previous bands.

** The volumes for Firm A and Supply Band I are the same.

† As determined by the equations:

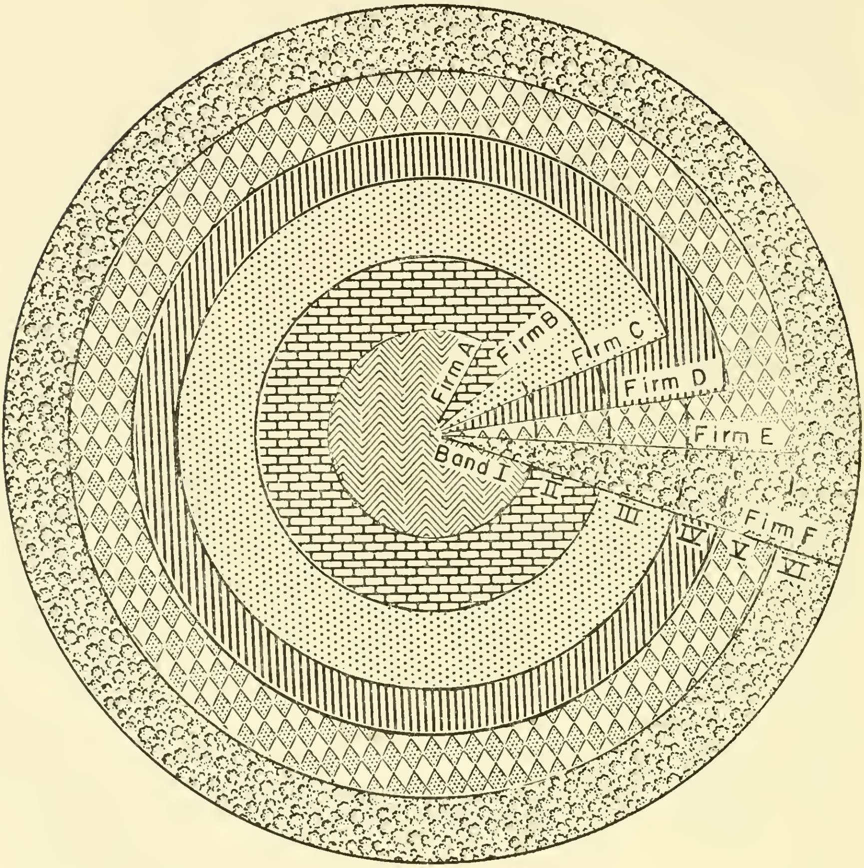
when radial distance is in excess of 10 miles $RM = -1.534 + 1.351 R$

when radial distance is 10 miles or less $RM = 1.196 R$

when RM is the road miles and R is the radial distance in miles.

‡ As determined by the equation: $hours = 0.435 + 0.0221 RT$ when RT is the round trip road miles.

Figure 4. Relationship between Poultry Producing Bands and Firm Area with Density Constant



domly selected points around Concord were used to derive an equation. The equation is:

$$RM = -1.534 + 1.351R$$

where RM is the road mileage and R the radial distance. This equation has a negative intercept value as a result of the extreme concentration of roads in the immediate vicinity of the center. Because of the negative intercept value, the above equation is used to derive all road mileages for radial distances in excess of ten miles.

For radial distances of ten miles or less the following equation is used:

$$RM = 1.196R$$

where RM is the road mileage and R is the radial distance. Table 13 gives the radial distance and corresponding road mileage from the center or mill location to the average location in each of the bands at each density level.

Bulk Feed Distribution Operation

1. *Characteristics* — The bulk feed distribution operation consists of loading out trucks at a mill, travel to and unloading at one or more production units, and returning to the mill for another load. The operation is under the supervision of a dispatcher who prepares the daily delivery order schedule and assigns orders for delivery to the drivers. There is also an administrative staff for purposes of decision making and maintaining various records. The bulk feed distribution operation is closely coordinated with the feed manufacturing operation.

2. *Technical Relationships* — Before solving for the number of trucks and drivers needed by each firm to distribute feed at each density level, the technology and related physical input-output relationships must be defined. It is assumed that each firm uses 12-ton capacity trucks with four equal size compartments and a pneumatic unloading system.

Each trip includes three kinds of operations. These are (a) loading at the mill, (b) travel to production units and return to the mill, and (c) unloading at the production units. The data needed to develop relationships were collected from firms utilizing the 12-ton capacity truck.

(a) The loading stage commences when the driver arrives at the mill. The driver obtains the delivery orders for the trip from the dispatcher and positions the truck under the finished feed holding bins. The driver loads the quantities shown on the order into the compartments and records the net weight on each order slip. In no case does the driver put part or all of two orders for the same or different formulations in the same compartment.

The equation relating time to the tons loaded is:

$$H_1 = 0.133 + 0.0167T$$

where H_1 is the hours to load T tons of feed.

(b) The travel period is the hours for the round trip from the mill to production units and return. During this period, the driver may take some time for personal needs such as a coffee break or lunch. The equation for this stage is:

$$H_2 = 0.435 + 0.0221RT$$

where H_2 is the hours of travel for the round trip of RT miles. This equation is used to calculate the travel time from the mill to the average location in each band and return to the mill at each density level as shown in Table 13.

(c) The unloading time is the period required to position the truck at the poultry house, attach a pipe from the blower unit to a pipe leading to a bulk bin, start the blower unit to unload the feed. Once the feed is unloaded, the set-up procedure is reversed. The equation relating time to the tons unloaded is:

$$H_3 = 0.0702 + 0.1146T$$

whereH_3 is the hours to unload T tons.

Feed Distribution Model

1. *Conditions and Assumptions* — A number of assumptions and conditions pertinent to the analysis follow:

(a) "Day old" broiler and breeder chicks are placed continually in specified quantities throughout the area.

(b) The production period for breeders and broilers is not varied in length.

(c) Seasonal variations in feed conversion are ignored thus keeping the quantity of feed produced and distributed each day by each firm constant.

(d) Feed deliveries during any one day are planned to be primarily confined to an erea segment equivalent to one-fifth of the poultry producing area, the daily requirement set by a 5-day week. This arrangement reduces to a minimum the intraband travel. The truck proceeds to one or more units and returns by the same route.

(e) Broiler flock sizes of a single age group are 4,800 birds in Band I, 9,600 in Band II, 14,400 in Band III, 11,200 in Band IV, and 20,000 in Bands V and VI.

(f) Mature breeder flock sizes consist of 2,595 birds in Band I, 5,190 in Band II, 7,785 in Band III, 6,055 in Band IV, and 5,405 in Bands V and VI. Birds in these flocks consist of several age groups.

(g) Replacement flock sizes average 1,343 birds in Band I. 2.686 in Band II, 4,029 in Band III, 3,364 in Band IV, and 3,014 in Bands V and VI.

(h) The work day for each truck and driver cannot exceed ten consecutive hours. This assumption prevents the shifting of the effects of an increasing producing area onto drivers and trucks through use of overtime payments and increased truck utilization.

(i) Each truck and driver can undertake only those trips that can be completed in ten hours or less. This means that a truck and driver cannot initiate a trip one day and return the next.

(j) The quantity of feed delivered to a production unit plus the quantity in bins at the production unit is restricted to the amount that will be consumed in the following two weeks. The purpose of this assumption is to simulate as closely as possible prevailing practices.

(k) Only the quantities of each feed formulation as prescribed by the adopted feeding practices are delivered to each production unit.

2. *Number and Size of Daily Delivery Orders* — The feed tonnage delivered to a production unit is a function of the projected feed consumption for the following two weeks, as determined by the size and age of flock and the compartment size of the truck. Considering these factors simultaneously with the intent of utilizing the maximum hauling capacity of the truck on each trip, the number and size of orders are established for each of the six bands.

Table 14 gives the daily delivery schedule for each band by formulation. tonnage, and the number of truck body compartments needed to transport each order. Many of these orders are in units of or multiples of three tons which provides for maximum use of feed compartments. Orders for formulations in other tonnage units result from either the assumption concerning the amount of feed allowed to be in storage at a production unit or the balance needed to finish feeding a particular formulation.

Table 14. Number and Size of Feed Orders by Formulation Delivered into Each Band Each Day

Band	No. Orders per Day	Formulation: Broiler Starter					Broiler Finisher				Breeder Starter		Breeder Grower		Breeder "Breeder"		Total
I	8	1.25 (1)	3.00 (1)	2.65 (1)			6.00 (2)	4.74 (2)			.24 (1)		.56 (1)		2.46 (1)		20.90 (10)
II	9	2.50 (1)	6.00 (2)	3.00 (1)	2.30 (1)		12.00 (4)	9.49 (4)			.48 (1)		1.11 (1)		4.93 (2)		41.81 (17)
III	11	3.00 (1)	3.00 (1)	6.00 (2)	3.00 (1)	5.69 (2)	12.00 (4)	9.00 (3)	11.23 (4)		.72 (1)		1.68 (1)		7.40 (3)		62.72 (23)
IV	10	2.91 (1)	6.00 (2)	3.00 (1)	4.18 (2)		12.00 (4)	6.00 (2)	7.07 (3)		.55 (1)		1.30 (1)		5.75 (2)		48.76 (19)
V	15	3.00 (1)	3.00 (1)	6.00 (2)	9.00 (3)	7.72 (3)	12.00 (4)	12.00 (4)	12.00 (4)	8.77 (3)	.50 (1)	.50 (1)	1.16 (1)	1.16 (1)	5.14 (2)	5.14 (2)	87.09 (33)
VI	15	3.00 (1)	3.00 (1)	6.00 (2)	9.00 (3)	7.72 (3)	12.00 (4)	12.00 (4)	12.00 (4)	8.77 (3)	.50 (1)	.50 (1)	1.16 (1)	1.16 (1)	5.14 (2)	5.14 (2)	87.09 (33)

Figures in parentheses are the number of truck compartments required to hold the indicated tonnages.

3. *Truck and Driver Requirements* — The daily schedule of delivery orders for each band and the three technical input-output relationships for determining the time required to make a trip provides the means for deriving the number of trucks, drivers, man-hours, and miles of travel for each firm at each production density level. In all instances the number of drivers is the same as the number of trucks. These requirements are developed on a daily basis, but are readily convertible to an annual basis since the roster is typical for every day of operations. The relationships are assumed to hold over any given time period.

The requirements are calculated with the objective of maximizing the tons hauled per trip and the number of trips by each truck and driver in the allowed ten-hour work day.

The number of trips and tons delivered a day by a truck and driver of a given firm depends on the distance between the mill and the average location of units in the bands, or the production density. As density is increased, the mileage and travel time between origin and destinations is reduced, allowing a truck to make more trips. Thus a firm with a given volume to distribute is able to reduce the number of trucks and drivers. However, as firm size and volume is increased with density constant, the added trips increase in length and travel time, thereby reducing the average number of trips and tons hauled per day per truck.

The requirements of each firm at each density level are summarized in Table 15. At the lowest density level considered, 1.31 tons distributed per square mile per year, with the 10-hour work day restriction on the use of trucks and drivers, it is not possible for firm F to distribute into Band VI, thus making the entire operation of firm F an impossibility. Most of the trucks and drivers can complete only one or two trips and average between 200 and 280 miles a day. The tonnage distributed per truck varies between 12.4 and 20.9 a day.

Increasing density from 1.31 to 6.55 tons distributed per square mile per year allows all six firms to operate and reduces the number of trucks and drivers needed for all firms except Firm A. Trucks and drivers can complete from two to three trips and average between 84 and 235 miles a day. Each truck delivers from 20.4 to 25.1 tons a day.

At the highest density level considered, 32.73 tons per square mile per year, trucks and drivers are further reduced in number. At this density level, trucks and drivers complete from three to four trips and travel from 37 to 156 miles a day. Each truck delivers from 20.9 to 34.8 tons a day.

Investment

Trucks are the largest investment item for the feed distribution firm. However, additional investment is needed for a garage in which to house the trucks, office space for the administrative personnel, and office equipment.

1. *Truck* — The type of bulk delivery truck considered here has a cost of $19,500. The tandem-axle, heavy-duty chassis costs $13,000, and the bulk feed tank with the pneumatic unloading equipment costs $6,500. These prices include all the extra equipment required by safety rules and regulations.

Table 15. Number of Trucks and Drivers, Miles and Man-Hours per Day and per Ton for Six Firms Distributing Feed at Three Density Levels

Firm	Tons per Day	Number of Trucks	Miles per Day	Miles per Ton	Number of Drivers	Man-Hours per Day*	Man-Hours per Ton
			1.31 Ton Density Level				
A	20.9	1	199	9.53	1	9.34	.45
B	62.7	4	812	12.95	4	31.32	.50
C	125.4	8	1,974	15.74	8	69.33	.55
D	174.2	13	3,272	18.79	13	107.92	.62
E	261.3	21	5,837	22.34	21	181.83	.70
F	348.4	**					
			6.55 Ton Density Lovel				
A	20.9	1	84	4.02	1	6.85	.33
B	62.7	3	351	5.61	3	21.14	.34
C	125.4	5	861	6.88	5	44.82	.36
D	174.2	7	1,433	8.25	7	67.42	.39
E	261.3	12	2,566	9.80	12	109.47	.42
F	348.4	17	3,989	11.48	17	157.98	.45
			32.73 Ton Density Level				
A	20.9	1	37	1.78	1	5.83	.28
B	62.7	2	149	2.37	2	16.67	.27
C	125.4	4	368	2.93	4	33.88	.27
D	174.2	5	616	3.54	5	49.28	.28
E	261.3	8	1,110	4.25	8	77.24	.30
F	348.4	11	1,719	4.94	11	107.75	.31

* Day limited to 10 hours.
** Firm F cannot distribute at this density level.

For any given firm, the truck investment varies according to density in the producing area. A firm distributing a given quantity of feed generally needs more trucks at low density levels than at higher density levels.

At the lowest density levels considered, total truck investment varies from $19,500 for Firm A to $409,500 for Firm E. The investment per ton distributed annually increases from $3.59 for Firm A to $6.03 for Firm E. At the intermediate density level, investment varies from $19,500 for Firm A to $331,500 for Firm F. Investment per ton decreases from $3.59 for Firms A and B to a low of $2.99 for Firm C and increases to $3.66 for Firm F. This five-fold increase in density results in no reduction in truck investment for Firm A to a reduction of $175,500 for Firm E.

Increasing density to the maximum considered in this study results in further reductions in truck investment for all Firms but A. Firm F realizes the largest reduction, $117,000. Investment per ton at this density level decreases with increasing firm size and volume from $3.59 for Firm A to a low of $2.15 for Firm D and increases to $2.37 for Firm F. Total investment for trucks is given in Table 16.

2. *Garage* — It is assumed that each firm has sufficient garage space to house all its trucks. According to engineering estimates, garage space

requires an investment of $1,200 for each truck. However, the requirement for garage space varies according to the number of trucks needed to distribute at each density level. Total garage investment is given in Table 16 for each firm at each of the three density levels.

3. *Office and Office Equipment* — Office space and equipment are two minor investment items. Estimates are based on the number of administrative and clerical personnel and their equipment needs. The investment by firms is given in Table 16.

4. *Total Investment* — Total investment for all the firms except Firm A varies with changes in density level. As density is increased, substantial reductions in capital outlay for trucks and garage space becomes apparent. The total investment for the six distribution firms with density at each of the three levels considered is shown in Table 16.

Table 16. Investment for Trucks, Garage, Office and Office Equipment for Six Firms at Each of Three Density Levels

	Firms					
	A	B	C	D	E	F
	5,434*	16,302	32,609	45,287	67,933	90,577
			(dollars)			
			1.31 Ton Density Level			
Trucks**	19,500	78,000	156,000	253,500	409,500	‡
Garage†	1,200	4,800	9,600	15,600	25,200	
Office	300	600	750	900	1,150	
Office Equipment	110	177	320	361	427	
Total	21,110	83,577	166,670	270,361	436,277	
Investment per Ton	3.88	5.13	5.11	5.97	6.42	
			6.55 Ton Density Level			
Trucks**	19,500	58,500	97,500	136,500	234,000	331,500
Garage†	1,200	3,600	6,000	8,400	14,400	20,400
Office	300	600	750	900	1,150	1,400
Office Equipment	110	177	320	361	427	539
Total	21,110	62,877	104,570	146,161	249,977	353,839
Investment per Ton	3.88	3.86	3.21	3.23	3.68	3.91
			32.73 Ton Density Level			
Trucks**	19,500	39,000	78,000	97,500	156,000	214,500
Garage†	1,200	2,400	4,800	6,000	9,600	13,200
Office	300	600	750	900	1,150	1,400
Office Equipment	110	177	320	361	427	539
Total	21,110	42,177	83,870	104,761	167,177	229,639
Investment per Ton	3.88	2.59	2.57	2.31	2.46	3.91

* Figures across are tons delivered annually.
** Truck investment is $19,500 each.
† Garage stalls at $1,200 for each truck.
‡ Firm F cannot operate at this density level.

Feed Distribution Costs

Application of standardized costs to the several input-output quantities establishes the relationship between cost and the volume of feed distributed. The costs used are appropriate to New England conditions. The distribution costs are classified as truck, driver, administrative personnel and miscellaneous.

1. *Truck Costs* — A function relating cost to distance expressed in miles was developed from technical data provided by several feed distributing firms and equipment manufacturers. Truck costs include a number of items which are either fixed or variable costs or a combination of both. The fixed costs include truck registration, insurance, license and anti-freeze. The variable costs associated with use are gas, oil, and lubrication. Those costs associated with use and ownership are depreciation, interest on investment, maintenance and repair, taxes, and tires.

A cost was derived for each truck-cost item for each of several annual mileage levels, and the costs were summed to determine an annual total operating cost for each respective mileage level. A relationship between the two was derived by the least-squares method, and the equation is:

$$AC = 3{,}157.5N + 0.18309M$$

where AC is the total annual operating cost in dollars, N is the total number of trucks, and M is the miles of travel per year. The annual fixed cost per truck is $3,157.50 and the variable cost is 18.3 cents per mile. Figure 5 illustrates the relationship. The equation is used to determine the annual cost of operating the trucks for each firm size at each of the three density levels. These costs and the average cost per ton are given in Table 17.

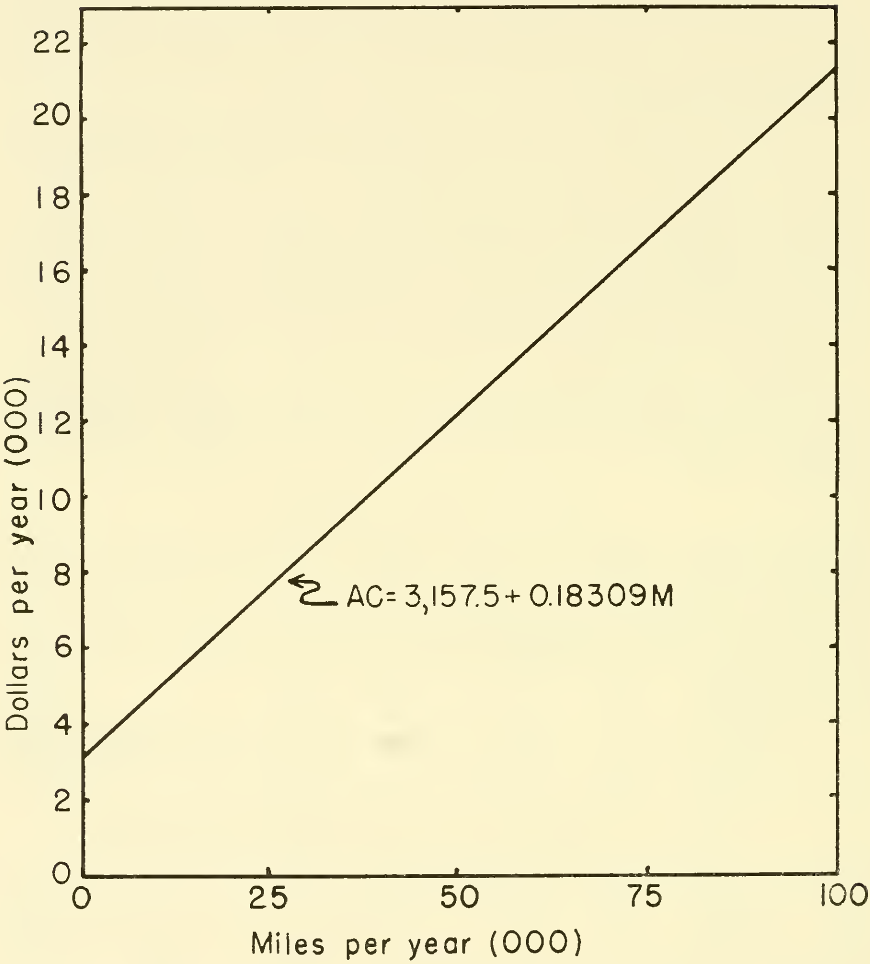
2. *Driver Costs* — Truck driver wage rates vary considerably in the New England region. Generally, rates become progressively lower, the

Table 17. Truck Costs for Six Firms Distributing Feed at Three Density Levels

Density	Firm A 5,434*	Firm B 16,302	Firm C 32,609	Firm D 45,287	Firm E 67,933	Firm F 90,577
(tons per square mile per year)			(annual cost in dollars)			
1.31	12,629	51,284	119.229	196,806	344,170	**
6.55	7,156	26,182	56,774	90,319	160,040	243,568
32.73	4,919	13,408	30,148	45,112	78,100	116,563
			(dollars per ton)			
1.31	2.32	3.15	3.66	4.35	5.07	**
6.55	1.32	1.61	1.74	1.99	2.35	2.69
32.73	.91	.82	.92	1.00	1.15	1.29

* Figures across are tons delivered annually.
** Firm F cannot operate at this density level.

Figure 5. Relationship between Annual Mileage and Total Annual Operating Costs for 12-Ton Capacity Bulk Feed Trucks



farther north in the Region. The rate adopted for bulk feed truck drivers is a base wage of $2.00 per hour plus 40 cents an hour in fringe benefits. Fringe benefits include vacation and sick leave, Social Security, medical and health insurance, and a company-sponsored pension program.

This rate is used to determine the annual drivers' wage cost for each of the six firms with distribution at each of three density levels. The annual and per ton cost for drivers is given in Table 18.

3. *Administrative Personnel and Costs* — Administrative functions include managing the distribution operation, scheduling and dispatching trucks and drivers, and performing various clerical and bookkeeping chores. Estimates of personnel requirements and costs were obtained

Table 18. Driver Costs for Six Firms Distributing Feed at Three Density Levels

Density	A 5,434*	B 16,302	C 32,609	D 45,287	E *67,933	F 90,577
(tons per square mile per year)			(annual cost in dollars)			
1.31	5,828	19,544	43,262	67,342	113,462	**
6.55	4,274	13,191	27,968	42,070	68,309	98,580
32.73	3,638	10,402	21,141	30,751	48,198	67,236
			(dollars per ton)			
1.31	1.07	1.20	1.33	1.49	1.67	**
6.55	.79	.81	.86	.93	1.01	1.09
32.73	.67	.64	.65	.68	.71	.74

* Figures across are tons delivered annually.
** Firm F cannot operate at this density level.

from firms distributing feed and applied to the model firms. Table 19 presents the estimated personnel requirements and annual costs.

4. *Miscellaneous Costs* — Miscellaneous costs include three general categories. They are (1) ownership costs of the garage, office, and office equipment, (2) service costs consisting of utilities and telephone, and (3) supply costs consisting of weigh tags and other administrative supplies. Cost for these items are relatively small and are shown in Table 20.

Table 19. Administrative Personnel Costs and Man-Equivalents for Six Feed Distribution Firms

Item	A 5,434*	B 16,302	C 32,609	D 45,287	E 67,933	F 90,577
	(dollars — with man-equivalents in parentheses)					
Manager**	625	1,250	1,875	2,500	3,750	5,000
	(.05)	(.1)	(.15)	(.2)	(.3)	(.4)
Dispatcher†	600	1,500	2,700	3,600	4,800	6,000
	(.1)	(.25)	(.45)	(.6)	(.8)	(1.0)
Bookkeeper-Typist‡	225	675	1,125	1,500	2,025	2,700
	(.05)	(.15)	(.25)	(.33)	(.45)	(.6)
Total Annual Cost	1,450	3,425	5,700	7,600	10,575	13,700
Cost per Ton	.27	.21	.18	.17	.16	.15

* Figures across are tons distributed annually
** Annual Salary rate of $12,500
† Annual salary rate of $ 6,000
‡ Annual salary rate of $ 4,500

Table 20. Miscellaneous Costs for Six Firms Distributing Feed at Three Density Levels

	Firm					
	A	B	C	D	E	F
Item	5,434*	16,302	32,609	45,287	67,933	90,577
	(dollars)					
	1.31 Ton Density Level					
Ownership	192	652	1,247	1,962	3,105	**
Services	87	174	277	351	507	
Supplies	109	326	652	906	1,359	
Total Annual Costs	388	1,152	2,176	3,219	4,971	
Cost per Ton	.07	.07	.07	.07	.07	
	6.55 Ton Density Level					
Ownership	192	514	833	1,134	1,863	2,600
Services	87	174	277	351	507	672
Supplies	109	326	652	906	1,359	1,812
Total Annual Costs	388	1,014	1,762	2,391	3,729	5,084
Cost per Ton	.07	.06	.05	.05	.06	.06
	32.73 Ton Density Level					
Ownership	192	374	695	858	1,311	1,772
Services	87	174	277	351	507	672
Supplies	109	326	652	906	1,359	1,812
Total Annual Costs	388	874	1,624	2,115	3,177	4,256
Cost per Ton	.07	.05	.05	.05	.05	.05

* Figures across are tons distributed annually.
** Firm F cannot operate at this density level.

The ownership cost includes depreciation, interest on investment. taxes, maintenance and repair, and insurance. Annual depreciation is figured by the straight-line method and is four percent of the initial investment for the garage and office and ten percent of the initial investment for office equipment. The annual interest charge is three percent of the initial investment. Annual taxes are $25 per thousand on half of the new investment value. Annual insurance, maintenance and repair are each assumed to be one percent of the initial investment.

Utility and telephone costs are estimated from information supplied by firms. Supplies are a constant unit cost and are assumed to be two cents per ton of feed distributed.

5. *Total Distribution Cost* — Table 21 gives the total annual and average per ton feed distribution costs for each firm operating at three density levels. For each situation, truck costs constitute approximately half of the total cost. Drivers' wages are the second largest cost item and vary from about 25 to 35 percent of the total. The administrative and miscellaneous costs constitute the balance.

Table 21. Summary of Feed Distribution for Six Firms Distributing Feed at Three Density Levels

Item	Firm A 5,434*	Firm B 16,302	Firm C 32,609	Firm D 45,287	Firm E 67,933	Firm F 90,577
			(dollars)			
			1.31 Ton Density Level			
Trucks	12,629	51,284	119,229	196,806	344,170	**
Drivers	5,828	19,544	43,262	67,342	113,462	
Administrative	1,450	3,425	5,700	7,600	10,575	
Miscellaneous	388	1,152	2,176	3,219	4,971	
Total Annual Cost	20,295	75,405	170,367	274,967	473,178	
Cost per Ton	3.74	4.63	5.22	6.07	6.96	
			6.55 Ton Density Level			
Trucks	7,156	26,182	56,774	90,319	160,040	243,568
Drivers	4,274	13,191	27,968	42,070	68,309	98,580
Administrative	1,450	3,425	5,700	7,600	10,575	13,700
Miscellaneous	388	1,014	1,762	2,391	3,729	5,084
Total Annual Cost	13,268	43,812	92,204	142,380	242,653	360,932
Cost per Ton	2.44	2.69	2.83	3.14	3.57	3.98
			32.73 Ton Density Level			
Trucks	4,919	13,408	30,148	45,112	78,100	116,563
Drivers	3,638	10,402	21,141	30,751	48,198	67,236
Administrative	1,450	3,425	5,700	7,600	10,575	13,700
Miscellaneous	388	874	1,624	2,115	3,177	4,256
Total Annual Cost	10,395	28,109	58,613	85,578	140,050	201,755
Cost per Ton	1.91	1.72	1.80	1.89	2.06	2.23

* Figures across are tons distributed annually.
** Firm F cannot distribute at this density level. (To distribute at this density level requires changes in the restriction on overtime.)

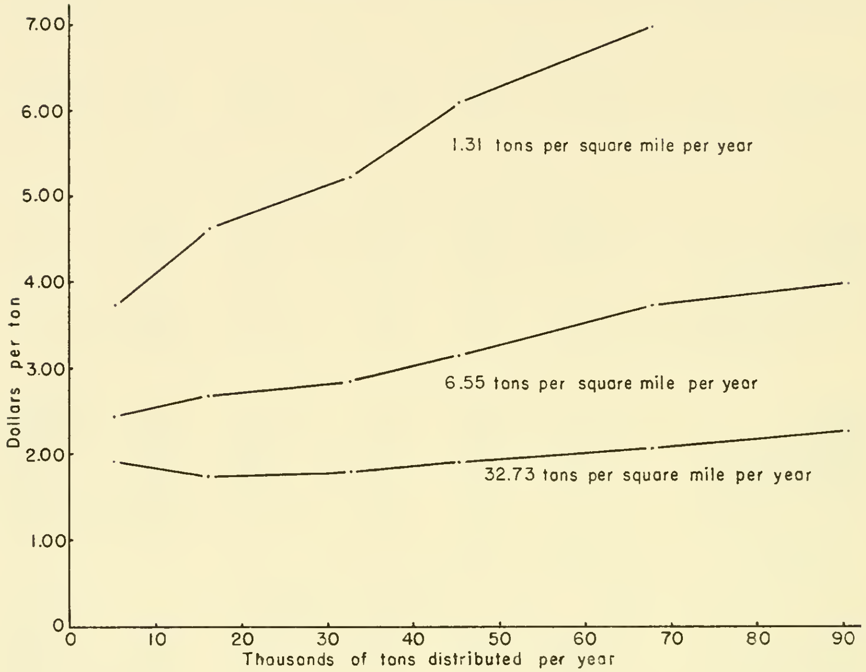
For the five firms able to distribute feed at the lowest density level considered, total annual cost increases from $20,295 for Firm A to $473,178 for Firm E. Average cost increases continuously with increasing volume from $3.74 for Firm A to $6.96 a ton for Firm E.

All six firm sizes can distribute feed at the intermediate density level. Total annual cost increases from $13,268 for Firm A to $360,932 for Firm F. Average cost also increases continuously with increasing volume from $2.44 for Firm A to $3.98 a ton for Firm F.

Distributing feed at the highest density level results in annual costs increasing from $10,395 for Firm A to $201,755 for Firm F. However, average cost decreases from $1.91 a ton for Firm A to $1.72 for Firm B and increases continuously with further increases in volume to $2.23 a ton for Firm F.

The relationship between average cost and volume at each density level is shown in Figure 6. The relationship between average cost and density for each of the six firms is illustrated in Figure 7.

Figure 6. Average Cost per Ton for Bulk Feed Distribution at Three Density Levels



With a given firm size, decreasing the size of the broiler producing area results in substantial reductions in the average cost per ton for distributing feed. However, the reductions diminish with successive decreases in area.

For Firm A, most of the reductions occur over a range in density from 1.31 to 10 tons per square mile and amounts to approximately $1.50 per ton. With increases in firm size and volume, reductions in average cost occur over a wider density range, 1.31 to 20 tons per square mile and increase in magnitude. The reduction in average cost increases from approximately $2.60 per ton for Firm B to $4.70 a ton for Firm E. Increasing density from 20 to 32.73 tons per square mile results in small reductions varying from 19 cents per ton for Firm A to 25 cents per ton for Firm F.

These data indicate the general positive relationship between distance and feed distribution costs. The methodology used does not, however, precisely determine the effect of distance on the cost of distributing a ton of feed. To develop such a relationship, the cost of distributing a ton of feed to each band at each density level was determined and paired with its respective one-way road mileage. An equation expressing the relationship is derived by the least-squares method and is:

$$C = 1.250 + 0.0489M$$ [4]

[4] $R^2 = .97$.

where C is the cost per ton for delivering a ton of feed from a mill to a production unit located M miles from the mill. The added cost per ton for each mile (one way) is 4.89 cents, and the fixed cost associated with each ton is $1.25. Figure 8 illustrates this relationship.

Figure 7. Relationship between Average Cost per Ton and Feed Distributed per Square Mile per Year for Six Firms

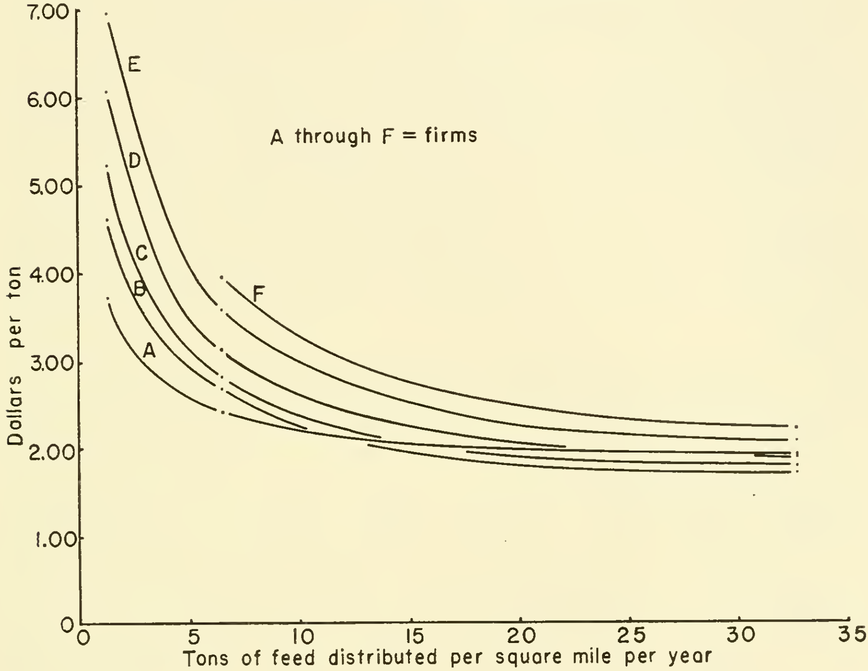
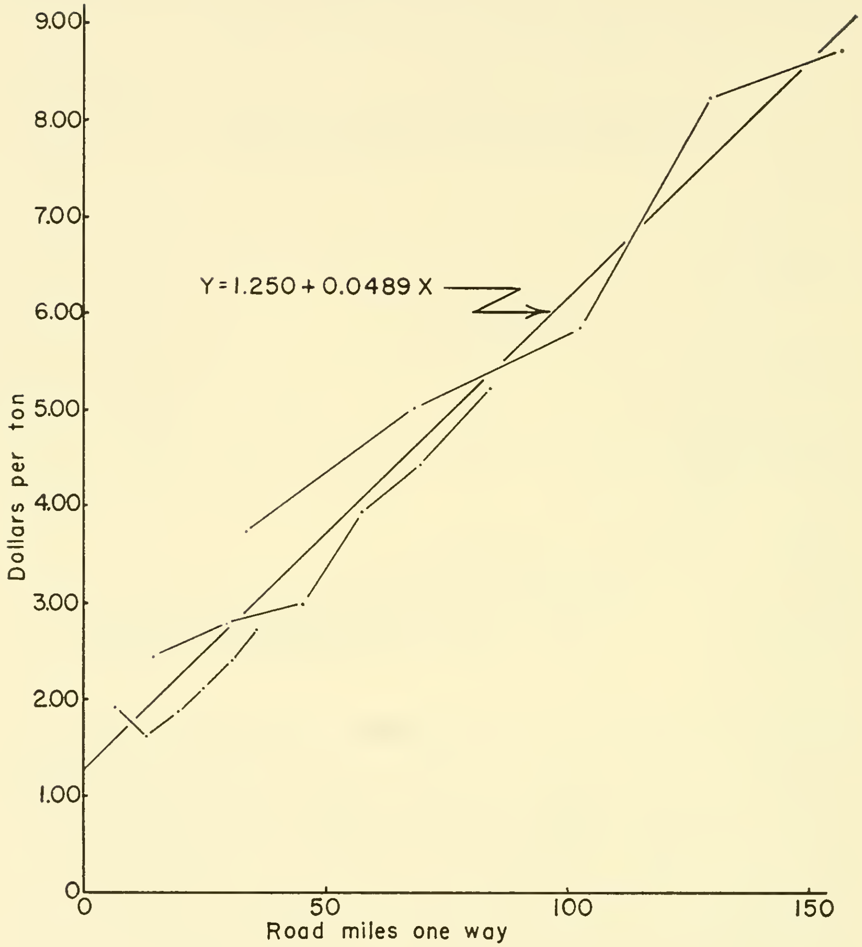


Figure 8. Relationship between Distance in Road Miles and Distribution Cost per Ton



VI. Total Cost for Feed Manufacturing and Distribution

The optimum size of a feed manufacturing plant requires simultaneous consideration of feed manufacturing and distribution costs. Consideration of each independently might result in a higher total average cost than otherwise could be achieved and place the firm at a competitive disadvantage. The purpose of this section is to combine the manufacturing and distribution costs developed in the previous sections to determine the manner in which the two variables, plant size and density, affect optimum size. The combined or total costs are presented for six firms ranging in annual output from 5,434 to 90,577 tons with feed distributed at three density levels, 1.31, 6.55, and 32.73 tons per square mile per year.

Effect of Density Level

The total average cost for each of the six firms at each density level is given in Table 22. The volume-cost relationship for each density level is illustrated in Figure 9.

At the lowest density level, total average cost decreases from $12.33 a ton for Firm A to $10.45 for Firm C and increases with further increases in size and volume to $11.26 for Firm E. The least-cost size firm at this density, Firm C, is producing 32,609 tons of feed a year and distributing into an area with a radius of 89 miles. This quantity of feed is sufficient to produce the hatching eggs and broilers for a firm processing 7.5 million finished live broilers (26.2 million pounds) a year with a plant capacity of 3,600 broilers an hour on a single shift basis.[1]

Increasing density to the intermediate level results in the average total cost per ton decreasing from $11.03 for Firm A to a low of $7.82 for Firm D and increasing with further increases in firm size and output to $7.99 for Firm F. The least-cost size firm at this density, Firm D, pro-

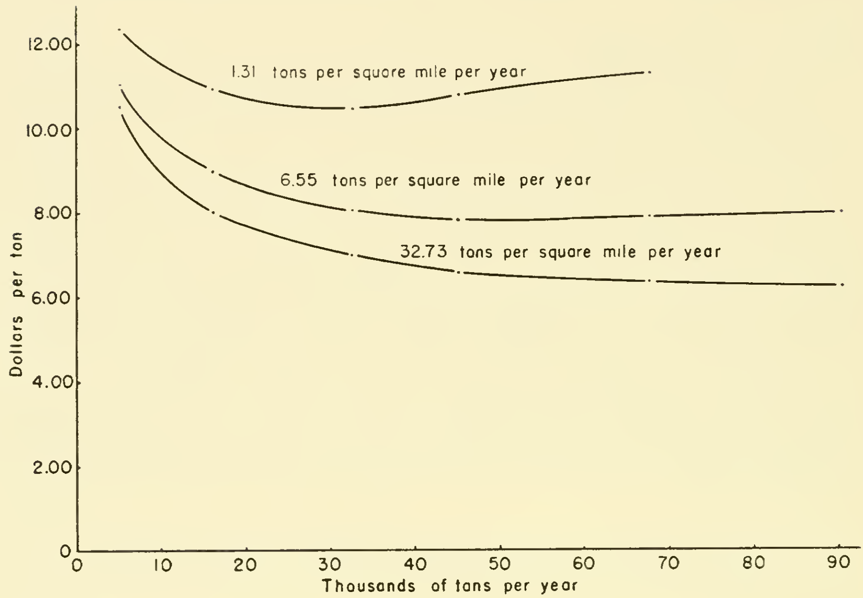
Table 22. Total Feed Manufacturing and Distribution Cost per Ton for Six Firms with Feed Distributed at Three Density Levels

	Firm					
	A	B	C	D	E	F
Item	5,434*	16,302	32,609	45,287	67,933	90,577
			(dollars per ton)			
			1.31 Ton Density Level			
Feed Manufacturing	8.59	6.29	5.23	4.68	4.30	
Feed Distribution	3.74	4.63	5.22	6.07	6.96	**
Total	12.33	10.92	10.45	10.75	11.26	
			6.55 Ton Density Level			
Feed Manufacturing	8.59	6.29	5.23	4.68	4.30	4.01
Feed Distribution	2.44	2.69	2.83	3.14	3.57	3.98
Total	11.03	8.98	8.06	7.82	7.87	7.99
			32.73 Ton Density Level			
Feed Manufacturing	8.59	6.29	5.23	4.68	4.30	4.01
Feed Distribution	1.91	1.72	1.80	1.89	2.06	2.23
Total	10.50	8.01	7.03	6.57	6.36	6.24

* Figures across are annual volumes in tons.
** Firm F cannot distribute at this density level.

[1] The feed manufacturing and distribution cost for Firm C is equivalent to 1.3 cents a pound of finished live broiler.

Figure 9. Total Average Cost per Ton of Feed Manufacturing and Distribution with Feed Distributed at Three Density Levels



duces 45,287 tons of manufactured feed a year and distributes into an area with a radius of 46.9 miles. This output is sufficient to produce 10.4 million finished live broilers (36.4 million pounds) annually and to keep a processing plant with a line capacity of 5,000 broilers per hour operating at its designed output on a single shift basis throughout the year.[2]

Manufacturing and distributing feed at the highest density level considered results in a decreasing total average cost over the entire range of firm sizes considered. The cost per ton decreases from $10.50 for Firm A to $6.24 for Firm F. Firm F produces 90,577 tons of finished feed a year and distributes into an area with a radius of 29.7 miles. The feed volume is sufficient to grow out 20.8 million finished live broilers (72.8 million pounds) annually.[3] This volume of broilers will keep a processing plant with a line capacity of 10,000 broilers an hour operating at its designed output on a single shift basis throughout the year.

1. *Long-Run Changes* — The effect on total average cost from long-run changes in mill size and output and density can be determined from the data in Table 22. Increasing density from the 1.31 to 6.55-ton density levels requires an increase in mill size and output from 32,609 to 45,287 tons a year and reduces the average manufacturing cost by $.55 a ton.

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[2] The feed manufacturing and distribution cost for Firm D is equivalent to 0.97 cents a pound of finished live broiler.

[3] The feed manufacturing and distribution cost for Firm F is equivalent to 0.78 cents a pound of finished live broiler.

The producing area is reduced in radius from 89 to 46.9 miles resulting in a reduction of the distribution cost of $2.08 per ton. The total reduction amounts to $2.63 per ton.

Increasing density from the 6.55 to 32.73-ton level requires a doubling in mill size and output from 45,287 tons to 90,577 tons a year. This reduces the average manufacturing cost by $.67 a ton. The poultry producing area is reduced from a radius of 46.9 miles to 29.7 miles and the average distribution cost is reduced by $.91 a ton. The total reduction is $1.58 a ton which is substantially less than the previous reduction.

2. *Short-Run Changes* — In the short-run, while the firm is not able to change plant size, substantial reduction in cost may be realized by increasing density by dropping producers on the fringe and adding producers close to the mill. Increasing density from 1.31 to 6.55 tons reduces the distribution cost by amounts varying from $1.30 per ton for Firm A to as much as $3.39 per ton for Firm E. Only 24 cents a ton then separates the costs for Firms C. D. E. and F.

Increasing density from the 6.55-ton to the 32.73-ton level provides further reductions in cost varying from $.53 a ton for Firm A to a high of $1.75 a ton for Firm F. The average costs of the three lowest cost Firms D, E, and F, fall within a range of 34 cents.

APPENDIX A

Determination of Feed Mill Capacities and Outputs

The feed manufacturing capacity and output of each model feed mill is based on the feed requirements of the vertically coordinated broiler marketing organization consisting in part of broiler processing, live broiler production, hatching egg production, and broiler chick hatching. The organization controls other stages such as broiler assembly and chick distribution, but neither affects the quantities of broilers and eggs produced. It is assumed that the organization produces only the quantities of inputs necessary to ultimately operate the broiler processing plant at its designed capacity and output.

Eight processing plants ranging in capacity from 600 to 10.000 broilers per hour serve as the basis for establishing feed requirements. These plants are assumed to process straight-run broilers averaging 3.5 pounds live. Plants operate eight hours a day, 260 days a year. The quantity of broilers needed varies from 1.248 million a year for the smallest firm to 20.8 million for the largest firm size considered. Appendix Table A-1 gives the annual requirements.[1]

The input for the processing plants establishes the output for the live broiler production stage. However, the input of day-old chicks needed is somewhat larger to compensate for bird mortality during the growing-out period. A mortality rate of 4.2 percent is used to derive the required chick input. This input varies from 1.303 million a year to 21.712 million chicks as shown in Table A-1.

Hatchery outputs are equivalent to the broiler chick inputs. Converting chicks to hatching eggs is based on a 72 percent hatchability rate of good chicks. Egg inputs to the hatcheries vary from 5,026 cases to 83,765 cases a year. The quantities for the intermediate size firms are given in Table A-1.

Mature breeders are assumed to produce an average of 118 hatching eggs per bird over a 40-week laying period. At this rate, the total annual number of female breeders required varies from 15,333 to 255.553 with 11,795 to 196,579 being in production at any one time. There is a minimum of one male for each ten females. The total annual number of males varies from 1,533 to 25,555 with 1,179 to 19,658 being fed at any one time.

The breeders are purchased as day-old chicks from a primary breeder hatchery and grown out to maturity by the firm. During this period, an assumed 15 percent of the females are lost through mortality and culling. For each 100 purchased female chicks, 15 male chicks are purchased. The total number of day-old chicks purchased annually varies from 18,039 females and 2,705 males to 300,651 females and 45.098 males. Table A-1 gives the quantities of chicks purchased by each of the eight firms.

[1] Derived from G. B. Rogers and E. T. Bardwell, *op. cit.* In that report the hourly capacities of the processing plants are the same as those used in this report: however, the work year was 247 days in the Rogers and Bardwell report, but is 260 in this one, so that total annual capacities are not the same.

Appendix Table A-1. Annual Output of Broilers and Inputs of Chicks, Hatching Eggs, Breeders, and Feed for Eight Vertically Coordinated Firms.

Items	Firms							
	A	A′	B	B′	C	D	E	F
Live Broilers Produced (million) *	1.248	2.496	3.744	4.992	7.488	10.400	15.600	20.800
Broiler Chicks Placed (million) **	1.303	2.605	3.908	5.211	7.816	10.856	16.284	21.712
Hatching Eggs Produced (30 doz. cases) †	5,026	10,052	15,078	20,104	30,156	41,883	62,824	83,765
Number of Mature Females‡	15,333	30,667	46,000	61,333	92,000	127,779	191,666	255,553
Number of Mature Males§	1,533	3,067	4,600	6,133	9,200	12,778	19,167	25,555
Total Mature Breeders	16,866	33,734	50,600	67,466	101,200	140,557	210,833	281,108
Number Female Breeder Chicks Purchased‖	18,039	36,079	54,118	72,156	108,235	150,328	225,489	300,651
Number Male Breeder Chicks Purchased¶	2,705	5,412	8,118	10,823	16,235	22,549	33,823	45,098
Total Breeder Chicks Purchased	20,744	41,491	62,236	82,979	124,470	172,877	259,312	345,749
Feed Manufactured (tons)	5,434	10,868	16,302	21,739	32,609	45,287	67,933	90,577

Coefficients Used
* 260 day year
** mortality 4.2%
† hatchability 72%
‡ 118 hatching eggs per bird over a 40 week period

§ one male to 10 females
‖ mortality 15%
¶ 15 males per 100 females

Feeding Practices[2] and Coefficients

Straight-run broilers averaging 3.5 pounds live are grown out in eight weeks on a feed conversion of 2.10 pounds of feed per pound of broilers. At the time of assembly for processing, each broiler has consumed an average of 7.35 pounds of feed, all in crumble form. A broiler-starter formulation is fed for the first five weeks of the growing period. During this period, birds consume an average of 2.9 pounds each. The balance of the feed, 4.5 pounds of finisher formulation, is consumed during the last three weeks.

Breeders are fed three formulations, two during the growing period and one during the laying period. A starter formulation in mash form is fed for the first six weeks at the rate of six pounds per chick started. This formulation is followed by a grower formulation for the next 14 weeks in pellet form at the rate of 14 pounds per started chick. During this 14-week period, birds are on a restricted feeding program. A mash form breeder formulation is fed during the production period at the rate of 8.5 pounds per dozen hatching eggs. The tonnages of each formulation mixed daily by each of the eight mills and the total tonnages mixed annually are given in Table 1, page 7.

[2] Input-output relationships and feeding practices provided by the Poultry Division, Animal Science Department, University of New Hampshire.

APPENDIX B

Poultry Feed Formulations

The two broiler and three breeder feed formulations used in this report are given in Table B-1. The formulations are adopted from the 1963 New England College Conference Chicken and Turkey Rations. The breeder formulations are modified by substituting 50 percent protein soybean oil meal for the recommended 44 percent. This eliminates the need for the model mills to purchase and store two different grades of meal. The substitution reduces the pounds of soybean meal per ton and is offset by the addition of a like number of pounds of corn.

Appendix Table B-1. Broiler and Breeder Feed Formulations*

Ingredient	Broiler		Breeder		
	Starter	Finisher	Starter	Grower	Breeder
			(pounds)		
Corn, yellow No. 2	1,075	1,225	1,175	1,260	1,365
Soybean Meal (50%)	500	350	500	220	175
Stabilized fat	80	80	20	20	20
Corn gluten meal	100	100	....	....	....
Fish meal (60%)	100	100	50	50	75
Distillers dried sol.	50	50	50	50	50
Alfalfa meal	50	50	50	50	50
Standard wheat midds	...	...	100	300	100
Dicalcium phosphate	18	18	22	24	10
Ground limestone	20	20	24	20	100
Iodized salt	5	5	5	5	5
Meat and bone scrap	....	....	....	....	50
Manganese sulfate	.5	.5	.5	.5	.5
dl Methionine	.5	.5	..	..	...
Antioxidant	.25	.25	....	..	....
Organic arsenical supplement	.1	.1	....	....	....
Antibiotic supplement		**	**	**	**
Total lbs.†	1,999.35	1,999.35	1,996.5	1,999.5	2,000.5

* New England College Conference Chicken and Turkey Rations, Department of Animal Sciences, University of New Hampshire, Durham, New Hampshire, 1963.

** Add one to five pounds per ton depending on product and manufacturer's recommendations.

† Add or subtract corn to adjust to 2,000 pounds.

APPENDIX C

Major Equipment Items for Eight Model Mills

Mill A

20.9 tons per day

1 ea.	40	hp	Hammermill and blower
1 ea.	5	hp	Vertical mixer, 1 ton
1 ea.	40	hp	Pellet mill
1 ea.	10	hp	Cooler and crumbilizer
1 ea.	3½	hp	Fat applicator
1 ea.	20	hp	Boiler

Mill A′

41.8 tons per day

1 ea.	50	hp	Hammermill
1 ea.	20	hp	Pneumatic conveyor
1 ea.	10	hp	Vertical mixer, 2 ton
1 ea.	75	hp	Pellet mill
1 ea.	10½	hp	Pellet cooler
1 ea.	7½	hp	Crumbilizer
1 ea.	3½	hp	Fat applicator
1 ea.	45	hp	Boiler

Mill B

62.7 tons per day

1 ea.	75	hp	Hammermill
1 ea.	25	hp	Pneumatic conveyor
2 ea.	7½	hp	Vertical mixers, 1½ ton
1 ea.	60	hp	Pellett mill
1 ea.	50	hp	Pellet mill
1 ea.	15½	hp	Pellet cooler
1 ea.	10	hp	Crumbilizer
1 ea.	3½	hp	Fat applicator
1 ea.	60	hp	Boiler

Mill B′

83.6 tons per day

1 ea.	100	hp	Hammermill
1 ea.	25	hp	Pneumatic conveyor
1 ea.	15	hp	Horizontal mixer, 1½ ton
2 ea.	75	hp	Pellet mills
2 ea.	10½	hp	Pellet coolers
2 ea.	10	hp	Crumbilizers
1 ea.	5	hp	Fat applicator
1 ea.	80	hp	Boiler

Mill C

125.42 tons per day

2 ea.	75	hp	Hammermills
1 ea.	50	hp	Pneumatic conveyor
1 ea.	20	hp	Horizontal mixer, 2 ton
1 ea.	100	hp	Pellet mill
1 ea.	125	hp	Pellet mill
1 ea.	10½	hp	Pellet cooler
1 ea.	15½	hp	Pellet cooler
2 ea.	10	hp	Crumbilizers
1 ea.	5	hp	Fat applicator
1 ea.	125	hp	Boiler

Mill D

174.18 tons per day

2 ea.	100	hp	Hammermills
1 ea.	60	hp	Pneumatic conveyor
1 ea.	25	hp	Horizontal mixer, 3 ton
2 ea.	100	hp	Pellet mills
1 ea.	125	hp	Pellet mill
2 ea.	10½	hp	Pellet coolers
1 ea.	15½	hp	Pellet cooler
3 ea.	10	hp	Crumbilizers
1 ea.	5	hp	Fat applicator
1 ea.	200	hp	Boiler

Mill E

261.28 tons per day

3 ea.	100	hp	Hammermills
1 ea.	60	hp	Pneumatic conveyors
1 ea.	30	hp	Pneumatic conveyor
2 ea.	20	hp	Horizontal mixers, 2 ton
3 ea.	125	hp	Pellet mills
1 ea.	100	hp	Pellet mill
3 ea.	15½	hp	Pellet coolers
1 ea.	10½	hp	Pellet cooler
4 ea.	10	hp	Crumbilizers
2 ea.	5	hp	Fat applicators
1 ea.	250	hp	Boiler

Mill F

348.37 tons per day

3 ea.	125	hp	Hammermills
3 ea.	40	hp	Pneumatic conveyors
2 ea.	25	hp	Horizontal mixers, 3 ton
4 ea.	125	hp	Pellet mills
1 ea.	100	hp	Pellet mill
4 ea.	15½	hp	Pellet coolers
1 ea.	10½	hp	Pellet cooler
5 ea.	10	hp	Crumbilizers
2 ea.	5	hp	Fat applicators
1 ea.	300	hp	Boiler

APPENDIX D

Short-Run Average Costs

Appendix Table D-1. Short-run Average Costs for Eight Mills Producing 95 percent of the Broiler Feed Requirement and 100 percent of the Breeder Feed Requirement.

	Mills							
	A	A′	B	B′	C	D	E	F
	(tons per year)							
Item	5,205	10,409	15,614	20,819	31,233	43,376	65,064	86,752
	(dollars per ton)							
Labor								
Production	1.96	1.58	1.43	.86	.63	.39	.30	.26
Maintenance	.31	.23	.21	.20	.15	.13	.11	.11
Utilities	.83	.79	.77	.74	.76	.71	.71	.68
Equipment repairs and service	.63	.51	.44	.56	.43	.42	.40	.37
Mill Supplies	.09	.09	.09	.09	.09	.09	.09	.09
Inventory	.08	.08	.08	.08	.08	.08	.08	.08
Shrink	.17	.17	.17	.17	.17	.17	.17	.17
Ownership	2.90	2.27	1.98	2.45	1.93	1.84	1.70	1.56
Administrative and Supervisory	1.50	1.21	1.03	.95	.89	.80	.70	.63
Miscellaneous	.35	.30	.27	.25	.22	.20	.19	.14
Total Cost per Ton*	8.82	7.23	6.45	6.35	5.35	4.81	4.43	4.08
	(dollars)							
Total Cost per Year	45,882	75,278	100,773	132,097	167,190	208,769	288,168	354,035

* These totals may not add due to rounding.

Appendix Table D-2. Short-run Average Costs for Eight Mills Producing 80 percent of the Broiler Feed Requirement and 100 percent of the Breeder Feed Requirement.

Item	A	A′	B	B′	C	D	E	F
	Mill							
	(tons per year)							
	4,517	9,034	13,551	18,069	27,105	37,643	56,465	75,286
	(dollars per ton)							
Labor								
Production	2.03	1.62	1.46	.88	.65	.40	.31	.26
Maintenance	.31	.24	.21	.20	.16	.13	.11	.11
Utilities	.88	.84	.81	.79	.81	.75	.75	.72
Equipment repairs and service	.63	.51	.44	.56	.43	.42	.40	.37
Mill Supplies	.09	.09	.09	.09	.09	.09	.09	.09
Inventory	.08	.08	.08	.08	.08	.08	.08	.08
Shrink	.17	.17	.17	.17	.17	.17	.17	.17
Ownership	3.34	2.62	2.28	2.82	2.22	2.12	1.96	1.80
Administrative and Supervisory	1.73	1.39	1.18	1.10	1.03	.92	.80	.72
Miscellaneous	.40	.34	.31	.29	.25	.23	.21	.21
Total Cost per Ton*	9.67	7.91	7.04	6.98	5.89	5.30	4.87	4.53
	(dollars)							
Total Cost per Year	43,670	71,441	95,440	126,067	159,513	199,621	275,267	341,347

* These totals may not add due to rounding.

Appendix Table D-3. Short-run Average Costs for Eight Feed Mills Producing 60 percent of the Broiler Feed Requirement and 100 percent of the Breeder Feed Requirement.

	Mill							
	A	A′	B	B′	C	D	E	F
	(tons per year)							
Item	3,600	7,200	10,800	14,400	21,600	30,000	45,000	60,000
	(dollars per ton)							
Labor								
Production	2.13	1.71	1.55	.93	.68	.42	.32	.28
Maintenance	.33	.25	.22	.21	.17	.14	.12	.12
Utilities	.99	.94	.91	.88	.90	.84	.84	.81
Equipment repairs and service	.63	.51	.44	.56	.43	.42	.40	.37
Mill Supplies	.09	.09	.09	.09	.09	.09	.09	.09
Inventory	.08	.08	.08	.08	.08	.08	.08	.08
Shrink	.17	.17	.17	.17	.17	.17	.17	.17
Ownership	4.19	3.29	2.87	3.54	2.79	2.66	2.45	2.26
Administrative and Supervisory	2.17	1.75	1.49	1.38	1.29	1.15	1.00	.91
Miscellaneous	.51	.43	.39	.37	.32	.29	.27	.26
Total Cost per Ton*	11.28	9.21	8.20	8.19	6.91	6.25	5.74	5.33
	(dollars)							
Total Cost per Year	40,619	66,334	88,538	117,994	149,234	187,380	258,165	319,800

* These totals may not add due to rounding.

Appendix Table D-4. Short-run Average Costs for Eight Feed Mills Producing 40 percent of the Broiler Feed Requirement and 100 percent of the Breeder Feed Requirement.

	Mill							
	A	A′	B	B′	C	D	E	F
	(tons per year)							
Item	2,683	5,366	8,049	10,732	16,098	22,355	33,533	44,710
	(dollars per ton)							
Labor								
Production	2.32	1.83	1.66	1.00	.73	.45	.34	.31
Maintenance	.35	.27	.24	.23	.18	.15	.13	.13
Utilities	1.21	1.14	1.11	1.07	1.10	1.02	1.02	.98
Equipment repairs and services	.63	.51	.44	.56	.43	.42	.40	.37
Mill Supplies	.09	.09	.09	.09	.09	.09	.09	.09
Inventory	.08	.08	.08	.08	.08	.08	.08	.08
Shrink	.17	.17	.17	.17	.17	.17	.17	.17
Ownership	5.62	4.41	3.85	4.75	3.74	3.57	3.29	3.03
Administrative and Supervisory	2.91	2.34	1.99	1.85	1.74	1.54	1.35	1.21
Miscellaneous	.68	.58	.52	.49	.42	.39	.36	.35
Total Cost per Ton*	14.07	11.44	10.15	10.28	8.68	7.88	7.23	6.72
	(dollars)							
Total Cost per Year	37,744	61,376	81,689	110,325	139,682	176,180	242,477	300,451

* These totals may not add due to rounding.