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6. Economies of Scale in Hatching and Cost of Distributing Broiler Chicks

By

Clark R. Burbee and Edwin T. Bardwell

AGRICULTURAL EXPERIMENT STATION
UNIVERSITY OF NEW HAMPSHIRE
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in cooperation with

Agricultural Experiment Station, University of Massachusetts,
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Preface and Acknowledgements

This bulletin is the sixth in a series to be issued by the Agricultural Experiment Stations in the New England States and involves, in most instances, direct cooperation with the Economic Research Service, U.S.D.A. The series is concerned with various aspects of poultry marketing in New England. This publication analyses the potential economies of scale in hatching straight-run broiler chicks, the cost of distributing broiler chicks, and the combined costs of an integrated poultry system consisting of broiler processing, chick hatching, broiler assembling, and chick distributing functions.

The authors appreciate the cooperation of the hatchery operators who provided information and data on input-output relationships and costs and those manufacturers and suppliers of hatchery equipment and supplies who furnished data on specifications, capacities and costs. The authors wish to acknowledge the assistance and critical appraisal received from W. F. Henry, of the Resource Economics Department of the University of New Hampshire; A. A. Brown, of the University of Massachusetts; and George B. Rogers, Marketing Economics Division, Economic Research Service, U. S. Department of Agriculture.

TABLE OF CONTENTS

Summary and Conclusions

This study was undertaken with four objectives in mind. One objective was to determine the physical input-output relationships, operational procedures, and costs for broiler chick hatching and eventually to synthesize the long-run average cost curve. The second was to determine the effect on hatchery operations and costs from adding two types of service operations, debeaking and vaccination, often performed in hatcheries. Third, to synthesize the costs of distributing chicks by motor vehicle under each of three different levels of broiler production density for several different sizes of hatchery operations. This objective was to determine how costs change with increasing size of operations and increasing production density. Fourth, to combine the synthesized hatching and chick distributing costs with broiler assembling and processing costs, to acquire insight concerning the long-run costs of the integrated poultry system.

Eight model hatcheries were synthetically constructed and operated. Their egg holding capacities and annual chick outputs range respectively from 121,800 eggs and 1.30 million chicks to 2,029,500 eggs and 21.71 million chicks.

Labor inputs were classed in one of two groups. Labor inputs for performing the various production operations and surveillance of the incubating and hatching in conjunction with production operation, were the variable labor input category. The labor input used specifically for surveillance was the surveillance labor input category. Treatment of labor inputs in this manner revealed how increasing scale permits spreading of the variable operations over an increasing proportion of each day and diminishes the labor requirement for surveillance.

Labor productivity for hatching increases rapidly with increasing scale for two reasons. First, the amount of otherwise unproductive time associated with the surveillance operation diminishes rapidly. Second, different technologies are adopted which increase labor productivity. The principle changes are in traying eggs and tray washing. Labor productivity increases from 145 chicks per man-hour for a hatchery with an egg capacity of 121,800 to 710 chicks for a hatchery with an egg capacity of 1,522,300. Labor cost at 100 percent of capacity decreases from 0.932 cents per chick to 0.190 cents.

Economies in building ownership exist throughout the range of hatcheries analysed. These costs decline from 0.130 cents per chick for a hatchery with egg capacity of 121,800 to 0.061 cents for a hatchery with egg capacity of 2,029,500 with operations at 100 percent of capacity.

Economies in equipment ownership exist but are extremely small and discontinuous. Cost per chick ranges from a high of 0.305 cents to a low of 0.271 cents with operations at 100 percent of capacity.

Economies were also found to exist in management, supplies and miscellaneous input groups throughout the range of hatchery capacities analysed. Management costs decrease from 0.277 cents to 0.143 cents per chick. The economies from supplies are small. Cost of supplies decrease from 0.247 cents to 0.234 cents per chick. Economics were also found for the miscellaneous items such as electricity and fuel. These costs decrease from 0.115 cents to 0.069 cents per chick.

The total economies of scale in broiler chick hatching are continuous, and the average costs decrease from 2.005 cents to 0.968 cents per chick for hatcheries ranging in capacity from 121.800 eggs to 2,029,500 eggs. The cost per chick initially decreases relatively fast with increasing scale, but the economies are small with increases in scale above a capacity of 700,000 eggs and an annual output of 7.5 million chicks. Savings in labor accounts for 72 percent of the economies.

The combining of a debeaking operation along with hatching increases labor, equipment, and supervisory costs. The net additions to hatching costs are not continuous with increased capacity, and the debeaking cost ranges from 0.115 cents and 0.077 cents per chick. The combined costs for hatching and debeaking fall continuously with increasing scale from 2.120 cents to 1.045 cents per chick.

Performing vaccination concurrently with debeaking increases labor, supply, and supervisory costs per chick by a relatively constant amount for all hatcheries analysed. The added cost amounts to between 0.448 cents and 0.444 cents per chick. Combined costs for hatching, debeaking, and vaccination decrease from 2.568 cents per chick to 1.489 cents over the range of hatchery sizes analyzed.

Chick distribution costs were synthesized for six of the eight model hatcheries. The volume ranged from 25.000 chicks distributed during two days a week to 417,500 chicks distributed over six days a week. Costs were developed for each distribution model for each of three area density levels: 298, 1491, and 7,455 chicks per square mile per year. At any of the density levels, average cost initially decreases with increasing volume but eventually increases. The vehicle cost per chick decreases as the number of hatch removals and distribution days a week increases and as firms adopt larger vehicles with lower unit operating costs. Once these features are exploited, vehicle costs commence to increase.

The labor cost per chick increases with increased volume at any density level. This occurs because the time expended in travel increases while labor productivity at the farm for placing chicks is constant at 5,000 chicks per man-hour.

With increasing volume at the low density level, distribution costs decrease from 0.231 cents per chick for a model distributing 12,500 chicks a day twice a week, to 0.176 cents per chick for a model distributing 18,800 chicks a day four times a week. Costs increase for larger volume models. At the density level of 1,491 chicks per square mile per year, the distribution cost decreases from 0.196 cents per chick for the smallest model to 0.113 cents per chick for a model distributing 25,050 chicks a day six days a week. Costs increase for larger volume models but discontinuously. At the high density level of 7,455 chicks per square mile per year, the distribution cost decreases from 0.182 cents per chick to 0.078 cents per chick for a model distributing 34,800 chicks a day six days a week, and costs increase discontinuously for larger volume models.

For any given volume of chicks, increasing density reduces distribution costs. However, the reduction is not the same for all volumes. Increasing density from the 298 to the 1,491 chick level resulted in reductions ranging from 15 to 51 percent. The reductions increased with increases in the volume distributed. Increasing density from the 1,491 to

7,455 chick level resulted in additional but smaller reductions in cost. These reductions ranged from 7 to 33 percent.

In-plant economies of scale exist throughout the range of the six poultry marketing systems consisting of processing, hatching, broiler assembling and chick distributing functions. The cost per bird for processing and hatching decreases from 15.491 cents for a system processing 1.19 million birds per year to 10.287 cents per bird for a system processing 19.76 million birds annually.

Depending on the density of broiler production, the addition of the transfer functions, chick distribution and broiler assembly, tends to or does overcome the in-plant economies. At the low production density level of 1,000 pounds per square mile per year (298 chicks per square mile per year) the total combined cost per bird decreases from 18.816 cents for a system processing 1.19 million birds per year to 15.726 cents for a system processing 7.11 million birds per year. Costs increase for larger scale systems. At the 5,000 pound (1,491 chick) density level, total combined cost per bird is less for each system than at the previous density level, and decreases continuously throughout the range of systems analysed. Costs decrease from 17.925 cents to 13.635 cents per bird. However, the economies are extremely small for systems processing more than 9.88 million birds per year. At the high density level of 25,000 pounds (7,455 chicks) each system has slightly lower costs, and economies exist throughout the range of systems analysed. Costs decrease from 17.491 cents per bird to 12.663 cents per bird with most of the economies occurring between systems processing 1.19 million and 14.82 million birds per year.

Poultry systems consisting of these four functions can reduce costs by reducing the size of the broiler producing area. Systems increasing in scale cannot continue to expand broiler production at a given density level but must increase broiler production density to gain the potential economies from the in-plant functions.

Marketing New England Poultry

6. Economies of Scale in Hatching and the Cost of Distributing Broiler Chicks

By

Clark R. Burbee and Edwin T. Bardwell[1]

I. Introduction

Numbers, sizes, and types of hatcheries in New England have been undergoing major changes during the last two decades. Between 1941 and 1950, the number of firms increased 11 percent while total egg capacity increased 116 percent (table 1). The average egg capacity of hatcheries doubled. Between 1950 and 1960, the number of hatcheries declined by 80 percent while egg capacity decreased only 5 percent. The average size of hatcheries increased more than four fold. The reduction in numbers was essentially confined to hatcheries with less than 200,000 egg capacity.

During this period, a new type of hatchery organization appeared, the large scale broiler chick hatchery affiliated with or owned and operated by processor-integrators. Processors require large and scheduled quantities of specific broiler chick strains for their contract broiler producing operations. In order to guarantee an uninterrupted supply, they purchased or became affiliated with existing hatcheries or constructed new facilities.

The size and location of broiler producing areas in New England have also changed drastically. Broiler processing has shifted from urban to rural locations. Originally, New England was one large broiler producing area, with broilers being transported as far as 100 to 150 miles from farms to processing plants. Integrators intent on reducing their transfer costs have reduced their radius of contract broiler producing operations down to 50 to 60 miles.

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[1] Mr. Burbee is Agricultural Economist, Marketing Economics Division, Economic Research Service, U.S.D.A., stationed at the University of New Hampshire. Mr. Bardwell is Cooperative Agent, New Hampshire and Massachusetts Agricultural Experiment Stations and Economic Research Service, U.S.D.A., stationed at the University of New Hampshire.

Table 1. New England Chick Hatcheries Ranked by Size for the Years 1941, 1950 and 1960.*

Hatching Egg Capacity	Years 1941	1950	1960
(thousand)		(number)	
0 – 24.9	476	415	37
25.0 – 49.9	45	102	23
50.0 – 99.9	18	55	19
100.0 – 199.9	9	24	17
200.0 – 499.9	4	10	14
500.0 – 999.9	1	6	10
1000.0 – 1499.9	1	3	2
1500.0 –	0	0	2
Total hatcheries (number)	554	615	124
Total capacity (million eggs)	10.9	24.5	23.2
Average capacity (thousand eggs)	19.7	39.9	187.4

* *Hatcheries and Dealers Participating in the National Poultry Improvement Plan,* U.S.D.A., ARS, 1941, 1950, 1960.

II. Objectives and Source of Data

The trend toward larger hatcheries integrated into other poultry marketing operations has created a need for additional information concerning economies of scale in hatcheries, efficient use of labor and capital, and cost associated with chick distribution. The first part of this study presents the physical input-output relationships, operational procedures, investments, costs and economies of scale for inplant hatching of straight-run broiler chicks. Two service operations performed by some hatcheries, debeaking and vaccinating, are also analysed to determine what effect they have on resources and costs.

In the second part of the study, chick distribution costs and resources are developed under several sets of conditions. For each of the several volumes, chicks are distributed into broiler producing areas the sizes of which are determined by three different broiler production density levels. This analysis determines how costs vary with increases in volume for an expanding area with a constant density, and how costs change with a constant volume and an increasing density.

The final objective is to combine the synthesized costs of this study with the costs of processing and broiler assembly developed in two previous studies.[2] This provides further information on the long-run costs

[2] Rogers, George B. and Bardwell, E. T., *Marketing New England Poultry, 2. Economies of Scale in Chicken Processing,* University of New Hampshire, Agricultural Experiment Station Bulletin 459, April 1959; and Henry, W. F. and Burbee, C. R., *Marketing New England Poultry, 5. Effect of Firm Size and Production Density on Broiler Assembly Costs,* University of New Hampshire, Agricultural Experiment Station Bulletin 482, April 1964.

and operation of an integrated poultry marketing system. Additional studies will be made to determine feed milling and feed distribution costs. All these results will provide a thorough analysis on a type of vertically integrated organization which has developed in New England as well as in other regions.

Eleven hatcheries operating in New England and many manufacturers and suppliers of hatchery equipment and supplies were the sources of data used in developing the hatchery and distribution models. Data collected from hatcheries consisted of labor productivity relationships, operational procedures, equipment and labor resource requirements, wage rates, and costs and inputs of supplies, electricity, and fuel. Manufacturers and suppliers provided technical specifications and costs on equipment and supplies.

III. Economies of Scale in Hatching of Straight-run Broiler Chicks

Procedure

The synthetic or budgetary approach is adopted for this study since it provides a method of surmounting problems encountered with other methods. For each of several defined capacities, a model plant is synthetically constructed and operated. Each one is efficiently designed and equipped to produce its intended capacity output. This approach provides the element of control needed in determining the physical input-output relationships. With standardized cost assigning procedures, this determines the short-run average costs and economies of scale.

Hatchery Capacities and Operating Schedules

Eight model hatcheries ranging in egg capacity from 121,800 to 2,029,500 are developed.[1] The outputs of these hatcheries coincide with the needs of eight broiler producing operations for eight processing plants developed in a previous study.[2] These processing plants range in capacity from 600 to 10,000 broilers per hour and operate 40 hours a week.

Three assumptions are essential to determine the hatchery egg capacities:

1. The hatching process requires 21 days to hatch an egg into a chick. The eggs are placed for 19 days in the incubating area and transferred to the hatching area for the two final days. A full output cycle is completed once each 21 days or 17.3 times a year which maintains a schedule that will permit the settings of eggs to fall on identical days each week.

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[1] Egg capacity is the total egg holding capacity of all incubating and hatching equipment in a hatchery in terms of eggs weighing 26 ounces a dozen.

[2] Rogers and Bardwell, op. cit., p. 16.

2. Egg hatchability, that is the number of eggs that hatch into satisfactory quality chicks for growing-out into broilers, is assumed to be 72 percent.

3. Of all the chicks distributed to production facilities, an assumed 4.2 percent are lost to mortality during the growing-out period. Table 2 gives the capacities and outputs for the model hatcheries and processing plants.

Operating the hatcheries at 100 percent of capacity on an annual basis provides a quantity of chicks equivalent to 260 days of processing. However, 100 percent of annual capacity for processing was established at 247 days.[3] Consequently, hatcheries would operate at 95 percent of annual capacity in supplying chicks to the growing-out operations for the processing plants.

Hatcheries schedule 2, 4, or 6 days a week for egg setting and hatch removal. Generally, the number of scheduled days increases with increasing size of hatcheries. Several reasons explain the variation. First, by increasing the number of scheduled hatch-removal days, the day to day fluctuations in the work load are minimized. Second, the quantity of chicks scheduled for a day's hatch should be sufficient to fill the facilities of one or more broiler producers to prevent age differences in the individual flocks. For purposes of this study, the number of days per week of egg setting and hatch removal is based on flock sizes ranging from 10,000 to 25,000 birds. This range includes most commercial broiler flocks in New England. Third, the operating schedule of a hatchery has a major influence on the organization and resources required for distributing chicks. A hatchery that removes hatches six days a week has essentially continuous distribution which enables a high utilization of its fixed distribution resources. Table 2 gives the number of hatch-removal days adopted for the model hatcheries.

Hatchery Labor

Labor is required to perform a minimum of 11 production operations in a broiler chick hatchery. The labor input required for these operations is determined by the methods used and the volume of eggs set or chicks hatched. Job analyses and time and motion studies were made in hatcheries to derive input-output relationships for each operation.[4] Most of these operations were found to be performed with similar methods. Major differences existed in the methods employed for traying eggs, washing trays, and counting and boxing chicks in conjunction with the debeaking operation.

In addition to these operations, a number of service operations may be conducted. However, operations of this type are generally limited to debeaking or vaccination of chicks or both. Labor standards were also determined for each of these two operations.[5]

[3] Op. Cit., p. 8.

[4] See Appendix A for a description of labor productivity standards.

[5] See Appendix A.

Table 2. Capacities and Outputs of Eight Model Broiler Processing Plants and Chick Hatcheries.

Model	Processing Plants			Hatcheries				
	Capacity per hour	Output per week* Birds	Output per year**	Hatchery capacity† Eggs	Output per week‡	Output per year§ Chicks	Output required per year¶	Number of hatches per week
		(thousand)	(million)	(thousand)	(thousand)	(million)	(million)	
A	600	24.0	1.19	121.8	25.0	1.30	1.24	2
B	1,200	48.0	2.37	243.6	50.1	2.61	2.47	2
C	1,800	72.0	3.56	365.4	75.2	3.91	3.71	4
D	2,400	96.0	4.76	487.2	100.2	5.21	4.95	4
E	3,600	144.0	7.11	730.6	150.3	7.82	7.42	6
F	5,000	200.0	9.88	1,014.8	208.8	10.86	10.31	6
G	7,500	300.0	14.82	1,522.3	313.2	16.29	15.47	6
H	10,000	400.0	19.76	2,029.5	417.5	21.71	20.62	6

* Forty hours.
** Two hundred forty seven operating days.
† Incubator and hatcher egg capacity.
‡ Includes expected mortality loss of 4.2 percent during the growing-out period.
§ At 100 percent of capacity.
¶ Based on 247 days of processing plant operation.

The biological nature of the hatching process establishes a requirement for additional inputs of labor. Hatching is a 24 hour a day, 21 day process which is primarily accomplished by automated means. Although the incubators and hatchers used are equipped with various controls, this equipment is subject to malfunctions and requires some degree of human surveillance. However, this is not a full-time operation for a worker, and he can perform some other operation concurrently.

Management generally schedules the majority of the production operations during the morning and afternoon hours. A crew generally performs these operations in a consecutive sequence and the surveillance operation as well. In order to minimize the total labor requirement, such operations as box fabrication, egg traying, and maintenance are scheduled for evening and weekend hours. A worker is in the hatchery during these hours to perform these operations and the surveillance. However, there is a limit to the extent that production operations can be spread over each day. Small scale hatcheries do not have sufficient work to spread out and consequently have to have labor inputs specifically for surveillance. As scale increases, operations can be spread over an increasing proportion of each day thereby diminishing the requirement for specialized surveillance labor.

Labor requirements were synthetically determined for the hatching process at several output levels for each model hatchery. The requirements are for seven day periods since each consecutive seven day period has identical labor input requirements for a given chick output. Production operations were generally scheduled in a consecutive sequence. The labor inputs for each of the 11 production operations were determined by budgeting with the labor productivity standards. For those operations that can be performed by several methods, each was tested in the models to determine which one minimized the total labor input without disrupting the operating schedule.

Labor inputs are categorized under one of two headings. The man-hours required to perform the production and service operations and time expended in performing these operations concurrently with surveillance are summarized under the heading of variable labor inputs. Labor inputs required specifically for surveillance are summarized under the heading of surveillance. This separation of labor inputs is necessary to determine the relationship between them with changes in volume for any particular model and with changes in scale.

The analysis was repeated for a hatching-debeaking process and a hatching-debeaking-vaccination process. The objective was to determine what effect service operations have on labor requirements and chick costs.

Table 3 summarizes the synthesized labor productivities and crew sizes for the 11 production and two service operations, debeaking and vaccination, for each model with operations at 100 percent of capacity. Eggs are trayed by hand in hatchery A, and a vacuum lift machine is used in each of the other models. Trays are washed by hand in hatcheriesA through D, and a mechanical tray washer is used in each of the others. Chick removal from hatching trays, counting, and boxing and debeaking are accomplished as separate operations in hatchery A but are incorporated into a single operation in the remaining models.

Table 3. **Labor Productivities and Crew Sizes for 11 Production and Two Service Operations Adopted for Eight Hatcheries.**

Operation	Hatchery A	B	C	D	E	F	G	H
	PRODUCTION OPERATIONS (eggs per man-hour)							
Receive and store eggs	55,000 (1)*	55,000 (1)	55,000 (1)	55,000 (1)	55,000 (1)	55,000 (2)	55,000 (2)	55,000 (2)
Tray eggs	1,800 (1)	3,750 (1)	3,750 (1)	3,750 (1)	3,750 (1)	4,700 (2)	4,700 (2)	4,700 (2)
Set eggs	30,000 (1)	30,000 (1)	30,000 (1)	30,000 (1)	30,000 (1)	30,000 (1)	30,000 (1)	30,000 (1)
Transfer eggs	14,800 (1)	14,800 (1)	14,800 (1)	14,800 (1)	14,800 (1)	14,800 (1)	14,800 (1)	14,800 (1)
Clean and disinfect hatchers	9,800 (1)	9,800 (1)	9,800 (1)	9,800 (1)	9,800 (1)	9,800 (1)	9,800 (1)	9,800 (2)
Wash trays**	6,240 (1)	6,240 (1)	6,240 (1)	6,240 (1)	15,600 (1)	15,600 (1)	15,600 (1)	15,600 (1)
	(chicks per man-hour)							
Remove chicks, count and box	3,000 (2)	3,000 (3)	3,000 (3)	3,000 (3)	3,000 (3)	3,000 (3)	3,000 (3)	3,000 (4)
Assemble chick boxes†	4,000 (1)	4,000 (1)	4,000 (1)	4,000 (1)	4,000 (1)	4,000 (1)	4,000 (1)	4,000 (1)
Clean chick boxes	8,400 (1)	8,400 (1)	8,400 (1)	8,400 (1)	8,400 (1)	8,400 (1)	8,400 (1)	8,400 (1)
Load chick boxes in vehicles	30,000 (2)	30,000 (2)	30,000 (2)	30,000 (2)	30,000 (2)	30,000 (2)	30,000 (2)	30,000 (2)
Maintenance and custodial	5,300 (1)	5,300 (1)	5,300 (1)	5,300 (1)	5,300 (1)	5,300 (1)	5,300 (1)	5,300 (1)
	SERVICE OPERATIONS							
Remove chicks, count, box, and debeak	750 (3)	1,070 (3)	1,070 (3)	1,070 (3)	1,070 (3)	1,280 (5)	1,200 (8)	1,280 (10)
Vaccinate	1,000 (2)	1,000 (3)	1,000 (3)	1,000 (3)	1,000 (3)	1,000 (6)	1,000 (9)	1,000 (12)

* Crew size for each operation in parentheses.

** Standard tray holds 156 26-ounce-per-dozen eggs.

† Chick box holds 100 chicks.

Table 4 summarizes the labor inputs for the two groups with operations at 100 percent of capacity. For the hatching process, the variable input increases from 50.7 man-hours a week for hatchery A with an output of 25,000 chicks to 588.3 man-hours a week for hatchery H, with an output of 417.500 chicks. The man-hours a week for surveillance decreases from 121.9 for hatchery A to zero for hatcheries G and H. The addition of the debeaking operation to the hatching process increases the variable input to 75.2 man-hours for hatchery A and 775.4 man-hours a week for hatchery H. This operation extends the length of the work day for variable labor operations in hatcheries A through F which re-

Table 4. Man-hours Per Week, Output Per Man-hour, and Number of Workers for Three Processes Performed by Eight Model Hatcheries with Operations at 100 Percent of Capacity.

Process	Item	Hatchery							
		A	B	C	D	E	F	G	H
Hatching	Man-hours variable per week	50.7	81.4	121.0	162.2	223.0	294.3	441.9	588.3
	Man-hours surveillance per week	121.9	102.1	74.1	40.9	22.6	13.0	0.0	0.0
	Total man-hours per week	172.6	183.5	195.1	203.1	245.6	307.3	441.9	588.3
	Output per man-hour, chicks	145	273	385	493	612	679	710	710
	Number of full-time workers	3	3	4	4	5	5	8	10
	Number of part-time workers	1	2	1	1	1	2	2	4
Hatching and Debeaking	Man-hours variable per week	75.2	111.3	165.5	222.5	302.3	387.8	598.9	775.4
	Man-hours surveillance per week	116.1	90.8	61.0	34.3	16.5	12.1	0.0	0.0
	Total man-hours per week	191.3	202.1	226.5	256.8	318.8	399.9	598.9	775.4
	Output per man-hour, chicks	131	248	332	390	471	522	523	538
	Number of full-time workers	3	3	4	4	5	6	8	10
	Number of part-time workers	2	3	3	3	2	3	7	9
Hatching, Debeaking and Vaccination	Man-hours variable per week	100.2	161.4	240.7	322.7	452.6	596.6	912.1	1,192.9
	Man-hours surveillance per week	116.1	90.8	61.0	34.3	16.5	12.1	0.0	0.0
	Total man-hours per week	216.3	252.2	301.7	357.0	469.1	608.7	912.1	1,192.9
	Output per man-hour, chicks	116	199	249	281	320	343	343	350
	Number of full-time workers	3	3	4	4	7	7	8	10
	Number of part-time workers	5	6	6	6	3	8	16	19

sults in a slight reduction for surveillance labor. Chick vaccination added to the hatching-debeaking process increases the variable labor input from 25 man-hours for hatchery A to 417.5 man-hours a week for hatchery H. This operation is conducted by a separate crew working concurrently with the debeaking crew. Consequently, vaccination operations have no effect on the requirement for surveillance labor.

Labor productivity and estimates of the size of the labor force are contained in Table 4. Productivity for hatching increases with scale from 145 to 710 chicks per man-hour. Of this increase, 62 percent is from elimination of the surveillance labor input while the remainder is from productivity increases in egg traying and tray washing. The size of the labor force increases from three full-time and one part-time employees for hatchery A to ten full-time and four part-time employees for hatchery H.

Labor productivity for the hatching-debeaking process increases from 131 chicks to 538 chicks per man-hour over the range of hatchery sizes considered. The addition of the debeaking operation to hatching reduces labor productivity substantially more in the larger scale hatcheries than in the smaller hatcheries. The labor force for this process ranges from three full-time and two part-time employees for hatchery A to ten full-time and nine part-time employees for hatchery H. Debeaking is generally performed by part-time labor.

For the hatching-debeaking-vaccination process, labor productivity increases from 116 chicks per man-hour for hatchery A to 350 chicks per man-hour for hatchery H. The addition of the vaccination operation reduces labor productivity further, but the reduction is greater in the larger scale hatcheries. The labor force ranges from three full-time and five part-time employees for hatchery A to ten full-time and 19 part-time employees for hatchery H. Vaccination is also generally performed by part-time labor.

As scale increases, the man-hours added by the service operations become an increasing proportion of the total labor input and reduce the rate of increase in labor productivity. The explanation is that productivity for the service operations either remains constant or increases at a slower rate than productivity for the hatching process. Consequently, the service operations reduce productivity by only 20 percent for hatchery A and by 51 percent for hatchery H.

Labor Cost

The observed hatcheries generally hired labor on an hourly basis, and the base wage rate ranged from $1.10 to $1.80 per hour. In addition were a number of fringe benefits such as Social Security, vacation pay, and medical insurance. For purposes of this study, labor is assigned a cost of $1.35 per hour which is assumed to include fringe benefits.

The labor cost per chick decreases rapidly with initial increases in scale but tends to level off beyond hatchery D (Table 5). For the hatching process, the cost per chick decreases from 0.932 cents for hatchery A to 0.190 cents for hatcheries G and H. Labor costs decrease from 1.033 cents per chick for hatchery A to 0.251 cents per chick for hatchery H for the hatching-debeaking process. For the hatching-debeaking-vaccina-

Table 5. Labor Costs Per Chick for Three Processes Performed in Eight Hatcheries with Operations at 100 Percent of Capacity.

Process	Hatchery A	B	C	D	E	F	G	H
	(cents)							
Hatching	0.932	0.494	0.350	0.274	0.221	0.199	0.190	0.190
Hatching and debeaking	1.033	0.545	0.407	0.346	0.286	0.259	0.258	0.251
Hatching, debeaking and vaccination	1.168	0.680	0.542	0.481	0.421	0.394	0.393	0.386

tion process, labor costs decrease from 1.168 cents per chick for hatchery A to 0.386 cents per chick for hatchery H. Most of the labor economies occur between hatcheries A and E.

Investment and Costs for Building and Equipment

Building Investment

The size and layout that would minimize construction costs and provide a satisfactory arrangement for scheduling and performing operations was determined by analysing space requirements for various makes of equipment, numbers of hatches per week, and types of work patterns. Space for inventory storage of such items as chick boxes, pads, and feeder trays was standardized at a supply level sufficient for 30 days operation at 100 percent of capacity. Egg storage was standardized to hold the maximum quantity required for the next scheduled egg setting. Space for debeaking and vaccination was not added since these operations are incorporated into existing aisle space or in the general work area. The buildings were designed for a specific capacity but with no consideration for future expansion.

Table 6 shows the constructed floor space requirements for the eight hatcheries. Square footage does not increase proportionately with the increase in capacity. Certain areas such as the office, boiler room, and rest rooms are not directly related to capacity and increase in size at a slower rate. Increasing the number of hatches each week increases the frequency of use of space for egg storage, general work area, and tray washing. Consequently, only nominal increases in space are required for these three areas for those models involved in this adjustment. An index of changing space requirements with increases in scale, is the egg capacity per square foot of floor space shown in table 6. Egg capacity per square foot increases from 76 for hatchery A to 129 for hatchery H.

The buildings are assumed to be single story, concrete block structures on a concrete slab. All buildings are designed to provide room for the same facilities except for hatcheries A and B which have the loading area combined with the general work area. Each building is essentially square to facilitate a circular work flow.

Table 6. Floor Space and Construction Costs for Model Hatcheries*

Item	A	B	C	D	E	F	G	H
				Hatchery				
				(square feet)				
Incubator and Hatcher Room	675	1,260	1,840	2,440	3,645	5,075	7,525	10,100
Egg Storage Room	40	73	60	75	108	145	213	280
Dry Storage Room	55	144	173	200	290	395	585	770
Office	80	80	100	120	150	150	150	150
Power and Boiler Room	75	100	125	150	200	250	350	450
Rest Rooms	30	30	30	60	60	60	60	60
General Work Area	448	796	872	996	1,196	1,432	1,604	1,764
Tray Washing Room	200	400	450	500	600	800	1,000	1,200
Loading Dock	....	....	300	400	600	600	900	900
Total Square Feet	1,603	2,853	3,950	4,941	6,849	8,907	12,387	15,674
Hatching Egg Capacity Per Square Foot	76	85	92	99	107	114	123	129
				(dollars)				
Construction Cost	13,545	22,681	30,415	37,058	49,655	62,795	86,090	107,367
Cost Per Square Foot	8.45	7.95	7.70	7.50	7.25	7.05	6.95	6.85
Cost Per Unit of Hatching Egg Capacity	.1112	.0931	.0832	.0761	.0680	.0619	.0566	.0529

* No investment for land nor a source of water is included.

Construction costs developed for the buildings range from $8.45 a square foot for hatchery A to $6.85 for hatchery H. The cost figures include the building itself and heating, ventilation, electrical and plumbing systems. Costs of construction are given in table 6.

Hatching Equipment Investment

Equipment is the largest investment item for a hatchery. Most of this investment is required for incubating and hatching units. Other investment items include egg traying, tray washing, stand-by generating, and miscellaneous equipment.

Many combinations and sizes of incubating and hatching equipment were found available for purchase by hatchery operators. This equipment was rated by hatching egg capacity, and this rating was generally based on eggs weighing 26 ounces per dozen. However, hatching eggs range from 22 to 28 ounces a dozen, and operators have been known to use smaller eggs when hatching eggs were scarce. Consequently, rated capacity is a relative measurement instead of absolute. By using the standard egg capacity rating, combinations of a particular make and type of incubating and hatching equipment were derived equivalent to the model hatchery capacities. No physical breakdown is given since this would identify the manufacturer.

Hatcheries B through H are each equipped with a vacuum lift egg traying machine. Hatcheries E through H each are equipped with a tray washing machine of the same model and manufacture. Budget and labor requirement analyses were used to determine which hatchery should be equipped with mechanized methods of accomplishing these operations.

Each hatchery is equipped with a stand-by generator and automatic line transfer equipment for use in event of electrical failures. Estimates on the type and capacity required by the model hatcheries were developed from data on electricity demands and usage in operating hatcheries. This equipment has sufficient capacity to meet normal demands and allow the hatcheries to continue to operate without curtailing output.

Miscellaneous equipment items include egg tray carts, work tables, office equipment, pumps, and other minor items essential to hatchery operations. Inputs of these items are synthesized.

Table 7 summarizes the investment in equipment for eight model hatcheries. Investment was determined from price lists furnished by equipment manufacturers plus costs of transportation and installation.

Investment per egg of hatching capacity decreases discontinuously with increasing hatchery capacity (table 7). Investment decreases from 19.47 cents per egg for hatchery A to 17.70 cents per egg for hatchery H. Investment per egg is higher for hatcheries B and E than their immediate predecessors. This reflects adoption of egg traying equipment in hatchery B and a tray washer in hatchery E.

Investment for Debeaking and Vaccination

The debeaking operation requires additional investment in equipment. Since hatchery A performs the debeaking operation independent of the chick removal, counting, and boxing operation, only a small investment is necessary in conventional debeaking equipment. Another type of machine that combines debeaking with the chick removal, counting, and

Table 7. Investment in Equipment for Hatching and Debeaking for Eight Hatcheries.

Item	A	B	C	Hatchery D	E	F	G	H
				(dollars)				
Incubating and hatching	20,097	40,194	60,291	80,388	120,549	167,442	251,180	334,868
Heavy equipment*	2,400	5,525	6,685	7,620	14,195	15,800	17,250	18,800
Office and miscellaneous**	1,220	2,135	1,805	2,235	2,335	3,050	4,365	5,500
Total	23,717	47,854	68,781	90,243	137,079	186,292	272,795	359,168
				(cents)				
Investment per egg of hatching capacity	19.47	19.65	18.82	18.52	18.76	18.36	17.92	17.70
				(dollars)				
Debeaking	150	3,000	3,000	3,000	3,000	6,000	9,000	12,000
				(cents)				
Investment per egg of hatching capacity	.12	1.23	.82	.62	.41	.59	.59	.59

* Heavy equipment includes egg traying, tray washing, stand-by generating, automatic line transfer, and pumping equipment.
** Miscellaneous equipment includes egg tray carts, work benches, and so on.

boxing operation has been adopted for the other hatcheries. This type of machine requires a much higher investment. Hatcheries B through E are equipped with one each; F, two; G, three; and H, four. Table 7 summarizes the investment for debeaking equipment.

The vaccination operation does not require any additional equipment. Vaccine is shipped in plastic disposable containers which are used to vaccinate chicks by the ocular method.[6]

Building and Equipment Ownership Costs

The ownership cost of building and equipment is considered a fixed cost to the firm. Included under this heading are depreciation, taxes, insurance, and maintenance and repair of the building. Table 8 shows the rates expressed as a percent of new investment that were developed or adopted for determining the costs.

Table 8. Rates for Determining Fixed Ownership Costs of Building and Equipment.

Item	Percent of Capital Investment
Depreciation	
Building	5.0
Incubating and hatching equipment	6.7
Other	10.0
Interest*	6.0
Taxes**	2.5
Insurance	1.0
Repairs	
Building	1.0

* Six percent on average undepreciated investment or 3 percent on initial investment.

** Fifty dollars per thousand assessment on average undepreciated investment.

Neither land nor a source of water are included as cost items. Land and water costs vary considerably depending on location and would be insignificant over the length of the useful life of the hatchery.

Equipment maintenance and repair costs are variable and were determined on the basis of utilization of hatchery capacity or hours of use. Maintenance includes periodic inspections, cleaning, and various preventive maintenance procedures performed by the hatchery's labor force. Equipment maintenance costs are divided into two classes: (1) labor costs which are included under hatchery labor; and (2) materials which are included under supplies.

[6] See Appendix A for description of ocular method.

Repair costs are incurred in replacing equipment components that fail or need overhauling. The hours of use per week determine the cost (per chick) for egg traying, tray washing, and debeaking equipment. Utilization of hatchery capacity is the cost determinant for the remaining equipment items. Table 9 gives the rates that were developed for deriving repair costs.

Table 9. Rates for Determining Repair Costs for Equipment in Eight Model Hatcheries.

Item	Hours of use per week	Percent new investment	Item	Percent of hatchery capacity	Percent of new investment
Egg traying, tray washer, and debeaking equipment	0	0.00	Incubating, hatching, generating, office and miscellaneous equipment	0	0.0
	10	0.75		20	0.6
	20	1.50		40	1.2
	30	2.25		60	1.8
	40	3.00		80	2.4
	50	3.75		100	3.0
	60	4.50			

Table 10 gives the weekly ownership costs for the eight hatchery buildings and the cost per chick with operations at 100 percent of capacity. Substantial economies are evident over the range of hatchery sizes considered. The cost per chick decreases from 0.130 cents for hatchery A to 0.061 cents for hatchery H. This represents a 53 percent decrease, and most of the economies occur between hatcheries A and E.

Table 10. Weekly Costs and Cost Per Chick for Eight Hatchery Buildings with Operations at 100 Percent of Capacity.

Item	Hatchery A	B	C	D	E	F	G	H
				(dollars)				
Depreciation	13.02	21.81	29.25	35.63	47.75	60.38	82.78	103.24
Taxes	6.51	10.90	14.62	17.82	23.87	30.19	41.39	51.62
Interest	7.81	13.09	17.55	21.38	28.65	36.23	49.67	61.94
Insurance	2.60	4.36	5.85	7.13	9.55	12.08	16.56	19.37
Repairs	2.60	4.36	5.85	7.13	9.55	12.08	16.56	19.37
Total	32.54	54.52	73.12	89.09	119.37	150.96	206.96	255.54
				(cents)				
Cost per chick	.130	.109	.097	.089	.079	.072	.066	.061

Table 11 gives the weekly equipment ownership costs and the cost per chick with operations at 100 percent of capacity. Very minor economies are evident. The cost per chick decreases discontinuously from 0.304 cents for hatchery A to 0.271 cents for hatchery H.

The combined cost for equipment and building ownership decreases continuously over the range of hatchery sizes considered. The cost per chick decreases from 0.434 cents for hatchery A to 0.332 cents for hatchery H, and is a reduction of 24 percent.

Equipment ownership costs for debeaking vary considerably depending on technology and utilization. Hatchery A has the lowest cost per chick: 0.002 cents. Hatchery B has the highest cost per chick, and cost decreases continuously through model hatchery E. The cost per chick for the three larger scale hatcheries is the same but is slightly higher than that for hatchery E. Table 11 gives the equipment cost for debeaking.

Table 11. Weekly Costs and Cost Per Chick for Incubating and Hatching Equipment and Debeaking Equipment in Eight Model Hatcheries with Operations at 100 Percent of Capacity

	Hatchery							
Item	A	B	C	D	E	F	G	H
	(dollars)							
Depreciation								
Incubating and hatching equipment	25.77	51.54	77.68	103.06	154.63	214.77	322.19	429.54
Other equipment	6.96	14.73	16.33	18.95	31.78	36.25	41.57	46.73
Taxes	11.40	23.01	33.07	43.39	65.90	89.56	131.15	172.67
Interest	13.68	27.61	39.69	52.06	79.07	107.48	157.38	207.21
Insurance	4.56	9.20	13.23	17.35	26.37	35.83	52.46	69.07
Repairs	13.68	27.90	39.26	51.97	77.71	105.62	156.74	207.76
Total	76.05	153.99	219.26	286.79	435.47	589.51	861.49	1,132.98
	(cents)							
Cost per chick	.304	.307	.292	.286	.290	.282	.275	.271
	(dollars)							
Total for debeaking equipment	.56	10.21	10.53	10.85	11.54	21.81	32.71	41.88
	(cents)							
Cost per chick	.002	.020	.014	.011	.008	.010	.010	.010

Management Requirements and Costs

Integration has presented an opportunity for reducing managerial costs. Those hatcheries integrated with marketing systems that conduct broiler growing operations do not require sales organizations since the chick outputs are utilized within the systems. Consequently, these hatcheries do not have to maintain a sales force in various parts of the country, managerial or clerical personnel to supervise sales, and costs of travel, advertising, and office space associated with the sales program.

In observed hatcheries integrated with poultry marketing systems, few personnel were required to perform the managerial functions of decision making, labor supervision, and clerical work. In hatcheries with less than 500,000 egg capacity, decision making and supervision were often the responsibility of one individual while clerical work was performed by personnel hired on a part-time basis. In some cases the manager assisted the crew in performing some of the hatchery operations. With increased scale, separation of these responsibilities became more evident. Managers confined themselves primarily to decision making while a foreman was hired to supervise operations in the hatchery. The foreman was generally a working foreman since he often assisted the crew. Hatcheries exceeding a million egg capacity generally had several workers performing each function. Managers had assistant managers to supervise clerical work and assist in the management process. Several foremen were required, each supervising different operations in the hatchery.

Estimates on the personnel requirements to perform the managerial functions as well as information on salaries paid were collected from the observed hatcheries. This information was used to determine the requirements for the eight synthesized hatchery models. Salaries for each of the positions were standardized and applied to the requirements to determine the weekly costs for each of the three process combinations conducted in the model hatcheries (table 12). Management costs range from 0.277 cents to 0.143 cents per chick for the hatching process with operations at 100 percent of capacity. Addition of the service operations increase supervisory costs and the cost per chick by a small amount.

Cost of Supplies

Supplies for a hatchery include chick boxes, box pads, feeder trays, fumigants, and miscellaneous items such as housekeeping and administrative supplies. Egg cases are not included as a supply item since they are assumed to be provided by the hatching egg suppliers.

Supply costs are variable since the quantity required varies directly with changes in chick output. For purposes of establishing inventories hatcheries are assumed to maintain a 30-day inventory for a 100 percent of capacity operation. Supply costs were developed from published price lists of hatchery supply manufacturers and dealers.

Minor economies are evident for supplies over the capacity range considered. The economies are derived through mass purchasing in truckload or carload lots. Cost per chick, shown in table 13, decreases from 0.247 cents for hatchery A to 0.234 cents a chick for hatchery H.

No supplies are required for debeaking. Vaccine is purchased for the vaccination operation. Many types of vaccine are available for use in controlling various diseases. For purposes of this study, vaccine costs are set at $3.00 per thousand chicks vaccinated. Table 13 shows the vaccine costs per week and the chick cost with operations at 100 percent of capacity.

Table 12. Administrative and Supervisory Personnel Weekly Costs and Costs Per Chick for Hatching; Hatching and Debeaking; and Hatching, Debeaking, and Vaccinating for Eight Model Hatcheries Operating at 100 Percent of Capacity.

Process	Item	Hatchery A	B	C	D	E	F	G	H
		(dollars)							
Hatching	Manager*	38.46	61.54	80.97	100.00	123.08	153.85	153.85	153.85
	Assistant Manager**	......	......	......	......	......	......	46.15	86.54
	Clerical†	11.54	21.34	31.00	40.38	57.69	75.00	115.38	150.00
	Foreman‡	19.23	33.65	48.07	62.50	86.54	110.58	158.65	206.73
	Total per week	69.23	116.53	160.04	202.88	267.31	339.43	474.03	597.12
	Cost per chick (cents)	.277	.233	.213	.202	.178	.163	.151	.143
Hatching and Debeaking	Manager	38.46	61.54	80.97	100.00	123.08	153.85	153.85	153.85
	Assistant Manager	......	......	......	......	......	......	46.15	86.43
	Clerical	11.54	21.34	31.00	40.38	57.69	75.00	115.38	150.00
	Foreman	22.11	38.70	55.28	71.88	99.52	127.17	182.45	237.74
	Total per week	72.11	121.58	167.25	212.26	289.29	356.02	497.83	638.13
	Cost per chick (cents)	.288	.243	.222	.212	.186	.171	.160	.153
Hatching, Debeaking, and Vaccinating	Manager	38.46	61.54	80.97	100.00	123.08	153.85	153.85	153.85
	Assistant Manager	......	......	......	......	......	......	46.15	86.54
	Clerical	11.54	21.34	31.00	40.38	57.69	75.00	115.38	150.00
	Foreman	25.42	44.51	63.57	82.66	114.48	146.24	209.82	273.40
	Total per week	75.42	127.39	175.54	223.04	295.25	375.09	525.20	663.79
	Cost per chick (cents)	.302	.254	.233	.223	.196	.180	.168	.160

* Manager's annual salary, $8,000.

** Assistant manager's (annual) salary, $6,000.

† Clerical labor and bookkeeper's salary (annual), $3,000.

‡ Foreman's annual salary, $5,000.

Table 13. Cost of Supplies Per Week and Cost Per Chick for Eight Model Hatcheries Operating at 100 Percent of Capacity.

Item	A	B	C	D	E	F	G	H
				Hatchery				
				(dollars)				
Chick boxes*	27.40	54.27	81.58	108.56	162.83	226.20	339.30	438.48
Chick box pads**	12.00	24.05	36.10	48.10	72.14	100.22	150.34	200.40
Feeder trays†	17.50	35.07	52.64	70.14	105.21	146.16	209.84	279.73
Miscellaneous supplies‡	4.80	8.52	12.58	16.64	24.04	29.23	43.90	57.21
Cost per week	61.70	121.91	182.90	243.44	364.22	501.81	743.38	975.82
				(cents)				
Cost per chick	.247	.243	.243	.243	.242	.240	.237	.234
Vaccine cost				(dollars)				
per week	75.00	150.30	225.60	300.60	450.90	626.40	939.60	1,252.50
				(cents)				
Cost per chick	.30	.30	.30	.30	.30	.30	.30	.30
Total cost per chick	.547	.543	.543	.543	.542	.540	.537	.534

* Chick boxes 32.5 cents each for hatcheries A-G, 31.5 cents for hatchery H.

** Box pads $12.00 per thousand.

† Feeder trays $70.00 per thousand for models A-F, $67.00 per thousand for models G and H.

‡ Miscellaneous supplies include fumigants, housekeeping, and administrative supplies, etc.

Combined costs for hatchery supplies and vaccine range from 0.547 cents a chick for hatchery A to 0.534 cents a chick for hatchery H. Costs decrease slightly in excess of two percent over the range of hatchery sizes.

Miscellaneous Costs

Miscellaneous cost items include electricity, fuel and telephone service. Electricity and fuel costs are developed from physical data obtained from observed hatcheries. Representative rates are applied to the data to derive costs. Telephone cost estimates are based on information given by the observed hatcheries.

The cost of electricity decreases with increased use, mainly because of declining rates. Economies exist in the purchasing of fuel oil, and consequently, larger hatcheries have a lower unit cost for this input.

Table 14 shows the weekly costs and costs per chick for these items with operations at 100 percent of capacity. The cost per chick decreases from 0.115 cents for hatchery A to 0.069 cents for hatchery H. Most of the economies occur between the capacity range of hatcheries A and E.

Table 14. Weekly Costs and Cost Per Chick for Electricity, Fuel and Telephone for Eight Model Hatcheries Operating at 100 Percent of Capacity.

Item	A	B	C	D	E	F	G	H
				Hatchery				
				(dollars)				
Electricity	22.86	40.65	55.37	67.62	88.70	119.57	170.88	224.12
Fuel*	4.19	7.50	10.32	12.85	15.50	20.00	27.75	35.50
Telephone	1.79	3.59	5.38	7.17	10.76	14.95	22.43	29.89
Cost per week	28.84	51.74	71.07	87.64	114.96	154.52	221.06	289.51
				(cents)				
Cost per chick	.115	.103	.095	.087	.076	.074	.071	.069

* Fuel cost per week derived by averaging annual fuel costs over a 52-week period.

Summary of Costs

Table 15 is a summary of costs for hatching straight-run broiler chicks by the eight model hatcheries with operations at 100 percent of capacity. The unit cost of each input category decreases with increased scale. Most of the economies are derived from labor as a result of diminishing labor requirements for the variable and surveillance operations. Labor provides 72 percent of the economies determined in this study. In order of decreasing importance, the remaining categories provide the balance of the economies: management, building, miscellaneous, equipment, and supplies.

Table 15. Summary of Hatching Costs for Operating Eight Model Hatcheries at 100 Percent of Capacity.

Item	A	B	C	D	E	F	G	H
				Hatchery				
				(cents)				
Cost per chick								
Building	.130	.109	.097	.089	.079	.072	.066	.061
Equipment	.304	.307	.292	.286	.290	.282	.275	.271
Labor	.932	.494	.350	.274	.211	.199	.190	.190
Management	.277	.233	.213	.202	.178	.163	.151	.143
Supplies	.247	.243	.243	.243	.242	.240	.237	.234
Miscellaneous	.115	.103	.095	.087	.076	.074	.071	.069
Total hatching cost per chick	2.005	1.489	1.290	1.181	1.086	1.030	0.990	0.968

The average cost per chick decreases from 2.005 cents for hatchery A with an annual output of 1.30 million chicks to 0.968 cents for hatchery H with an output of 21.71 million chicks. Labor is the largest cost item in hatcheries A through C and ranges from 0.932 cents to 0.350 cents per chick. With further increases in hatchery size, labor costs per chick continue to decrease and become less than either equipment or supply costs.

The debeaking operation increases costs for all the models but not proportionately. The added cost for debeaking decreases discontinuously from 0.115 cents per chick for hatchery A to 0.077 cents per chick for hatchery H with operations at 100 percent of hatchery capacity. The discontinuity is a result of differences in technology, crew size, and utilization of equipment. The combined cost for hatching and debeaking decreases continuously from 2.120 cents per chick for hatchery A to 1.045 cents per chick for hatchery H. Table 16 gives the costs for debeaking.

Table 16. Net Added Cost Per Chick for Debeaking and Vaccination Operations and Combined Costs with Hatching for Eight Model Hatcheries Operating at 100 Percent of Capacity.

Item	Hatchery A	B	C	D	E	F	G	H
	(cents)							
Debeaking								
Labor	.101	.050	.056	.072	.066	.060	.068	.060
Equipment	.002	.020	.014	.011	.008	.010	.010	.010
Supervision	.012	.010	.010	.009	.009	.008	.008	.007
Total	.115	.080	.080	.092	.083	.078	.086	.077
Cost per chick for hatching and debeaking	2.120	1.567	1.370	1.273	1.169	1.108	1.075	1.045
Vaccinating								
Labor	.135	.135	.135	.135	.135	.135	.135	.135
Vaccine	.300	.300	.300	.300	.300	.300	.300	.300
Supervision	.013	.012	.011	.011	.010	.009	.009	.009
Total	.448	.447	.446	.446	.445	.444	.444	.444
Cost per chick for hatching, debeaking and vaccinating	2.568	2.014	1.816	1.719	1.614	1.552	1.519	1.489

The cost of chick vaccination is essentially the same for all model hatcheries. The cost per chick decreases from 0.448 cents for hatchery A to 0.444 cents for hatchery H as a result of minor economies in supervisory costs. Vaccine represents more than half of the total cost. The combined cost per chick for a hatching-debeaking-vaccinating process decreases continuously from 2.568 cents for hatchery A to 1.489 cents for hatchery H. Table 16 gives the costs of vaccinating with operations at 100 percent of hatchery capacity.

The Effect of Short-run Changes in Output on Costs

Average costs were derived for several different levels of output for each hatchery.[7] The output levels are 40, 60, 80 and 95 percent of capacity. Because of the biological nature of the hatching process no operations in excess of 100 percent are considered. The short-run average cost curves are illustrated in Figure 1.

Analysis of the average cost curves reveals the effect of a given change in output on average cost. Reductions in output cause average cost to increase for each model since the overhead or fixed costs are spread over a smaller number of chicks, and some efficiency of operation is lost. However, a given percentage reduction in output from some given operating level does not have the same effect on average cost for all hatcheries. For example, reducing output to 60 percent from 100 percent of capacity results in smaller percentage increases in cost for each successively larger size hatchery. The average cost per chick increases from 2.005 cents to 3.068 cents for hatchery A, an increase of 52 percent, but the average cost increases from 0.968 cents to 1.275 cents for hatchery H, an increase of only 32 percent.

Economies of Scale

A line connecting the 100 percent of capacity points on the short-run average cost curves is known as the economies of scale curve or long-run average cost curve. The curve for the eight model broiler chick hatcheries is illustrated in Figure 1.

Economies of scale exist throughout the range of hatchery sizes considered. The chick cost decreases rapidly as capacity increases up to a hatchery size of approximately 700,000 eggs with an annual output of 7.5 million chicks. Further increases in scale result in minor decreases in chick cost.

Although the differences in the average cost per chick are extremely small between large scale hatcheries, the annual difference in aggregate costs would be large. For example, hatching 21,710,000 chicks in a hatchery with 2,029,500 egg capacity would cost $210,153. However, the same output hatched in two hatcheries with egg capacities of 1,014,800 each would cost $223,666, a difference of $13,513.

IV. Chick Distribution and Costs

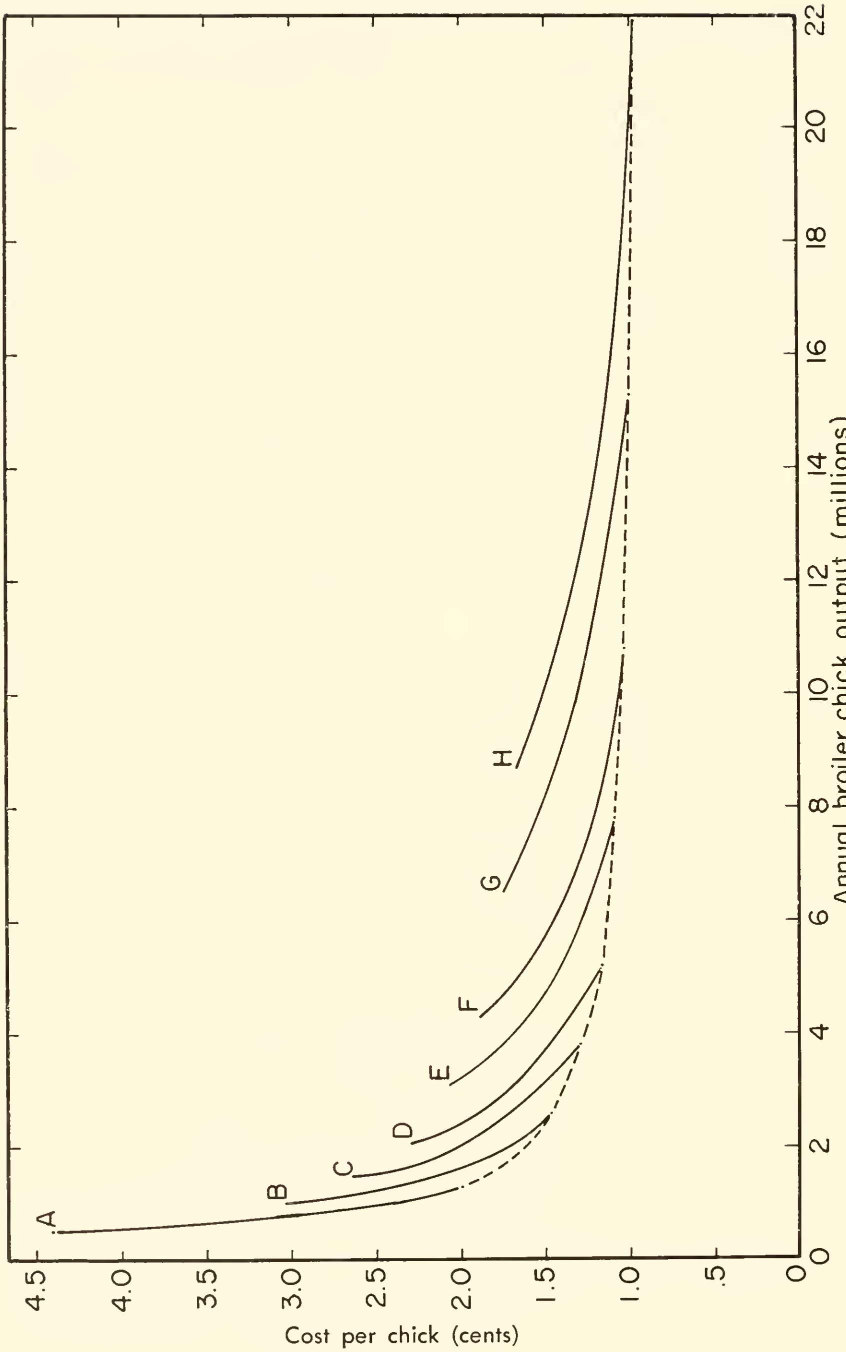
Procedure

The procedure for analysing an integrated poultry system's broiler assembly and chick distribution was originally developed and applied to an analysis of live broiler assembly[1]. That particular study established the methods, physical characteristics, and assumptions for all subsequent

[7] See Appendix B for the average costs per chick for eight hatcheries operating at several output levels.

[1] Henry and Burbee, op. cit.

Figure 1. Economies of Scale Curve and Average Cost Curves for Eight Hatcheries.



studies, under this project heading, on transfer functions. A summary of the procedure is presented below to provide sufficient comprehensive background information concerning this phase of the study on chick distribution.

Six model processing plants serve as the bases for constructing the transfer functions. The capacities of these plants are: 600, 1,800, 3,600, 5,000, 7,500, and 10,000 birds per hour. Each plant receives broilers from contract broiler producers who in turn receive their chicks from a hatchery. The six hatcheries are models A, C, E, F, G, and H developed in the previous section of this bulletin. Each hatchery has the responsibility of delivering chicks to and placing chicks at the broiler producing facilities. Distribution models carry the same letter designation as the hatchery each serves.

The broiler producing area for each firm is assumed to be a perfect circle on a plane with the integrator's fixed facilities (processing plant, hatchery, and so on) located at the center. The size of the area is determined by the requirements of the integrated firm and the density of broiler production on the surrounding plane. The density levels were established at 1,000, 5,000, and 25,000 pounds of 3.5 pound broilers per square mile per year. To produce this output and cover mortality losses during the growing period, the densities are equivalent to 298, 1,491, and 7,455 chicks distributed per square mile per year.

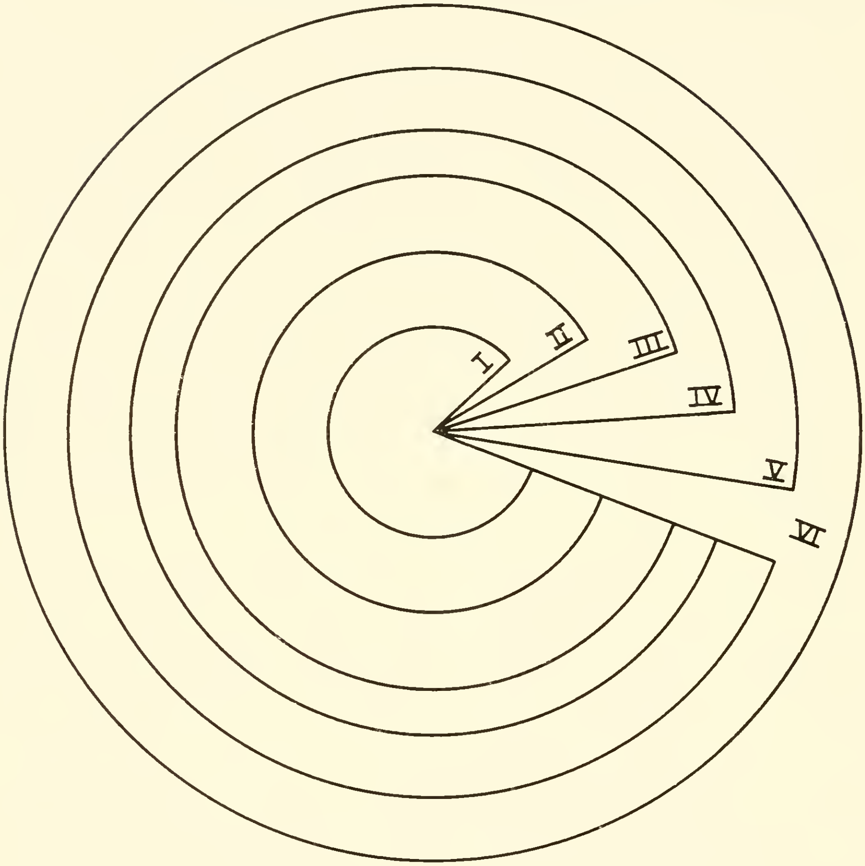
Any increase in the number of broilers produced requires a proportionate increase in the size of the producing area. Plotting these areas for the six firms as perfect circles with a common center and same density level reveals a small circle surrounded by five bands (Figure 2). The circle represents the area required by firm A. Moving out from the center, each band represents the area that must be added to the existing area to meet the increased area requirement for each successively larger size of firm.

The circle and each band are considered separate entities with a specified broiler producing capability. Each of these areas produces the same market class of broilers on a schedule that provides a given number for assembly and processing on each scheduled operating day of the processing plant. To assure continuous supply, a quantity of chicks equivalent to the number of broilers assembled plus the quantity expected to be lost during the growing out period are distributed into the bands for replacement. Table 17 gives the annual chick input and broiler output for each band.

Table 17. Chicks Distributed and Broilers Assembled Annually in Six Broiler Producing Bands

Band	Chicks Distributed	Broilers Assembled
	(millions)	
I	1.24	1.19
II	2.47	2.37
III	3.71	3.55
IV	2.89	2.77
V	5.16	4.94
VI	5.16	4.94

Figure 2. Relationship Between Broiler Producing Areas of Six Firms with Broiler Production at a Given Density.



Assembly and processing are conducted five days a week throughout the year except for a two week period and one week when they are limited to two days. The hatcheries distribute chicks two, four, or six days a week[2]. In actuality, the failure of hatch removal and distribution days to coincide with processing days would cause minor variations in the average weight per bird between flocks. It is assumed for purposes of this study, that all finished birds average 3.5 pounds live weight.

It is assumed that the transfer functions are organized and conducted in a specified manner. The broiler production units in each of one or more bands are serviced by one or more complements, each consisting of a vehicle and labor. Each complement initiates each trip at the hatchery and proceeds out along a primary radial highway and system of secondary roads which cut across the bands in the production plane. In each

[2] See Table 2 for the number of scheduled hatch removal days for the model hatcheries.

band chicks are distributed to an impound point which represents the "average" location of production units in that segment of the band. After the chicks have been distributed at an impound point in one or more bands, the complement returns to the hatchery by the same route. Over time, chicks are distributed to producing units throughout the entire area by using the several radial highways and the adjoining secondary roads.

A number of technical coefficients were developed in the assembly study. These concerned the "average" location or impound point of producing facilities in each band, distance between the impound points and the fixed facilities of the firm at the center of the producing area, and the time required to travel these distances. The coefficients are applicable in this study and are summarized in table 18.

Other assumptions pertinent to the analysis of the transfer function are given below:

1. Maximum flock sizes were established in the original study at 9,600 broilers in band I, 19,200 in band II and III, 22,400 in band IV, and 40,000 in bands V and VI. The number of chicks required to produce these broilers and meet expected mortality losses are 10,021, 20,042, 23,382, and 41,754 respectively.

2. Each flock must receive the required number of chicks in a period not exceeding three days.

3. Employees and vehicles are assumed to work ten hours or less a day. This restriction prevents the shifting of the effects of an increasing producing area onto labor and vehicles through use of overtime payments and increased vehicle utilization.

4. Each complement can undertake only those trips that it can complete on a round trip basis within the ten hour day. This means that a complement cannot proceed out one day and return the next.

5. The production density of broilers for a firm is not necessarily the total density for the area. The firm has the alternative of increasing density by acquiring additional existing production facilities close to the center to reduce the size of its producing area.

6. The distribution of chicks encompasses transport from the hatchery to a broiler producing facility, placing the chicks, and returning to the hatchery. Loading the vehicle at the hatchery and unloading the empty boxes upon return are responsibilities of the in-plant hatchery employees.

7. The chicks removed during each hatch removal day must be distributed that day. This means that no chicks can be held over to a non-hatch or another hatch removal day.

Labor Productivity in Placing Chicks

Before a budgeting analysis can be made of chick distribution, a labor productivity coefficient for placing chicks at the producing facilities in the broiler producing area is necessary. This phase encompasses

Table 18. Determination of Average Locations of Broiler Production Units in Each Broiler Producing Band and Travel Time from the Plant to the Producing Units for Three Density Levels.

Firm	Size of Supply Area	Radius of Firm's Supply Area	Radial Distance Added by Each Firm*	Average Distance to Broiler Producing Units**	Road Distance One Way†	Travel Time One Way‡
	(thousand sq. miles)		(miles)			(hours)
	Density Level — 298 chicks per square mile per year					
A	4.25	36.4	36.4	25.7	33.2	1.33
C	12.5	63.0	26.6	51.4	67.9	2.30
E	24.9	89.0	26.0	77.1	102.6	3.08
F	34.6	104.9	15.9	97.3	129.9	3.68
G	51.9	128.5	23.6	117.3	156.9	4.25
H	69.2	148.4	19.9	138.8	186.0	4.87
	Density Level — 1,491 chicks per square mile per year					
A	.8	16.3	16.3	11.5	14.0	.63
C	2.5	28.2	11.9	23.0	29.5	1.22
E	5.0	39.8	11.6	34.5	45.1	1.75
F	6.9	46.9	7.1	43.5	57.2	2.03
G	10.4	57.5	10.6	52.5	69.3	2.37
H	13.8	66.4	8.9	62.1	83.7	2.62
	Density Level — 7,455 chicks per square mile per year					
A	.2	7.3	7.3	5.1	6.2	.32
C	.5	12.6	5.3	10.3	12.4	.58
E	1.0	17.8	5.2	15.4	19.3	.84
F	1.4	21.0	3.2	19.5	24.3	1.05
G	2.1	25.7	4.7	23.5	30.2	1.25
H	2.8	29.7	4.0	27.7	35.9	1.42

* Width of the band.

** Average location in each band derived from the equation, $D = \sqrt{\frac{X^2 + Y^2}{2}}$. X equals the distance from the center of the producing area to the inner perimeter of the band, and Y equals the distance from the center to the outer perimeter of the band.

† Road mileage derived from one or the other of two equations. When D is greater than 10 miles, road mileage derived from the equation, $R = -1.534 + 1.351D$. When D is equal to or less than 10 miles, road mileage derived from the equation, $R = 1.196D$.

‡ Hours derived from following equations:

0—59.9 miles one way $T = 2.865 + 2.6818R - 0.0102R^2$

60—and over one way $T = 50 + 1.299R$

when T is time in minutes and R is road mileage one way.

several operations that the distribution personnel must carry out at each broiler producing facility. In actuality, the broiler grower may assist the personnel in these operations. However, he is not obligated to assist. and it is assumed that he does not.

The operations performed at each farm are listed below:

1. Preparation
   a. Position the truck
   b. Release tie downs on the load
   c. Inspect broiler house for such conditions as proper temperature, ventilation and equipment operation
2. Unloading and emptying chick boxes
   a. Carry boxes of chicks to brooders
   b. Remove chicks from boxes
   c. Carry empty boxes back to truck
3. Preparation for leaving
   a. Load and secure empty boxes
   b. Conduct any necessary paperwork
   c. Leave farm

Some additional time is necessary for personal needs of the crew.

The policy for chick distribution is to assign one man to a vehicle to drive and place the chicks. On occasions when the scheduled trip is longer than usual or the load larger than usual, a second man, a helper, is added to assist the driver at the farm or in driving. For purposes of this study, two men per vehicle is the maximum permissable crew.

Data on labor productivity for distribution was collected from several integrated hatcheries. In placing chicks at production units crews consisting of one or two men averaged 5,000 chicks or 50 boxes per man-hour provided no time was lost waiting for the grower to finish preparing the facilities for receiving the chicks. This is the productivity standard adopted for use in constructing the distribution model.

Chick Distribution Vehicles

A variety of sizes and types of vehicles were found available to hatcheries for chick distribution. Hatcheries generally used the straight-back truck with van, but buses, panel trucks, and tractor-trailer combinations were also in evidence.

One specific vehicle size was not suitable for all hatcheries. Five different load capacity vehicles representative of the sizes that were found in use are utilized in developing the distribution models. The load capacities range from 14,000 to 34,800 chicks (table 19).

Cost of Distribution Inputs

Chick distribution requires three inputs: labor, vehicles, and management. No buildings are included since hatcheries use the indoor loading areas as garages or leave the vehicles outside.

Labor Costs

Drivers are assigned a cost of $1.70 per hour which was the prevailing wage found for hatchery vehicle drivers. Helpers are assigned a cost of $1.35 per hour. These wage rates include such fringe benefits as

Table 19. Load Capacity, Gross Vehicle Weight and Chassis and Van Investment for Five Vehicle Types.

Vehicle Type	Load Capacity	Gross Vehicle Weight*	Chassis Investment	Van Investment	Total Investment
	(chicks)	(pounds)		(dollars)	
M	14,000	16,000	3,300	3,000	6,300
N	19,600	16,000	3,300	3,200	6,500
O	23,600	16,000	3,300	3,500	6,800
P	30,400	19,500	3,800	4,000	7,800
Q	34,800	21,000	4,200	4,500	8.700

* Gross vehicle weight is the vehicle weight and maximum load weight according to manufacturer ratings.

Social Security, insurance, and paid vacations. Labor is paid straight-time pay for all hours worked.

Vehicle Investment and Operating Costs

The technical specifications of truck chassis and vans were analysed to determine which model truck chassis is satisfactory for each size van. One basic model chassis differing only in cab-to-axle length is satisfactory for the three smaller van sizes, types M, N, and O. Heavier duty chassis are required for the two larger van sizes, types P and Q. Investment in chassis and vans is given in table 19 for each type vehicle. The investment includes excise taxes and minimum safety equipment required for registration purposes. Investment per chick of vehicle load capacity decreases from 45 cents for the type M vehicle to 25 cents for the type Q vehicle.

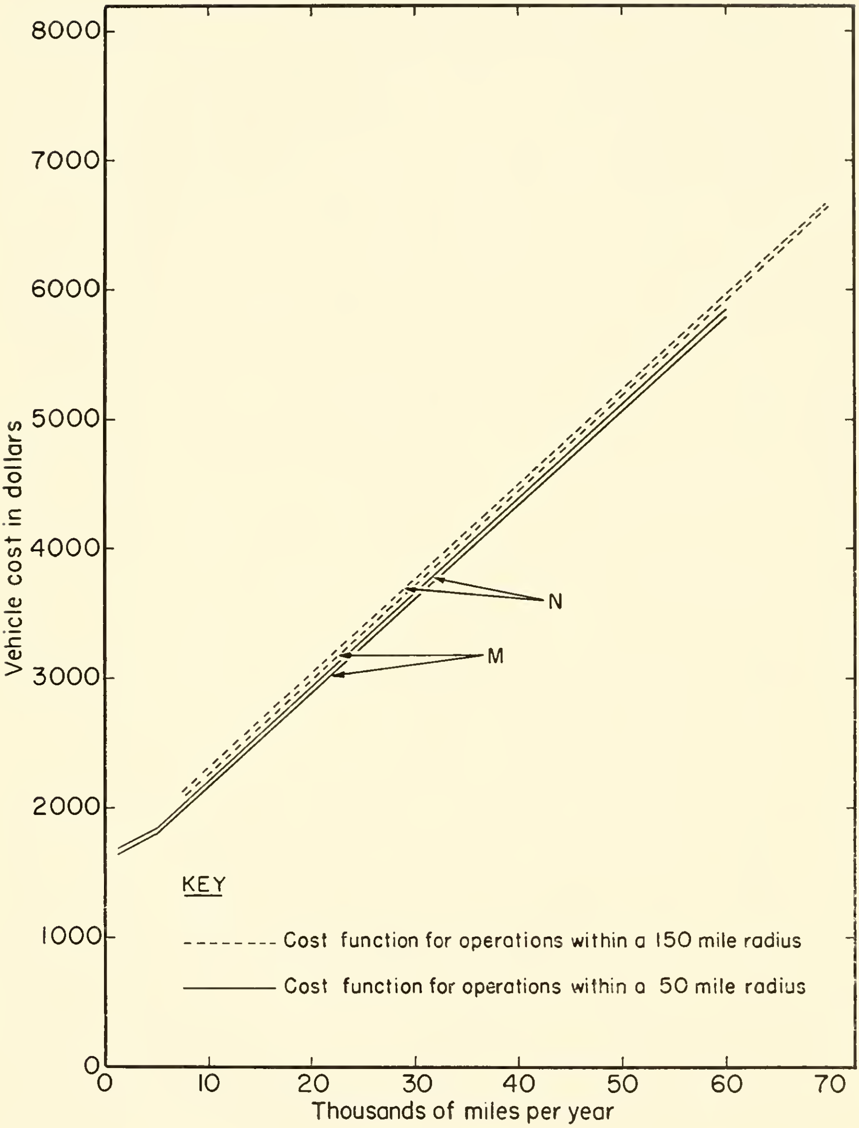
The total cost of owning and operating a vehicle is an aggregate of such items as gas, depreciation, and so on. The cost of some items is a function of use while others are a function of use and/or time. A relationship for each item was developed between cost and the common variable, mileage[3]. These relationships were then combined to form the relationship between total cost and mileage for each vehicle type as shown in Figures 3 and 4.

For each vehicle, two relationships were developed. One is for operations conducted within a 50 mile radius and the other is for operations within a 150 mile radius of the center. The two relationships are necessary because insurance costs were found to vary with the radius of the area of operation.

For a given annual mileage, the cost increases with increasing vehicle size but not in proportion to the increase in load capacity. At 30,000 miles a year with operations within a 50 mile radius, the cost per mile ranges from a low of 12.1 cents for a type M vehicle to a high of 14.7

[3] See Appendix C for a description and derivation of vehicle costs.

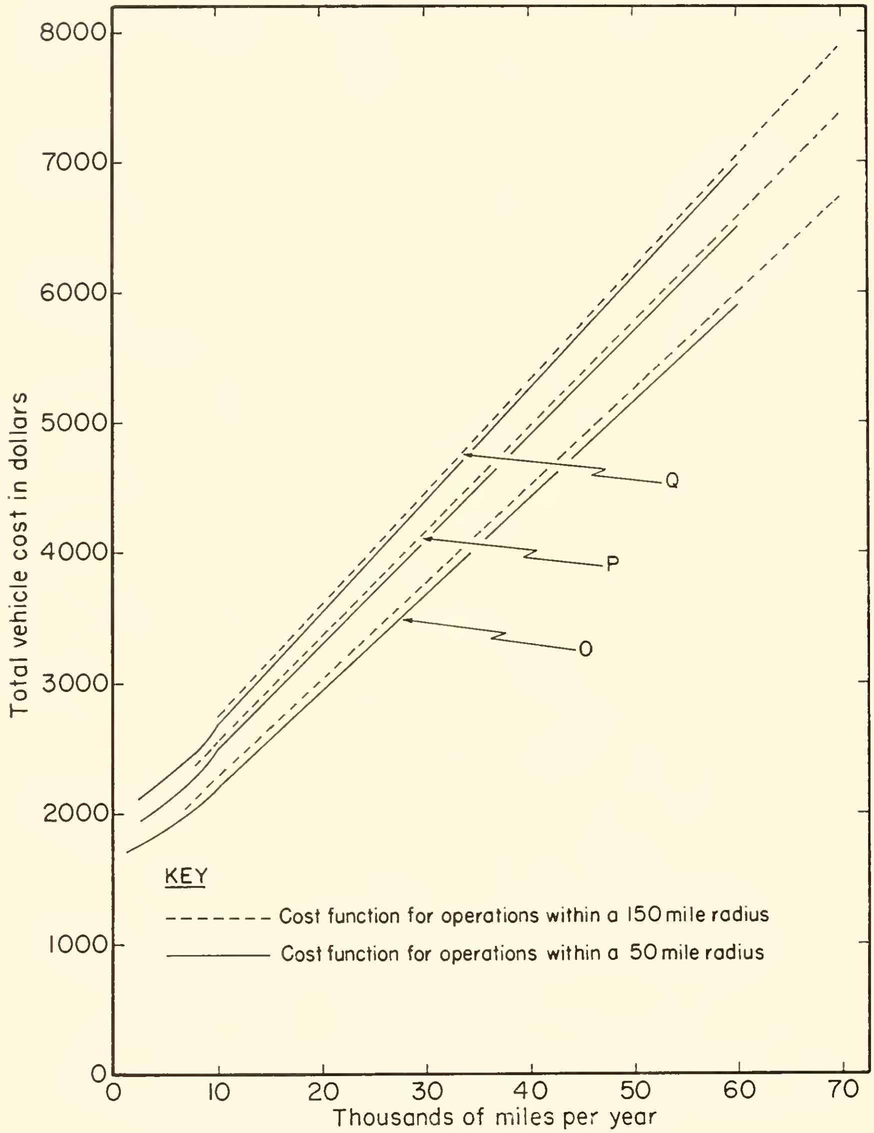
Figure 3. Total Operating Cost for Vehicle Types M and N at Various Annual Mileages.



cents for a type Q vehicle. But the cost per chick of load capacity decreases from a high of 25.9 cents for the type M vehicle to a low of 12.6 cents for the type Q vehicle.

The cost per mile decreases with increasing mileage for each type vehicle. For example, a type O vehicle operating within an area of a 50 mile radius has a cost of 22 cents per mile at 10,000 miles per year, and a cost of 10.4 cents per mile at 50,000 miles per year.

Figure 4. Total Operating Cost for Vehicle Types O, P, and Q at Various Annual Mileages.



Management Costs

Management has several functions to perform. These functions essentially consist of scheduling chick distribution, supervising personnel, and purchasing vehicles and their inputs such as gas, tires, and so on. Annual costs assigned to management are as follows: firm A, $80.00, C, $200.00, E, $320.00, F, $400.00, G, $600.00, and H, $800.00.

The Distribution Model, Resources, and Costs

The Model

Each band in the producing area of a firm has a requirement for a specific number of chicks from each hatch. The objective is to organize chick distribution in such a manner as to derive the lowest possible cost. This is accomplished by using the resources, coefficients, assumptions, and cost relationships previously developed.

Since the marginal productivity of labor is constant, the man-hours of labor for placing a given quantity of chicks at a broiler producing unit is also always constant. Consequently, the problem is one of determining what combinations of vehicles and labor will minimize the number of trips into the producing area, and then determining which combination performs the operation at the lowest cost. This is accomplished once for each density level for each of the six hatcheries.

For each hatchery, the trip alternatives are established by arranging the individual bands into the maximum number of unlike groups. Some groups contain as few as a single band while the largest contains all the bands. The groups are then arranged into the maximum number of combinations each of which is equivalent in sum and identify to the bands in the producing area. The combinations represent the various alternatives for distributing the chicks by each distribution model.

The sequence for analysing these various combinations is to proceed with the combination consisting of a single group. This group represents a single trip which minimizes the number of vehicles and miles travelled as well as man-hours of driver time expended in transit. In addition, this alternative requires the largest capacity vehicles that would be used resulting in the lowest possible vehicle cost per chick distributed. If this complement fails to meet the restrictions, the analysis is shifted to combinations consisting of two groups and so on until satisfactory solutions are found. Once a combination with a particular number of groups proves satisfactory, all other combinations with the same number of groups are analysed and the physical inputs determined for those that satisfy the restrictions. The inputs are converted into costs, and the least cost method is found. Combinations consisting of larger numbers of groups do not require calculation since they would involve additional trips and inputs and result in higher cost operations.

As an example of the above procedure, hatchery F has to distribute 34,800 chicks a day, six days a week into four bands: I, II, III, and IV. The first combination tested to determine whether one complement can service the bands in one trip consists of one group containing all four bands. This alternative requires a type Q vehicle which has a load capacity of 34,800 chicks. At the density level of 1,491 chicks per square mile per year, a round trip through the bands is 114.4 miles and requires 4.06 hours of travel time. Placing of chicks in the broiler houses requires 6.96 hours utilizing the smallest crew, a driver. This alternative requires a total of 11.02 hours which exceeds the 10 hour work day restriction. The addition of a helper to the distribution complement then reduces the time spent in placing chicks at the farms to 3.48 hours. This reduces the duration of the entire operation to 7.54 hours which is a satisfactory solution.

The inputs for the alternative are calculated and transformed into costs. On an annual basis, the type Q vehicle is operated 33,977 miles at a cost of $4,990. The labor input is 2,238.7 man-hours of driver time and 2,231.0 man-hours of helper time (the helper is not required on one trip for a partial load). At $1.70 per hour, the wages for the driver amount to $3,806, and at $1.35 per hour, the wages for the helper total $3,013. The annual cost for distribution, including $400 for management, is $11,929.00 or 0.116 cents per chick.

Distribution Resources

Table 20 summarizes the number and types of vehicles and labor used by the six distribution models at each of the three density levels. As the volume increases, a larger load capacity vehicle is substituted until this factor is exploited or the restrictions force the use of several small capacity vehicles. Hatchery F at the two higher density levels uses the maximum capacity vehicle, but has to use two smaller capacity vehicles at the low density level. For hatcheries G and H, vehicle numbers increase. Hatchery G which distributes a volume of chicks one and a half times that of F uses two type P vehicles, and H uses two type Q vehicles.

The size of the labor force increases with increasing volume at each density level. At the low density level, helpers assist drivers of hatcheries E and F. At the 1,491 chick density level, helpers are used by hatcheries F through H, and no helpers are required for chick distribution at the highest density level. The number of drivers is equivalent to the number of vehicles.

When density increases for a given volume, vehicle numbers and size do not change except for hatchery F. Hatcheries E through H eliminate the requirement for helpers and F eliminates one driver.

The solutions for distribution by hatcheries G and H at the low density levels are not presented. The required travel time is approaching the 10 hour work day restriction and leaves very little time to place the chicks at the broiler producing facilities. To accomplish the placement within the imposed restrictions would require the addition of many vehicles and men and result in a very high cost. Firms distributing chicks beyond a radius of 150 miles would probably use some other alternative such as using sleeper-cab vehicles and two days to complete a trip. If broiler production facilities are spread over a very large area, the firm could operate two hatcheries, each servicing a section of the full area. However, it is not the intent of this study to examine the alternatives available to hatcheries for servicing such distant areas.

Chick Distribution Costs

Table 21 is a summary of costs for chick distribution by the six hatcheries. As volume increases at each density level, the distribution cost per chick initially decreases but at a decreasing rate. Eventually, the cost commences to increase but at a different volume for each density level.

At the low density level, the cost per chick decreases from 0.231 cents for hatchery A distributing 12,500 chicks a day, two days a week and 1.24 million chicks annually to 0.176 cents for hatchery C distribut-

Table 20. Number and Types of Vehicles and Labor Used by Six Hatcheries to Distribute Chicks at Three Density Levels.*

Hatchery	Density Level								
	298 Chicks			1,491 Chicks			7,455 Chicks		
	Number and type vehicle	Number of drivers	Number of helpers	Number and type vehicle	Number of drivers	Number of helpers	Number and type vehicle	Number of drivers	Number of helpers
A	1 – M	1	0	1 – M	1	0	1 – M	1	0
C	1 – N	1	0	1 – N	1	0	1 – N	1	0
E	1 – P	1	1	1 – P	1	0	1 – P	1	0
F	1 – M 1 – O	2	1	1 – Q	1	1	1 – Q	1	0
G	....	....	....	2 – P	2	1	2 – P	2	0
H	....	....	....	2 – Q	2	2	2 – Q	2	0

* Load capacity of vehicles given in table 19.

Table 21. Costs Per Chick for Distribution by Six Hatcheries at Three Density Levels.

Hatchery	Vehicle	Labor	Management	Total
		(cents per chick)		
		298 chick density level		
A	.154	.070	.007	.231
C	.095	.076	.005	.176
E	.089	.106	.004	.199
F	.114	.118	.004	.236
		1,491 chick density level		
A	.138	.051	.007	.196
C	.062	.056	.005	.123
E	.051	.058	.004	.113
F	.046	.066	.004	.116
G	.057	.071	.004	.132
H	.053	.071	.004	.128
		7,455 chick density level		
A	.132	.043	.007	.182
C	.050	.045	.005	.100
E	.035	.045	.004	.084
F	.030	.044	.004	.078
G	.037	.048	.004	.089
H	.032	.050	.004	.086

ing 18,800 chicks a day, four days a week and 3.71 million chicks annually. At the 1,491 chick density level, the cost decreases from 0.196 cents per chick for A to 0.113 cents for E distributing 25,050 chicks a day, six days a week and 7.41 million chicks a year. At the high density level, the cost decreases from 0.182 cents a chick for A to 0.078 cents for F distributing 34,800 chicks a day, six days a week and 10.3 million chicks a year.

This is a different result than would be expected in a theoretical sense. If distance was the only feature of distribution that varied as size of firm, and therefore size of distribution area, increased, the cost per chick for distribution should rise. However, this decrease in cost with increasing volume is the result of the direction and rate of change in the costs for vehicle operation and labor. Vehicle operating costs decrease at a decreasing rate as each successively larger hatchery operates a single but larger load capacity vehicle. This introduces economies in some of the operating costs which offset those operating costs that increase with expansion of the broiler producing area. Furthermore, the number of distribution days increase from two for hatchery A to six for E. This increase spreads the fixed vehicle costs over an increasing number of chicks and reduces the unit cost.

At each density level, labor costs per chick increase with increasing volume. This is a result of an increasing number of man-hours being expended in travel in an expanding broiler producing area. Eventually, the increasing unit labor cost overcomes the diminishing decrease in the unit vehicle operating cost and the unit distribution cost commences to increase.

Further increases in volume and distribution of the volume by single complements results in an increasing distribution cost. Depending on the density level, a volume is reached which cannot be delivered by a single complement because of the restrictions imposed on the length of the work day and crew size. Volumes in excess of this quantity must be delivered by two complements. At the low density level, two complements are required for volumes in excess of approximately 30,000 chicks a day and 9.0 million chicks a year. The distribution cost increases rapidly up to this volume and then increases moderately for further increases in volume (Figure 5). Hatchery F has a distribution cost of 0.236 cents per chick for delivering 34,800 chicks a day and 10.3 million chicks a year.

At the 1.491 density level, the cost function for volumes distributed by a single complement intersects the function for volumes distributed by two complements at approximately a volume of 43,000 chicks a day and 13 million chicks a year. The distribution cost at this point is 0.134 cents per chick (Figure 5). With further increases in volume, the distribution cost with two complements commences to decrease slightly. For hatchery G distributing 52,200 chicks a day, six days a week and 15.47 million chicks a year, the distribution cost is 0.132 cents per chick (Figure 5). Hatchery H distributing 69,600 chicks a day, six days a week and 20.63 million chicks a year has a distribution cost of 0.128 cents per chick. At this density level, any additional volume would probably require adding a third complement, and the distribution cost would commence to increase.

The intersection of the two distribution cost functions at the 7.455 chick density level occurs at approximately a volume of 52,200 chicks distributed a day which is the same volume as that handled by Hatchery G. The distribution cost for this volume is 0.089 cents a chick. The cost decreases slightly with additional volume to 0.086 cents a chick for Hatchery H. Any additional volume would probably be distributed at a slightly lower unit cost, but the cost would eventually increase as more complements are required.

A combination of factors explains the difference in direction of the two complement cost functions. At the low density level, increasing volume requires large increases in the size of the producing area. The increases in travel and the restrictions used in developing the models increase the distribution cost more than any reductions in cost that accrue from the added flexibility in conducting the distribution function with two complements. At the two higher density levels, the effect of these factors is reversed resulting in a declining distribution cost.

Figure 6 illustrates the effect of increasing density on distribution costs for the six hatcheries. Increasing density from 298 chicks to 1,491 chicks per square mile per year reduces distribution costs from a minimum of 15 percent for hatchery A to a maximum of 51 percent for model F. Distribution costs are further reduced by increasing density from 1.491 chicks to 7,455 chicks per square mile per year. The minimum reduction is 7 percent for hatchery A, and the maximum is 33

Figure 5. Effect of Volume on Distribution Costs at Three Density Levels.

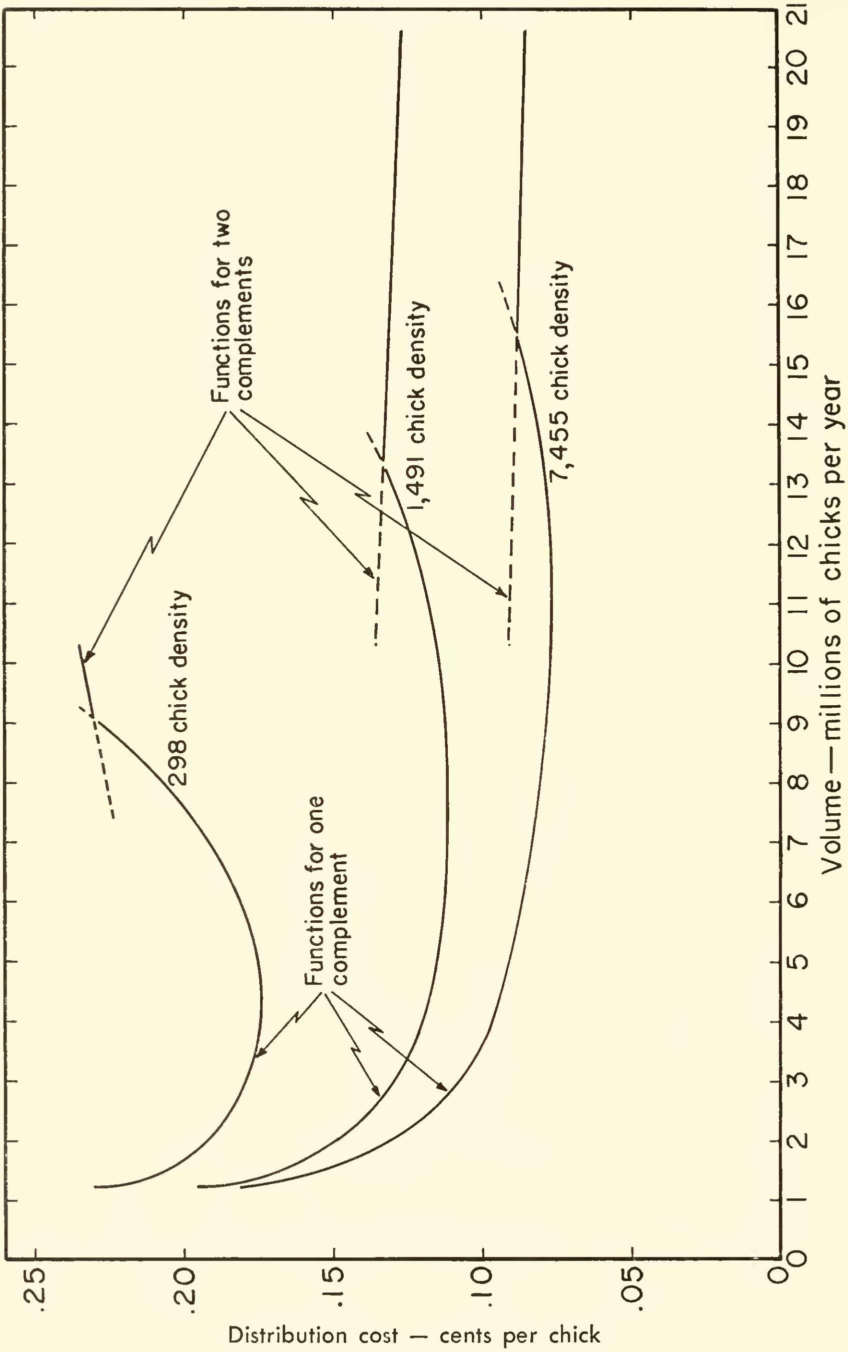
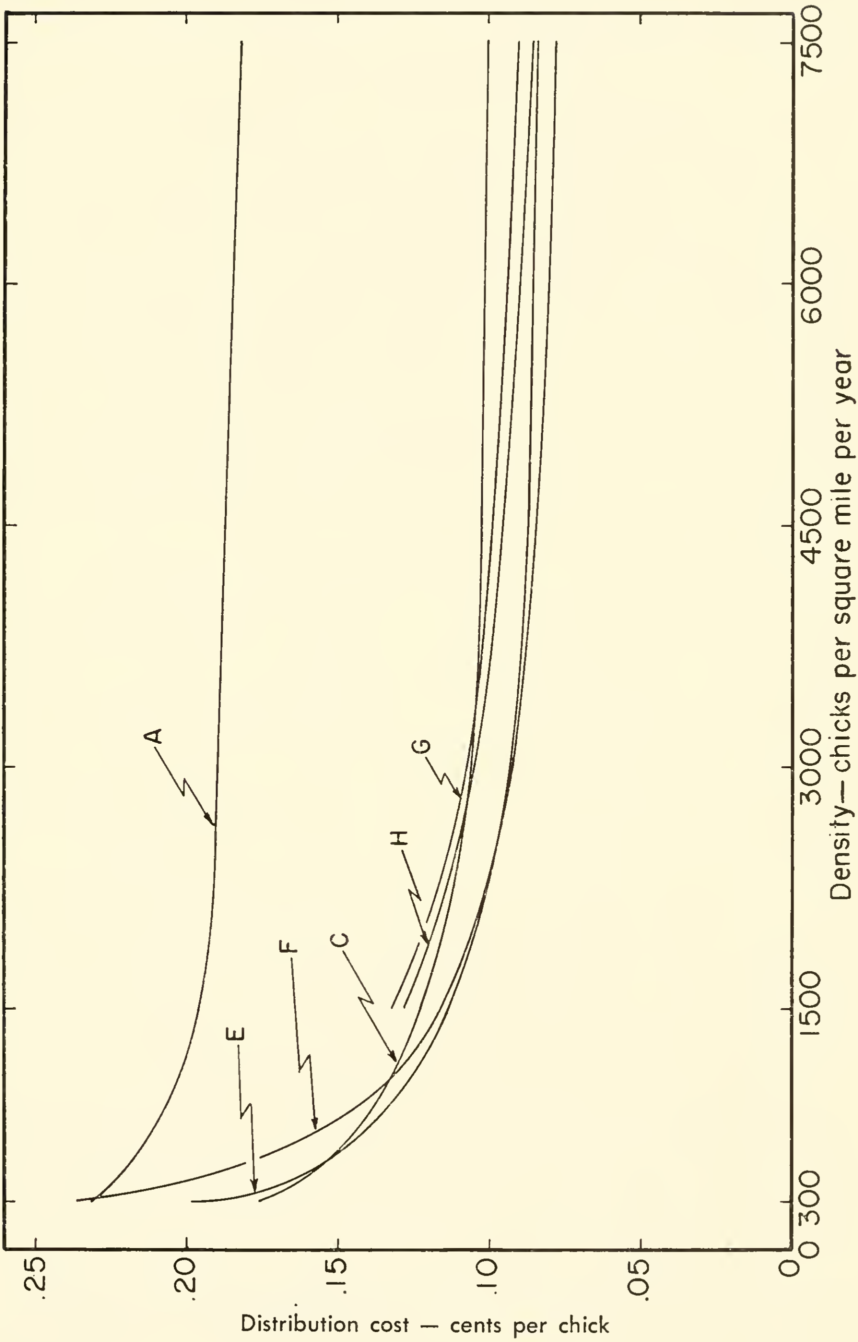


Figure 6. Effect of Density on Broiler Chick Distribution Costs for Six Hatcheries.



percent for the three largest hatcheries considered, F, G, and H. Examination of the relationships indicates that reductions in distribution costs are relatively minor for increases in density above the 3,000 chick per square mile per year level.

V. Combined Costs for a Poultry Marketing System

Costs and economies of scale for broiler chick hatching and chick distribution are synthesized in this study. Costs for broiler assembly and eviscerated processing were synthesised in two previous studies in this series. Combining the results of the three studies provides the long-run relationships between costs and size for a poultry marketing system consisting of these four functions. It is irrelevant whether each function is individually owned or the four functions comprise a wholly owned integrated organization since the entrepreneurial demands are not included as costs. The important feature is that the capacities of the hatching, chick distribution, and broiler assembly functions are equivalent to the capacity requirements of the processing plants they serve. This eliminates any one function from being a "bottleneck" in the system or any function having unnecessary excess capacity.

Table 22 summarizes the costs for each of the four functions conducted by six model systems operating at 100 percent of capacity. Economies exist throughout the range of processing plants and hatcheries considered. The processing cost per bird decreases from 13.311 cents for system A processing 1.19 million birds annually to 9.247 cents for system H processing 19.76 million birds annually, a reduction of 4.064 cents per bird. The hatcheries which operate at 95 percent of capacity have a cost per processed bird ranging from 2.180 cents for system A to 1.037 cents for system H. This is a reduction of 1.043 cents per bird. Note that the processing costs per bird are six to nine times greater than the hatching costs and dominate the in-plant costs for this type of integrated system.

Considerable difference exists between broiler assembly and chick distribution costs. Assembly costs are 13 to 27 times greater than chick distribution costs. Furthermore, the relationships between assembly and distribution costs and size of operation are different at any given density level. Assembly costs increase continuously with increasing volume if all other factors are held constant, but distribution costs initially decrease and eventually increase.

Figure 7 illustrates the combined in-plant scale curves, transfer cost curves for three production density levels, and the total combined cost curves for the four functions at three density levels. The combined scale curve for processing and hatching is similar in shape to the processing scale curve but is somewhat steeper in slope. Economies exist throughout the entire range of system sizes considered but are small for annual outputs in excess of 9.0 million birds.

The combined transfer cost functions used in this study reveal the tendency for this cost to increase with increasing volume at a given density level. At the low density level, 1,000 pounds of live broilers per

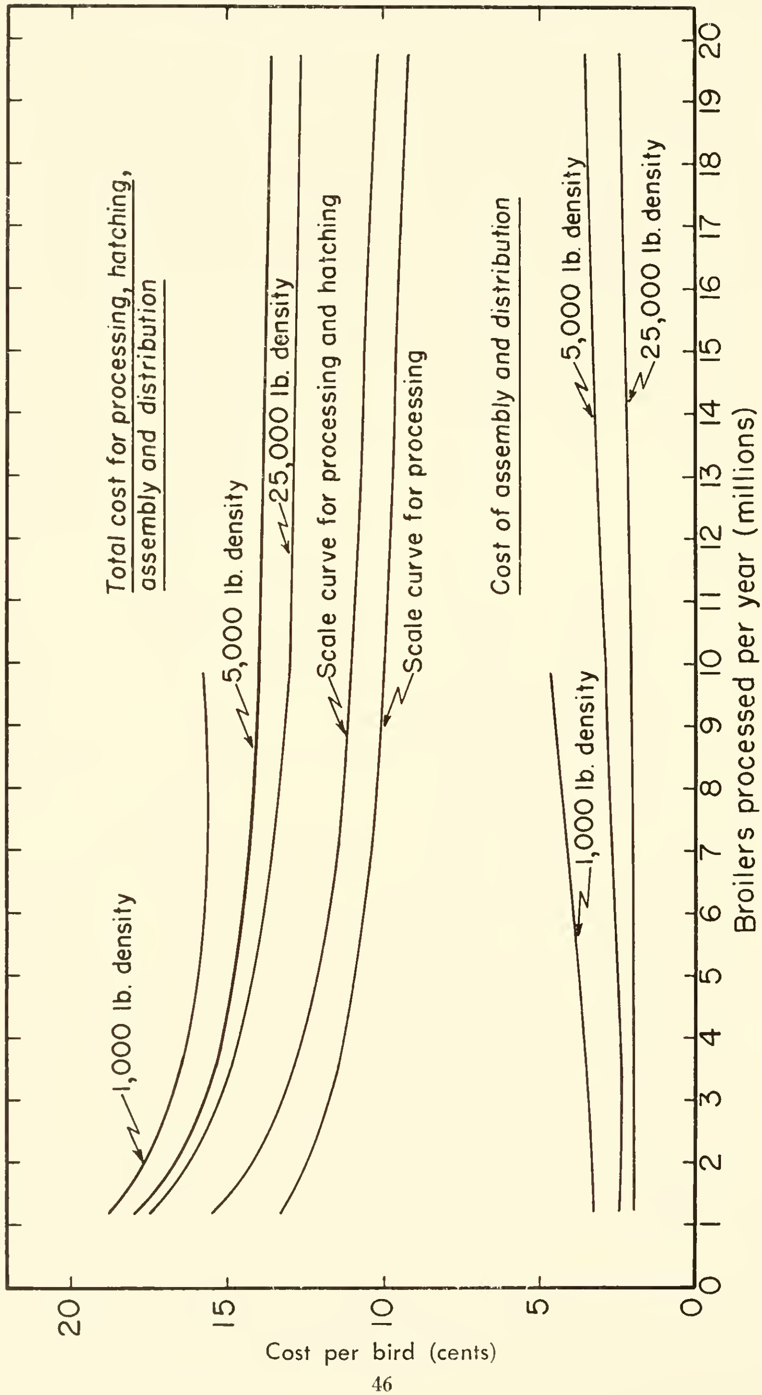
Table 22. Long-run Average Costs for Six Poultry Marketing Systems Operating at 100 percent of Capacity with Broiler Production at Three Density Levels.

System	Output Birds per year	Processing	Hatching*	Broiler Assembly			Chick Distribution*			Combined Costs		
				Density Level in Pounds**								
				1,000	5,000	25,000	1,000	5,000	25,000	1,000	5,000	25,000
	(million)	(cents per bird)										
A	1.19	13.311	2.180	3.034	2 230	1.810	.241	.204	.190	18.816	17.925	17.491
C	3.56	11.536	1.400	3.343	2 265	1.880	.184	.128	.104	16.463	15.329	14.920
E	7.11	10.392	1.174	3.952	2 545	1.901	.208	.118	.088	15.726	14.229	13.555
F	9.83	10.007	1.105	4.393	2.741	1.950	.246	.121	.031	15.751	13.974	13.143
G	14.82	9.597	1.062		2 939	2.100		.138	.093	....	13.786	12.852
H	19.76	9.247	1.037		3 217	2.289		.134	.090	....	13.635	12.663

* Cost of 4.2 percent chick mortality during the growing out period, prorated and added to these operations.

** These density levels are equivalent to chick density levels used previously.

Figure 7. Long-run Average Cost Curves for a Poultry Marketing System Consisting of Processing, Hatching, Broiler Assembly and Chick Distribution Functions for Three Broiler Production Density Levels.



square mile per year, transfer costs per bird increase continuously from 3.325 cents for system A with an output of 1.19 million birds annually to 4.639 cents for system F with an output of 9.88 million birds. However, at the 5,000 and 25,000 pound density levels, transfer costs initially decrease slightly before commencing to increase. Transfer costs decrease slightly from the 1.19 million bird output to the 3.56 million bird output. The decrease is the result of chick distribution costs decreasing more than the increase in broiler assembly costs.

The combined in-plant and transfer costs represent the full cost of a specific type of broiler marketing system for various system sizes. At the low production density level of 1,000 pounds per square mile per year, increasing transfer costs eventually overcome the diminishing processing and hatching economies causing the full cost per bird to increase. The cost per bird decreases from 18.816 cents for an annual output of 1.19 million birds to 15.726 cents for an output of 7.11 million birds. The cost is higher for larger size systems.

With production density increased to the 5,000 pound level, the cost per bird decreases continuously throughout the range of system sizes considered. The cost per bird decreases from 17.925 cents for an output of 1.19 million birds to 13.635 cents for an output of 19.76 million birds. However, most of the economies are realized at an output level of 7.11 million birds per year.

At the 25,000 pound production density level, combined costs per bird also decrease continuously over the range of system sizes considered. The cost per bird decreases from 17.491 cents for an annual output of 1.19 million birds to 12.663 cents for an output of 19.76 million birds. Most of the economies are realized at an output level of 9.88 million birds.

The results of this analysis indicate that economies of scale exist for the range of combined processing and hatching operations considered. However, consideration must be given to the production density of broilers to determine the size of the least cost system. An increase in production density tends to shift the least cost operation to a larger size system.

Systems may increase production density in several ways and possibly reduce transfer costs. The system can offer higher payments to attract additional producers located closer to the center of production and drop its producers out on the fringe of the producing area. The system might also elect to construct and operate its own broiler producing facilities close to the processing and hatching facilities.

APPENDIX A

Job Descriptions and Performance Standards

Broiler chick hatcheries have a minimum of eleven variable labor input operations. These operations are primarily preparing eggs for incubation, taking-off the hatch, grading and boxing chicks, maintenance and clean-up after each hatch. In addition, hatcheries may conduct a number of service operations; however, only debeaking and vaccination are performed on a large scale.

Input-output data, information on the methods used, and conditions affecting productivity for each operation, were obtained from the observed hatcheries. Generally, the methods used to perform each operation were similar, and most were performed with a minimum of labor-saving equipment. However, labor productivity varied markedly for some operations due to one or more of the following differences: (1) the type and make of incubator and hatcher units, (2) the size of the crew performing the operation, and (3) the type and amount of labor-saving equipment utilized.

The methods for performing each operation were analysed, and a performance standard was derived. The standard represents the maximum number of hatching eggs or broiler chicks a worker may be reasonably expected to achieve in performing a particular operation. The methods and standards presented for operations that involve incubator or hatcher units are for a specific make and type of equipment. These had the lowest overall inputs of labor for a given output. Several descriptions and standards are presented for those operations in which productivity varied substantially with either changes in crew size or technology.

Descriptions of methods and performance standards are given below for eleven hatching operations and two service operations.

Receive and Store Eggs

Cases of eggs are unloaded from trucks and moved by roller conveyor or dollies to an egg storage room located near the unloading platform. This operation requires two men, and output is 55,000 eggs per man-hour.

Egg Traying

The cases of eggs are transferred from the egg storage room to the traying area by a roller conveyor or dolly. The operator opens the case and transfers eggs to an incubator tray by hand or vacuum lift machine[1]. When filled, one end of the tray is stuffed with paper to prevent movement of the eggs, and an identifying label is attached. The filled tray is placed in a rack, an empty tray positioned, and the operation repeated. The operator also removes accumulated empty egg cases to the loading platform for shipment back to farms.

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[1] A standard tray holds 156 eggs weighing 26 ounces to the dozen.

As a manual operation, one or more operators may be used, working independently of each other. A standard output is 1,800 eggs per man-hour.

Egg traying with a vacuum lift machine requires one or two operators. With one operator, a standard output is 3,750 eggs per man-hour. As a two man operation, one operates the machine while the second performs the other duties. A standard output is 4,700 eggs per man-hour.

Placing Eggs in Incubators

Racks containing trays of eggs are wheeled into the incubator room, and the trays are transferred to racks in incubators. Output and crew size vary with the type of incubator. With the type of incubator selected for this study, one man performs the operation, and a standard output is 30,000 eggs per man-hour.

Transferring Eggs

On the 19th day of incubation, the trays of eggs are transferred from the incubating area, to the hatching area. Guards are placed on each end of the tray. Eggs that have been in incubation less than 19 days are moved down in the incubator racks. Labor productivity and crew size for this operation again vary with the type of incubating and hatching equipment. With the type of equipment selected for this study, one man is required and the standard output is 14,800 eggs per man-hour.

Removing the Hatch

On the 21st day of the hatching process, the trays containing chicks and unhatched eggs are removed from the hatching area. The trays are taken to work benches by cart where the chicks are removed, graded, and counted into chick boxes[2]. Lids are secured on the filled boxes, and the boxes are tied together in pairs. The boxes are placed on carts and wheeled to the shipping area. Workers remove the labels from the trays as they are emptied and record information concerning hatchability. The trays are placed on carts and taken to the tray wash area. Generally two or more workers are used to perform this operation, and the standard output is 3,000 broiler chicks per man-hour.

Loading Chicks for Shipment

Boxes of chicks are loaded into trucks and stacked in columns. As each column is filled, the boxes are secured to prevent shifting. One or two men are used, and a standard output is 300 boxes or 30,000 chicks per man-hour.

Washing Trays

Trays are cleaned by one of two methods. One method consists of dumping the contents of a tray into refuse cans, washing the tray in a

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[2] The standard chick box has a capacity of 100 chicks.

sink, and placing it in a rack to dry. One operator is required and a standard output is 40 trays, capacity of 6,240 eggs, per man-hour.

The second method utilizes a tray washing machine. The operator dumps the contents of the trays into refuse cans, hangs the trays on a circular conveyor which moves them through the washer. Trays are allowed to pass through the washer two or three times if necessary before being removed and placed in racks to dry. The standard output is 100 trays, 15,600 egg capacity, per man-hour.

Cleaning Hatchers

A hatcher has to be vacuumed, washed, and disinfected after each hatch is removed. This operation requires one man, and the standard output is 9,800 eggs of hatcher capacity per man-hour.

Fabricating Chick Boxes

New chick boxes are knocked-down and tied in bundles when received at a hatchery. The bundles are broken, boxes and tops assembled, pads installed in the bottom of each box, and the boxes stacked. The operation requires one man, and a standard output is 40 boxes per man-hour.

Cleaning Chick Boxes

Hatcheries use chick boxes on an average of three times before they are discarded. This operation involves removing the boxes from the truck used for chick distribution, cleaning, and stacking. Cleaning involves removal of old pads and installation of new. One man is required, and a standard output is 84 boxes per man-hour.

Maintenance and Custodial

This operation consists of performing periodic inspections of equipment and custodial work such as washing the floors, cleaning rest rooms, and so on. Labor productivity varied between hatcheries depending on the type and condition of equipment and building. From the data collected, a standard was established at one man-hour for every 7,400 eggs set.

Debeaking

Debeaking, a service operation performed in many hatcheries, is done to prevent chicks from picking each other during the growing out period. Two methods were observed, but both used the same type of automatically activated debeaker. Under the first method, chicks are debeaked after having been removed from the hatcher, graded and boxed. The operator removes chicks one at a time, debeaks, and replaces the chick in the box. The second method combines the several operations through use of labor saving equipment. The piece of equipment has one or two debeakers, an electronic counter, and an automatically activated mechanism to eject full boxes of chicks and insert empty boxes in their place. A worker delivers trays of chicks from the hatcher to the debeaking operators. The operators grade and debeak the chicks, then drop the chicks into a chute that leads to the box. The chicks are automatically counted in the chute by the counter. The worker who delivers the trays or a second worker secures lids on the full boxes, ties two boxes together and moves them to the shipping area. This worker also removes empty trays to the wash area and loads chutes with empty boxes that feed into the debeaking machines.

A standard output for debeaking by the first method is 1,000 chicks per man-hour. In order to compare the two methods, the operations performed have to be identical. The standard output for the combined operations of hatch take-off, grading, counting, boxing, and debeaking by the first method is 750 chicks per man-hour. For the second method, labor productivity varies depending on the number of machines and workers used. Standard outputs per man-hour are 1,070 chicks for one machine and three workers, 1,280 chicks for two machines and five workers, 1,200 chicks for three machines and eight workers, and 1,280 chicks for four machines and ten workers.

Vaccination

Vaccination of chicks is generally performed concurrently with debeaking by another crew. Two methods were observed, injection and ocular, and the ocular method prevailed. For the ocular method, a worker removes a chick from the box, squeezes a drop of vaccine from a plastic bottle onto an eye of the chick, and replaces the chick in the box. The standard output per man-hour is 1,000 chicks.

APPENDIX B

Table B-1. Average Cost Per Bird for Processing, Hatching, and Mortality Losses During the Growing-out Period for Eight Integrated Firms Operating at Four Output Levels.*

Firm	Annual Volume	Operation	Percent of Capacity, Processing Plant 42.1	63.2	84.2	100.0
			Percent of Capacity, Hatchery 40.0	60.0	80.0	95.0
	(millions of birds)		(cents per bird)			
A	1.19	Processing	20.367	16.422	14.245	13.311
		Hatching	4.381	3.068	2.400	2.093
		Mortality	.182	.128	.100	.087
		Total	24.930	19.618	16.745	15.491
B	2.37	Processing	20.230	15.705	13.437	12.551
		Hatching	3.092	2.202	1.758	1.553
		Mortality	.135	.096	.077	.068
		Total	23.457	18.003	15.272	14.172
C	3.56	Processing	18.081	14.203	12.380	11.536
		Hatching	2.591	1.861	1.507	1.340
		Mortality	.115	.083	.067	.060
		Total	20.787	16.147	13.954	12.936
D	4.74	Processing	17.112	13.549	11.855	11.127
		Hatching	2.333	1.697	1.382	1.229
		Mortality	.102	.074	.060	.054
		Total	19.547	15.320	13.297	12.410
E	7.11	Processing	15.106	12.237	11.078	10.392
		Hatching	2.079	1.506	1.262	1.125
		Mortality	.091	.066	.055	.049
		Total	17.276	13.809	12.395	11.566
F	9.88	Processing	13.909	11.641	10.581	10.007
		Hatching	1.891	1.387	1.160	1.058
		Mortality	.083	.061	.051	.049
		Total	15.883	13.089	11.792	11.114
G	14.82	Processing	13.213	11.074	10.073	9.597
		Hatching	1.762	1.320	1.114	1.017
		Mortality	.077	.058	.049	.045
		Total	15.052	12.452	11.236	10.659
H	19.76	Processing	12.600	10.591	9.643	9.247
		Hatching	1.669	1.275	1.084	.994
		Mortality	.073	.056	.047	.043
		Total	14.342	11.922	10.774	10.284

* Cost of hatching does not include debeaking or vaccination.

APPENDIX C

Vehicle Costs

Vehicles costs are classified as fixed or variable. The fixed cost items are expressed as annual costs, and the variable cost items are expressed in the form of relationships between cost and miles traveled.

Fixed Costs

The fixed cost items include insurance, registration, license, and anti-freeze. Insurance rates were obtained from a secondary source and include charges for comprehensive, collision, and liability types of insurance. Two rates are given for each type vehicle since rates are based on the radius of the area of operation. The low rates are for vehicles operating in an area with a radius not exceeding 50 miles, and the high rates are for vehicles operating in an area with a radius not exceeding 150 miles.

Registration and license fees are based on rates established by the State of New Hampshire. The registration charge is 60 cents per hundred pounds of registered gross vehicle weight, and the license is $3.00 per vehicle.

Anti-freeze costs are based on radiator capacity and an assigned cost of $2.00 per gallon for the anti-freeze. Table C-1 summarizes the fixed costs for the five vehicle types.

Table C-1. Annual Fixed Costs for Five Vehicle Types*

Type Vehicle	Fixed Costs				
	Insurance**	Registration	License	Antifreeze	Total
			(dollars)		
M, N & O	583.00†	96.00	3.00	2.50	684.50
	659.00‡				760.50
P	605.00†	117.00	3.00	3.50	728.50
	689.00‡				812.50
Q	626.00†	126.00	3.00	4.00	759.00
	716.00‡				849.00

* Includes chassis and chick van.

** Does not include cargo insurance.

† For vehicles operating in an area with a radius of 0 to 50 miles.

‡ For vehicles operating in an area with a radius of 0 to 150 miles.

Variable cost items include gasoline, oil, lubrication, tires and truck chassis and van maintenance and repair, depreciation, interest, and taxes. The costs for gasoline, oil, and lubrication are a function of mileage while costs for the remaining items are a function of mileage or time.

As vehicle size and weight increase, gasoline consumption per mile increases. From data furnished by a secondary source, a relationship was developed between gross vehicle weight and miles per gallon of gasoline. Vehicle types M, N, and O get 8.6 miles per gallon, and types P and Q get 8.2 and 8.0 respectively. Gasoline has an assigned cost of 25 cents per gallon.

Oil consumption is a function of mileage and oil capacity of the motor. It is assumed that oil changes are made at intervals of 2,000 miles, and assigned amounts are added between changes. Vehicle types M, N, and O require 7.2 quarts for every 1,000 miles, and types P and Q require 8.9 and 9.0 quarts respectively. Oil has an assigned cost of 30 cents per quart.

Lubrications are performed at 1,000 mile intervals. Assigned costs for each vehicle type are as follows: $2.25 for types M, N, and O; $2.50 for type P; and $2.75 for type Q.

Tire cost is a function of mileage and time. Information and data from a secondary source indicated that tires have a useful life of six years or 90,000 miles. Thirty thousand miles is derived from the original tread. Tread is replaced by recapping, and a maximum of three recappings is assumed in this study. Each recapping is assumed sufficient for an additional 20,000 miles. The five vehicle types have the same tire size and ply and each vehicle has six tires (dual rear wheels) and a spare. New tires cost $110 and each retread costs $30. In some cases, permissable tire mileage exceeds the mileage on the trucks at the time of the trade-in. Tire costs were adjusted to take this factor into consideration.

Truck chassis and body maintenance and repair costs are a function of mileage and time. As truck mileage increases over a given period of time, these costs decrease on a per mile basis. Maintenance and repair costs were derived from the equation:

$$MR = \frac{C + (Y-X)\ .01N}{M}\ M'$$

MR = Annual maintenance and repair cost
C = Cycle cost of maintenance and repair by truck type
Y = Years to major overhaul at M' miles per year
X = Years to major overhaul at a rate of 10,000 miles per year
N = New cost of truck body and chassis in dollars
M = Miles in cycle to major overhaul
M' = Annual mileage

Table C-2 shows the constants developed for use in the equation.

Annual maintenance and repair costs for vans are considerably less than for truck chassis and cabs. For purposes of this study, this cost was fixed at a half on one percent of new van investment for the first 20,000 miles of annual travel. For additional mileage, the cost increases at a rate of one half on one percent of new investment for each 20,000 miles.

Table C-2. Constants for Deriving Truck Chassis Maintenance and Repair Costs.

Truck Type	Constants			
	C	X	N	M
M, N, and O	$1,460	8	$3,400	80,000
P	$1,690	8	$3,800	80,000
Q	$2,225	9	$4,200	90,000

Truck depreciation rates were derived from a published list that is presumed to reflect average time and wear depreciation.[1] It was assumed that trucks are traded at the time of the first major overhaul or ten years, whichever comes first. Table C-2 shows the mileages of the different types of vehicles at the time of major overhaul and Table C-3 shows the trade-in values in percentage of new investment.

Van depreciation costs were established from the same rates used for the truck chassis and cabs. According to information furnished by hatcheries, vans are replaced after 400,000 miles of use or ten years, whichever occurs first.

Annual interest costs were drived with the following equation:

$$I = (O-T) \ \frac{r}{2} \ \frac{(m + 1)}{m} + Tr$$

O = Original price minus cost of tires
T = Trade-in value
r = Interest rate
m = Years of life, cycle mileage divided by annual mileage

Constants for this equation are the same as those used in determining maintenance and repair and depreciation. An interest rate of six percent is assumed.

Property taxes were based on the method used in the State of New Hampshire. Taxes were levied at the rate of 17 mills per dollar of new investment for the first year, 12 for the second, 9 for the third, 5 for the fourth, and 3 for each additional year of use.

[1] Official Automobile Guide, Price Edition, Recorder & Statistical Corporation, 87th ed. (Jan. 1958).

Table C-3. Trade-in Values and Depreciation Rates on Trucks and Chick Vans.

Age	Trade-in value relative to original price	Annual depreciation relative to original price
(years)	(percent)	
0		25
1	75	15
2	60	9
3	51	8
4	43	7
5	36	6
6	30	5
7	25	4
8	21	3.5
9	17.5	3.25
10	14.25	2.5