Potatoes marketing

A STUDY OF POTATO PREPACKING COSTS

Thorald Warley *Donnan Baron*

School of agriculture

UNIVERSITY OF NOTTINGHAM

DEPARTMENT OF AGRICULTURAL ECONOMICS

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Thorald Warley

Donnan Baron

UNIVERSITY OF NOTTINGHAM SCHOOL OF AGRICULTURE

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I. STUDY OBJECTIVES AND SCOPE

At the present time there is a widespread demand from the agricultural, packaging and distributive industries in this country for accurate, detailed and objective information about the costs of prepacking fruits and vegetables.

In large measure the urgency of this need for information springs from the mushroom-growth of the produce prepacking industry in the past three or four years. In this short period produce prepacking has grown from being a novel method of presentation practised by the few to the status of an established and important feature of the marketing scene.

Inevitably, this rapid development has been disorderly and wasteful in so far as all manner of engineering firms have hastened into the manufacture of packing equipment, much of it poor in design and expensive in use and similarly, in that packers have invested large sums in equipment, buildings and materials without first having the opportunity of obtaining unbiased data and advice with which to ensure that their investments were best suited to their present and expected future needs. Furthermore, in the absence of sufficient knowledge about their own and their competitors' costs, many packers have made expensive mistakes in their pricing policies by selling at prices which were too low to reward adequately their capital and enterprise.

Amongst the prepacking plants which have recently sprung into being there is considerable variation in both the methods and scale of operation. Many of the plants employ technologies and are of a size quite efficient for the particular conditions under which the firms must operate. Others are operating with far less than maximum efficiency. In part this is due to the rapid pace of technological innovation in this new industry, for whilst improved equipment and methods are being introduced with bewildering frequency, packers are unwilling or unable to discard equipment which has been superseded. But perhaps of equal or greater importance in accounting for variations in efficiency is lack of information. Individual packers are ill-informed about such vital factors as the costs of operating different types of equipment, or the cost relationships amongst packing plants of different sizes.

In this situation the study upon which this present report is based was directed towards providing some of the information needed to solve the problems associated with the prepacking of maincrop potatoes, this product being the most important vegetable sold in prepacked form in this country.

To this end, the first objective of the study was to secure data on the comparative costs of operating as many as possible of the alternative makes of potato prepacking lines available to packers. In the event the resources available for conducting the study did not permit these data to be established for all the 15 or more makes of equipment from which packers can choose. Accordingly, the enquiry was confined to the two most commonly used equipment classes, return-flow tables and semi-automatic bagging lines. The costs of prepacking by hand and with the recently introduced fully-automatic baggers were not investigated. The former method is not widely practised by reason of its alleged high cost, whilst fully automatic baggers have only recently been installed in a few plants.

Other confines of the study which should be noted at this stage are firstly, that the washing of potatoes prior to packing was excluded; all subsequent cost data in this report refer to plants in which potatoes are merely dry brushed. Although likely to be of increasing importance in future years, the washing of potatoes was still practised by only a small minority of packers at the time of the enquiry. Secondly, the scope of the investigation was limited to the prepacking of maincrop potatoes in 5 lbs. units, the prepacking of earlies and of main-crop varieties into other sized units forming only a small fraction of the trade at the present time.

The second objective of the enquiry was to determine the short run cost curves for plants containing each of the seven makes of equipment embraced by the investigation: that is, to investigate the behaviour of average costs as the volume of prepacks produced by each type of equipment is varied from relatively low levels up to its capacity as defined by its size and the mode and period of its operation. The purpose of this facet of the investigation was to ascertain whether costs can be reduced by staffing each type and size of line up to the point where the output in any time period is at a maximum within the limits set by the mode of operation of the line, or whether costs are lower at rates of output less than capacity by reason of the savings in labour costs being more than sufficient to offset the increased incidence of fixed plant costs on each ton of the reduced volume.

The third and final purpose of the study was to see whether there were economies of scale in the prepacking of potatoes that is, to determine whether potatoes can be packed more cheaply in large plants than in small, assuming the existence of an optimum organisation in all plants in the scale range considered. Again, the scope of this aspect of the enquiry had to be confined to what was practicable, and economies of scale have only been examined in plants having capacity outputs of from approximately 950 to 4,600 tons in a packing season of normal length. In general terms this corresponds to the scale of operations covered by plants containing one, two or three double-headed bagging machines. Whilst it is known that there are numerous potato packing stations having capacity outputs both above and below this size range, there is good reason to believe that a majority of plants in this country fall within these limits.

Thus it will be apparent that although limited in scope—treating only of the costs of prepacking maincrop potatoes in 5 lbs. units, when dry brushed and packed on seven types of line in plants ranging in capacity from about 6 to 30 tons per day—nevertheless the objectives of the present study were such as to provide cost data which would assist packers in the formulation of decisions about the technologies they should employ, the scale on which they should operate, the pricing policies they should pursue and in the day to day management of their plants. In addition, the material disclosed by the study should be of interest and value to prepacking machinery and materials manufacturers, and to other trades, organisations and individuals directly concerned with the growth and development of the produce packaging industry.

II. DATA COLLECTION AND ANALYSIS

There are two distinct research methods which can be employed in the study of costs and efficiency in the performance of marketing services such as prepacking.

The first is the conventional method of collecting and analysing the accounting records of firms engaged in providing this service. In theory, provided the number of records available is large enough to permit their grouping according to the technologies they employ, and the outputs at which they operate, then by plotting the average costs of all firms against their output volumes some idea could be obtained of the shape of the short run cost curve for individual firms using a given technology, and of the relative economies of alternative methods and types of equipment. Similarly, the points on a chart plotting average packing costs against volume would give some idea of the possible existence and extent of scale economies or diseconomies.

There are, however, many practical and conceptual difficulties militating against the success of this approach. In the first place, experience has shown that very few firms keep more than the most rudimentary accounts of their prepacking activities, probably because prepacking is usually intimately interwoven with other aspects of their businesses such as growing, merchanting or retailing. Consequently, it is virtually impossible to secure access to a sufficient number of accounting records for the requirements of the above type of analylis. Even if this were not the case, inter-firm differences in accounting practices and investment policies, in the prices paid for labour and materials in a given period and for machinery and equipment purchased at different times, would together render accounts of limited value. It is improbable that accounts would give sufficient detail to permit accurate and uniform allocation of costs to particular operations and stages, and so allow the detection of improved techniques and practices and the making of meaningful comparisons of the relative economies of different types of line. Furthermore, whether from existing accounts or from records instituted by the researchers and maintained by the packers, it would be difficult to detect excess capacity in the co-operating plants resulting from internal maladjustments in methods, equipment, building layouts, etc., and hence to ascertain the true nature of intra-plant volume-cost, and inter-plant scale-cost relationships.

For these reasons an alternative research method, which has been variously described as the "synthetic," "block-building" or "economic-engineering" method of cost analysis, was employed in the present study.

In essence, this method involves the research workers spending several days in packing plants, obtaining firstly, descriptive data regarding the nature of the processes performed, the work methods used on individual jobs, plant layouts and process flows; and secondly, establishing the relationship between resource inputs and product outputs at each stage of the production process. Having obtained this information, the subsequent steps of the analysis are to develop performance standards for each job and each stage: synthesise these standards into alternative work methods: estimate the relative costs of the alternative work methods by applying uniform prices to the resources used in them: synthesise the least cost combination of the jobs and production stages into hypothetical or model plants of various sizes: estimate short-run plant cost curves for several sizes of plants using the various types of line under study in the least-cost manner: and finally, aggregate the short-run plant cost curves into an economies of scale curve for the scale range covered.

It will be seen that the synthetic method of cost determination differs from the analysis of accounting records essentially in the emphasis placed on the determination of the physical input-output relationships in plant processes and in the separate introduction of resource prices. Its main advantages are that it avoids the vagaries and non-comparabilities inherent in accounting records due to changes in costs, varying degrees of plant utilization, differences in the quality and composition of plant products, and differences in accounting policies and practices. Furthermore, it has the great advantage that once the physical relationships between factor inputs and product outputs in individual operations have been established, then the cost curves for hypothetical plants can be synthesised as readily as those of existing plants. In addition, improved methods and techniques not practised in existing plants can be evolved from the production standards obtained, and their costs incorporated in short-run and long-run plant and industry cost curves, thereby setting a standard of efficiency against which to compare technologies and scales in the packing industry as constituted at present.

It should, however, be appreciated from the foregoing paragraphs that implicit in the application of the synthetic method of cost analysis is the assumption of a higher standard of managerial efficiency than the actual average in the existing industry. Whilst the physical production standards used, and through these the cost standards evolved, are not top performances, they are nevertheless better than the industry averages. In short, they are standards which can be achieved and maintained under usual working conditions given a reasonable level of operating efficiency.

The details of the way in which this method of cost analysis was applied to individual cost components are described in subsequent pages, but a broad outline of the steps followed in the study, can best be given at this point.

The field work for the study was carried out between November and April of the 1957-58 packing season. Twelve plants were selected for detailed study, Of these, two were return-flow tables and five semi-automatic bagging machines. Apart from differences in the actual bagging equipment they contained, the plants varied widely in size, layout and location: in the numbers of workers employed: in the ancillary equipment associated with the bagging machines, and in the way that particular line jobs were organised and performed. They thus offered considerable scope for the establishment of physical input-output data relating to the various alternative machines and methods.

However, common to all plants were the several distinct packing operations and the sequence of their performance, namely, unloading unpacked potatoes into temporary storage: dumping loose potatoes into the line: dry brushing: quality grading on dressing tables: weighing, filling and sealing 5 lbs. units into polythene bags: conveying the filled bags to an assembly point: assembling, packing and sealing 10 bags into master or outer containers: stacking the filled outers prior to their collection from the packhouse and, finally, loading the packed produce from the stacks onto lorries. It should be noted that the cost data presented in this report relates solely to the costs of performing this sequence of operation. The costs of assembling loose potatoes for packing and of marketing packed potatoes are not included, nor are administrative costs such as office expenses. Within these limits, the report deals with most variable and overhead costs incurred between the point where the bulk potatoes arrive at the packhouse door, to the point where packed produce is on lorries ready for dispatch to markets.

From three to seven packing days were spent in studying the operation of each of the plants visited, and in particular, in establishing the physical input-output relationships between resource inputs and packed outputs according to the equipment and methods employed.

The most important single aspect of this process involved the determination by time studies of the work requirements of each plant task. From this information, together with information on prices supplied by the makers of packing materials and ancillary equipment, the most efficient method of operating each type of line was evolved. Furthermore, the work study data provided production standards for individual plant tasks, thereby enabling the capacity outputs of each unit of the several types of bagging machines to be determined, and providing the data needed to estimate the minimum staffing requirements of several sizes of plant containing each type of line when operated both at their capacity outputs and at lower rates than these.

Inventories of equipment other than the actual bagging machines were prepared for each plant visited, and from an analysis of this information the minimum equipment requirements for each of 22 model plants were synthesised. Similarly, each of the packhouses visited was surveyed in terms of its dimensions, construction, materials, cost and suitability, and from this data three suitable buildings to house the several sizes and types of packing lines in the 22 model plants were designed.

Current purchase prices and estimates of current construction costs were then applied to the schedule of equipment and building requirements for each of the model plants to give the probable total investment at present day replacement costs. Estimates of repair costs and length of expected useful life, based on operating and engineering experience and on the judgment of plant managers and machinery manufacturers, were then applied to the investment data to give the average annual costs of replacement and maintenance. To these costs was added an allowance to cover insurance, interest and rates.

The material requirements of potato prepacking were established by direct observation and measurement in the case of polythene bags, outers, tape, staples etc., and their costs were determined from information about current prices supplied by manufacturers. Power, heating and lighting costs were synthesised from engineering data concerning technical requirements in these aspects, and from price data provided by the suppliers of these services.

When completed, the measurement procedure outlined above provided all the information needed for synthesising individual plant cost functions. These functions are the basis for comparing the efficiencies of alternative technologies and for determining the economies that may be associated with the scale of operations. The procedure involved consisted of, firstly, a simple comparison of the cost functions at each stage of the packing process so as to identify the most efficient methods of operating each type of line; secondly, estimation of the short-run cost curves for three sizes of plants containing each type of equipment operated in accordance with the least-cost methods, and thirdly, the aggregation of the short-run cost curves for all model plants to determine the most efficient technologies and their total costs at scales up to 25 to 30 tons per day.

III. PERFORMANCE AND COST STANDARDS

The Machines

Because manufacturers of prepacking machinery are introducing innovations with great rapidity, some of the machines studied in the course of this enquiry are no longer being produced in exactly the same form. In consequence, it was decided that it might be misleading to the reader and unwarrantably harmful to the interests of the firms concerned if the various machines considered in this report were identified by their trade names. Accordingly, the seven different prepacking machines are identified throughout by code letters.

Machines A and B are both return-flow tables, but, whereas A is designed to operate with one weigher and one bagger to each scale, each weigher on B serves two baggers. Because of this, output per scale is lower on A than on B. Having regard to the sizes of table which the manufacturers are normally prepared to supply to their customers, and to the need to compare costs over a similar output range, the costs of operating plants containing four, six and eight station tables and two, four and six station tables have been evolved for A and B respectively.

Machines C to G are all semi-automatic baggers—C, F and G being of the double-headed variety, D and E having only one weighing station per head.

F and G are very similar in working principles, having two weigher-baggers to each head with a third person sealing the filled bags; however, at the time of the investigation F had not approved scales and so required a fourth worker to check-weigh. Machine C differed from F and G in having the operations of weighing and bagging done by separate workers, there being one weigher and two baggers per scale and so six workers to each double-headed bagging unit. The costs of operating model plants containing one to three double-headed units of each of these three types of machine have been synthesised.

Type D is a single-headed machine having a weigher and three baggers and sealers per scale. The costs of prepacking with one, two and three of these machines have been considered in this report.

Finally, machine E is a single-headed bagger staffed by three workers per head weighing, bagging, sealing and check-weighing, and resembling F in that the flow of potatoes into the weigh-pan is automatically started by the return of the empty pan to the horizontal position. In order to obtain outputs comparable to those of other machines, the costs of operating plants containing from one to four type E machines have been determined.

The above information, together with other relevant data which will be referred to at later stages, is summarised in Table 1.

Labour

Procedure. Three measurement techniques were used in the determination of the work requirements of individual line tasks.

Firstly, stop-watch time studies were made on the line operations in each plant visited. Wherever practicable the task performed by each worker was divided into its constituent elements and separate performance times obtained for each element. In all cases the observed level of performance was judged relative to a concept of a "normal" rate of activity and the individual observations were adjusted to this standard, thereby ensuring that the time measurements on different workers reflected a more uniform level of skill and rate of activity than is observed in practice. The adjusted observations on the time requirements of each task element were averaged for each worker, and for all workers performing work elements in exactly the same way. By this means the basic labour requirement of alternative methods of accomplishing the various elements were compared, and furthermore, time requirements for the various line tasks according to alternative methods were determined by adding the times for each element.

Before the data on basic time requirements could be translated into terms of staffing and labour costs at several levels of output for the types of line under study, the results of work sampling studies conducted in each plant visited were used to determine how the total time of the workers at each line stage were distributed between productive work, unproductive time caused by equipment breakdowns, interruptions in the flow of produce and materials etc., and idle time in the strict sense.

By combining the available data on basic time requirements as revealed by time studies, with the information on the way that available time was split between productive and unproductive activities, a measure was obtained of the maximum rate of output likely to be achieved in practice, as distinct from the theoretical outputs indicated by the uninterrupted task time requirements.

The third work measurement technique employed was the analysis of the rates of task accomplishment indicated by time-output logs maintained during the period spent in each packhouse. This procedure was used in respect of certain plant jobs which did not lend themselves to stop-watch time studies, notably quality grading where the application of subjective judgment by the workers is an element of the job not amenable to precise measurement.

Capacity Outputs. With given quantities of input factors available rate of line output can be expanded until some limiting point or bottleneck is reached. If the bottleneck lies in some variable factor such as labour then more workers can be employed and rate of output still further increased. If, however, the limit is imposed by some item of line equipment then, given that there is no "slack" to be taken up by the employment of better work methods, output cannot be expanded beyond this capacity rate except by changing the size or form of the item of equipment concerned, or in other words, by altering the plant.

The first step in the synthesis of plant labour costs was, therefore, to find the capacity rate of output of the seven types of bagging heads. This, by reason of these machines being designed to operate with fixed number of workers to each weighing scale, became a problem of determining from time study and work sampling data the capacity rate of output of the workers doing either the weighing or the bagging into 5 lbs. units, the limiting worker being the one with the longer time requirement per cycle.

In the 12 plants included in the inquiry, work sampling studies showed that

TABLE 1. CHARACTERISTICS OF THE LINES STUDIED

Machine type	A			B			C			D			E				F			G		
Class	Return flow tables						Semi-automatic baggers															
Staffing per scale	2			3			3			4			3				2			1.5(1)		
Size of plant (No. of weighing stations)	4	6	8	2	4	6	2	4	6	1	2	3	1	2	3	4	2	4	6	2	4	6
Output per scale (No. of 5 lbs. bags packed per minute of line operating time)	3.4			4.9			5.2			8.8			6.7				5.4			4.7		
Plant daily capacity output (tons per 7½ hours day)	12.8	19.3	25.7	9.2	18.4	27.6	9.7	19.3	29.0	8.2	16.5	24.7	6.3	12.6	18.9	25.2	10.2	20.3	30.5	8.9	17.7	26.6
Plant yearly capacity output (tons per 150 days season)	1,930	2,890	3,850	1,380	2,760	4,140	1,450	2,900	4,350	1,240	2,480	3,710	940	1,890	2,830	3,770	1,530	3,050	4,580	1,330	2,660	3,990

(1) Two weigher-baggers and one sealer to each pair of scales

the weighers and baggers were employed in productive work for from 79 to 95 per cent of the total hours worked, with an average for all plants of 85[1] per cent A further three per cent of the total working time was spent in the performance of tasks such as replenishing material stocks, the remainder being accounted for by equipment stoppages, breaking for lots, workers' personal needs and idling. In moving from basic cycle time requirements to capacity outputs it was, therefore, assumed that the key workers, the weighers and baggers, would be actively producing filled bags for only 85 cent of their total working hours.

Having obtained standard capacity rates of output *per scale* in this way for each of the seven types of bagging machine, capacity outputs *per day* and *per season* were calculated by simple multiplication for various sizes of plant containing each type of line. These are given in Table 1. For this purpose it was assumed firstly, that each plant operated for 7½ hours each day, of which half an hour was absorbed in two 15 minutes morning and afternoon tea breaks, leaving 7 hours per day line operating time: secondly, that each plant had a 150 days packing season, there being this number of working days in the period October to April inclusive. These assumptions were based on the practices and aggregate experience of the co-operating packers, and are considered to be typical amongst packers generally.

Should the industry become less dependent upon married female labour in future years, and if it solves the economic and technical problems of prepacking products other than maincrop potatoes, then it may be possible to secure a reduction in costs by shift and overtime working and by extending the packing season. As these are not practical possibilities for the industry as a whole at the present time, no attempt has been made to evaluate their results in this report.

Staffing at Capacity. Table 2 shows details of the minimum number of workers required to staff each type and size of line at their capacity rates of output.

As stated previously, the operation of the various types of bagging machines requires that *weighing* and *bagging* workers be provided in fixed proportions to the number of scales available; for some lines this applies to *sealers* and *check-weighers* too. This is not the case with the staffing of other line stages where the number of workers required is determined by the rate of output.

The staffing requirements of *dumping* and *grading* at capacity and other rates of output were determined from the information provided by time-output logs. In the 12 plants studied dumpers handled an average of 2.3[2] tons of bulk potatoes per man in each hour of line operating time, with a range from 1.3 to 3.6 tons per man per hour. This average was adopted as a reasonable performance for this operation.

Grading was invariably done by women, and the quantity of bulk potatoes handled per woman per hour of line operating time ranged from 0.8 to 2.3 tons over the period of study, this large difference being due to factors such as the quality of potatoes entering the plant, and the quality standards set by the management. The average quantity handled was 1.5[3] tons per woman honr, and as there was no apparent relationship between the amount of grading labour used and the standard of grading achieved in the plants visited, this figure was taken as a standard for building up an estimate of the number of graders required in the model plants although, clearly, the number of graders needed may vary from lot to lot and from day to day depending upon the quality of the incoming potatoes etc.

Minimum team sizes and best task organisations for *bulking* were evolved from work study data. Included under this head are the operations of filling an outer with 10 5 lbs. bags, folding and stapling the neck, and carrying the filled outer to a temporary storage stacking area. After adjusting for compensatory rest allowances, the elemental times for this sequence of operations were as follows:—

Elements	Time requirement (secs.)
1. Grasp outer, open whilst moving to packing table ...	10.6
2. Fill outer with 10 x 5 lbs. bags	39.5
3. Shake down, drag clear, fold outer neck	15.8
4. Grasp stapling pliers, apply five staples	10.1
5. Lift filled outer, carry to stack, put on stack, return to empty outer pile	18.6
Total time required	94.6

(1) Standard deviation, 5.3.
(2) Standard deviation, 0.3.
(3) Standard deviation, 0.5.

TABLE 2. MINIMUM STAFFING AT CAPACITY OUTPUT RATES

Machine Type	A			B			C			D			E				F			G		
Size of plant (No. of weighing stations)	4	6	8	2	4	6	2	4	6	1	2	3	1	2	3	4	2	4	6	2	4	6
Workers required																						
Dumpers	1	2	2	1	2	2	1	2	2	1	2	2	1	2	2	2	1	2	2	1	2	2
Graders	2	2	3	1	2	3	1	2	3	1	2	3	1	2	2	3	2	3	3	1	2	3
Bagging head operators	8	12	16	6	12	18	6	12	18	4	8	12	3	6	9	12	4	8	12	3	6	9
Bulkers/stackers	3	4	5	2	4	5	2	4	5	2	4	4	2	3	4	4	2	4	5	2	4	5
Manager	–	1	1	–	1	1	–	1	1	–	–	1	–	–	–	1	–	–	1	–	–	1
Total workers required	14	21	27	10	21	29	10	21	29	8	16	22	7	12	17	22	9	17	23	7	14	20
Estimated proportion of manager's time spent on line jobs (per cent)	*	*	0	*	0	0	*	0	4	*	*	34	*	*	*	40	*	*	43	*	*	0
Capacity output per standard day (tons)	12.8	19.3	25.7	9.2	18.4	27.6	9.7	19.3	29.0	8.2	16.5	24.7	6.3	12.6	18.9	25.2	10.2	20.3	30.5	8.9	17.7	26.6
Packed output per worker per standard day (cwts.)	18.3	18.3	19.0	18.4	17.4	19.0	19.3	18.4	20.0	20.6	20.6	22.5	18.0	21.0	22.2	22.9	22.6	23.9	26.5	25.3	25.3	26.6

* No manager required in these plants

The time required for element 5 obviously varies with the distance from the packing table to the stacking area. The figure of 18.6 seconds is based on the assumption that the average distance the filled outers are carried is 20 feet, and is evolved from the observed relationship that the basic time requirement was 5.8 seconds plus 0.3 seconds for every foot travelled between the packing table and the storage area.

One of the most difficult problems presented by the study was concerned with *supervisory labour.* Only a limited amount of useful information was obtained from the survey of existing plants about the relationship between scale of output and the incidence of the costs of this labour category. There was indeed no clearly discernible pattern in the plants studied, nor in other plants visited in the pilot stage of the enquiry, with regard to the output volumes at which it is found necessary, in practice, to assign this function to specialised personnel; that is, the circumstances peculiar to each firm dictated their policy and practices in this respect. However, in consultation with plant owners an acceptable working hypothesis has been evolved and applied to the model plants whose operating costs are dealt with in this report.

The hypothesis is that a specialised manager is likely to be employed in all plants having either outputs of 25 or more tons of packed potatoes per standard day or employing 20 or more line operatives in addition to the manager. The manager would be primarily responsible for recording, and supervision of the line, the workers, the flow of materials and the quality of the product, etc. but, in addition, he would be a working manager in so far as he would be available to help out line operatives (other than weighers and baggers) for up to 50 per cent of his day if variations in the flow of work or lack of skill on the part of individual workers should necessitate this. It is further assumed that in plants having daily outputs or numbers of workers lower than the 25 tons or 20 workers levels, supervision would be the responsibility of a chargehand who combined supervision duties with the performance of a line task, normally the operation of carrying and stacking the filled outers.

In support of the above hypothesis it may be stated that work sampling studies conducted in the plants visited on the activities of working managers and chargehands and the analysis shown in Table 2, both suggest that the demands of supervisory duties on the time of chargehands and of line duties on that of working managers would not be so large as to rule out these assumptions on the grounds of technical unfeasibility. Nevertheless, it is recognised that the inability to check the validity of the assumptions is an important weakness of this stage of the analysis.

The labour requirements of line *preparation, maintenance* and *cleaning* are of minor importance and may be dealt with summarily. The most important variable influencing the magnitude of the costs of these operations is the size of the plant and the output of the equipment in it, and there is a rough association between these factors and the number of scales on the line. The time output logs maintained in each plant showed that cleaning (i.e. washing the scales and sweeping the floor) required approximately half a woman hour per scale per day, and that line preparation and maintenance required about one man hour per scale each day. The tasks involved in the latter job category included oiling and greasing equipment, filling the line with potatoes prior to the arrival of the packers each morning, and ensuring that there was an adequate supply of materials such as bags, tape, staples etc. to hand before packing commenced.

Finally, the labour requirements of *loading* packed potatoes out of the plant onto lorries and of *unloading* sacks of loose potatoes into the plant, were derived from a study of these operations in plants where mobile power-operated elevators were used. On average, both loading and unloading required 0.3 man hours per ton, and costs have been based upon this standard, and upon the assumption that plant labour was assisted by the drivers of the vehicles visiting the plants.

Staffing-volume Changes. Since the rates of operation of packing lines of the return-flow table and semi-automatic types studied are operator-paced rather than machine-paced, it is apparent that a wide range of rates of output can be obtained from each kind of equipment. As output falls progressively below the capacity rate it becomes possible to operate the plant with successively smaller numbers of workers. The "dropping off" of workers occurs at the dumping, grading and bulking stages of the packing operation, the numbers of workers required to man each scale remaining constant. There are, therefore, a number of "labour increment" points in the staffing of packing plants of all sizes, corresponding to the daily output rates at which the services of workers can be dispensed with as output falls below the capacity rate, or conversely, to the levels of daily output at which it becomes necessary to add another worker as the rate of output is raised from very low levels to capacity. The daily output rates which mark these major discontinuities in labour forces and costs are summarised in Table 3.

TABLE 3. LABOUR INCREMENT OUTPUTS

DUMPING		GRADING		BULKING	
Tons packed per standard day	No. of workers required	Tons packed per standard day	No. of workers required	Tons packed per standard day	No. of workers required
14.3	1	9.7	1	5.9	1
28.5	2	19.3	2	11.2	2
		29.0	3	14.8	3
				22.2	4
				29.6	5

It will be seen that for dumping and grading the increment points are simple multiples of the previously given standards of 2.2 and 1.5 tons handled per worker hour respectively after making adjustments to convert hourly bulk throughputs into terms of daily packed outputs. This is because the operators on each of these jobs work independently of each other, with little or no scope for increasing efficiency by division of labour over the scale range considered. This is not the case with bulking, where there is scope for organising the separate tasks involved in a variety of ways as the output increases. Thus, whereas one man alone can cope with the full cycle of operations if the output does not exceed 5.9 tons per day, one man and a woman are a cheaper team than two men for outputs ranging from 5.9 to 11.2 tons per day and are effective when the tasks are so organised that the woman packs while the man closes and stacks the filled outers. Similarly, still further division of labour gives lower costs than replicating the one man/one woman team when the output exceeds 11.2 tons per day, since having two, three or four girls packing, folding and stapling the outers, and one man doing nothing but carry the sealed outers away to the stacking area gives teams capable of dealing with outputs of up to 14.8, 22.2 and 29.6 tons per standard day.

Labour Costs. In translating estimates of the staffing requirements of the model plants at their various daily output levels into terms of labour costs per ton packed, it was necessary to assign plant tasks realistically between different classes of labour and to adopt a uniform scale of wage rates.

All line jobs necessitating the lifting of weights greater than 5 lbs. were assumed to be done by men, all other jobs by women. That is, unloading and dumping hundredweight sacks of potatoes into the line, and the carrying, stacking and loading of 50 lbs. outers were assigned to men: the jobs of grading, weighing, bagging and packing the outers with prepacks and cleaning the plant were assigned to female labour. These assumptions follow closely the practices encountered in the plants surveyed.

There was some variation between the surveyed plants in the wages paid to comparable classes of labour, but based upon the most common rates amongst these plants, the scale of wage rates adopted was as follows. All female labour was regarded as being "regular casuals," paid at the standard rate of 2s. 6d. per hour: ordinary male workers were charged at £8 per 47 hour week: chargehands at £9, and working managers at £10. After making allowances for paid holidays and for the employer's share of the cost of the weekly insurance stamp, the labour price was 33.3d., 45.7d., 51.1d. and 56.5d. per hour worked for women, ordinary men, chargehands and managers respectively.

Labour (and other) costs were calculated for each type and size of machine when operated at their own capacity rates, and at the daily output rates shown in Table 3. These data are summarised in Table 4, where the italicized figures in the columns mark the capacity outputs of each plant.

The first thing immediately apparent from the table is that there are large differences in the labour costs of operating different machines at common rates of output, this being a reflection of the varying numbers of workers required to operate the lines at those outputs. Secondly, the labour costs of operating any one type of machine are seen to vary widely with the size of the plant, and with the daily output rate at which each size of plant is operated. Thirdly, it will be seen that with only minor exceptions, labour costs per ton packed fall with increasing output from any one size of plant. Finally, the table shows a general tendency for labour costs at the capacity output rates for each type of machine to fall with increasing size of plant, despite the inclusion of specialist managerial costs in the largest plants.

Output per Worker. An operating standard which has been much quoted in the industry is that plant managers should aim at a target output of one ton packed per day per plant worker employed. Assuming that the $7\frac{1}{2}$ hours standard day used in this report is comparable to the "day" mentioned, then it would seem from the data presented in the last line of Table 2 that the above rule-of-thumb may be somewhat outdated. For, whilst the return flow tables (A and B) had outputs per worker approaching the 20 cwts. per day mark, most of the semi-automatic baggers (D, E. F and G) gave outputs per worker higher than this, with the three sizes of plant containing machine type G having outputs per worker more than 25 per cent higher than the standard.

It will be evident at a later stage that, in general, high labour productivity and low average total packing costs per ton go together, so that output per worker employed is one measure of operating efficiency that plant managers can look to with ease and with profit.

Materials

The costs of materials contained within the final product are amongst the easiest of the cost items of prepacking to measure, for they normally enter into the product in fixed proportions. The physical inputs were determined by the simplest of measurement techniques, and the costs of their use obtained by multiplying these quantities by prices supplied by manufacturers.

LABOUR COSTS ACCORDING TO MACHINE TYPE, OUTPUT PER STANDARD DAY AND SCALE.

TABLE 4. shillings per ton

Packed output per standard day	Machine type						
	A	B	C	D	E	F	G
(tons)							
5.9	45.9	37.8	37.8	30.6	27.1	30.3	27.3
6.3					*28.9*		
8.2				*24.6*			
8.9							*20.7*
9.2		*27.0*					
9.7	30.7	39.3	*25.7*	30.0	25.7	21.4	26.4
10.2						*22.5*	
11.2	28.5	35.9	35.9	27.8	24.1	28.5	24.8
12.6					*23.4*		
12.8	*26.7*						
14.3	30.6	30.1	30.1	23.7	25.4	24.2	21.3
14.8	31.4	30.9	30.9	24.8	26.4	25.3	22.5
16.5				*23.7*			
17.7							*20.2*
18.4		*27.9*					
18.9					*22.1*		
19.3	*27.2*	33.6	*26.7*	26.5	26.7	20.8	22.3
20.3						*20.8*	
22.2	28.8	30.3	30.3	24.4	24.6	24.7	20.5
24.7				*21.9*			
25.2					*21.7*		
25.7	*25.9*						
26.6							*19.4*
27.6		*25.4*					
29.0			*23.9*				
30.5						*19.1*	

Polythene Bags and Paper Outers. Most of the packhouses visited used 10 inches by 5 inches 150 gauge, two-colour printed polythene bags for packing 5 lbs. units, and these specifications have been adopted in costing bags for the model plants.

It has been assumed that loose bags are used. Rolled bags have had only fleeting popularity since their introduction, and they were encountered in only two of the plants visited. Loose bags were quicker in use than rolls. It required 5.2 seconds to grasp, tear off and open a bag from a roll, whereas picking up and opening a loose bag took only 4.0 seconds. Furthermore the wastage rate was lower with loose than with rolled bags, on average 2.2 bags per ton packed for the former but 7.6 per ton packed for rolls. Slower handling and more hold-ups due to torn and split bags are disadvantages of the rolled bag with important repercussions, by reason of their adverse effect on plant output.

TABLE 5. COSTS OF POLYTHENE BAGS AND PAPER OUTERS

Quantity purchased ('000s.)		Packed tonnage equivalent	Lowest price quoted (shillings. per 1,000)		Cost per ton packed (shillings.)	
Bags	Outers		Bags	Outers	Bags	Outers
250	25	555	86.8	408.5	39.1	18.4
500	50	1,110	86.0	403.3	38.7	18.2
1,000	100	2,220	84.8	400.0	38.2	18.0
1,500	150	3,330	84.8	389.0	38.2	17.5

Price schedules were obtained from seven leading bag manufacturers. Cost per 1,000 varies with the size of the order, and with the supplier, although so far as can be ascertained there is little to choose between the firms concerned in respect of quality, delivery dates etc. In consequence, it has been assumed that managers of the various model plants would buy at the lowest prices quoted for quantities corresponding to their yearly outputs. On this basis, and making an appropriate allowance for wastage, the cost of bags ranges from 38.2 to 39.1 shillings per ton packed as shown in Table 5.

Like most firms in the industry, the surveyed plants bulked their prepacks 10 to a non-returnable paper outer. Consequently no information was obtained from the enquiry with which to compare the economy of this method with that of using returnable master containers, e.g. bushel boxes, hessian or jute sacks.

Costs have been based upon the use of a two-ply outer, this being the type most frequently encountered and also widely agreed to be the best for general purposes. Taking into account outer wastage—on average one paper outer was unuseable for every five tons of potatoes packed—the cost of using the cheapest available one colour printed two ply outers ranged from 17.5 to 18.4 shillings per ton packed.

Taking the purchase of polythene bags and paper outers together, the largest firms had a price advantage of about 1.8s. per ton over their smallest competitors.

Tape and Staples. Of the three ways of sealing polythene bags encountered in the survey, namely the use of adhesive tapes, plastic-covered wire twists and rubber bands, the first was met most frequently. Furthermore, the study showed that popularity of tape is well founded since, although more expensive in material cost, this is offset by the greater speed with which they can be applied, with commensurate advantages in terms of worker and line output rates. Thus, whereas it required 7.3 and 5.5 seconds to apply rubber bands and plastic twists respectively, sealing a bag with tape took only 2.8 seconds.

Measurement showed that sealing each bag required 2¼ inches of tape after making allowances for wastage. Combining this standard with manufactuers' price schedules showed tape costs to range from 2.2 to 2.0s. per ton packed in plants producing from 900 to more than 3,500 tons per season.

Two alternative methods of sealing the paper outer containers were studied, namely, stapling and wire-tying bunched necks. Labour requirements of each method were virtually the same, staples were slightly cheaper to buy. However, material costs of both methods are minor items—0.6s. per ton for staples and 0.7s. for twists. Costs (and labour requirements) have, therefore, been based upon the stapling method firstly, because it is believed to be the more widely used in the industry as a whole, and secondly, because it is generally agreed that it gives the more attractive appearance to the product.

Sack Wear and Tear. In all the plants surveyed bulk potatoes were assembled in one cwt. sacks belonging to the packer. It has been assumed that this situation exists in the model plants and an allowance has been made for sack wear and tear.

None of the packers visited could provide precise information about the average number of journeys between farms and packhouse made by sacks of different qualities, but in discussion with the packers concerned an arbitrary figure of 3d. per sack journey was agreed upon. Allowing for the sacks needed to transport "waste" in the form of culls, soil and the excess weight given in each prepack, the cost on this basis is 5.5 shillings per ton packed.

Culls, Soil and Turn of Scale. The losses incurred by packers on the poor quality and oversized potatoes out-graded, on soil adhering to the in-coming potatoes, and to the overweight given in each bag, are by their nature highly variable between lots. However, the experience of the 12 plants in which the costs of these items were determined can be used as an empirical guide to their probable costs over a period in the model plants.

Amongst the surveyed plants the total weight of out-graded potatoes ranged from 0.2 to 2.9 cwts. per ton packed during the period of observation, with an average for all plants of 1.1 cwts. per ton. Differences between the weight of potatoes bought in and the weight packed due to soil and turn of scale losses ranged from 0.3 to 2.7 cwts. per ton packed, with an average for all plants of 0.8 cwts. However, because of exceptional circumstances surrounding the extreme values recorded for these losses, it was felt that somewhat lower values gave more satisfactory standards than the average figures. Accordingly, the approximate modal values of 1.0 and 0.5 cwts. have been used to estimate these losses in the model plants.

Further, guided by the practices with regard to the disposal of culls in the sample plants, and by the combined experience and judgment of the plant managers in respect of realistic values to be placed upon culls and the purchase prices of potatoes of a prepacking standard, it has been assumed that all culled potatoes are sold for stockfeed at a price of £3 10s. per ton and that the buying in price of potatoes is £20 per ton. Working upon these assumptions the loss per ton due to out-graded potatoes is 16.5 shillings and the loss incurred for soil and turn of scale is 10.0 shillings. These figures have been applied uniformly to all model plants.

Equipment

The items included in the schedules of minimum equipment requirements built up for each of the 22 model plants from observations and manufacturers' recommendations have been divided into the "line" itself and ancillary or "other" equipment.

Under the first head fall the bagging heads, dressing tables, dry brushers and feed elevators. The manufacturers of three of the seven bagging machines studied build and supply all of these items, and in these cases investment costs have been based upon their quotations for completed line installations. The remaining four manufacturers build bagging heads only, although they are normally prepared to act as intermediaries in arranging the purchase of brushers and dressing tables for buyers of their baggers. In estimating the total investment in these four lines, account has been taken of the bagging-head manufacturers' recommendations in respect of the types and sizes of brushers, etc., with which their baggers are designed to be operated.

"Other equipment" comprises circulating belt conveyors, packing tables and powered loading elevators as the major items, with tape dispensers, stapling pliers, platform scales, hand trucks, sack and metal barrows, and brushes and shovels as less costly items. Also included under this head are the costs of electrical installations, i.e. the costs of wiring the buildings for a three-phase supply, and purchasing and connecting power, heating and lighting units.

TABLE 6. EQUIPMENT CAPITAL AND ANNUAL COSTS

Machine type	A			B			C			D			E				F			G		
Size of plant (No. of weighing stations)	4	6	8	2	4	6	2	4	6	1	2	3	1	2	3	4	2	4	6	2	4	6
Replacement investment costs (£'s) – Line	1,399	1,883	2,146	1,116	1,466	1,713	612	893	1,515	1,357	1,905	2,453	620	1,010	1,440	1,780	1,011	1,767	2,405	908	1,734	2,397
– Other	609	686	1,152	420	503	596	425	839	1,027	425	822	993	424	451	796	962	506	684	1,225	424	839	997
Total	2,008	2,569	3,298	1,536	1,969	2,309	1,037	1,732	2,542	1,782	2,727	3,446	1,044	1,461	2,236	2,742	1,517	2,451	3,630	1,332	2,573	3,394
Average annual costs – (£'s)																						
Depreciation and interest	502	653	805	390	504	590	245	393	602	460	682	868	247	364	544	669	373	620	891	330	636	841
Repairs and insurance	103	132	170	79	101	119	53	89	131	92	140	177	54	75	115	141	78	126	187	69	132	173
Total	605	785	975	469	605	709	298	482	733	552	822	1,045	301	439	659	810	451	746	1,078	399	768	1,014

Estimates of total investment were obtained by applying prices current in July, 1958 to the schedules of equipment requirements prepared for the model plants, making an allowance of £2 per cent for the costs of equipment delivery and installation where these items are separately charged.

Deciding upon appropriate depreciation, interest and repair rates to apply to the investment totals so as to give an estimate of annual equipment ownership and maintenance costs presents many difficulties, mainly because most of the equipment at present in use in the industry has been installed for too short a time to allow this information to accumulate. In these circumstances the rates chosen must inevitably be arbitrary. However, it is clear from discussions with packers and manufacturers that obsolescence is regarded as a more important factor than wear and tear in determining the economic life of prepackaging equipment at present installed.

Accordingly, the main items of equipment subject to obsolecence (and, as it happens, the equipment most subject to wear), i.e. the bagging heads, brushers and dressing tables comprising the lines, have been written off over four years. "Other" equipment, which is less specialised and probably has a longer life in use, has been written off over eight years. Interest on the investment in equipment has been charged at six per cent per year on written down values. Repairs and replacement have been covered in an allowance of five per cent of the initial investment per year, this latter figure being based upon information supplied by one manufacturer in respect of the repairs and replacements carried out over a three years period for users of his equipment.

Finally, the costs of insuring the line and other equipment against the usual hazards have been based upon a rate of 3s. 0d. per cent.

The magnitudes of the total investments and estimated annual fixed costs of the various types and sizes of lines and their ancillary equipment are summarised in Table 6.

Table 7 shows the incidence of the annual costs of depreciation, interest, repairs and insurance upon each ton packed when the lines are operated at various levels of output up to their capacity rates (denoted by italicized figures).

TABLE 7. ANNUAL EQUIPMENT COSTS PER TON PACKED

Packed output per standard day	Equivalent output per 150 day season	Machine Type						shillings per ton
		A	B	C	D	E	F	G
(tons)	(tons)							
5.9	892	13.6	10.5	6.7	12.4	6.8	10.1	9.0
6.3	944					*6.4*		
8.2	1,237				*8.9*			
8.9	1,328							*6.1*
9.2	1,379		*6.8*					
9.7	1,448	8.4	8.4	*4.1*	11.4	6.1	6.2	10.6
10.2	1,526						*5.9*	
11.2	1,684	7.2	7.2	5.7	9.8	5.2	8.9	9.1
12.6	1,887					*4.7*		
12.8	1,925	*6.3*						
14.3	2,138	7.4	5.7	4.5	7.7	6.2	7.0	7.2
14.8	2,221	7.1	5.5	4.3	7.4	5.9	6.7	6.9
16.5	2,473				*6.6*			
17.7	2,656							*5.8*
18.4	2,758		*4.4*					
18.9	2,831					*4.7*		
19.3	2,897	*5.4*	4.9	*3.3*	7.2	5.6	5.2	7.0
20.3	3,052						*4.9*	
22.2	3,330	5.9	4.3	4.4	6.3	4.9	6. 5	6.1
24.7	3,710				*5.6*			
25.2	3,775					*4.3*		
25.7	3,851	*5.1*						
26.6	3,984							*5.1*
27.6	4,137		*3.4*					
29.0	4,347			*3.3*				
30.5	4,577						*4.7*	

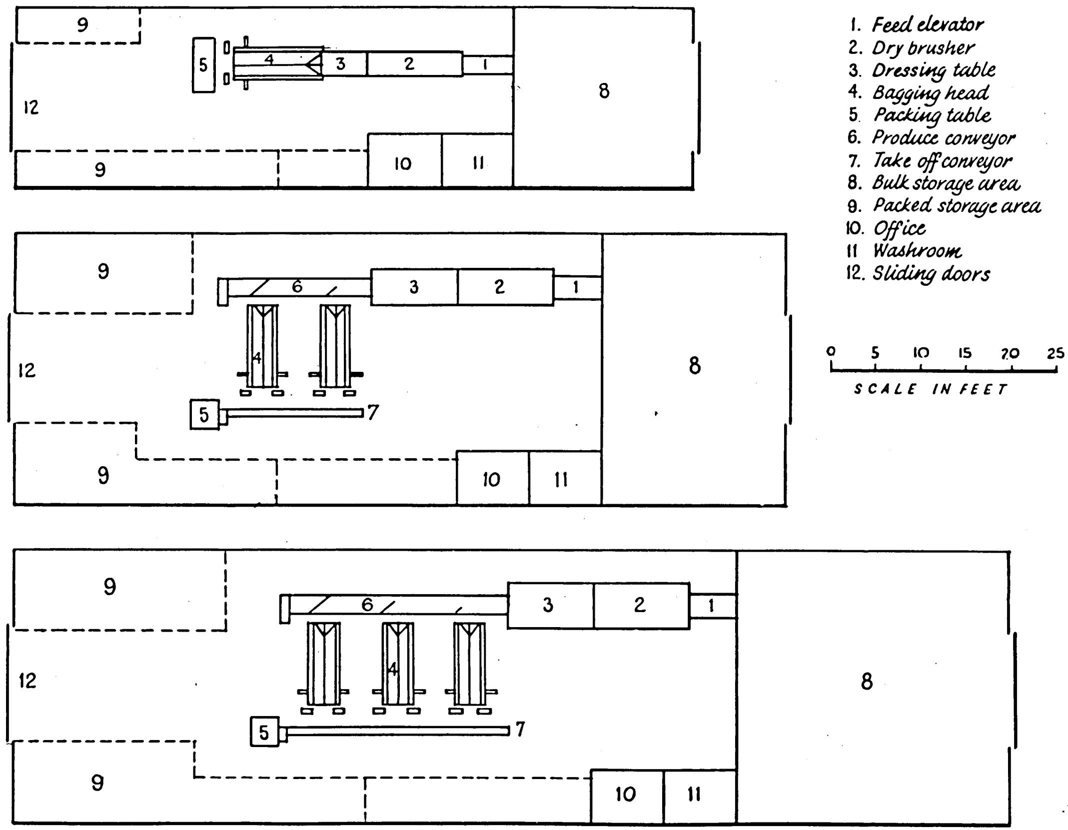


FIG. 1. STANDARD BUILDINGS AND LAYOUT.

There are, of course, large differences between machine types in the level of these costs at common output rates, paralleling the differences in their capital costs. The table illustrates the expected fall in fixed costs per ton as the output of each size and type of line is increased from low levels to capacity. However, the most interesting relationship emerging from the table is that, at capacity output rates, fixed costs per ton packed fall with increasing size of plant for virtually all machine types, a result attributable to the fuller utilisation in the larger plants of the capacities of equipment which cannot be purchased in a wide variety of sizes. For instance, the smallest and cheapest dry brusher obtainable for installing with one double-headed C-type bagger, also has adequate capacity to deal with the output of two bagging heads. Economies in the use of capital enjoyed by the larger plants match their competitive advantages in the use of labour, and in the purchase of materials.

Buildings

Designs and specifications for three sizes of packing shed were built up from the information obtained from surveys of the buildings used by the 12 firms co-operating in the enquiry.

The dimensions of the buildings were evolved from measurements made of the floor space requirements of stored bulk, culled and packed potatoes, the various sizes and types of equipment, aisles, offices and washrooms, and stored bags and outers. The dimensions of the various lines and their respective rates of capacity outputs are of course the major variables, but it was found that the total floor space requirements varied only slightly for comparable sizes of the various machines. Accordingly, only three sizes of building were finally considered, and they are adequate to house one, two or three double-headed baggers of the semi-automatic types C, F and G, and sizes of line having comparable outputs in the case of the return-flow tables A and B, and semi-automatic baggers D and E.

In determining the dimensions of these three buildings the rule of thumb that sufficient storage space for three days requirements should be provided for bulk potatoes was observed. On the other hand, sufficient storage space for only one day's packed output was built into the plants, on the assumption that packed potatoes would be marketed daily. Standardised layouts for all machines of comparable sizes were as shown in Fig. 1, these layouts being those most commonly found in the sample plants, and they would seem to be most suitable in so far as they make the best use of floor space.

The outline material specifications of the buildings were based on steel frames, the walls being constructed of brickwork, the floors and aprons of concrete, and the single span roofs of asbestos cement sheeting with perspex roof lights. Provision was made for the storage of bulk potatoes on a raised platform of timber construction, and entry to the buildings for vehicles was through sliding end doors mounted on external metal runners. Because food products are being handled provision has been made for washing and toilet facilities in all three buildings, although these were not commonly provided in the plants surveyed.

Detailed specifications and estimates of the costs of erecting each building were drawn up by an architect, current prices and the absence of any peculiar site difficulties being assumed throughout.

The estimated capital costs of providing the three buildings, together with their respective annual ownership costs on the assumptions of a 30 years life, a six per cent interest rate, repairs and maintenance at one per cent of initial capital cost per annum, and insurance of 3s. 0d. per cent, and assuming that the premises qualify for industrial derating in an area where local rates are 20s. in the £, are as shown in Table 8. When spread over the capacity outputs of the various sizes of plant they are designed to house, the smallest building entails charges ranging from 2.5s. to 3.9s. per ton packed depending upon the capacity outputs of the various one unit or equivalent lines, the corresponding ranges for the medium and largest buildings being from 2.0s. to 2.5s. and from 1.6s. to 1.9s. per ton packed respectively. Average figures of 3.2s., 2.3s. and 1.8s. per ton packed have, therefore, been uniformly ascribed to the various lines according to the size of building appropriate to each of the model plants, in the belief that this gives a reasonable estimate of the incidence of building costs throughout the scale range considered in this report. This simplifying procedure, which was necessitated by the limited resources available for the study, means that some of the model plants are associated with buildings very slightly larger than strictly necessary. Consequently, economies in building costs between lines of a comparable size but with differing daily capacity outputs are not revealed. On the other hand, this procedure does preserve an approximate measure of the economies in building costs enjoyed by larger plants.

TABLE 8. BUILDING DIMENSIONS AND CAPITAL AND ANNUAL COSTS

Building	Small	Medium	Large
Capacity output ranges housed (tons per 150 day season)	1,237 – 1,925	2,473 – 3,052	3,710 – 4,577
Overall dimensions: (feet)			
Length	75	85	110
Width	20	30	30
Height to eaves	12	12	12
Height to ridge	17	19	19
Estimated capital costs (£'s)	2,450	3,070	3,680
Estimated annual costs (£'s)			
Depreciation and interest	178	225	269
Repairs	25	31	37
Rates and insurance	40	51	61
Total annual costs	243	307	367

Power, Heating and Lighting

Estimates of electrical power requirements for running the equipment contained in the model plants were evolved from engineering data pertaining to the numbers and ratings of the motors driving each item. The common procedure of equating one brake horse power with one kilowatt was followed so as to allow for motor efficiency, line losses, etc.

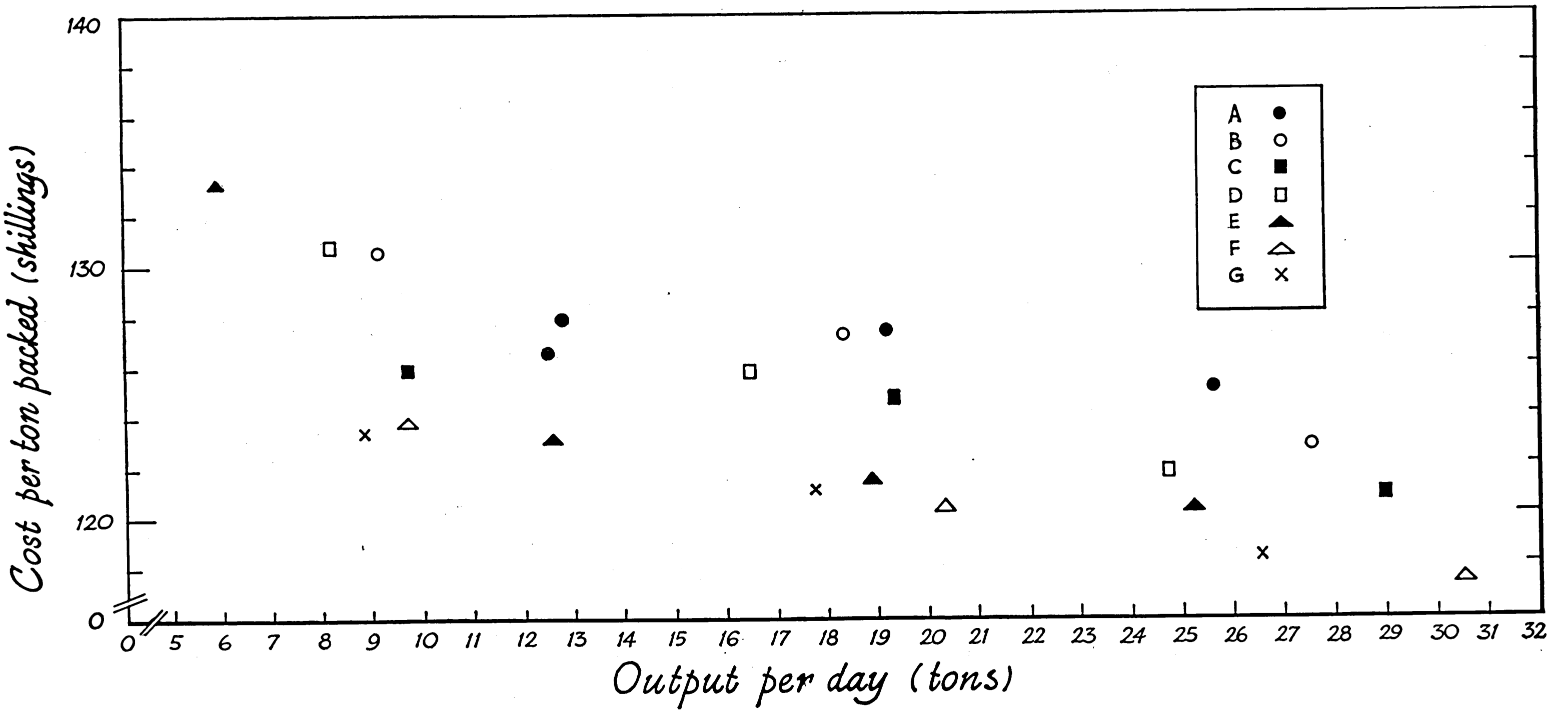
Heating costs have been based upon the use of electrical unit heaters. This was the most common practice in the sample plants, and is probably the most suitable method in terms of cleanliness, flexibility and convenience. However, it may be the case that other forms of space heating such as hot water, low pressure steam etc., could in some circumstances be cheaper, though this possibility has not been fully explored.

Advice was sought and obtained from the suppliers of electricity concerning the heating installation needed in each size of building to ensure a reasonable working temperature around the line, and to maintain the temperature above freezing point in the building as a whole. It was suggested that four 3 kilowatt unit heaters would be adequate in the smallest building, and that the medium and largest buildings required four and six 10 kilowatt heaters. In each case the heaters would be so positioned that the line workers obtained the direct benefit from them, whilst thermostats would maintain the temperatures of the storage areas at suitable levels. These recommendations have been built into the model plants. Electricity consumption has been estimated by assuming that the heaters would be running for 12 hours in each day, and for one third of the season's total packing days.

Good lighting is required for graders and weighers to do their jobs properly, and it also makes work easier and safer. Accordingly, adequate illumination has been stipulated for the model plants. Provision was made for fluorescent lighting over the lines since it produces a more uniform light with less glare, but incandescent bulbs were adjudged adequate for other areas of the plants. Capital costs and electricity consumption have been based on the provision of fifty foot candles of illumination over the lines and five foot candles for general plant lighting. This involved providing one five foot fluorescent tube to each pair of scales, to each grading table and in offices and washrooms, with four incandescent lights in loading and unloading areas.

Power, heating and lighting costs have been based upon a uniform tariff of 1½d. per unit, and the resulting average costs per ton packed range between 1.0s. and 2.2s. for the various types and sizes of model plants.

FIG. 3. LEAST COST POINTS IN 22 MODEL PLANTS.



IV. THE RESULTS

The information presented in previous sections is drawn together in Fig. 2, which shows estimated average total potato packing costs for seven different types of prepacking lines in each of three sizes of plant (four in the case of type E).

Average total costs have been calculated for each type and size of machine at its capacity rate of daily output, and at successively lower output levels down to the capacity output of the next smallest machine for the two and three unit or equivalent plant sizes, and down to an output of 5.9 tons per standard day for the smallest plants. The points between these extremes represent the output levels at which it is necessary to add one further worker as the rate of output rises from low levels to capacity. The daily output volumes for which costs have been calculated are represented by solid points, and these points are joined by dotted lines to indicate the trend in costs over intermediate outputs.

Thus, each curve shows the behaviour of average total costs as the rate of output from a particular size and type of machine is expanded up to the limits set by its construction and mode of operation. Furthermore, the cost curves for different sizes of plant containing any one type of machine show the trend of costs as the scale of operations is increased up to the capacity of plants containing three double-headed semi-automatic baggers or equivalent.

Considering first cost-volume relationships for each of the 22 model plants, it is evident that, with two minor exceptions, there is a general tendency for average total packing costs per ton to fall as the outputs of the various types and sizes of lines are expanded to their capacity. This tendency is, of course, mainly attributable to the spreading of plant fixed costs over larger output volumes. However, the lower incidence of fixed costs on each ton packed with increasing plant volumes is offset to some extent by the sudden rise in labour costs which occur at the outputs at which it becomes necessary to add additional line workers and introduce a manager. Consequently, the cost volume curves show marked discontinuities, although having a general tendency to fall with the spreading of the fixed and quasi-fixed costs of equipment and labour.

The practical implication of this is that plant managers should ensure that their prepacking lines are run at capacity output rates, for by so doing they will achieve lowest costs. This means careful buying of potatoes so as to avoid hold-ups due to low rates of output from the dressing tables, regular maintenance of the line so as to avoid equipment failures, buying good quality bags so as to prevent torn bags adversely affecting the output of the baggers and, perhaps most important of all, it is advisable to pick out the most industrious and dexterous workers from those available and put them, and keep them, on the key jobs of weighing and bagging, for it is these workers who primarily determine the productivity of the whole plant.

The apparent exceptions to the general coincidence of least costs and capacity outputs, the one unit machine types E and F, arise from a rigid adherence in cost synthesis to the bulking and grading standards given earlier. Thus, in terms of the standards, in order to expand output of plant E1 from 5.9 to 6.3 tons per day it is necessary to bring in a woman to assist the man who can handle all tonnages up to the former level. Similarly, with the one unit plant F, it is theoretically necessary to increase the grading labour force from one to two persons when daily output rises from 9.7 to 10.2 tons. The extra wage charges incurred in these two situations is not offset over the respective additional outputs of 0.4 and 0.5 tons by falling overheads.

It is recognised that, in practice, additional workers would probably not be brought in for such small output increments, rather the existing workers would be persuaded to work at more than the standard rating, or their rest periods would be marginally encroached upon. Nevertheless, in order to preserve uniformity in making comparisons between machines it is important that performance standards once defined, be strictly adhered to.

Turning now to scale-cost relationships it is evident from Figs. 2 and 3 that, without exception, as the scale of operating the seven machine types under consideration increases, successively lower costs can be achieved. That is, over the scale range 6 tons to 30 tons per day potato prepacking seems to be more economically carried on in large plants than in small. The extent of the scale economies secured range from 3s. per ton in moving from the smallest to the

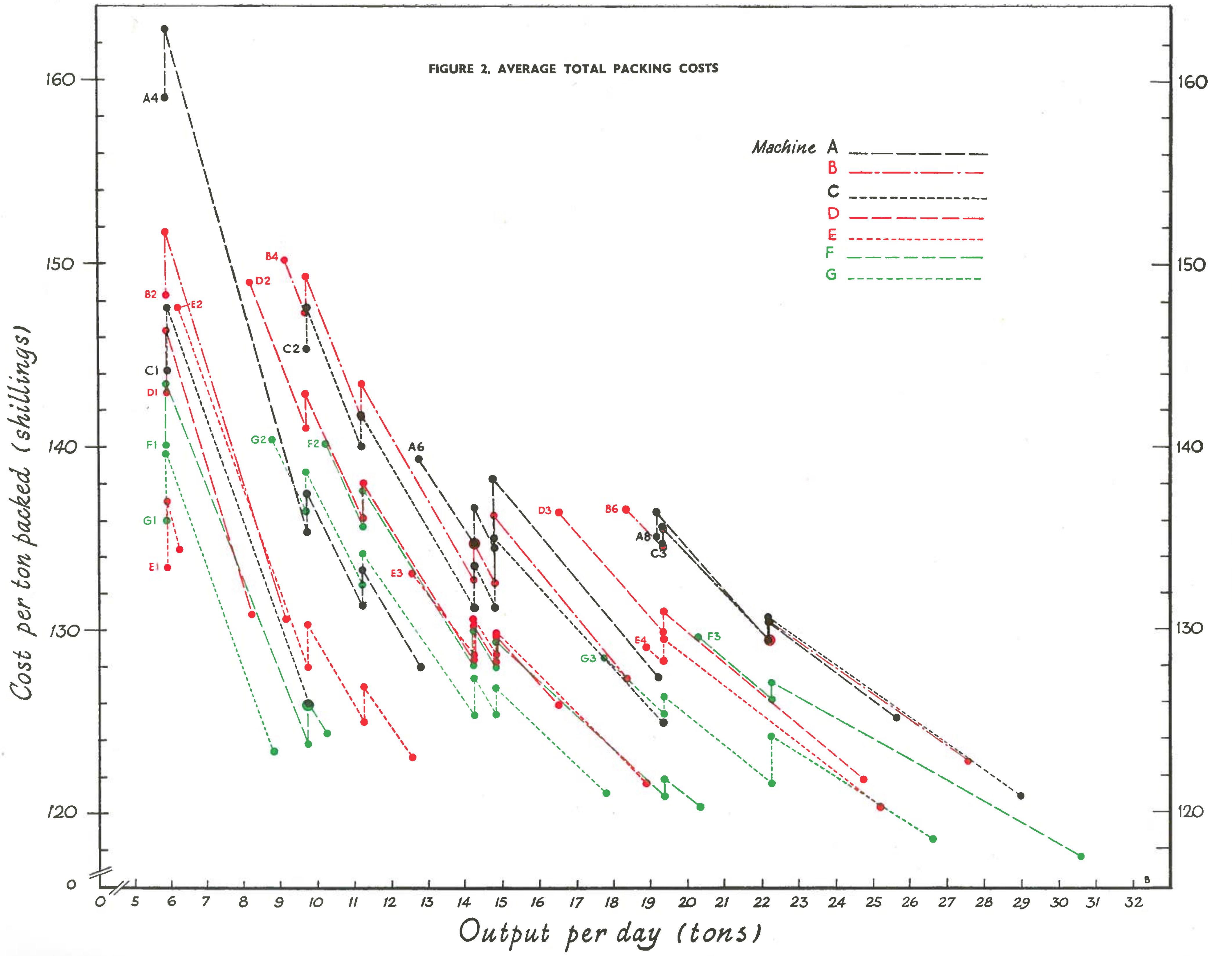


FIGURE 2. AVERAGE TOTAL PACKING COSTS
Machine A
B
C
D
E
F
G
A4
A6
A8
B2
B4
B6
C1
C2
C3
D1
D2
D3
E1
E2
E3
E4
F1
F2
F3
G1
G2
G3
160
150
140
130
120
0
0 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
Cost per ton packed (shillings)
Output per day (tons)

largest plant containing machine type A, to as much as 13s. per ton as the difference between the lowest average total costs of packing with one and four unit type E bagging lines. For the other five machines, least average total cost differences between the smallest and largest plants range from 5s. to almost 9s. per ton packed.

The factors contributing to these scale economies have been indicated previously; they include a general tendency for labour costs to be lower in the larger plants by reason of the capabilities of ancillary workers being more fully utilised, advantages in the purchase of material requisites, and lower capital charges because, although greater investment is needed for larger scale production, capital requirements expand proportionately less than output through the more efficient use which can be made of certain "indivisible" items.

Whilst scale economies of the magnitude shown are important, it is quite clear from Fig. 2 that variations in possible costs within the output range of each plant are far greater than variations between different sizes of plant. In other words, concentrating effort on the efficient management of plants of any given size seems to be more important than ensuring that prepacking is undertaken on an optimum scale.

With the exception of machine E, the least cost points of the various plant sizes of any one machine tend to lie on a straight line. This is evident in Fig. 3, and is mainly attributable to the fact that the impact on costs of changes in technology with scale is relatively minor, the major increases in rates of output being obtained by multiplication of similar types of operating units. However, at plant sizes beyond the upper limits of the scale range considered, increasing difficulties of management and administration and of assembling bulk potatoes might result in an upward turning of average costs. In this connection, it is as well to remember that assembly and administration are two cost categories in which there might possibly be offsetting diseconomies within the scale range covered by the model plants here considered, though no account of their incidence has been taken in the present study in a manner paralleling the treatment of managerial costs.

An envelope curve tangent to the cost-volume curves shown in Fig. 2 would, in theory, provide a segment of the long run cost curve or "planning curve" for the industry as a whole. No attempt has been made here to draw such a curve, for the reason that all types of equipment and alternative technologies available to the industry were not included in the present study, and it is possible that, for instance, the efficient use of fully automatic baggers or the employment of mechanical outer stitchers and other packing aids, would give costs lower than those here presented.

Also emerging from the study and apparent in Figs. 2 and 3, are the existence of large differences in the costs of using different machines. This does not necessarily mean that there is one "best" type of prepacking line which is always cheaper to use than the rest, for the output at which each machine is operated is a vitally important factor. This is evident from Table 9 in which the seven types of line are ranked in descending order of economy when operated at seven common output levels, and which shows that the status of any one machine is constantly changing relative to others. Nevertheless, reference to Fig. 2 will show that over wide scale and output ranges some machines are consistently cheaper to operate than others, and it is clear that the choice of line to pack any given output can have a very substantial effect on the average costs of prepacking and so on the profitability of the enterprise.

RANKING OF SEVEN TYPES OF PREPACKING LINE AT COMMON RATES OF OUTPUT

TABLE 9.

Packed output per standard day	Ranking in descending order of costs						
	1	2	3	4	5	6	7
5.9	E	G	F	D	C	B	A
9.6	F	C	E	A	G	D	B
11.2	E	A	G	F	D	C	B
14.2	G	F	D	E	C	B	A
14.8	G	F	D	E	C	B	A
19.3	F	C	G	A	E	D	B
22.2	G	E	D	F	A	B	C

In summary, it would appear from this study that there are three main ways in which the potato prepacking industry can reduce its general level of costs, apart of course from the constant search for technological innovations; firstly, by informed choice of equipment so as to ensure that the most economical types of line are installed in relation to the volume of potatoes to be packed; secondly, improved efficiency in day to day management so as to make better use of existing facilities and in particular, to operate plants at output rates nearer to their capacities; thirdly, there is some evidence that an increase in the average size of plants in the industry would be rewarded by lower costs. But before this last point can be fully substantiated, it will be necessary to make the costs of assembly, administration and distribution the subject of further study in order to see whether scale diseconomies associated with these functions do, beyond a certain point, offset the economies enjoyed in the actual packing operation.

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