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Economics of Location, Number and Size of New England Apple Packing Plants

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F. Richard King and S. K. Seaver

INTRODUCTION

Problem Area and Objectives of this Study

Rapid changes are taking place in the commercial apple industry both in production and marketing. Recent years have seen the development of controlled atmosphere and tectrol storage, changes in type of rootstock grown and techniques of packing, and a major decrease in the number of farms but increasing apple production.

Decision-makers in the New England commercial apple industry are aware of the pressure for adjustment resulting from recent structural and technological changes. Periodically, there has been discussion by New England commercial growers on a regional approach to solve common problems relating to storage, packing, distribution, processing and point of sale representation of grower interests.[1]

The present New England marketing system results in a large number of small packing plants. Typically, apple growers even those with small orchards, do their own packing and grading. In many cases, the equipment is obsolete and extreme care is necessary to prevent excessive bruising. It is difficult for these packers to meet increasing consumer demands for polyfilm over-wrap tray packs. Small orchardists with packing plants also find they cannot fill large orders of a particular grade or quality simply because they do not have the necessary volume. Consequently a buyer will frequently need to contact several growers to fulfill order requirements, generally resulting in a pack of uneven quality. In addition, there are economies to be gained in packing on a larger scale.[2] The economies to be gained in packing in larger plants, the increased size of the production unit, and the pressure on buyers to purchase from fewer sources all indicate a trend toward more consolidated packing. There may also be an increase in contract packing. In this arrangement the small grower produces and stores the apples, but the marketing function, or at least the packing function, is performed by a large packing plant.

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[1]New England Apple Conference Report, March 26-27, 1963, Worcester, Massachusetts. (Mimeographed)

[2]Carman, Hoy F., An Analysis of Apple-Packing Costs in Michigan, Marketing Research Report Number 786, U.S.D.A., ERS, March 1967.

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Large scale consolidated packing plants might lead to a more uniform, better quality pack in sufficient volume to bargain effectively with large scale buyers. The New England commercial apple industry is seeking answers to questions concerning the size and location of packing plants, giving due consideration to present and expected location of production and consumption centers. This study attempts to provide information which will be of use to industry leaders who are making decisions about the organization of the New England commercial apple industry.

The objectives of this study were:

1. To determine the number, size, and location of apple packing facilities in New England in order to minimize aggregate marketing costs associated with the region's commercial apple production.

2. To evaluate the effects of change in the density of production on the plant pattern and total cost of packing the New England crop.

3. To investigate the changes in the shipment patterns and the addition to aggregate marketing costs which result as packing and transfer costs are increased.

Background

A study of this type requires information concerning the location of production for certain designated supply areas. The Census of Agriculture provides information relative to trends in number of trees, farms and volume of apple production. A detailed survey, such as the 1965 New England Fruit Tree Survey, provides more complete information. The starting point for this study was the Census of Agriculture and the New England study.

Tables 1-4 describe the New England commercial apple industry in terms of production, total number of trees, number of farms, and value of apple production for each New England state for selected years.

Table 1

Apple Production in New England, Selected Years

Area	1954	1959	1964	1965
		Bushels		
Maine	616,754	1,813,673	1,326,890	1,510,918
New Hampshire	855,127	1,478,182	803,397	1,435,914
Vermont	851,771	943,186	821,877	873,462
Massachusetts	1,749,963	2,702,697	1,998,032	2,183,364
Connecticut	1,277,707	1,268,050	1,003,962	1,036,190
Rhode Island	101,376	192,051	142,876	185,969
Total	5,452,698	8,397,839	6,097,034	7,225,817

Source: Census of Agriculture, U.S.D.A., for 1954, 1959, and 1964 and for 1965 the 1965 New England Fruit Tree Survey.

Table 1 indicates that Volume of production first increased up to 1959 and then decreased to 1964. But both the increase and the decrease resulted largely from the fact that 1959 was the largest crop during the entire 11 year period from 1954-1964. Actually all states maintained or increased production over this time period. The number of trees and number of farms fell substantially in all states except Vermont. (Tables 2 and 3). The value of production, Table 4, shows an increase for all states except Connecticut and Vermont.

Table 2

Total Number of Apple Trees in New England, Selected Years

Area	1954	1959	1964	1965
Maine	384,733	372,851	324,048	240,790
New Hampshire	274,745	211,829	180,026	168,662
Vermont	176,426	145,663	213,170	161,208
Massachusetts	533,298	405,804	390,129	315,252
Connecticut	329,793	225,184	227,539	141,055
Rhode Island	50,883	31,392	25,095	23,337
Total	1,749,878	1,392,723	1,360,007	1,050,304

Source: Census of Agriculture, U.S.D.A., for the appropriate years, and the 1965 New England Fruit Tree Survey.

Table 3

Number of Farms Reporting Apple Production in New England, Selected Years

Area	1954	1959	1965
Maine	1,943	1,625	881
New Hampshire	921	554	301
Vermont	589	530	341
Massachusetts	1,792	984	617
Connecticut	1,710	778	484
Rhode Island	253	120	81
Total	7,208	4,591	2,705

Source: Census of Agriculture, U.S.D.A., for the appropriate years.

Table 4

Value of Apple Production in New England, Selected Years

Area	1954[1]	1959[1]	1964[2]
		Dollars	
Maine	1,418,535	3,445,978	5,165,000
New Hampshire	2,009,549	2,660,729	3,305,000
Vermont	2,342,371	1,744,895	2,202,000
Massachusetts	4,112,414	4,999,991	6,726,000
Connecticut	3,449,810	2,409,295	3,363,000
Rhode Island	289,915	384,102	510,000
Total	13,622,594	15,644,990	21,271,000

[1] Census of Agriculture for appropriate years.

[2] Statistical Report, U.S.D.A., Crop Reporting Board, FRNT 2-1 (7-65) "Fruits, Non-citrus by States, 1964 and 1965."

Table 5 indicates the great change which took place in the type of bearing trees. In 1965, for New England, 43.6 percent of all trees six years old and younger were on dwarf and semi-dwarf rootstock. In contrast only 3.5 percent of the trees seven years and older were on dwarf and semi-dwarf rootstock. The more recent plantings result in more trees per acre with the expectation of higher yields per acre, and trees bearing at a much earlier age. The trend to smaller trees and different cultural practices is an indication that the orchardists are taking advantage of improved technology to ease labor problems due to picking from standard sized trees and problems due to rising land values and taxes. This trend to dwarf and semi-dwarf trees is expected to continue or even increase, especially in the more heavily populated southern New England states.

There also have been changes in the type of storage and packing techniques being used in New England. The advent of controlled atmosphere and Tectrol storage made it possible to spread the marketing season over a much longer period and still provide the consumer with a high quality product. Larger storage has enabled many growers to increase the size of their operation. The increased length of the storage season has brought with it new marketing problems such as a new system for choosing the volume to sell at particular times during the marketing season in order to maximize returns. This problem was studied in 1964 for McIntosh apples.[3]

Until approximately fifteen years ago, most apples were sold to consumers in a jumble pack with a facing and cell-pack. These have given way to polybags and overwrapped tray packs. The retail store generally prefers not to become involved in packing and the store buyer deals with a wholesaler, or a grower-packer, who is equipped to provide the desired package. Thus the packer needs more and varied equipment than was required for the old jumble pack.

METHODOLOGY

The Analytical Model

The location of a packing plant depends upon many factors in addition to economic considerations. There are psychological, sociological, and institutional factors influencing plant location, but evaluation of these is beyond the scope of this study. The economic factors of importance are those related to production of and demand for the product, the transfer costs between areas and the processing or packaging function. The framework employed was that of partial equilibrium analysis where the transfer costs of the raw product, as well as the final product, were studied along with the cost of packing in various sized plants.

The study is concerned with the determination of a system of plants and shipment patterns that will minimize the cost of assembling, packing and distributing apples. The analytical model used was a linear-programming, transportation model developed by Hurt and Tramel.[4] The model is designed to find optimum shipments given fixed supply, demand, processing capacity, (but not number of plants in each location), and fixed transport costs. Thus the model determines optimum volume for each processing location but does not determine optimum capacity of each plant.

The use of the transportation model as a solution procedure for location of packing plants requires certain basic information. Production and consumption areas must be designated and transfer costs between these areas determined. The cost of packing raw product must be calculated for various size plants and added to the transfer-costs.

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[3]Myers, Lester,H., "Intraseasonal Allocation of McIntosh Apples," (unpublished Masters thesis, University of Connecticut, Storrs, Connecticut. 1964).

[4]Hurt, V. G. and Tramel, T. C., "Alternative Formulations of the Transshipment Problem," Journal of Farm Economics, Vol. 47, Number 3, August 1965, p. 763.

Table 5

Number of Apple Trees by Type and Age, New England, 1965

Area	Rootstock	Trees Age 1-6 Years (Nonbearing)	Percent of Total	Trees Age 7 Years and Older (Bearing)	Percent of Total	Total	Percent of Total
Maine	Standard	36,641	65.3	179,342	97.1	215,983	89.7
	Dwarf and	19,439	34.7	5,368	2.9	24,807	10.3
	Semi-Dwarf	---	--	---	--	---	--
Total		56,080	100.0	184,710	100.0	240,790	100.0
New Hampshire	Standard	20,691	39.4	110,608	95.2	131,299	77.8
	Dwarf and	31,832	60.6	5,531	4.8	37,363	22.2
	Semi-Dwarf	---	--	---	--	---	--
Total		52,523	100.0	116,139	100.0	168,662	100.0
Vermont	Standard	43,423	76.9	100,888	96.4	144,311	89.5
	Dwarf and	13,077	23.1	3,820	3.6	16,897	10.5
	Semi-Dwarf						
Total		56,500	100.0	104,708	100.0	161,208	100.0
Massachusetts	Standard	35,531	55.3	242,147	96.5	277,678	88.1
	Dwarf and	28,689	44.7	8,885	3.5	37,574	11.9
	Semi-Dwarf	---	--	---	--	---	--
Total		64,220	100.0	251,032	100.0	315,252	100.0

Table 5 (continued)

Number of Apple Trees by Type and Age, New England, 1965

Area	Rootstock	Trees Age 1-6 Years (Nonbearing)	Percent of Total	Trees Age 7 Years and Older (Bearing)	Percent of Total	Total	Percent of Total
Connecticut	Standard	11,845	38.4	106,550	96.7	118,395	83.9
	Dwarf and	18,977	61.6	3,683	3.3	22,660	16.1
	Semi-Dwarf	---	--	---	--	---	--
Total		30,822	100.0	110,233	100.0	141,055	100.0
Rhode Island	Standard	479	13.5	19,501	98.6	19,980	85.6
	Dwarf and	3,074	86.5	283	1.4	3,357	14.4
	Semi-Dwarf	---	--	---	--	---	--
Total		3,553	100.0	19,784	100.0	23,337	100.0
New England	Standard	148,610	56.4	759,036	96.5	907,646	86.4
	Dwarf and	115,088	43.6	27,570	3.5	142,658	13.6
	Semi-Dwarf	000	--	---	--	---	--
Total		263,698	100.0	786,606	100.0	1,050,304	100.0

Source: 1965 New England Fruit Tree Survey, New England Crop Reporting Service and New England State Department of Agriculture Cooperating.

Methodological Procedure and Collection of Data

Production Areas

The first procedural step was the determination of production areas. Designation of the states as production areas would not allow sufficient precision but on the other hand, the problem would become large and unwieldly if counties were so designated. To render the study manageable, New England was rather arbitrarily delineated into 14 production areas. Production in each of the 14 areas was based upon the Census of Agriculture and the 1965 New England Fruit Tree Survey data. The counties included in each area are given in Table 6.

Apple production in the states of Maine, New Hampshire, and Massachusetts is highly concentrated in certain areas (Table 7). Over 70 percent of the apples grown in Maine are concentrated in area 2. The southern New Hampshire area contains approximately 86 percent of that state's production. The western and central areas of Massachusetts produce 71 percent of its production with 42 percent concentrated in Worcester county. Connecticut has somewhat less concentrated production.

Consumption Areas

The next step was to determine consumption for the fourteen previously described areas. A fifteenth consumption area was added representing all shipments out of the region. Consumption data for each of the 14 areas is not available. To estimate consumption, national per capita consumption information was utilized. Average per capita consumption of fresh apples for the six year period, 1960 through 1965, was 17.4 pounds.[5] Total consumption was obtained by multiplying the United States' per capita consumption of apples by population estimates for each area. Population and consumption estimates are shown in Table 8, along with the percentage of total consumption which is accounted for by each area of the state. Note that 50 percent of New England consumption is concentrated in the highly populated areas of northeastern and southeastern Massachusetts and southwestern Connecticut. Figure 1 provides a geographical perspective and shows the fourteen production and consumption areas.

Potential Location of Plant Sites

The study was not designed to undertake a complete enumeration of all present packing plants or their location. There are hundreds of small and large packing plants; producers of any size pack their own apples. Having divided New England into 14 production areas, initially, a single plant with sufficient capacity to pack all the apples was located in each area.

A number of factors were taken into consideration in designating the plant location within the area including an adequate labor supply, access to major highways, power and other utilities, and access to the market area. Obviously a number of alternative locations would be equally satisfactory in regard to all the factors considered, hence the designated location was somewhat arbitrary. Within each of the 14 production areas, a city or large town, located as near as possible to the center of the producing area, was designated as the potential plant site.

[5] Food Consumption, Prices, Expenditures, Supplement for 1969, U.S.D.A., Economic Research Service, Report Number 138.

Table 6

Production Areas By County Groupings

Area	State	Counties Included
1	Maine (northern)	Aroostook, Hancock, Penobscot, Piscataquis, Somerset, Waldo, Washington, Franklin, Kennebec, Knox, Lincoln, Sagadahoc
2	Maine (southern)	Oxford, Cumberland, Androscoggin, York
3	New Hampshire (northern)	Coos, Belknap, Grafton, Carroll, Strafford
4	New Hampshire (southern)	Merrimack, Hillsborough, Sullivan, Rockingham, Cheshire
5	Vermont (northern)	Essex, Lamoile, Orange, Orleans, Chittendon, Addison, Franklin, Washington, Grand Isle, Caledonia
6	Vermont (Southern)	Windsor, Rutland, Bennington, Windham
7	Massachusetts (western)	Berkshire, Franklin, Hampden, Hampshire
8	Massachusetts (central)	Worcester
9	Massachusetts (northeastern)	Middlesex, Essex, Suffolk
10	Massachusetts (southeastern)	Norfolk, Plymouth, Nantucket, Bristol, Barnstable, Dukes
11	Rhode Island	Bristol, Kent, Newport, Providence, Washington
12	Connecticut (eastern)	New London, Tolland, Windham
13	Connecticut (northwestern)	Hartford, Litchfield
14	Connecticut (southwestern)	Middlesex, New Haven, Fairfield
15	Region outside of New England	

Table 7

Apple Production in Designated Areas[1/] and Volume to be Packed

Area	State	1965 Volume of Production (bushels)	Percent of State Production	Volume to be Packed[2/] (bushels)
1	Maine (northern)	440,904	29.2	365,950
2	Maine (southern)	1,070,014	70.8	888,112
3	New Hampshire (northern)	207,310	14.4	172,067
4	New Hampshire (southern)	1,228,604	85.6	1,019,741
5	Vermont (northern)	472,952	54.1	392,550
6	Vermont (southern)	400,510	45.9	332,423
7	Massachusetts (western)	624,769	28.6	518,558
8	Massachusetts (central)	920,054	42.2	763,645
9	Massachusetts (northeastern)	550,880	25.2	457,230
10	Massachusetts (southeastern)	87,661	4.0	72,759
11	Rhode Island	185,969	100.0	154,354
12	Connecticut (eastern)	137,212	13.2	113,886
13	Connecticut (northwestern)	371,639	35.9	308,460
14	Connecticut (southwestern)	527,339	50.9	437,691
Total		7,225,817		5,997,426

1/ Production for each area was calculated from the 1965 New England Fruit Tree Survey.
2/ It was assumed that 83 percent of the total volume produced would meet the quality level for packing.

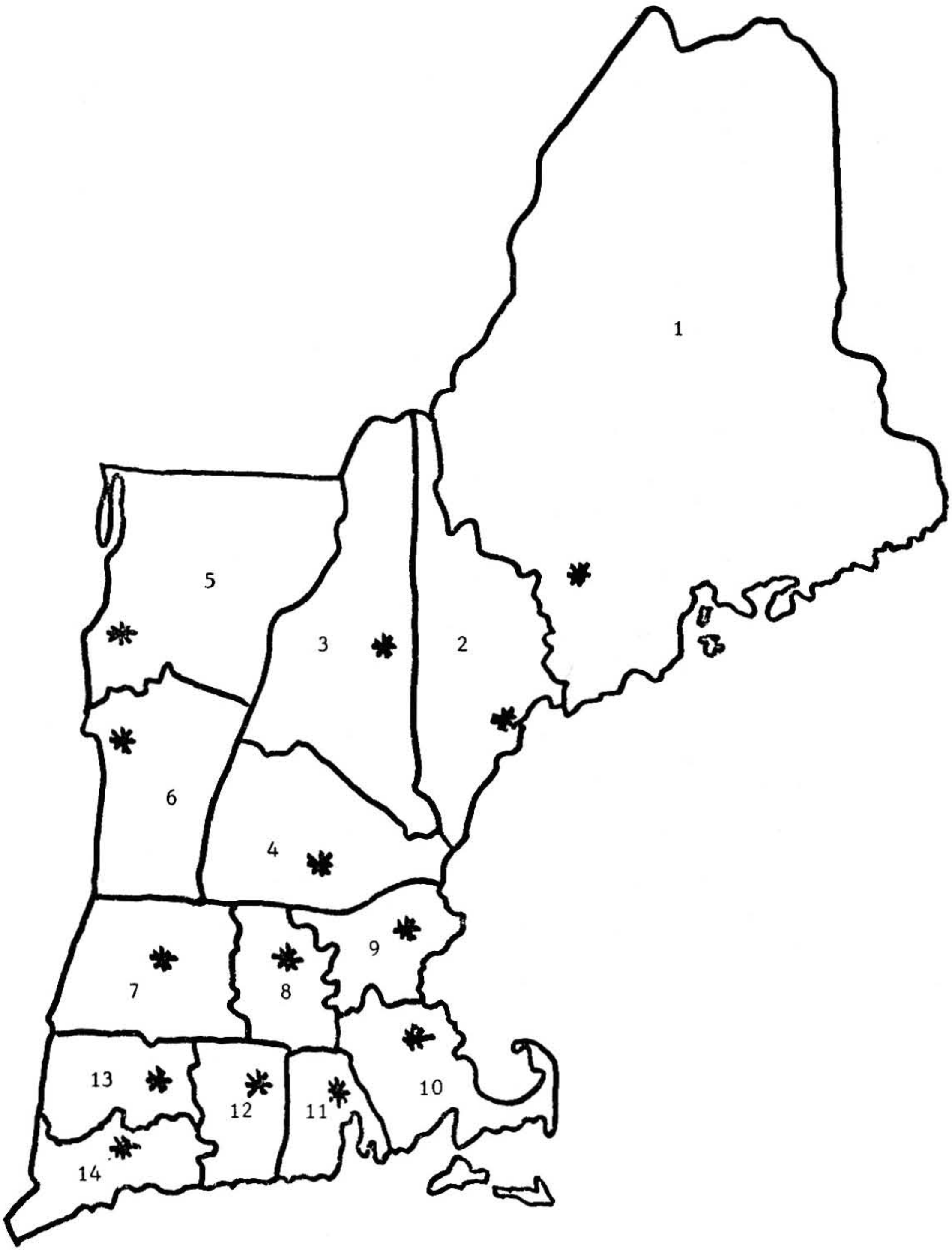
Table 8

Estimated Population and Apple Consumption by Areas, 1965

Area	Estimated Population	Estimated Consumption (bushels)	Percent of Total State Consumption	Percent of Total New England Consumption
1	566,060	204,914	57.4	5.1
2	419,937	152,017	42.6	3.8
3	211,283	76,484	31.4	1.9
4	461,718	167,142	68.6	4.1
5	254,715	92,206	63.0	2.3
6	149,283	54,040	37.0	1.3
7	759,682	275,005	14.2	6.8
8	607,291	219,839	11.3	5.4
9	2,706,129	979,619	50.5	24.3
10	1,287,898	466,219	24.0	11.6
11	891,000	322,542	100.0	8.0
12	360,615	130,543	12.8	3.2
13	903,519	327,074	31.9	8.1
14	1,565,865	566,843	55.3	14.1
15#	---	---	---	---
Total	11,144,995	4,034,487	---	---

Artificial or dummy consumption area representing export of fresh apples out of New England.

Figure 1. Location of Production
and Consumption Areas



*Approximate plant locations.

Plant sites selected are shown in Table 9. The exact location of the plant within the city was not specified.

Table 9

Locations of Apple Packing Plants within each Production Area

Area	Location		Area	Location
1	Augusta, Maine	::	8	Leominster, Massachusetts
2	Portland, Maine	::	9	Concord, Massachusetts
3	Conway, New Hampshire	::	10	Brockton, Massachusetts
4	Manchester, New Hampshire	::	11	Providence, Rhode Island
5	Middlebury, Vermont	::	12	Putnam, Connecticut
6	Rutland, Vermont	::	13	Hartford, Connecticut
7	Northampton, Massachusetts	::	14	Wallingford, Connecticut

Transfer Costs

A necessary condition in using the transportation model is that transfer costs per unit are known, non-negative, and constant for any quantity transferred. These costs were obtained between all areas and all plants with considerable difficulty because no standard information on rates or truck costs exists. Actual rates depended on negotiation, size of truck, availability of backhaul, and other factors. Trucking charges for apple hauling are not regulated.

In view of the foregoing, several large shippers and grower-shippers were contacted by mail. The survey showed that although there was no uniform rate pattern, there were certain practices generally followed in the industry. The rates obtained include unloading the apples from the orchard at the packing shed and loading costs from the packing plant for distribution to consumption points. The rates reported do not include loading at the farm, storage or unloading at distribution points. It was assumed the rates obtained reflect actual costs and not those assigned for intra-firm accounting purposes. It was further assumed that the rates charged were on a "for hire" basis, and the trucker paid for insurance.

The truckers interviewed, and some answering the mail questionnaire, felt some cost saving could be realized by using pallet boxes but most reported that backhauling empty boxes largely canceled any savings due to increases in efficiency.

From the questionnaires and interviews, the initial transfer costs were developed. A rate of 15 cents per bushel was assigned for shipment of raw product within an area. In a few situations, in the final computations, the same rate was used for shipment to the packing plant of an adjacent area if the distance was within a 25 mile radius. A rate of 25 cents per bushel was assigned to assemble the product from an immediately contiguous area except in those cases where the adjacent area was within a 25 mile radius. A charge of 33 cents per bushel was made for shipment from areas located 50 to 75 miles from the plant. Shipments of raw product beyond 75 miles were charged at the rate of 40 cents per bushel. Distribution rates were obtained from the survey on a carton basis. When converted to a bushel basis, the comparable transfer costs for distribution of the product were 21 cents per bushel for shipment within an area, 27 cents for adjoining areas, 36 cents for intermediate areas, and 42 cents per bushel for long distance shipments.

Packing Costs

The cost relationships from a Michigan study by Hoy F. Carman were reflective of conditions facing packers in this region.[6] The present study was not designed to determine packing costs. It was designed to use given packing and transportation costs for the purpose of determining number and size of plants and the areas in which packing should take place in order to minimize packing and distribution costs.

In the Michigan study, the plant was organized to handle a sequence of operations. For ease of analysis, the sequences of operations were grouped into production stages. Each stage was analyzed separately and a cost equation developed for that stage. The stages were assumed to be independent. The technology utilized in one stage did not affect the choice of technology for another stage. A least-cost plant organization was derived for each size plant and various lengths of season by adding least-cost techniques for each stage. The cost components of apple packing plants were defined as consisting of five operating stages and four indirect components which were associated with one or more of the operating stages. The operating stages inclued (1) dumping, (2) sorting and sizing, (3) packing, (4) container closing, and (5) in-plant handling of products and materials. Indirect cost components include (1) office and administrative expense, (2) packaging materials, (3) building costs, and (4) supervision and miscellaneous labor, equipment and materials.[7] The following assumptions were made by Carman:

1. The mixture of varieties packed included approximately 50 percent Johnathan, 25 percent McIntosh, 15 percent Delicious, and 10 percent other varieties.

2. Five percent of the apples dumped were eliminated as undersized, those less than 2¼ inches in diameter. Another twenty-five percent were sorted out as culls or utilities. Seventy percent of the total volume was assumed to be packed.

3. The plant operated for eight or ten hours a day. No overtime wages were paid.

The type of container used did affect costs but there was no indication that the mixture of varieties greatly influenced cost of packing. The mixture of varieties in New England would include approximately 65 percent McIntosh, 15 percent Delicious, 10 percent Cortland and 10 percent other varieties. The influence of this change on costs of packing was assumed to be minimal and hence was ignored. The hours of operation of the plant, the type of container used, the percentage of apples eliminated as undersized and the percentage of culls or utilities can be adjusted to fit any desired amount by making changes in the cost equation. Table 10, taken from the Michigan study, summarizes the coefficients derived by Carman and used to develop the plant cost equations used in this study.[8] A total plant cost equation is obtained by adding the relevant cost for the particular type package to total costs which are common to all type packages. In order to ob[illegible] costs for particular operations, the following must be specified:

1. Hours of plant operation

2. Output capacity of the plant

3. Percentage of apples sorted as culls and utilities

4. Proportion of total output in each of the various types of packages.

[6] Carman, Hoy F., An Analysis of Apple-Packing Costs in Michigan, Marketing Research Report Number 786, U.S.D.A., ERS, March 1967.

[7] Carman, op. cit., pp. 54-55.

[8] Carman, op. cit., p. 102.

Table 10

Summary of Planning Cost Equations for Operating Stages
and Indirect Cost Components for Apple Packing Plants
1963-64

Cost Category	Variables 1/				
	a	H	C	HC	HCP
	Coefficients				
Common Costs					
Dumping		131.78	272.93	15.32	
Sorting and sizing	1740.76	143.33	549.73	244.45	3.24
Container closing	52.59			139.19	
Handling	299.96	-62.71	1038.28	251.01	
Office & administration	1041.51			301.88	
Building costs	920.40		1699.20		
Supervision & miscellaneous	608.90	64.40	159.50	138.20	
Total	4594.12	276.20	3719.64	1090.05	3.24
Costs Based on Package					
Packing Costs					
4# bags	417.00	109.80	928.00	757.20	
3# bags	417.00	247.80	928.00	757.20	
Tray pack	315.00	65.70	431.82	1141.36	
Jumble pack	296.26	9.73	352.77	822.02	
Package Material Costs					
4# bags	182.20	64.75		4295.38	
3# bags	180.20	63.71		4473.56	
Tray pack				5062.00	
Jumble pack				1955.00	

1/ The cost equation variables are described as follows:
a = A constant cost that is incurred regardless of length of season or size of plant.
H = Hundred hours of plant operation per season.
C = Capacity output of plant in hundred cartons.
P = Percent of apples sorted out as culls and utilities.
HC = Total season pack in ten thousand cartons.
HCP = A relative measure of total season sortout.

Estimates of these four variables for this study were obtained by personal interview of operators of apple packing plants in the area and of industry leaders. The following were taken to reflect conditions in the New England industry:

1. Plants were assumed to operate for 8 hours per day, 5.5 days per week over a 36 week packing season. Total hours of plant operation in a season was 1,600.

2. Plants operating at five levels of capacity were studied. These were 100, 200, 300, 400, and 500 forty pound packed cartons per hour.

3. Culls and utilities averaged twelve percent.

4. Sixty percent of the output was assumed to be packed in poly bags. One-half of this would be four pound, and one-half three pound. Twenty percent was assumed to be in cell or tray pack and twenty percent jumble and other packs.

Total season costs for packing are indicated by the following equation for the plants studied:

$$TSC = 5803.58 + 595.01\ (H) + 3719.64\ (C) + 1.90.05\ (H)\ (C) + 3.24\ (H)(C)(P) + 928.00\ (P_1)\ (C) + 5141.67\ (H)(P_1)(C) + 431.82\ (P_2)(C) + 6203.36\ (H)(P_2)(C) + 352.77\ (P_3)(C) + 2777.02\ (H)(P_3)(C).$$

The coefficients for the equation were calculated from Table 10 where:

H = Hundreds of hours of operation per season

C = Capacity of plant in hundred cartons

P = Percentage sorted out as culls and utilities

P_1 = Percentage packed in poly bags

P_2 = Percentage packed in tray pack and

P_3 = Percentage packed in jumble and other packs.

The variables were specified for five sizes of packing plants and the total season and unit costs were calculated. Table 11 indicates the results of the calculations for the plants used in the analysis. These calculations give costs for plants operating at 100 percent of capacity. The costs used throughout the study were long range planning costs. Cost for packing assumed use of the best technology available at each stage.

No adjustment was made in the costs used in the models between 1965 and 1970. Therefore, the level of aggregate cost which would have prevailed in 1970 is understated. Estimates of 1970 costs could be made by applying appropriate cost changes. For instance weekly earnings in non-agricultural employment increased from $95.06 in 1965 to $119.46 in 1970, in current dollars, or a 25.7 percent increase. Materials used in food manufacturing rose from an index of 97.6 to 112.9 between 1965 and 1970 (with 1967=100) or a 16 percent increase.[9] However, it should be pointed out that the changes in the pattern of shipment and sensitivity of the optimum solution to changes in costs were more important to this study than the absolute level of aggregate marketing costs.

[9] From Economic Indicators August 1973 and the Economic Report of the President, January 1973.

Table 11

Estimated Costs of Packing Apples

Capacity of plant	Total Season Pack		Total Cost	Average Cost/Carton[1]	Average Cost/Bushel[1]
(ctns./hr.)	(cartons)	(bushels)	(dollars)	(dollars)	(dollars)
100	160,000	133,333	115,917.23	.724	.869
200	320,000	266,667	216,510.71	.676	.812
300	480,000	400,000	317,104.20	.661	.793
400	640,000	533,333	417,615.68	.652	.783
500	800,000	666,667	518,291.17	.647	.777

[1]Average costs based on the assumption the plants are operated at capacity.

ANALYSIS

Number, Size, and Location of Packing Plants

The starting point for the analysis was a system of plants in which a plant of sufficient size to pack the total output of the area was located in each of the 14 production areas. The determination of the number, size, and location of apple packing facilities which would minimize the aggregate marketing costs associated with the 1965 New England commercial apple crop was an iterative procedure. Plants were systematically removed from solution beginning with the smallest capacity, highest cost, plant. If the value of the objective function was decreased by removing a plant, it remained out of solution. If aggregate marketing costs were not reduced, the plant was returned and the next largest plant removed. Various combinations of plants were tested which allowed removal of more costly plants and transshipment of product to other plants.

Table 12 indicates the location and capacity of the 12 plants in the final solution. The final solution, showing the inter-area movements to plants and distribution to consuming points, is shown in Tables 13 and 14. In this solution, total packing capacity exceeded total production by only 2,575 bushel. (The total quantity to be packed is 5,997,426 bushels as shown in Table 7.) Adjustments in capacities of various plants, with appropriate packing costs adjustments, resulted in aggregate marketing costs of 7.4 million dollars.

Table 12

Location and Capacity of Apple Packing Plants, 1965*

Plant Number and Location	Plant Capacity
	(bushels/season)
1. Augusta, Maine	266,667
2. Portland, Maine	666,667
3. Conway, New Hampshire	133,333
4. Manchester, New Hampshire	1,333,334**
5. Middlebury, Vermont	400,000
6. Rutland, Vermont	266,667
7. Northampton, Massachusetts	533,333
8. Leominster, Massachusetts	666,667
9. Concord, Massachusetts	533,333
11. Providence, Rhode Island	266,667
13. Hartford, Connecticut	400,000
14. Wallingford, Connecticut	533,333
Total	6,000,001

*Plants (10) Brockton, Mass. and plant (12) Putnam, Conn. dropped out of solution.
**Two 666,667 bushel plants.

Table 13

Assembly Pattern - Origins, Plant Locations, Volumes, 1965 Solution*

Production Origin Area	Processing Plant Location											
	(1) Augusta	(2) Portland	(3) Conway	(4) Manchester	(5) Middlebury	(6) Rutland	(7) Northampton	(8) Leominster	(9) Concord	(11) Providence	(13) Hartford	(14) Wallingford
	Bushels											
(1)	266667			7308						18679		73296
(2)		666667		221445								
(3)			133333	38734								
(4)				1019741								
(5)					392550							
(6)				43531	7450	266667	14775					
(7)							518558					
(8)								666667	96978			
(9)									436355	20875		
(10)										72759		
(11)										154354		
(12)											113886	
(13)											73296	235164
(14)											212818	224873

Location of areas is given in Table 7, page 12.

* The numbers is parenthesis correspond to initial packing plant locations for each production area as shown in Table 9. Note that plants in area (10) Brockton, Mass. and (12) Putnam, Conn. dropped out of the initial solution.

Table 14

Distribution Pattern - Plant Locations, Destinations, Volumes, 1965 Solution

Consumption Area	Processing Plant Location											
	(1) Augusta	(2) Portland	(3) Conway	(4) Manchester	(5) Middlebury	(6) Rutland	(7) Northampton	(8) Leominster	(9) Concord	(11) Providence	(13) Hartford	(14) Wallingford
	Bushels											
(1)	204914											
(2)		152017										
(3)			76484									
(4)				167172								
(5)					92206							
(6)						54040						
(7)							206259	68746				
(8)				219839								
(9)				540556				228814	210249			
(10)								199010	542	266667		
(11)									322542			
(12)								130543				
(13)							327074					
(14)											400000	166843
(15)												366490

The pattern of product flows is consistent with expectation. In general, apples were packed within the area in which they were grown, up to the capacity of the plant located therein. Shipments out of the area were to adjacent larger plants or an area which was a high density consumption area. The two areas from which plants were dropped (10 and 12) were the two lowest production areas.

Tables 13 and 14 which present the solution are interpreted as follows: The solution tables indicating assembly patterns show plant location across the top of the table with origins of production on the left. Numbers in the body of the table indicate the bushels shipped. For example, Table 13, shows 266,667 bushels shipped from area 1, northern Maine, to plant number 1, (within the area) located in Augusta, 7,308 bushels to plant 4 in Manchester, 18,679 bushels to plant 11, Providence and 73,296 bushels to plant 14 in Wallingford. Table 14, indicating distribution patterns, shows the plant locations and production areas as in Table 12. For example, Table 14 indicates that plant number 1, in Augusta, shipped 204,914 bushels to consumption area 1, and 61,753 bushels outside the New England area. For all of New England 1,962,939 bushels are exported to outside areas.

Effect of Production Changes

The second objective of the study was to evaluate the effect changes in the density of production of apples would have on the optimum plant pattern. Data in Table 15 show the annual change in production and were derived from the Crop Reporting Service's published estimates. New England apple production has been highly variable.

Table 15

Annual Fluctuations in New England Apple Production, 1965-1970

Area	1964-1965	1965-1966	1966-1967	1967-1968	1968-1969	1969-1970#	1965-1970
	Percent change from previous year						
Maine	+ 8.1	- 9.4	+ 6.5	- 1.9	- 7.6	+ 1.6	-11.2
New Hampshire	+14.3	-13.0	+12.1	-17.0	-17.4	+36.6	- 8.6
Vermont	- 7.9	+ 2.4	+24.0	-24.5	+ 4.7	0.0	+ 0.3
Massachusetts	+ 5.3	-16.2	+13.5	- 8.9	+12.0	+ 7.8	+ 4.7
Connecticut	+ 3.0	-23.5	+ 5.9	- 6.7	+ 0.6	+ 4.6	- 9.0
Rhode Island	+11.1	-20.0	-32.8	+ 6.7	-16.7	+70.0	-19.0
Total	+ 5.6	-13.4	+10.9	- 8.8	- 0.4	+ 9.6	- 4.4

#Preliminary. 1970 Apple Production estimates were not available at the time of the analysis.

Apple production for 1970 was estimated by applying the percentage change from 1965 to 1970, for each state, to the New England Fruit Tree Survey data for 1965. Table 16 shows these estimates.

The estimated 1970 state production was then distributed by areas within the state by applying the 1965 percentage each county was of the total. (See Table 6 for the counties included in each area.) The production for each area was then converted to packed equivalent, (First Estimate Table 17) and these volumes were used in the model. The solution was obtained with these first estimates of 1970 production, with all other factors the same as the final 1965 solution presented in Table 13.

Table 16

Estimated 1970 Apple Production in New England, by States

Area	1970
	(bushels)
Maine	1,341,695
New Hampshire	1,312,425
Vermont	876,082
Massachusetts	2,285,982
Connecticut	942,933
Rhode Island	150,635
Total	6,909,752

One of the objectives of the study was to determine the effects changes in density of production would have upon patterns of assembly and distribution. The 1970 estimates of production were approximately 260,000 bushels, packed equivalent less than the 1965 packed volume. These new (first 1970) estimates were introduced into the 1965 solution previously presented and the assembly pattern results are shown in Table 18. Contrasting Table 18 with Table 13 indicates that shipments from production area to packing plants occurred for five areas, namely, 1, 2, 6, 7, and 9. The results indicate that assembly patterns are fairly sensitive to changes in density. No shifts in distribution patterns occurred, hence are not reported here.

As a further check on the relationship between production density and assembly and distribution patterns it was assumed that even if total production remained the same in each state the high producing counties would continue to increase at the expense of the low producing counties. The percentage change, between 1965 and 1970, in production of each state was again used as the basis for adjusting the production data from the 1965 New England Fruit Tree Survey. A solution was obtained using this second estimate of 1970 production (Table 17) but with all other factors in the model the same as the 1965 final solution. Thus, the only difference between the two 1970 solutions was the estimate of volume of production for each area, i.e., the distribution of production within the state. When the solutions, using the two estimates of 1970 production were compared with each other, differences in the pattern of assembly from production area to plants occurred in seven cases. These results would indicate that the solution is sensitive to changes in production density.

The sensitivity of the optimum plant and shipment pattern to changes in consumption was tested by introducing, into the model, estimates of 1970 consumption for each area based upon data from the 1970 census of population and estimated per capita consumption of fresh apples. The results indicated that the distribution pattern for plants located at Northampton and Leominster, Massachusetts were the most sensitive to the changed consumption (volumes) and that the assembly pattern for shipments from production areas to plants was unaffected by changes in consumption.

An optimum solution was next determined using the second estimates of 1970 (the most likely production pattern) and 1970 consumption. This allowed comparison of the 1965 solution with a most likely 1970 solution, each having been determined independently. Both optimum solutions were obtained with all plants fully utilized. Table 19

Table 17

Two Estimates of 1970 New England Apple Production by Areas

Area	First Estimate of Production	Second Estimate of Production
	(Packed equivalent, bushels)	
1	325,173	225,495
2	788,434	888,112
3	156,861	69,572
4	932,452	1,019,741
5	393,387	393,387
6	333,761	333,761
7	542,646	552,627
8	800,688	814,748
9	478,136	457,231
10	75,894	72,759
11	125,027	125,027
12	103,308	36,483
13	280,966	308,460
14	398,361	437,691
Total	5,735,094	5,735,094

indicates the location and capacity of the eleven packing plants in the final solution (1970 data). Compared with the results in Table 12, the major change is the dropping of the Conway plant. The pattern of assembly and distribution for the solution is shown in Tables 20 and 21.

A detailed comparison can be made of the 1965 and 1970 solutions by a study of Tables 13, 14, 20, and 21.

Changes in production volume affected assembly shipment patterns most directly and packing plant locations are sensitive to the changes in the density of production. Changes in plant locations will, of course, disturb distribution patterns even in the absence of any shift in population between areas. In this study, the net effect of changes in plant locations and population shifts upon distribution patterns was not determined.

Effect of Changes in Transfer Costs

There are many reasons for increases in transfer costs. A partial list would include changes in highway and excise taxes, increases in licensing fees, and labor costs rising differentially and in absolute terms. Several adjustments in transfer costs were made and results compared in order to test the effect on the pattern of assembly and distribution of product and the effect on aggregate marketing costs. The following situations were tested:

1. All assembly costs were increased ten percent with distribution costs unchanged.

2. Local and intermediate assembly costs were increased ten percent with distribution costs unchanged.

3. Local and intermediate distribution costs were increased ten percent with assembly costs unchanged.

Table 18

Assembly Pattern -- Origins, Plant Locations, Volumes
1965 Optimal Solution with First Estimate of 1970 Production

Production Origin Area	Augusta (1)	Portland (2)	Conway (3)	Manchester (4)	Middlebury (5)	Rutland (6)	Northampton (7)	Leominster (8)	Concord (9)	Providence (11)	Hartford (13)	Wallingford (14)
	Processing Plant Location											
	Bushels											
1	266667											58506
2		666667		99369								22398
3			133333	23528								
4				932452								
5					393387							
6					6613	266667						60481
7							533333				9313	
8								666667	134021			
9				13078					399312	65746		
10										75894		
11										125027		
12											103308	
13											141385	139581
14											145994	252367

Location of Areas is given in Table 7, page 12.

Table 19

Optimum Location and Capacity of Apple Packing Plants, 1970

Plant Number and Location	Annual Packing Capacity
	(Bushels)
(1) Augusta, Maine	266,667
(2) Portland, Maine	666,667
(4) Manchester, New Hampshire	1,333,334
(5) Middlebury, Vermont	400,000
(6) Rutland, Vermont	266,667
(7) Northampton, Massachusetts	533,333
(8) Leominster, Massachusetts	668,426
(9) Concord, Massachusetts	400,000
(11) Providence, Rhode Island	266,667
(13) Hartford, Connecticut	400,000
(14) Wallingford, Connecticut	533,333
Total	5,735,094

4. All local and intermediate transfer costs were increased ten percent.

5. All distribution costs were increased ten percent with assembly costs unchanged.

6. Long distance assembly costs were increased ten percent with distribution costs unchanged.

7. Long distance distribution costs were increased ten percent with assembly costs unchanged.

8. All long distance transfer costs were increased ten percent.

Study of the pattern of assembly of the product from producing areas to packing plants indicated only four areas were affected by the eight possibilities tested. The changes which occurred resulted when local and intermediate assembly costs, and all local and intermediate transfer costs, were increased ten percent (situations 2 and 4).

The pattern of distribution of product from packing plants to consumption centers also appeared to be only slightly sensitive to a ten percent change in the cost of distribution. When local and intermediate distribution costs were increased ten percent (situations 3 and 5) shipments from four plants were affected.

The percentage increases in the aggregate marketing costs resulting from the eight situations tested are indicated in Table 22. The greatest increase in aggregate marketing cost occurred when all local and intermediate transfer costs and all distribution costs were increased with assembly costs unchanged. Further, it is apparent that increased long distance assembly cost with distribution cost unchanged had little effect on aggregate cost.

Table 20

Assembly Pattern - Origins, Plant Locations, Volumes
1970 Solution

Production Origin Area	Processing Plant Location: Augusta (1)	Portland (2)	Manchester (4)	Middlebury (5)	Rutland (6)	Northampton (7)	Leominster (8)	Concord (9)	Providence (11)	Hartford (13)	Wallingford (14)
	Bushels										
(1)	225495										
(2)	41172	666667	109349								70924
(3)			69572								
(4)			1019741								
(5)				393387							
(6)				6613	266667						60481
(7)						533333				19294	
(8)							668426	146322			
(9)			134672					253678	68881		
(10)									72759		
(11)									125027		
(12)										36483	
(13)										131405	177055
(14)										212818	224873

Table 21

Distribution Pattern - Plant Locations, Destinations, Volumes
1970 Solution

Consumption Center	Processing Plant Location										
	Augusta (1)	Portland (2)	Manchester (4)	Middlebury (5)	Rutland (6)	Northampton (7)	Leominster (8)	Concord (9)	Providence (11)	Hartford (13)	Wallingford (14)
	Bushels										
(1)	159877										
(2)		126825									
(3)		60849									
(4)			152340								
(5)				82439							
(6)					54973						
(7)						228785					
(8)			184373								
(9)			333291				425232	42107			
(10)							80292	83423	266667		
(11)								274470			
(12)						26869	94021				
(13)						277679					
(14)										400000	77595
(15)	106790	478993	663330	317561	220694		68881				455738

Table 22

Changes in Objective Function as Transfer Costs Change by 10 Percent

Transfer Cost Change	Percentage Increase in Aggregate Marketing Costs
Increase all assembly costs, distribution costs unchanged	1.33
Increase local and intermediate assembly costs, distribution costs unchanged	1.17
Increase local and intermediate distribution costs, assembly costs unchanged	1.24
Increase all local and intermediate transfer costs	2.41
Increase all distribution costs, assembly costs unchanged	2.34
Increase long distance assembly costs, distribution costs unchanged	.13
Increase long distance distribution costs, assembly costs unchanged	1.05
Increase all long distance transfer costs	1.18

Effect of Selective Increases in Packing Costs

The model was next used to gain insight into the sensitivity of the optimum shipment patterns as packing costs were increased. It seemed reasonable to expect that the southern New England area (Massachusetts, Connecticut, and Rhode Island) might have somewhat higher costs of operation. For example, these higher costs could be due to higher wage rates, increased property taxes, or increased utility costs. Accordingly, packing costs for plants in southern New England were increased 15 percent while costs at plants in northern New England remained constant and the patterns of assembly and distribution were studied.

Increasing packing costs fifteen percent for the seven plants located in the southern New England area resulted in a 4.6 percent increase in the aggregate marketing costs when compared with the most likely 1970 solution. The flows from production areas 2, 6, 8, 9, and 13 to the packing plants were modified somewhat from the previous solution. Increased packing costs alone had no effect upon the distribution pattern of shipments from the packing plant to the consumption area.

Effect of One, Two, or Three Plants for all of New England

In order to gain insight into the effect of reducing the total number of plants, fourteen solutions were investigated and compared with the most likely 1970 solution.

The three areas with the highest volume of production were southern New Hampshire, southern Maine, and central Massachusetts. These three areas were tested for the potential location of a single plant for all of New England. Aggregate marketing cost

was the lowest when a single plant was located in the high production density area of central Massachusetts rather than in either of the other two areas. The total seasonal cost for the Massachusetts plant was 12.2 percent greater than the previous eleven plants (Table 23).

Table 23

Summary of Unit Costs for Packing New England Commercial Apple Crop, Derived from Aggregate Marketing Cost

	1965 Final Solution	1970 Final Solution	1970 Solution with Packing Cost Increased	Single Plant Solution
			(Cost per bushel)	
Assembly Cost	$0.165	$0.166	$0.166	$0.294
Packing Cost	0.787	0.786	.844	0.777
Distribution Cost	0.284	0.292	.292	0.325
Total	$1.236	$1.244	$1.302	$1.396

The three areas of northeastern Massachusetts, southeastern Massachusetts, and southwestern Connecticut contained the highest consumption volume. Each of these areas was tested for the potential location of a single plant for all of New England and none produced lower total cost than the location of a single plant in central Massachusetts.

Solutions were then investigated in which the packing capacity has divided equally between two New England plants, each located in a high production area. Solutions were also obtained with capacity divided between two plants in the high density consumption areas. Lowest cost was obtained with plants located in northeastern Massachusetts and southwestern Connecticut, two of the high consumption areas. Total season marketing costs were still 4.8 percent higher than the 11 plant costs.

Solutions were obtained with three plants of equal capacity located either in the high density production or the high density consumption areas. Location of three plants of equal capacity in the areas resulted in the lowest costs when located in the high density consumption areas. However, total cost was 5.7 percent higher than with 11 plants.

The packing costs utilized in these investigations assumed that the very large plants could be operated as efficiently as the largest plant in the original 1965 solution. Carman's investigations indicated that most economies of size were attained by the time the plant reached 500 cartons per hour.[10]

Aggregate Marketing Costs

Table 23 summarizes the aggregate per unit marketing cost for the New England region. These average aggregate costs were calculated for four of the major solutions obtained.

These costs represent an average cost per unit for assembly, packing, and distribution. As such, they are only representative of actual costs in a particular area. Total packing cost increased almost 6 cents per unit when packing costs were increased 15 percent for the seven plants in southern New England. Total cost increased 15 cents

[10] Carman, op. cit., p. 106.

per unit for a single, large plant, over the optimum 1970 eleven plant solution. In keeping with theoretical expectations, this increase was due to increased costs of assembly and distribution which were not offset by decreased packing costs.

LIMITATIONS

Several factors limited the study. The synthesized cost data may not accurately represent present costs and in this study synthesizing total cost data results in marginal costs which are inconsistent with theoretical expectations.

No consideration was given to intra-seasonal changes in demand and supply and the industry practice of marketing a large proportion of the total crop in the early fall. For example, packing capacity sufficient to handle the total season pack of fresh apples would not be sufficient to pack fifty percent of that crop in the two months of October and November. The analysis did not attempt to determine by areas where the shortages in capacity for peak months occurred, but additional plants could be built in those areas where the most extreme shortages of capacity exist. The problem is of short-run duration hence plants could run extra shifts. Theoretically, the seasonality problem could be solved by operating all plants for two shifts instead of one. This, of course, would increase the per unit cost estimates presented in Table 23. There could be some temporary problems with storage at plants operating a double shift. The question of single and double shift operation and its effect on costs of packing per unit might be an area for further research.

SUMMARY AND CONCLUSIONS

Apple production is highly concentrated in certain areas of New England and for this study 14 areas were delineated to assess the number, size, and location of packing plants which would result in lowest total costs for the region. Initially a packing plant with sufficient capacity to pack local production was arbitrarily located in each of the 14 areas. This resulted in a large amount of excess plant capacity for the industry. In order to operate the plants closer to the designed capacity, transshipment between areas was necessary. To pack the region's estimated 1970 crop of 5,735,094 bushels (packed equivalent units) only 11 plants were required. Aggregate marketing costs of assembly, packing, and distribution to consuming markets totaled $7,136,743.

Changes in production within the region, changes in consumption, and changes in transfer and packing costs were appraised to determine impacts these forces have on plant numbers, their location, shipment patterns, and the level of aggregate marketing costs. If packing costs were increased 15 percent, aggregate marketing costs would increase by approximately 4.5 percent. Changes in transfer costs of the same size would have a much smaller effect upon aggregate marketing costs.

The results of this study provide a number of general guides for the New England commercial apple industry. One of the long-run questions concerns the effect changes in production and consumption density and volume would have on the number, size, and location of packing plants. Changes in the location of production and volume from each producing area affected the volume of the flow of apples from production areas to packing plants, within the capacity constraints imposed by the analytical model. Thus, flows changed to plants and resulted in changes in optimal plant sizes for the region. However, changes in production density did not materially affect the patterns of assembly. Patterns of shipment were influenced by the extent of total excess capacity in the region. Changes in the pattern of shipment occurred more frequently as excess capacity increased. Since a great deal of unused packing capacity now exists, the industry should expect changes in production density and volume to have a greater effect on shipment patterns as small, high-cost plants exit from the industry and total capacity is reduced.

Changes in production density and volume had little effect on patterns of distributing apples from packing plants to consumption centers. However, the distribution patterns and flows were influenced by changes in consumption density.

Changes in transfer costs did not exert a strong influence on either the patterns of assembly or distribution. Thus, increases in transfer and packing costs, due to possible location of plants in areas of high population density, would not be barriers to movement by the industry toward larger, more efficient plants near major consumption centers.

Currently, approximately one-half the crop is marketed in September, October, and November. This seasonality puts tremendous strain on total industry packing capacity for the peak month of October, and leaves six months of minimal operation. Such variability is costly.

The large number of small plants presently in operation also contribute to industry excess capacity. The ability to pack consistently high quality fresh apples in the volume required by present buyers is essential to the maintenance of the competitive position of the New England apple industry. This can be done more efficiently in large, modern, well-equipped packing plants. It would be to the advantage for the industry to move in the direction of fewer and larger apple packing plants. It appears that changes in production and consumption density, or in transfer cost, would not be a barrier to movement in this direction.

Presently there are many small orchards doing their own packing. Because of the small volume they are unable to supply most retail outlets with the quality, variety, and consumer pack required. Buyers must contact several packers in order to obtain sufficient quantities to supply even a small chain of retail stores. Many of these small growers and packers should be encouraged to coordinate their packing and marketing activities.

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