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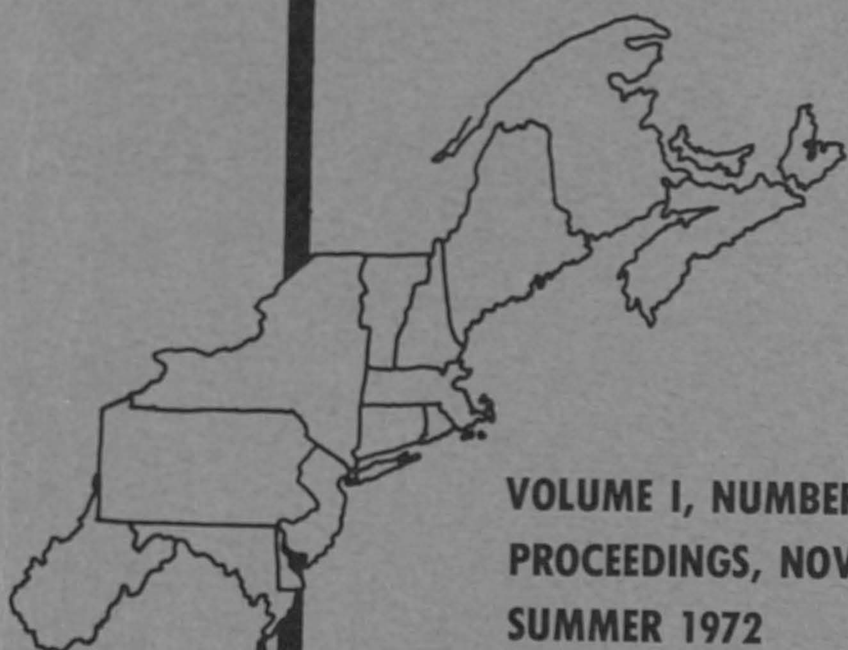

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OPTIMUM LOCATION, NUMBER AND SIZE OF NEW ENGLAND APPLE PACKING PLANTS

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The Problem

Rapid changes are taking place in the commercial apple industry. Recent years have seen the development of controlled atmosphere and Tectrol storage, changes in the type of rootstock grown and changes in the techniques of packing. Furthermore, buyers of fresh apples are much more conscious of quality and demand a more uniform, higher quality pack. Certain problems relating to storage, packing, distribution, processing, and point of sale representation of grower interests have been of concern to the industry. Many of these problems are appearing due to the reflection of these industry changes in the New England commercial apple industry.

Large scale consolidated packing plants might lead to a more uniform, better quality pack in sufficient volume to bargain effectively with large scale buyers. Decision makers in the New England commercial apple industry are seeking answers to questions concerning the optimum number, size and location of packing plants, giving due consideration to present and expected location of production and consumption centers. The sensitivity of the optimum location, size, and number of plants to changes in production and consumption, transfer costs, and packing costs is also important when considering these problems. 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 the study were:

1. To determine the optimum 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.

1/ The study upon which this paper is based was conducted while the author was a graduate student at the University of Connecticut. Appreciation is extended to Dr. S. K. Seaver for his assistance in the study. However, the author accepts responsibility for content.

2. To evaluate the effects of change in the density of production on the optimum plant pattern and total cost of packing the New England crop.
3. To investigate the changes in the optimum shipment patterns and the addition to aggregate marketing costs which result as packing and transfer costs are increased.

The Model

The analysis is concerned with the determination of a system of plants and shipment patterns that would minimize the cost of assembling the raw product, packing the product, and distributing the final product. The analytical model used was the linear-programming, transportation model developed by Hurt and Tramel [2].

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

The accumulation of information concerning the quantity available at the source, the quantity demanded at each consumption point, and the transfer and packing costs could each be a research project in itself. However, in this study the basic objective of determination of optimum number, size, and location of apple packing facilities so as to minimize aggregate marketing cost was attained using information available from secondary sources.

Production Areas

The first procedural step was the designation of production areas. Designation of the states as six production areas would not allow sufficient precision in the analysis. However, the problem would be too large and unwieldy if each county in New England were designated as a production area. To reduce the problem to a manageable size, production in New England was delineated into 14 areas. Multi-county groupings also helped isolate major apple producing areas of the New England region. Table 1 indicates estimated production in each of the 14 areas for 1965 and 1970. The data for 1965 was based upon the 1965 fruit tree survey. The 1970 production was projected as the results of the 1970 survey were not yet available at the time of the study. Two estimates of the distribution of the production within each state was made because the effect of the density of production upon the optimum plant pattern was of interest. Initially, it was assumed that the distribution of production within a state was the same in 1970 as in 1965 when the New England Fruit Tree survey was conducted. In the second estimate, 1970 total state production was distributed in such a way that high producing areas within a state would at least hold their own as overall production within the state declined, and that the decline would come in areas which were already producing only a small share of the state's total production.

Table 1.
Apple Production by Areas on a Packed Equivalent Basis 1965 and 1970

	Area	1965 (bushels)	1970 (bushels) 1st Estimate	1970 (bushels) 2nd Estimate
1.	Northern Maine	365,950	325,173	225,495
2.	Southern Maine	888,112	788,434	888,112
3.	Northern New Hampshire	172,067	156,861	69,572
4.	Southern New Hampshire	1,019,741	932,452	1,019,741
5.	Northern Vermont	392,550	393,387	393,387
6.	Southern Vermont	332,423	333,761	333,761
7.	Western Massachusetts	518,558	542,646	542,627
8.	Central Massachusetts	763,645	800,688	814,748
9.	Northeastern Massachusetts	457,230	478,136	457,231
10.	Southeastern Massachusetts	72,759	75,894	72,759
11.	Rhode Island	154,345	125,027	125,027
12.	Eastern Connecticut	113,886	103,308	36,483
13.	Northwestern Connecticut	308,460	280,966	308,460
14.	Southwestern Connecticut	437,691	398,361	437,691
	Total	5,997,446	5,735,094	5,735,094

Consumption Areas

Consumption for the fourteen previously described areas within the New England region was estimated. A fifteenth consumption area was added for computational purposes as the New England states are a net surplus producing area and the fifteenth area represents all shipments out of the region. Consumption data for each of the 14 areas was not available. To estimate consumption, national per capita consumption information was utilized. Consumption estimates for 1965 and for 1970 are shown in Table 2. It may be noted that 50 percent of the New England apple consumption is located in the highly populated areas of northeastern and southeastern Massachusetts and southwestern Connecticut. These areas provide excellent market outlets for apples produced in New England.

Table 2.
Apple Consumption by Areas
1965 and 1970

Area	1965 (bushels)	1970 (bushels)
1. Northern Maine	204,914	159,877
2. Southern Maine	152,017	126,825
3. Northern New Hampshire	76,484	60,849
4. Southern New Hampshire	167,142	152,340
5. Northern Vermont	92,206	82,439
6. Southern Vermont	54,040	45,973
7. Western Massachusetts	275,005	228,785
8. Central Massachusetts	219,839	184,373
9. Northeastern Massachusetts	979,619	800,630
10. Southeastern Massachusetts	466,219	430,383
11. Rhode Island	322,542	274,470
12. Eastern Connecticut	130,543	120,890
13. Northwestern Connecticut	327,074	277,679
14. Southwestern Connecticut	566,843	477,595
Total	4,034,487	3,423,108

Location of Plant Sites

The next step was to designate the location of the potential plant sites. Initial formulations specified a single location within each production area. A number of factors were taken into consideration in picking the plant location but a partial listing includes an adequate labor supply, access to major highways, power and other utilities, and access to the market area. Fourteen potential plant sites were selected. One site was located in each of the 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.

Transfer Costs

A necessary condition using the transportation model is that transfer costs per unit are known, non-negative, and constant for any quantity transferred. These costs had to be obtained between all areas and all plants. It was very difficult to obtain any standard information concerning trucking costs because there were no standard rates anywhere in the area. The rates were variable for both trucking the orchard-run raw product and shipping the packed fruit to the consumption area. Actual rates depended on negotiation, size of truck, availability of backhaul, and other tangible and intangible factors. The truckers were not regulated as to the charges which could be applied.

It was felt that a reasonable estimate of average charges for shipping between areas, point-to-point, could be made by contacting several of the larger shippers and grower-shippers. Accordingly, this was done by mail questionnaire and follow-up visits.

The survey showed that although there was no uniform pattern as to what these rates included, there were certain practices generally followed in the industry. It was assumed that the rates obtained reasonable reflected actual costs, not costs assigned for intra-firm accounting purposes and that they included unloading the product in the case of assembly cost, but not the loading cost, and that they included loading, but not unloading cost on the distribution side.

The following initial transfer costs were developed. A cost of 15 cents per bushel was assigned for shipment of raw product within an area. In a few situations the same cost was used for shipment to the packing plant of an adjacent area if the distance was within a 25 mile radius. In most situations, a cost of 25 cents per bushel was assigned to assemble the product from an immediately contiguous area. A charge of 33 cents per bushel was made for shipment from intermediate areas, those places which, in general, were located 50 to 75 miles from the plants. Shipments of raw product over greater distances were charged at the rate of 40 cents per bushel. 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 final procedural step was to determine packing costs. A complete analysis of fresh apple packing costs would be a research study in itself. It was felt, however, that for purposes of this analysis the cost relationships from a Michigan study by Hoy F. Carman were reflective of conditions facing packers in this region [1].

Based upon planning cost equations obtained from the Michigan study and adapting them to reflect New England conditions, costs of packing in various size plants were calculated. The per unit costs for the five sizes of plant used in the study are shown in Table 3.

Number, Size and Location of Packing Plants

Solutions were obtained with total packing plant capacity at two levels. The initial solution was obtained by minimizing marketing costs, given the restriction that there would be sufficient packing capacity within each area to pack the production for that area. However, this could result in a great amount of excess packing capacity for the industry as a whole and within certain areas because plant size was limited to five discrete sizes, corresponding to packing rates of one, two, three, four, and five hundred cartons per hour and to obtain sufficient packing capacity within an area the next larger size had to be chosen.

Table 3.
Estimated Costs of Packing Apples

Capacity of Plant (ctns./hour)	Total Season Pack (cartons)	(bushels)	Total Cost (dollars)	Average Cost/carton (dollars)	Average Cost/bushel (dollars)
100	160,000	133,333	115,917	.724	.869
200	320,000	266,667	216,511	.676	.812
300	480,000	400,000	317,104	.661	.793
400	640,000	533,333	417,616	.652	.783
500	800,000	666,667	518,291	.647	.777

The second solution was obtained by minimizing aggregate marketing costs, given that there would be sufficient total packing capacity to pack the commercial apple crop of the region but with all plants in solution operating at the planned capacity and allowing transhipment between areas to occur.

The initial solution, structured with packing capacity in each area sufficient to pack production from that area, used production volume and density data from the 1965 New England Fruit Tree Survey. The initial solution was comprised of twelve plants packing the total production, 5,997,426 units, on a packed equivalent basis. Aggregate marketing costs, denoting costs, of assembly, packing, and distribution of the New England apple crop totaled $7,335,627 in this initial solution. Total packing plant capacity, in this situation, was capable of handling approximately 1.7 million additional units. However, the packing costs used were calculated for plants assumed to be operating at planned capacity. Since fixed costs continue regardless of the rate of operation of the plant, unit costs in plants that were not used to planned capacity would be underestimated. The procedure used to handle this problem was to adjust packing plant costs to fit the total volume which flowed through the plant and increase unit costs for those plants which were not fully utilized. Accurate cost data were available for five discrete plant sizes used and plant volumes were adjusted, using only these five sizes of plant, to insure sufficient capacity to pack the total season crop. The capacity of the plant and unit costs of packing were thus adjusted to correspond more closely to the flow of product through the plant. As plants were eliminated to reduce excess capacity, transhipment was forced to occur and average per unit plant costs in the industry increased because of movement to the left on the industry long-run average cost curve. The optimum solution, determined by finding the combination of plants and locations which gave the lowest aggregate marketing cost with all plants operating at or near the planned capacity, also resulted in twelve plants packing the total 1965 production for the New England region.

Effect of Production and Consumption Changes

Another objective of the study was to evaluate the sensitivity of the optimum plant pattern to changes in volume and density of production. The number of active plants and the pattern of raw product assembly from the producing area to the packing plants were essentially unchanged, in the solution in which there was excess packing capacity, as a result of production changes.

Changes in production density and volume were also tested in the optimal plant solution. New England apple production declined between 1965 and 1970, resulting in more excess capacity when 1970 production was utilized in the model. This lessened the capacity constraint and allowed some shifting of the shipments from production areas to packing plants. Shipments from the areas of northern and southern Maine, southern Vermont, and western and northeastern Massachusetts were slightly sensitive to the changing volume of production and the smaller capacity constraint.

Two estimates of the 1970 production for each area, based upon the two methods used to distribute 1970 production for each New England state, were introduced to gain insight into the changes in assembly and distribution patterns which might come about with a different assumption concerning production density. Two solutions again were obtained; one with capacities in each area sufficient to pack total production from each area, which created a large amount of total excess capacity, and the second with all plants fully utilized. The solutions involving a large amount of excess packing capacity again resulted in more shipment pattern changes.

The sensitivity of the solution to changes in consumption was tested by introducing estimates of 1970 consumption for each area based upon the 1970 population by states and the estimated per capita consumption of apples. Using the second estimate of 1970 production and 1970 estimated consumption, independent solutions for 1970 were calculated. The initial solution was again obtained with sufficient capacity available in each area to pack that area's production. The adjustment to a solution with all plants fully utilized resulted in a 1.17 percent increase in total cost over the solution in which plants were allowed to be underutilized. The optimum 1970 solution contained eleven plants of various sizes. This procedure allowed a comparison of the 1965 optimum and the 1970 solutions.

The comparisons indicated that the pattern of assembly of product from the producing area to packing plant and the distribution pattern from packing plant to consumption area were affected, to a limited extent, by changes in consumption and production density and capacity of the plants involved. Changes in production affected assembly patterns most strongly. Conversely, changes in consumption most directly influenced patterns of distribution from plant to consumption centers. The greatest influence on the pattern of shipment was changes in available packing capacity. Further, as the amount of excess capacity available in the total system was reduced, the extent of influence on the shipment patterns was greatly increased.

Effect on Changes in Transfer and Packing Costs

Insights into the sensitivity of the patterns of assembly, distribution of product, and the value of the objective function were obtained by applying certain changes in transfer costs. The results indicated a limited degree of sensitivity to increase in transfer costs. The influence appeared to be greater on distribution patterns than on assembly patterns; but it was not strong in either case.

Increasing packing costs by 15 percent for the seven plants located in the southern New England area resulted in a 4.6 percent increase in aggregate marketing costs over the previously obtained optimum. The pattern of distribution from the packing plants to the consumption areas was unaffected by the increase in packing costs. The pattern of assembly was changed slightly.

Considerations such as availability of labor and nearness to market, in order to provide daily store-door delivery, might cause large plants to be built near the high density consumption centers rather than in the production areas. This might occur even if resulting packing costs were higher since the solution for the case of increasing packing costs 15 percent, in southern New England plants, did not indicate a strong influence upon the optimum pattern of assembly.

The increased packing costs were tested in combination with an increase in transfer costs. The general effect on the optimum pattern of assembly and distribution was the same as has been described for the separate effects of the increase in transfer costs. This reinforced the finding that increasing packing costs in the southern plants had little effect on the optimum pattern of assembly and distribution of product.

The least-cost location for a single plant was in production area 8, the central Massachusetts location of Leominster. Total season cost with a single plant doing all packing was 12.2 percent greater than the cost obtained with the optimum solution including eleven plants.

The optimum locations for two plants of equal capacity were in two of the high density consumption areas. The least-cost solution, was obtained with plants located at Concord, Massachusetts and Wallingford, Connecticut. Total season costs were increased 4.8 percent over the optimum solution including eleven plants but were 7 percent less than if only one plant were used.

Total season cost was estimated when three plants of equal capacity were located at Concord and Brockton, Massachusetts and Wallingford, Connecticut. This solution, restricted to three plants located in the three highest consumption areas, was 5.7 percent more costly than the optimum solution including eleven plants.

As packing plants increase in size, the supply to operate the plant must be obtained from greater distances. Thus, as packing costs decrease due to economies of size, transfer costs increase. A 10 percent increase in transfer costs, with as few as eleven plants packing the total production, resulted only in a 1 to 3 percent increase in overall marketing costs and very little change in the patterns of assembly or distribution. Increase costs for packing in areas of high consumption density resulted in 4.6 percent greater costs. These additional costs must be weighed against the possible ability to provide a better quality pack more consistently on a store-door delivery basis. Since certain modern techniques of packaging are not economically feasible, except in large packing plants, it would seem that the industry should be encouraged to move in the direction of fewer but larger apple packing plants.

Conclusions

The results of this study provide some general guides for the New England commercial apple industry. One of the long-run questions concerns the effect of changes in production and consumption density and volume upon optimum number, size, and location of packing plants. Changes in the production density and volume did affect the volume of the flow of apples from production areas to packing plants, within the capacity constraints imposed on the model. However, changes in production density did not materially affect the patterns of assembly. Assembly patterns were unaffected by changes in consumption volume and density. The smaller the amount of excess packing capacity which existed, the greater the changes in the patterns of shipment. Since a great deal of excess packing capacity now exists within the industry, the industry should expect changes in production density and volume to have a greater effect on shipment patterns if this excess capacity is reduced in the future.

The patterns of distribution of product from packing plants to consumption centers were basically not affected by changes in production density and volume. The distribution patterns and flows were influenced by changes in consumption density. Slight changes in transfer costs did not appear to exert a strong influence on the patterns of either assembly or distribution of product. Increases in transfer and packing costs, due to possible location of plants in areas of high population density, did not appear to be barriers to movement, by the industry, in the direction of larger, more efficient plants located close to consumption centers.

The ability to pack consistently high quality fresh apples in the volume required by present buyers in the industry 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. With too many packing plants in the industry, most plants handle a volume of product which is too small to provide consistently, to the consumer, the type of pack which would maintain the competitive position of the industry. 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 by the industry. The strongest influence on the pattern of assembly and distribution and, therefore, location of plant was the amount of packing capacity available. Reducing capacity in an area forced transhipment but this could occur at only a slight increase in aggregate marketing cost. As the industry is now structured, there is a great deal of excess packing capacity in terms of the total packing season. This takes place mainly because of the method of marketing common to the industry. It is not uncommon for more than half the crop to be marketed in September, October, and November. The remaining portion is spread out over the months from November through June. This seasonality puts tremendous strain on total packing capacity for the peak month of October, and leaves six months of minimal operation of the packing plant. This flexibility is costly. It might be justified if there were expectations of volume increases in the future, but this is not the case. The model assumed plants operated at planned capacity. One area where further research could provide better information is in the cost of operating plants at less than the planned capacity. This would allow a better analysis of the cost of preserving the flexibility which exists by building plants large enough to handle seasonal peaks in packing. Additional research might also indicate that the building of more storage facilities would allow the industry to market the crop more evenly and allow savings to accrue to the industry.

The general conclusion reached was that there were too many apple packing plants in the New England commercial apple industry. Most of these plants therefore handled a volume of product which was too small to provide consistently the type of pack to the buyer which would maintain the competitive position of the industry. It would be to the advantage of the industry to move in the direction of fewer and larger apple packing plants.

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[2] Hurt, V. G. and Tramel, T. E. "Alternative Formulations of the Transhipment Problem," Journal of Farm Economics, Volume 41, No. 5 (1959).