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Case Handling Costs In Fluid Milk Plants

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PREFACE

This is the first in a series of studies designed to reduce the costs of distributing fluid milk. Publications are planned dealing with wholesale milk distribution and the costs and returns of operating branch sales plants.

This study shows that substantial reductions in the costs of case handling can be achieved by the proper selection of equipment, building design and work crew organization.

This study is a contribution to Southern Regional Project SM-10 revised, "Establishing Guides for Efficient Organization of the Dairy Industry Under Changing Conditions in the South." The project is a cooperative undertaking by the Agricultural Experiment Stations of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennessee, Texas and the Agricultural Marketing Service of the United States Department of Agriculture.

The author gratefully acknowledges the cooperation received from many fluid milk plants in North Carolina and Florida in offering their plant facilities and accounting data for analysis. Appreciation is expressed to Creamery Package Company, Cherry Burrell and the Mojonnier Company for aid in the design and costs of the conveyor systems, to Dr. Richard Knight of the Department of Mechanical Engineering for help in estimating refrigeration requirements, and to Armstrong Contracting and Supply and Recony Sales and Engineering for help in estimating building requirements and costs. Dr. William Roberts and Dr. Robert Redfearn provided helpful advice on the technical aspects of plant operation.

SUMMARY AND CONCLUSIONS

This study analyzes the costs of case handling in fluid milk plants. Four different case handling methods are analyzed for model plants comparable to actual plants in North Carolina. A complete list was made of the inputs and services necessary to accomplish the case handling operation. Building and equipment lists were compiled according to engineering specifications. Work crew requirements were estimated from time and motion studies. Electricity costs were estimated from the horsepower requirements of the power equipment. Waiting time of the truck drivers was estimated by the application of queuing theory to known frequencies of truck arrivals and loading times.

The analysis indicates that the proper design and use of an infloor conveyor system can accomplish the case handling function with a substantial cost saving over the older system of an above-floor conveyor. Still further cost savings can be realized by making up the shipping orders directly from the conveyor if the filling operation is correctly coordinated with the case handling work in the cold room. The magnitude of annual cost savings between the above-floor conveyor system and the infloor conveyor system with preformed loads ranged from $4,300 for a model plant bottling one million pounds of fluid milk per month to $26,000 for a model plant bottling eight million pounds per month.

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INTRODUCTION

Substantial variation currently exists in case handling methods among milk bottling plants in North Carolina. Variations occur in the type of equipment used, the design and layout of the plant and the size and organization of work crews. Part of the variation is attributable to differences among plants in the volume of milk bottled, the number and type of trucks loaded, space limitations, age and condition of equipment and the desired degree of accounting control over products. Unfortunately, however, much of the variation results from lack of knowledge about the effects of plant design on the efficiency of case handling. Plants are frequently remodeled long before the expiration of their useful life merely because they were found to be poorly designed. Experience can be an expensive teacher. It is important for plant managers and superintendents to have specific knowledge about the effects of equipment selection and plant design on case handling costs.

Purpose of Study

It is the purpose of this study to analyze several case handling technologies 1/ currently available for milk bottling plants and to indicate those which promise the greatest reduction in monetary cost for plants of the particular types and volumes which are common in North Carolina.

1/ Technology is defined here as a composite of such factors as the type of equipment, the design and layout of the plant, work crew organization and all other phases of organization which result in a distinct and describable method of accomplishing the case handling function.

Scope of Study

Only those portions of the plant which are directly affected by case handling are considered. These portions include the case conveyors, the loading and unloading docks (including the work of all of the driver-salesmen), the milk storage room, and the empty case storage room.

The study is necessarily limited in scope to the consideration of only the most important factors affecting case handling costs. Cost factors selected for specific analysis are (1) the volume of plant, (2) type of equipment and layout, (3) work crew organization, and (4) the number and type of trucks loaded. The effects of less important factors such as number of products, proportion of glass and paper, etc. are acknowledged, but the specific measurement of all of these factors would be quite costly in terms of research inputs. It is believed that the exclusion of these less important factors will not alter the major conclusions of the study.

Another limitation of the study is that it deals only with direct monetary costs. Psychological factors such as the morale of the workers, the degree of physical exertion required in different labor activities and the general desirability of the work may affect the choice of equipment but the lack of adequate procedures for quantifying such factors preludes their direct consideration.

Procedure

From the many different case handling methods currently available, four methods were selected as representing the latest and most promising technologies. Each of the four methods was studied for model plants of four different sizes as follows:

Plant A - 1 million pounds per month of fluid sales
Plant B - 2 million pounds per month of fluid sales
Plant C - 4 million pounds per month of fluid sales
Plant D - 8 million pounds per month of fluid sales

These four model plants represent a range in volumes which includes plants selling more than 80 per cent of the total fluid milk sales in North Carolina.

The characteristics of each of these plants in terms of number, type and volume of individual products, the wholesale-retail-transport distribution of total sales, etc.

are specified in detail and held constant for each plant size as the different case handling methods are analyzed.

Applicability of Results

Since the characteristics of some of the plants in North Carolina may differ in some degree from the attributes of model plants considered in the study, the derived cost estimates and conclusions may not be immediately applicable to every existing plant. However, the cost estimation procedure is outlined in sufficient detail so that the modification of the estimates to fit a special situation can be readily accomplished. Even though the cost estimates do not immediately fit the individual situations of each plant, it is believed that the study will be useful as a general comparison of the different case handling methods. To ensure broader applicability, considerable care was taken to design the model plants to conform closely to the characteristics of many North Carolina plants. It must be kept in mind, however, that the most efficient layout for any particular plant can best be determined by a detailed case study in which the design is engineered to fit the plant.

COST ESTIMATION PROCEDURE

For each model plant and each case handling method a complete list is made of the physical inputs and services required to move the product from the fillers through the storage room and onto the delivery trucks. Only those inputs which vary with the case handling method are considered. For example, the cost of land, the cost of case washing, water to clean the storage room, etc., are not measured since these costs will not vary significantly among case handling methods and thus will not affect the selection of the method.

The costs are divided into five categories--building costs, equipment costs, labor costs, the labor of the salesmen at the loading and unloading docks and utility costs. For ease in conceptual organization the cost components were further divided into two broad groups--fixed costs and variable costs. Fixed costs include interest payments on invested capital, taxes, insurance, depreciation and repairs. Variable costs are those incurred only on days of operation, such as electricity, hourly labor, etc. Variable costs are computed on a daily basis, multiplied by 313 days of operation per year and added to annual fixed costs to get total annual costs.

Each of the five major cost components are now discussed individually.

Building Costs

The size and shape of the cold room and the loading docks vary according to the case handling method used. For each size of plant and case handling method, the size and shape of the building were designed to provide sufficient storage space for milk stacked five cases high 1/ plus sufficient additional space for unhampered product handling. No provision was made for future plant expansion. Buildings were designed to handle a given volume of milk efficiently. Alteration of the building specifications as outlined in this study can be easily accomplished by individual plant managers to fit their own expansion plans. Guides for building designs were obtained from consultation with sales engineers from equipment manufacturing companies, talks with plant superintendents, studies of floor plans of existing plants and by detailed computations involving space allocation. After the size and shape of the buildings were selected, construction costs were estimated for a type of building having poured concrete floors and foundations, prefabricated wall and ceiling panels and a truss roof of tar and gravel covering. This type of construction was selected because of its ease and speed of construction, its flexibility in remodeling and its durability. Construction costs for the building were estimated by construction engineers.

The initial building costs are allocated on an annual basis over the physical life of the building.2/ Firm estimates of the life of the prefabricated wall and ceiling panels are not currently available since this type of construction material has not been in use long enough to need replacement. An expected life of 20 years was used as an estimate based primarily on the current condition of existing buildings of this type of construction. Annual

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1/ Other research studies, including one by Charles E. French and Harry R. Varney, Jr., "Labor Utilization in Cold Storage and Empty Bottle Rooms," Purdue University Research Bulletin No. 677, indicate that stacking cases five high results in the most efficient labor utilization.

2/ Since there is no objective method of predicting just when obsolescence will require a change in equipment, the sole criterion for estimating depreciation is the expected physical life of the equipment.

fixed costs in addition to depreciation are repairs (maintenance), insurance, taxes and interest on the investment. Repairs were estimated at two per cent of the purchase price and insurance, taxes and interest on the invested capital were estimated at one per cent, two per cent and five per cent of the unamortized value of the building.

Equipment Costs

Selecting the conveyor equipment for each case handling method is largely a matter of fitting the equipment to the building. For each building design the equipment specifications and prices were selected by experienced engineers from major dairy plant equipment companies. The initial installed cost of each item of equipment was allocated as depreciation over its estimated life. Here again a problem arose from the lack of a concrete basis to estimate the useful life of some of the equipment. Some of the equipment has been in use only a few years so that estimates of useful life for many items were based on experience with other machines and equipment of similar complexity operating under similar conditions.

The fixed costs due to repairs, taxes, insurance and interest were added to depreciation to get total annual fixed costs. Annual repairs were estimated at four per cent of the installed purchase price. Taxes, insurance and interest were included at the same rates as for the building.

Labor Costs

Estimates of physical labor requirements were based on time and motion production studies of actual plant operations. These studies were accomplished by close observation of workers performing specific tasks. Time measurements were recorded and analyzed for each required work category. The quantity of work performed (the number of cases stacked, for example) was recorded along with the time measurement. Extraneous activities which a worker may have performed and interruptions of the normal work were subtracted from the time measurements. If the work was of a continuous nature, allowances were made for fatigue and unavoidable delay. Thus the "labor standards" which were derived indicate the amount of work which a worker can normally and continuously perform when his full attention is directed to that particular task. By timing the efforts of different workers in different plants performing the same type of work, a good indication was obtained as to the output of average workers when working at an efficient rate. A more detailed description of the derivation of labor standards is given in Appendix A.

Labor costs were estimated by applying appropriate hourly wage rates to physical time requirements. Hourly wage rates were based on wages paid by two representative North Carolina plants. The basic hourly rates were expanded by 25 per cent to allow for slack labor to cover unforeseen contingencies 1/ and other payroll costs such as Social Security taxes, paid vacations, sick leaves and other fringe benefits paid by the employer.

Cost of Salesman Time at Loading Docks

The length of time which a salesman is required to spend at the loading dock can usually be considered a direct cost. With some case handling methods a salesman may have to spend considerable time waiting in line for space at the loading dock. Other plants keep large shipping crews on hand to avoid the waiting problem. The cost of the waiting time required of salesmen must be balanced against the cost of additional loading facilities in order to arrive at decisions regarding appropriate loading facilities for the plant.

The method of estimating salesman waiting time for each of the case handling methods is given in detail in Appendix B so only a brief explanation is given here. The order of arrivals of refrigerated trucks at the loading dock after the daily deliveries is not specified or controlled by the plant itself so that the trucks can be said to arrive randomly on a "first come-first served" basis. To say that trucks arrive randomly means that they do not arrive at regularly spaced intervals but are

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1/ Since work crews were estimated from "labor standards," they represent the minimum number of men required to accomplish the work. However, a prudent plant manager will not continuously operate a plant with minimum work crews, but he will keep some slack labor around to handle unforeseen contingencies, such as sickness. Rather than arbitrarily assign slack labor to each position, the hourly wage rate for each job was merely expanded approximately 20 per cent. Social Security taxes and other fringe benefits constitute the remainder of the 25 per cent expansion in wage rates.

scattered or clustered in some fashion. Even though it is not possible to predict accurately the exact times of truck arrivals at a loading dock, it is possible (by appropriate sampling procedures) to estimate the probability of (say) ten trucks arriving between 3:00 and 4:00 p.m. In fact, it is possible to estimate the probabilities of any number of trucks arriving in any specified interval. The sum total of the probability characteristics of truck arrivals is called a "probability distribution of arrivals." Given the probability distribution of arrivals, the average rate of arrivals per time period, the probability distribution of loading times and the average loading time, it is possible with well established mathematical procedures to estimate the total waiting time of the trucks.1/

The probability distribution of arrivals and the average arrival rate per hour were estimated by a sample at the loading dock of a North Carolina plant. For an entire week the times of arrival of all of the trucks were recorded. Labor standards from Appendix Tables A-3 and A-4 were used for the loading times. The analysis of these data using the procedures outlined in Appendix B provided estimates of the total dock time for trucks under each case handling method.

An appropriate hourly cost rate for salesman waiting time at the loading dock is difficult to determine. Some plant managers would impute a very low cost rate to this time. A few plant managers believe that most salesmen would waste a certain amount of time at the end of the day whether or not the dock was immediately available. Others believe that waiting is costly to the plant only when salesmen are on a straight salary basis and that salesmen who are paid on a commission basis are merely wasting their own time. However, it is easily seen that waiting time is costly to the plant even when salesmen are on a straight commission basis. Salesmen who are paid on a commission basis are normally dissatisfied at having to wait long intervals before loading. Waiting lines give the salesmen an opportunity to get together in "griping sessions." This dissatisfaction could lead to a more rapid turnover of sales personnel with resultant higher training costs. The elimination of waiting time may afford an opportunity to accomodate additional customers on each route, thus spreading the fixed truck costs over a larger volume or providing an opportunity to reduce the number of trucks.

1/ See, for example, Philip M. Morse, Queues, Inventories and Maintenance, John Wiley and Sons, 1958, New York.

These factors present difficulties in estimating appropriate cost rates for salesman waiting time. For lack of a more objective measure the physical waiting time as estimated in this study was costed at the full average hourly wage rate for salesmen. Individual plant managers who wish to impute a different cost rate to this activity can easily do so since the physical waiting time for each method is listed independently of the cost rate.

Since most salesmen in North Carolina are paid on a commission basis, the hourly wage rate was approximated by dividing the average monthly pay check by the average hours worked per month. Monthly income and hours worked were estimated from a sample of routes from several North Carolina plants.

Utilities

The two main items in this category are (a) electricity for the refrigeration units in the storage room and power units to drive the conveyor and (b) lubrication costs for the conveyor. These two factors can vary significantly with the case handling method used. Other utilities which may be required, such as water for cleaning, are considered insignificant and are not included in the analysis.

Refrigeration requirements vary considerably during the day and in different seasons of the year. Although the total tonnage necessary for peak loads is estimated as a part of the building requirements, the average amount of actual operating time of the compressors cannot be determined without extensive observation. Kilowatt requirements per ton of refrigeration for evaporated milk plants in the San Joaquin Valley of California have been estimated by refrigeration manufacturers to be .87 kilowatts per ton of refrigeration.1/ Since the mean temperature and temperature ranges in North Carolina are roughly similar to those in the San Joaquin Valley, these estimates were adapted for this study.

Kilowatt requirements for the conveyor drive units are estimated at one kilowatt per horsepower. The addition of these two factors gives the total kilowatt hours per hour.

1/ James N. Boles, "Economies of Scale for Evaporated Milk Plants," Hilgardia, Volume 27, No. 21, University of California, Berkeley, California.

Prices to be applied to these physical electricity requirements were derived from the following schedule which is an average of the schedules filed by three major power companies with the North Carolina Utilities Commission:

Billing demand 1/

$1.50 per K.W.H. for the first 25 K.W.H.
$1.20 per K.W.H. for the next 25 K.W.H.
$1.10 per K.W.H. for the next 50 K.W.H.
$1.00 per K.W.H. for the rest.

Energy charge

$.010 for the first 20,000 K.W.H.
$.008 for the next 50,000 K.W.H.
$.007 for next 100,000 K.W.H.
$.006 for next 200,000 K.W.H.
$.005 for the rest.

In computing the electricity costs for case handling, the procedure was to assume that the plant was already using enough electricity in other parts of the plant so that additional electricity for the cold room and conveyor could be obtained at one of the reduced rates. The particular reduced rate was determined for each plant on the basis of its size.

Lubrication costs for the conveyor were estimated to be $25 per lubrication unit per month. The number of lubrication units in each model plant is listed in the equipment lists.

This completes the explanation of the procedure for estimating costs. The next step is a discussion of the characteristics of model Plant C. The analysis for Plant C is accomplished first because of the importance of this size of plant in terms of the proportion of total sales in North Carolina.

COST ANALYSIS FOR MODEL PLANT C

Characteristics of Plant C

Cost handling costs depend largely on the number and type of trucks loaded. The following discussion of volume,

1/ Billing demand is a technical term used to describe the number of kilowatts used during a fifteen minute period of peak load.

product mix, the retail-wholesale-transport distribution of total sales and daily variation of sales is necessary to arrive at the appropriate number of trucks to be loaded. Also each of these factors affects case handling costs aside from affecting the number and type of trucks.

Model Plant C bottles an average volume of four million pounds of milk per month. The number of products and the quantity of each product are outlined in Table 1. This product mix was selected so that the monthly volume of each item constituted the same proportion of total volume as the average product mix of seven North Carolina plants of approximately this size. The number of products affects case handling costs by affecting the complexity of case handling in the storage room, the floor space requirements and the size of work crews. It was assumed that Plant C bottles all items in paper. This assumption departs somewhat from the characteristics of the average plant at present, but current trends toward all paper operations make the assumption more plausible for future use.

The distribution of total volume between retail, wholesale and transport sales is also shown in Table 1. This distribution also bears the same relationship as the average of seven North Carolina plants of the same size. Case handling costs are affected by the distribution of sales between retail, wholesale and transport because of the different time requirements for unloading and loading these different types of trucks. It is assumed that all trucks are refrigerated so that loading is accomplished in the afternoon. This assumption is also based on current trends in the North Carolina dairy industry toward completely refrigerated operations.

Plant volume in units is converted into total number of cases in Table 2. Since the number of products and the product mix is held constant as different case handling methods are varied, the total number of cases can be used as a standard measure of volume.

Table 3 shows the daily variation in retail and wholesale sales throughout the week. Since a plant must be designed to handle peak volumes over the week, the daily variation in volume affects costs by affecting the average utilization of floor space, filling equipment and work crews. The particular daily variation selected reflects average North Carolina conditions as determined by a sample of wholesale routes and conversations with industry representatives.

Table 1. Monthly Volume, Product Mix and Retail-Wholesale-Transport Sales Breakdown of Plant C

Product	Monthly volume				
	Unit	Retail	Wholesale	Transport	Total
(1)	(2)	(3)	(4)	(5)	(6)
Grade A pasteur.	qts.	13,780	920	2,594	17,294
Grade A homo.	3 gal.	--	547	97	644
	1/2 gal.	89,570	179,280	47,443	316,293
	qts.	170,500	170,500	60,180	401,180
	pts.	--	93,840	16,560	110,400
	1/2 pts.	--	1,129,300	199,290	1,328,590
Grade A special	qts.	23,460	7,820	5,520	36,800
Heavy cream	1/2 pts.	1,122	4,500	995	6,617
Medium cream	1/2 pts.	350	1,527	330	2,207
Half and half	qts.	644	3,422	720	4,786
	pts.	1,720	5,161	1,215	8,096
Choc. milk	qts.	14,860	14,860	5,244	34,964
	pts.	--	51,612	9,110	60,722
	1/2 pts.	--	91,338	16,120	107,458
Whole lactic	qts.	3,675	3,675	1,300	8,650
	1/2 pts.	--	14,390	2,540	16,930
Skim milk	qts.	23,000	20,790	7,730	51,520
Plain buttermilk	1/2 gal.	7,270	14,550	3,850	25,670
	qts.	35,690	35,690	12,420	83,800
	1/2 pts.	--	15,950	2,820	18,770
Multi-vit.	qts.	20,850	10,120	5,465	36,435
Misc.	1/2 gal.	5,865	5,870	2,070	13,805
Cot. cheese	lbs.	--	--	--	20,000

Sources:

Col. (1), (2): Selection of products was based on sales data from seven North Carolina plants of this same size. Minor items were grouped as miscellaneous.

Col. (3), (4), (5): Total retail sales were selected to be 27 per cent of total volume, wholesale sales were 57 per cent and transport sales were 16 per cent of total. These figures are an average of seven North Carolina plants of this same size. The breakdown of product was then accomplished by averaging the figures from the sales records of three of these plants.

Col. (6): Total volume is selected to equal an equivalent of 4 million pounds. The volume of individual products as a proportion of total sales is based on the average proportional relationships of seven North Carolina plants of the same size.

Table 2. Number of Cases of Milk per Month Sold as Retail, Wholesale, Transport

Product	Unit	Number of 16-quart cases				Number of 24-quart cases			
		Retail	Whsl.	Trans.	Total	Retail	Whsl.	Trans.	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Grade A past.	qts.	862	58	162	1,082	574	39	108	721
Grade A homog.	3 gal.	--	--	--	--	--	--	--	--
	1/2 gal.	9,953	19,920	5,271	35,144	7,464	14,940	3,954	26,358
	qts.	10,657	10,657	3,761	25,075	7,104	7,104	2,508	16,716
	pts.	--	3,352	592	3,944	--	1,955	345	2,300
	1/2 pts.	--	25,666	4,530	30,196	--	18,822	3,322	22,144
Grade A special	qts.	1,467	488	345	2,300	977	326	230	1,533
Heavy cream	1/2 pts.	26	102	23	151	19	75	17	111
Medium cream	1/2 pts.	8	35	8	51	6	26	6	38
Half and half	qts.	41	214	45	300	27	143	30	200
	pts.	60	185	44	289	36	108	26	170
Choc. milk	qts.	929	929	328	2,186	620	620	219	1,459
	pts.	--	1,845	326	2,169	--	1,076	190	1,266
	1/2 pts.	--	2,076	367	2,443	--	1,523	269	1,792
Whole lactic	qts.	230	230	82	542	153	153	55	361
	1/2 pts.	--	327	58	385	--	240	42	282
Skim milk	qts.	1,438	1,299	483	3,220	959	867	322	2,148
Plain buttermilk	1/2 gal.	808	1,616	428	2,852	606	1,212	321	2,139
	qts.	2,231	2,231	777	5,239	1,487	1,487	518	3,492
	1/2 pts.	--	363	64	427	--	266	47	313
Multi-vit.	qts.	1,303	632	342	2,277	869	422	228	1,519
Misc.	1/2 gal.	652	652	230	1,534	489	489	173	1,151
Cot. cheese	lbs.	--	1,000	333	1,333	--	750	200	950
Monthly total		30,667	73,877	18,599	123,139	21,390	52,643	13,130	87,163
Avg. daily total		1,179	2,842	716	4,736	823	2,025	505	3,353

Sources: Col. (3), (4), (5): Table 1, Col. (3), (4), (5) divided by appropriate number of that item in a standard wire case measuring 13 1/8 x 13 1/8 inches. Each case holds 16 quarts. Col. (6): Summation of Cols. (3)-(5). Col. (7), (8), (9): Table 1, Col. (3), (4), (5) divided by the appropriate number of items in a 24 quart wire case. Col. (10): Sum of cols. (7), (8), (9).

Table 3. Daily Variation in Sales

Day	Wholesale, per cent of wkly. tot.	Retail, per cent of wkly. tot.	Aver. no. of 16-quart cases per load		Aver. no. of 24-quart cases per load	
			Whsl.	Retail	Whsl.	Retail
	(1)	(2)	(3)	(4)	(5)	(6)
Mon.	14.0	15.8	92	33	66	24
Tues.	13.5	15.8	90	33	63	24
Wed.	13.1	15.8	87	33	62	24
Thur.	17.6	15.8	117	33	83	24
Fri.	22.5	19.1	149	40	105	29
Sat.	19.5	17.7	129	38	92	27

Sources: Col. (1), (2): Samples of wholesale routes in Raleigh and Charlotte and conversation with industry members. Col. (3), (4): Based on an average of 110 cases per day for each wholesale load and 35 cases per day for each retail load. Col. (5), (6): Based on an average of 78 24-quart cases for each wholesale load and 25 cases per retail load.

Each retail truck was assumed to load an average of 35 sixteen quart cases or 25 twenty-four quart cases, and the wholesale trucks are assumed to carry an average of 110 sixteen quart cases or 78 twenty-four quart cases.1/ These load sizes conform roughly to averages in North Carolina. Under these assumptions Plant C would operate 26 wholesale routes, 34 retail routes and send two tractor-trailer loads to branch sales plants.

In order to bottle the required volume of milk in one shift per day without exceeding the normal work week, Plant C uses five Purepak "senior" fillers (four model Q's and one model C). The number and type of fillers affect the rate at which the cases enter the cold room and hence affect work crew sizes.

This completes the description of the pertinent characteristics of Plant C. Each of the four case handling technologies are now analyzed.

1/ The case size may vary with the different types of case handling equipment.

Description of Case Handling Method No. 1

The floor plan and conveyor layout for case handling method 1 are shown in Figure 1. This layout is often called the "Hollywood" or "island box" system. This system is neither widely used nor understood in the Southeast at the present time although its popularity seems to be growing somewhat. The system is more widely used in California, Florida and the Northeastern states.

Its essential features are that the individual shipping orders for each truck are preformed 1/ and placed in prearranged areas near the individual loading doors through which the drivers load their own trucks. When the driver-salesmen return from the daily deliveries, they back up to the loading dock, place the empty cases and returned milk on the conveyor, open the door to the cold room, check their order for accuracy and slide the stacks of milk into the truck. There is virtually no waiting time on the part of the driver, and he loads his truck and arranges the milk within the truck at his own speed.2/

The cases of milk are conveyed into the storage room on an infloor conveyor in five-high stacks of cases. Since milk can be easily handled in stacks, the system is readily adaptable to automatic casing and stacking equipment should the use of such equipment prove economical. The feasibility of automatic equipment is a separate problem and is not analyzed in this study.

It is often possible to preform a large portion of the shipping orders directly from the filler as the milk comes down the conveyor. This is accomplished by placing the individual shipping orders near the appropriate floor spaces allocated for each load so that the required items can be quickly read off, selected and placed as the milk

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1/ Preformed loads are those that have been assembled and placed in previously assigned locations prior to the arrival of the trucks for loading.

2/ A modification to this basic plan is the enclosure of individual loads by barriers or cages which prevent the salesmen from entering any area of the storage room other than his own load. While this prevents any stealing, the cages cut down on effective floor space and hamper product movement. Since salesmen do not steal from each other as readily as from the plant itself, it is usually only necessary to erect a barrier between the inventory area and the rest of the cold room.

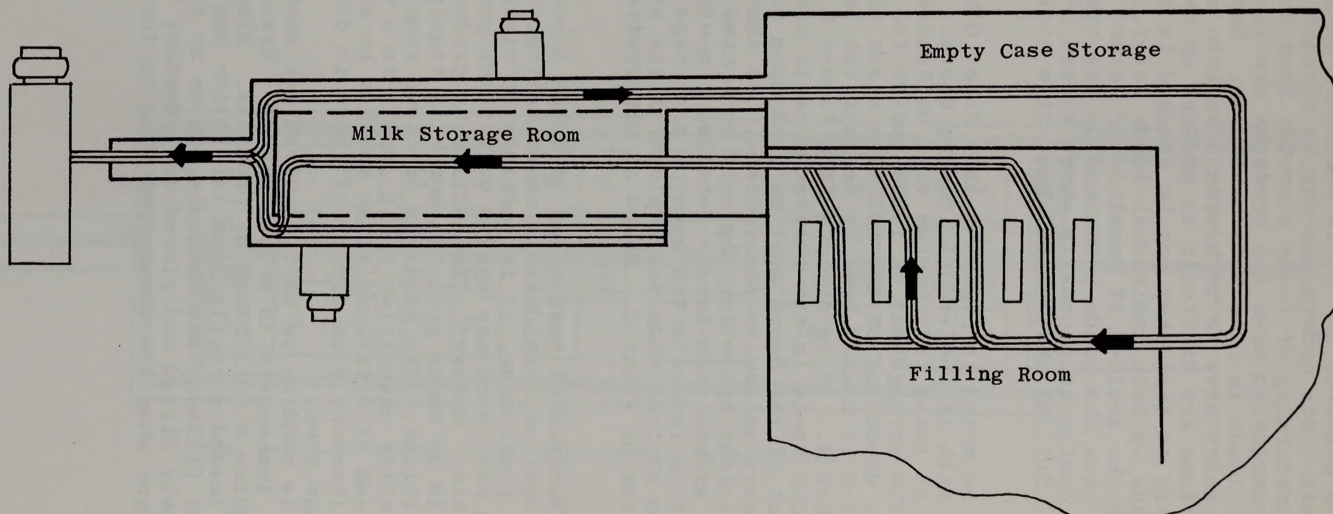

Figure 1. Building Design and Conveyor Layout for Plant C, Method 1

comes down the conveyor.1/ It is necessary that driver-salesmen submit their orders one day in advance of their needs. The preforming of loads directly from the conveyor is easily accomplished when the products are those required by individual loads in case lots or larger. However, there may be items which have to be broken down into smaller lots. Often these items are difficult to preform as rapidly as they are filled so that they may be stacked in the inventory area to be made up into individual loads later. This double handling is to be avoided if possible.2/ Since it is necessary to have the loads preformed by the time the trucks start coming in (normally about eleven o'clock in the morning), filling must start about five o'clock in the morning.

It will be noted in Figure 1 that Plant C has a cold storage room with 14 individual loading doors. It is planned that at least four trucks will be loaded through each door. The arrangement of loads inside the storage room can vary depending on the relative sizes of the loads, but for Plant C it seemed best to arrange the loads as shown in Figure 2. It is obvious from Figure 2 that considerable floor space in the storage room is unusable. The space in front of the doors must be kept open so that the drivers can have access to their loads. In addition, there must be sufficient space for the cold room crew to have "elbow room" around each load. Detailed computations of space allocation indicate the need of a storage room 115 feet long and 27 feet wide for a plant of the size and characteristics of Plant C. Based on observations of case

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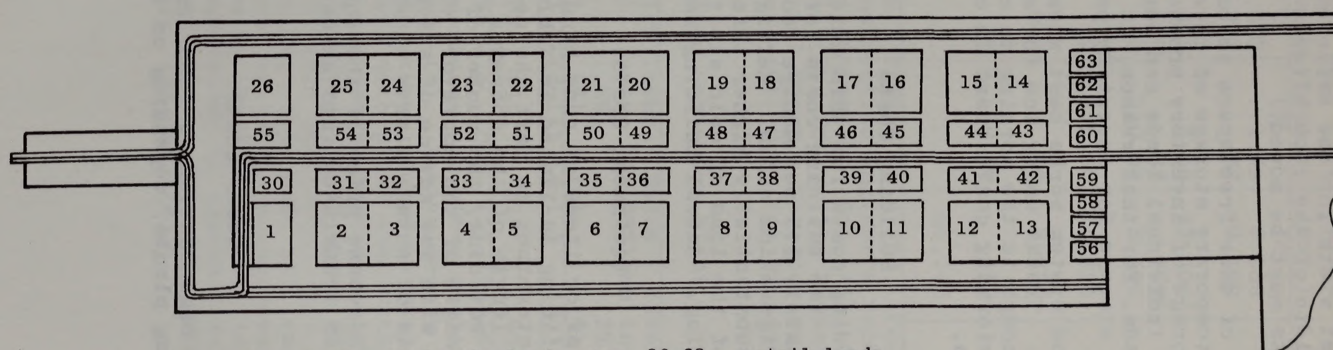
1/ The successful preforming of loads directly from the filler requires considerable organization. When two or more men are preforming, it is possible to divide up the products and have each man handle only those products assigned to him. However, the particular products assigned to each should be those products normally required in similar quantities. The handling of items required in vastly dissimilar quantities would result in a worker finishing loads at different rates so that he would soon be working simultaneously on different loads in different parts of the storage room.

2/ Double handing is also required for much of the milk going out of transports to branch plants. Branch plants normally require a full range of products. Since the number of products loaded directly from the filler can not exceed the number of fillers, the remaining 15 or 20 items must have been previously filled and placed in inventory to be replaced on the conveyor when the transports come in for loading.



Nos. 1-26 - wholesale loads, nos. 30-63 - retail loads

Figure 2. Arrangement of Preformed Loads in Cold Room, Method 1, Plant C

handling in existing plants of similar design, 27 feet seems to be a convenient width for the efficient handling of products. The width of the room affects the average distance which the products must be moved.

The 23 feet of door free space in one end of the cold room is for the temporary storage of inventory products. The temporary storage of inventory products in the spaces allotted for the individual loads can seriously impede the preforming of loads. For that reason, it is important to provide adequate storage for inventory products.

The Hollywood system works best when all of the trucks are refrigerated. Trucks using ice for cooling would not load out early enough in the morning to clear the storage space so that preforming could start in conjunction with the filling operation.

Building Costs

Initial building costs for this cold storage room are given in Table 4. The building costs for this particular room are approximately $13 per square foot of floor space exclusive of refrigeration units. Refrigeration costs for this system are substantially higher than for the other systems because of the loss of cold air through the loading doors during loading. Annual building costs are given in Table 5.

Equipment Costs

Each of the major items of case handling equipment needed for the building is listed in Table 6. The building design and size determines in part the necessary equipment. For instance, the length of the conveyor is affected by the length of the building, the number of power units is affected by the length of the conveyor, etc. The equipment list was compiled with the advice of sales engineers and by studying blueprints of actual plants under construction.

The initial purchase price of the equipment as estimated in Table 6 is translated into annual fixed costs and given in Table 7.

Labor Costs

The size and organization of labor crews differ substantially among plants, depending on the efficiency

Table 4. Initial Building Costs for Plant C, Method 1

Item	Unit	No. of units	Price per unit (dol.)	Purchase price (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Foundation	sq. ft.	4,033	1.50	6,050	40	151
Floor	sq. ft.	4,033	.67	2,700	40	68
Walls and ceiling	sq. ft.	6,628	3.50	23,200	20	1,160
Roofing	sq. ft.	3,840	.25	960	15	64
Doors	each	14	250.00	3,500	20	175
Refrig. (4 ton)	each	9	1,625.00	14,625	15	975
Diam. grid plates	sq. ft.	4,033	.90	3,630	20	181
Electric wiring	each	24	20.00	480	10	48
Total				55,145		2,822

Sources: Col. (1), (2): Figure 1, p. 23. Col. (3): Estimates from two construction engineers from two different construction companies. Col. (4): Col. (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research studies. Col. (6): Col. (4) divided by Col. (5).

Table 5. Annual Building Costs for Plant C

Initial cost (1)	Depreciation (2)	Repairs (2%) (3)	Insurance (.8%) (4)	Taxes (1.05%) (5)	Interest on invest. (3%) (6)	Total annual costs (7)
(dol.)	(dol.)	(dol.)	(dol.)	(dol.)	(dol.)	(dol.)
55,145	2,822	1,103	441	579	1,654	6,599

Sources: Col. (1): Table 4. Col. (2): Table 4. Col. (3): Based on experience and other published research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The rate will vary with plant and location, but this 1.6 per cent is considered representative. Rate is based on data submitted by three North Carolina plants. Col. (5): Equivalent to 2 per cent on undepreciated value. This rate will vary with location but 2 per cent is taken as representative. Based on rates quoted by three North Carolina plants. Col. (6): Equivalent to approximately 5 per cent of undepreciated value. Col. (7): Summation of Cols. (2), (3), (4), (5), and (6).

Table 6. Initial Equipment Cost for Plant C, Method 1

Item	Unit	No. of units	Price per unit (dol.)	Total cost (dol.)
	(1)	(2)	(3)	(4)
Infloor conveyor, straight double chain	ft.	536	27	14,472
Above floor conveyor, straight single chain	ft.	288	18	5,184
90° turns, infloor conveyor	each	3	360	1,080
90° turns, above floor conveyor	each	3	255	765
45° turns, infloor conveyor	each	1	180	180
45° turns, above floor conveyor	each	4	120	480
90° Y junctions, infloor conveyor	each	1	450	450
90° double Y junction, infloor conveyor	each	1	750	750
45° Y junction, infloor conveyor		3	325	975
90° Y junction, above floor conveyor	each	3	350	1,050
5 horsepower drive units	each	6	1,500	9,000
3 horsepower drive units	each	4	1,250	5,000
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	12	300	3,600
Lubricators	each	12	100	1,200
Traffic control	each	7	220	1,540
Unstacker	each	1	3,000	3,000
Total purchase price				49,878
Installation cost (20%)				9,976
Total purchase price				59,854
Freight				800
Total cost installed				60,654

Sources: Col. (1), (2): Estimates by sales engineers of several major dairy plant equipment manufacturers. Col. (3): Price lists supplied by dairy plant equipment manufacturers. Col. (4): Col. (2) multiplied by Col. (3).

Table 7. Annual Equipment Costs for Plant C, Method 1

Item	Initial price installed (dol.)	Est. life (years)	Annual depre- ciation (dol.)	Repairs (4%) (dol.)	Insur- ance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Straight conveyor chain	11,794	5	2,359	472	94	124	354	3,403
All other conveyor equipment	45,260	12	3,772	1,810	362	475	1,358	7,777
Unstacker	3,600	7	514	144	29	38	108	833
Total								12,013

Sources: Col. (1): Table 6, p. 28. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies and estimates from major dairy plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those assumed in other research studies. Col. (5): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 1.6 per cent on undepreciated value. Col. (6): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 2 per cent of value on undepreciated balance. Col. (7): Equivalent to 5 per cent interest on the average unamortized value.

of labor utilization and the number of different tasks and services performed in addition to the required minimum. Some plants employ a man to fill special orders, carry milk out to a salesman in case he should run out, etc. In some plants ice cream loading and milk loading overlap, with some men working part time in both areas. In order to achieve some semblance of generality it is necessary to confine the analysis to those activities necessary to accomplish the case handling for only those products normally kept in the milk storage room. Plants which perform services in addition to these must estimate the costs and add them to the costs as estimated in this study. Table 8 lists the work categories required to operate the Hollywood loadout system and the estimated time requirements for each job. The following discussion of each work category will explain the procedure for estimating work requirements. Supervisory work and work which does not vary with the case handling method were not considered.

First of all, the required work crew must include men to take the milk off the conveyor and preform the loads. These men will be rather steadily occupied during the entire filling operation. With the number and type of fillers used in model Plant C, it is possible for milk to enter the cold room at a rate varying from 12.3 cases per minute to 23.1 cases per minute, depending on the proportion of half-pints, pints, quarts and half gallons being filled at any particular time. Considerable care in organizing the filling schedule may be required if both the filling operation and the case handling operation are to work efficiently. The filling operation itself should be arranged to minimize stoppages for cleaning between products. The cold room work proceeds best if the rate of flow into the cold room is evenly distributed in terms of work load. It is usually possible to harmonize these two activities only by outlining in detail the daily filling schedule and checking resulting cold room work loads.

According to the labor standards outlined in Appendix Tables A-3 and A-4, a man can preform major items (those that do not have to be broken down into partial cases) at the rate of 14.1 cases per minute. For the items such as buttermilk, skim, cream, etc., which are required by loads in less than case lots, one man can preform 6.6 cases per minute. In preforming these latter items, nearly two-thirds of the total working time is spent in reading the load sheet and breaking down the cases.

A sample filling schedule designed for efficiency in both the filling and case handling is given in Table 9.

Table 8. Labor Costs for Plant C, Method 1

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
(1)	(2)	(3)	(4)	(5)	(6)
Receive major items off conveyor and preform loads	14.1 cases per min. per man	10.6 cases per min. a/	--	1	14
Receive minor items off conveyor and preform loads	6.6 cases per min. per man	4.4 cases per min. a/	--	1	14
Make up odd items	2.25 min. per load per man	--	135 min. c/	1/2	12
Check loads for accuracy	3 min. per load per man	--	180 min. d/	1/2	--
Receive empty cases from conveyor and place in case storage	14.7 cases per min. per man	10.9 cases per min. b/	370 min. e/	1	12
Check in returned milk	retail - .52 min. per truck per man	--	18 min.	--	
	wholesale-1.27 min. per truck per man	--	33 min.	--	
Supply empty cases to fillers	30 cases per min. per man	--	190 min. f/	1/2	6
			Total per day		58

Sources: Col. (1): Text, pp. 26-36. Col. (2): Appendix Tables A-3, A-4. Col. (3): a/ Table 9. b/ Average rate at which cases are returned on heaviest day during unloading hours of 11:00 a.m. and 5:30 p.m. (continued on next page)

Table 8 (continued)

Col. (4): c/ Performed between 9:00 a.m. and 11:15 a.m. d/ Performed from 11:15 a.m. until 5:30 p.m. e/ Total number of cases unloaded on heaviest day (5,600 cases) divided by labor standard. f/ Performed intermittently in alternate half hours from 5:00 a.m. until 1:00 p.m. during filling. Col. (5): Part time jobs involving 4 hours or less per day were lumped together into one man where the jobs dovetailed in terms of time of performance. Col. (6): Based on wage rates used by two representative plants. Actual wage rates were inflated 25 per cent to allow for fringe costs and additional labor for replacement in case of illness.

Table 9. Filling Schedule for Plant C for One Day and Product Assignments for Cold Room Workers, Plant C a/

Hour of day	Filler 1 (Model Q)	WORKER	Filler 2 (Model Q)	WORKER	Filler 3 (Model Q)	WORKER	Filler 4 (Model Q)	WORKER	Filler 5 (Model C)	WORKER	Hour of day
5	Sanitize		Sanitize		Sanitize		Sanitize		Sanitize		5
5–6	1/2 pt.cr.	A	1/2 pt.hom.	B	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 gal. homog.	B	5–6
6–8	Quarts homog.		Quarts homog.	A	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 gal. homog.	B	6–8
8–9	Quarts skim	A	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 gal. homog.	B	8–9
9	Creamed buttermilk	A	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 gal. homog.	B	9
9–10	1/2 pints buttermilk	A	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 pts. homog.	B	1/2 gal. homog.	B	9–10
10–11	Quarts buttermilk	A	1/2 pts. homog.	B	Pints homog.	B	Pints homog.	B	1/2 gal. butterm.	B	10–11

a/ Only homogenized milk is filled every day. Other fluid products are filled every other day. On each filling day the higher fat items are filled first so that any product remaining in the lines will not dilute the following product below

Table 9 (continued)

minimum standard fat requirements. Buttermilk and chocolate items are filled last so that the fillers will not have to be cleaned until the end of the day.

In order to keep cold room work requirements to a minimum the number of different items entering the cold room at any particular time is minimized. This is accomplished by using two or more fillers simultaneously to fill the same item. Although this procedure may increase the number of size changes on the fillers, it simplifies work in the cold room. Size changes can be accomplished in 5 minutes or less so they do not seriously retard the production procedure. (Another advantage in using two or more fillers simultaneously on a single item is that an automatic caser can be used to displace two or more case-off men.)

The two men are assigned products in such a way that each starts with one or more items at one end of the cold room and works completely through the entire length of the cold room before starting another item. For instance, Table 8 shows that worker A works with quarts of homogenized from about 6:10 a.m. until 8:25 a.m. He completely finishes all the quarts of homogenized before quarts of skim start coming in. Thus he can start back at one end of the cold room with skim and work the length of the cold room again instead of, perhaps, having to start the skim 100 feet away at the other end of the cold room while finishing the quarts of homogenized. Similarly, B finishes 1/2 pints of homogenized at 11:00 a.m. before starting with pints of homogenized and 1/2 gallons of plain buttermilk.

This schedule applies to only one day, but schedules for other days can be designed in the same general manner. This filling schedule is designed so that stoppages to clean the machine are completely eliminated, yet it is designed so that two men can easily accomplish the preforming of all of the items. Each man (denoted by A and B in Table 9) is assigned particular products in such a way that he works only in a small area of the cold room at a time and handles not more than two different products at one time. A more detailed explanation of the method of designing the filling schedule is given as a footnote in Table 9. The work capabilities of these two men exceed maximum requirements by a comfortable margin, leaving room for unforeseen contingencies.

Handling the milk which goes to the branch plants adds to the complexity of the preforming operation but does not seriously affect the time requirements when only two transports are loaded as in Plant C. If many more transports were loaded, each coming in at uncertain times and in undetermined order, the preforming operation for wholesale and retail loads might be somewhat disrupted. Of extreme importance is an adequate storage area where the milk for branch plants may be temporarily stored. It may be necessary in some cases for the plant to keep an extra man for loading transports. Some plants require the transports to load out before filling starts.

For Plant C a third man is employed to make up odd items such as cottage cheese, butter, eggs, orange drink, etc. which do not enter the cold room through the fillers.

Plant C also requires a man to receive empty cases from returning trucks, stack cases and place them in the case storage room. Although total daily work requirements for this job never exceed one man-day (for Plant C), there are certain times of the day when peak unloads of empty cases may exceed the time standard of 14.7 cases per man-minute. However, the surge capacity provided by the long conveyor extending the full length of the case storage room (with a case stop at the end) enables the empty case handler to work at a steady rate at considerably less than his full capabilities. Therefore, it is assumed that the empty case handler also performs the function of checking in the milk which the drivers return. The task of checking returns is expedited by having the driver "tag" their returns so that the empty case handler can check them at his convenience.

Another required job is that of supplying empty cases to the fillers during the filling operation. According to the time standards, a worker (aided by an automatic unstacker) can supply empty cases at the rate of about 30 per minute or about twice as fast as the fillers require. Furthermore, since it is possible to stack sufficient cases on the conveyor to supply the fillers for about half an hour, this job can be combined with another requiring intermittent attention so the allowance for supplying cases to the fillers is charged at the rate of half a man.

Appropriate wage rates were applied to these physical labor requirements and the total daily labor costs are given in Table 8.

In addition to these labor requirements, most plants would probably provide a shipping superintendent whose responsibility was divided between milk and ice cream, and a dock supervisor. Since these two jobs would not necessarily vary with the case handling system, they are not considered explicitly in the analysis.

Cost of Salesman Time

The cost of the time required by the salesmen to unload and load their trucks is given in Table 10. Since waiting time with the Hollywood system is zero, the only time charged as an expense is for loading and unloading.

Utilities

Table 6 indicates that a total of 40 horsepower is necessary to drive the conveyor. This is immediately translated into kilowatts per hour on the basis of one kilowatt per horsepower. It is assumed that the conveyors will operate continuously for 12 hours per day, 6 days per week. This would require a monthly total power consumption of 12,480 kilowatt hours. The contribution to billing demand, or the highest rate of consumption for any 15 minute period, would be 10 kilowatt hours.

Average annual electricity consumption rates for the refrigeration units are computed on the basis of one ton equals .87 K.W.H. For the 36 tons operating 24 hours per day the monthly consumption would be 22,864 K.W.H. The contribution to billing demand is computed on the basis of maximum consumption, which would be in the hottest part of the day and also when several loading doors are open. It can be assumed that all nine units will be operating continuously during this period. Assuming that one horsepower is required for each ton, the maximum consumption in a 15 minute period is 9 K.W.H.

Table 10. Cost of Salesman Time

Type truck	Unload (min.)	Load (min.)	Wait (min.)	Time for each driver (min.)	No. of trucks	Total time (min.)	Cost per min. (dol.)	Total daily cost (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Retail	5.12	10.10	0	15.22	34	517.48	.035	18.11
Wholesale	11.49	12.98	0	24.47	26	636.22	.04	25.45
Total								43.56

Sources: Col. (1): Assumed 35 case load for retail trucks and 110 case load for wholesale. Labor standards of .1463 minutes per case for retail trucks and .1045 for wholesale trucks. Col. (2): Labor standard of .2887 minutes per case for retail trucks and .1180 minutes per case for wholesale trucks. Col. (3): Truck driver loads from his own door. Col. (4): Summation of Cols. (1)-(3). Col. (5): Page 21 of text. Col. (6): Col. (4) multiplied by Col. (5). Col. (7): Assumed to be representative of wage rates in North Carolina. Col. (8): Col. (6) multiplied by Col. (7).

Total billing demand is thus estimated as 19 K.W.H. and the monthly energy usage is 37,549 K.W.H. It is assumed that other activities of the plant (such as homogenizing and pumping milk through the plant) consume at least 20,000 K.W.H. per month with a billing demand of 25 K.W.H. The appropriate cost for the electricity attributable to case handling according to the rate schedule in a preceding section would be .7 cents per K.W.H. for energy usage and $1.10 per K.W.H. for billing demand, for a total monthly cost of $283. These cost figures are shown in Table 11. Lubrication costs for the 12 lubrication units at $25 per month per lubrication unit amounts to $300 per month.

Description of Method 2 for Plant C

The plant layout for method 2 is illustrated in Figure 3. This method is similar to method 1 in that loads for individual routes are preformed prior to the arrival of the trucks for loading. However, in method 2 there are no individual loading doors. The loads are pulled onto the conveyor by a cold room crew, and the milk is conveyed out onto the loading dock where the driver pulls the milk into the truck and arranges the milk within the truck. Often the cases arrive so rapidly that the driver pulls the cases onto the dock along side the conveyor and loads the milk at a more leisurely rate. A wide loading dock is desirable for this method. Cases are handled on an infloor conveyor in five high stacks as in the previous method.

Table 11. Cost of Utilities

Item	Total horse-power	Average kilowatt hours per hour	Hours of operation per day	Maximum usage in a 15 min. period (K.W.H.)	Total monthly energy usage (K.W.H.)
	(1)	(2)	(3)	(4)	(5)
Conveyor	40	40	12	10	14,600
Refrigeration units	36	31.3	24	9	22,949
		Total billing demand		19	37,449
		Price per K.W.H.		$ 1.10	$ .007
		Total billing cost		$20.90	$262.14
					Total energy charge

Sources: Col. (1): Table 4, p. 27, gives the refrigeration horsepower and Table 6, p. 28, gives the horsepower of the conveyor or drive units. Col. (2): Based on one K.W.H. per H.P. for conveyor and .87 K.W.H. per H.P. for refrigeration. Col. (3): Based on plant observations. Col. (4): Col. (1) divided by 4. Col. (5): Based on 12 hours per day, 313 days per year for conveyor and 24 hours per day, 365 days per year for refrigeration.

Building, Equipment and Labor Costs

Nearly as much storage space is required for this method as for the Hollywood system. Computations indicate the need for a storage room 108 feet long and 27 feet wide. Initial building costs and annual fixed costs are given in Tables 12 and 13. It will be noted in comparing building requirements with the Hollywood system that considerably less refrigeration is required, the cost of doors is avoided, and hence building costs are somewhat lower.

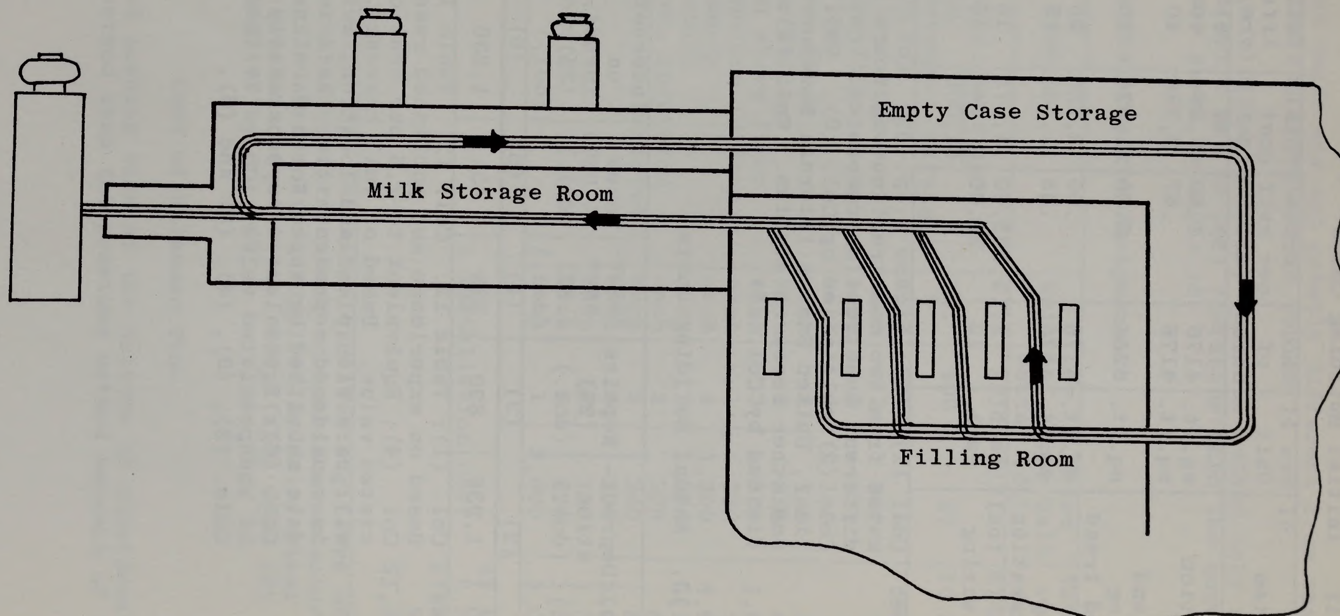


Figure 3. Building Design and Conveyor Layout for Plant C, Method 2

Table 12. Initial Building Costs

Item	Unit	No. of units	Price per unit (dol.)	Total cost (dol.)	Est. life (yrs.)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Foundation	sq.ft.	4176	1.50	6,264	40	157
Floor	sq.ft.	4176	.67	2,798	40	70
Walls and ceiling	sq.ft.	6264	3.50	21,924	20	1,096
Diamond tread plate	sq.ft.	4176	.90	3,758	20	188
Roofing	sq.ft.	4570	.25	1,142	15	76
Refrigeration units (3 ton)	each	3	1,625.00	4,875	15	325
Elec. wiring	each	12	20.00	240	10	24
Total				41,000		1,936

Sources: Col. (1), (2): Figure 3, p. 39. Col. (3): Estimates from two construction engineers from two different construction companies. Col. (4): Col. (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research studies. Col. (6): Col. (4) divided by Col. (5).

Table 13. Annual Building Costs

Initial cost (dol.)	Depreciation (dol.)	Repairs (2%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest on invest. (3%) (dol.)	Total annual costs (dol.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
41,000	1,936	820	328	431	1,230	4,745

Sources: Col. (1): Table 12. Col. (2): Table 12. Col. (3): Based on experience and published research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The rate will vary with plant and location, but 1.6 per cent is considered representative. Rate is based on data submitted by three North Carolina plants. Col. (6): Equivalent to approximately 5 per cent of undepreciated value. Col. (7): Summation of Cols. (2), (3), (4), (5) and (6).

Equipment costs are not greatly different from the previous method and are given in Tables 14 and 15.

Labor costs differ from the previous method only in requiring one extra man to pull the loads onto the conveyor. Labor costs are given in Table 16.

Table 14. Initial Cost of Equipment

Item	Unit	No. of units	Price per unit (dol.)	Total cost (dol.)
	(1)	(2)	(3)	(4)
Infloor conveyor, straight double chain	ft.	400	27	10,800
Above floor conveyor, straight single chain	ft.	288	18	5,184
90° turn, infloor conveyor	each	2	360	720
90° turn, above floor	each	3	255	765
45° turn, infloor	each	1	180	180
45° turn, above floor	each	4	120	480
45° Y junction infloor	each	3	325	975
90° Y junction above floor	each	3	350	1,050
90° double junction infloor	each	1	750	750
5 H.P. drive units	each	4	1,500	6,000
3 H.P. drive units	each	5	1,250	6,250
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	10	300	3,000
Lubricators	each	10	100	1,000
Traffic controls	each	6	220	1,320
Unstacker	each	1	3,000	3,000
				42,626
	Installation cost			8,525
				51,151
				800
				51,951

Sources: Col. (1), (2): Estimates by sales engineers of several major dairy plant equipment manufacturers. Col. (3): Price lists supplied by dairy plant equipment manufacturers. Col. (4): Col. (2) multiplied by Col. (3).

Cost of Salesman Time

The actual loading time of the drivers is considerably less in this method than the previous method because of the

Table 15. Annual Cost of Equipment

Item	Initial price installed (dol.)	Estimated life (years)	Annual depreciation (dol.)	Repairs (4%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Infloor conveyor straight double chain	9,791	5	1,958	392	78	103	294	2,825
All other conveyor equipment	38,560	12	3,215	1,543	309	405	1,157	6,629
Unstacker	3,600	7	514	144	29	38	108	833
Total								10,287

Sources: Col. (1): Table 14, p. 41. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies and estimates from major dairy plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those assumed in other research studies. Col. (5): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 1.6 per cent on undepreciated value. Col. (6): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 2 per cent of value on undepreciated balance. Col. (7): Equivalent to 5 per cent interest on the average unamortized value.

Table 16. Labor Costs for Plant C, Method 2

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
(1)	(2)	(3)	(4)	(5)	(6)
Receive major items off conveyor and preform loads	14.1 cases per min. per man	10.6 cases per min.a/	--	1	14
Receive minor items off conveyor and preform loads	6.6 cases per min. per man	4.4 cases per min.a/	--	1	14
Make up odd items	2.25 min. per load per man	--	135 min.c/	1/2	12
Check loads for accuracy	3 min. per load per man	--	180 min.d/	1/2	--
Receive empty cases from conveyor and place in case storage	14.7 cases per min. per man	10.9 cases per min.b/	370 min.e/	1	12
Check in returned milk	rtl.-.52 min. per truck per man	--	18 min.	--	
	whsl.-1.27 min. per truck per man	--	33 min.	--	
Supply empty cases to fillers	30 cases per min. per man	--	190 min.f/	1/2	6

Table 16 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
(1)	(2)	(3)	(4)	(5)	(6)
Pull preformed loads onto conveyor	23.4 cases per min. per man	--	240 min.	1	12
			Total per day		70

Sources: Col. (1): Text, pp. 26-36. Col. (2): Appendix Tables A-3, A-4. Col. (3): a/ Table 9. b/ Average rate at which cases are returned on heaviest day during unloading hours of 11:00 a.m. and 5:30 p.m. Col. (4): c/ Performed between 9:00 a.m. and 11:15 a.m. d/ Performed from 11:15 a.m. until 5:30 p.m. e/ Total number of cases unloaded on heaviest day (5,600 cases) divided by labor standard. f/ Performed intermittently in alternate half hours from 5:00 a.m. until 1:00 p.m. during filling. Col. (5): Part time jobs involving 4 hours or less per day were lumped together into one man where the jobs dovetailed in terms of time of performing. Col. (6): Based on wage rates used by two representative plants. Actual wage rates were inflated 25 per cent to allow for fringe costs and additional labor for replacement in case of illness.

lesser distance which they must move the milk. However, since only one load at a time can be placed on the conveyor, there is a possibility of one driver having to wait on another to load. Using the analytical method outlined in Appendix B with the standard loading times given in Appendix Tables A-3 and 4 the total waiting time is estimated to be 120 minutes per day. Total costs incurred by the driver-salesmen are given in Table 17.

Table 17. Cost of Salesman Time, Plant C, Method 2

Type truck	Unload time (min.)	Load (min.)	Wait per truck (min.)	Time for each driver (min.)	No. of trucks	Total time (min.)	Cost per min. (dol.)	Total daily cost (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Retail	5.12	4.94	2.00	12.06	34	410.04	.035	14.35
Whsl.	11.49	8.28	2.00	19.77	26	514.02	.04	20.56
Total								34.91

Sources: Col. (1): Assumed 35 case load for retail trucks and 110 case load for wholesale. Labor standards of .1463 minutes per case for retail trucks and .1045 for wholesale trucks. Col. (2): Labor standards of .1411 minutes per case for retail trucks and .0753 minutes per case for wholesale trucks. Col. (3): Estimated with the procedure outlined in Appendix B. Col. (4): Summation of Cols. (1)-(3). Col. (5): Page 21 of text. Col. (6): Col. (4) multiplied by Col. (5). Col. (7): Assumed to be representative of wage rates in North Carolina. Col. (8): Col. (6) multiplied by Col. (7).

Utilities

Using the same estimation procedure as was utilized in method 1, the total electricity costs attributable to case handling with method 2 are outlined in Table 18. Lubrication costs for the 9 lubrication units at $25 per month per lubrication unit amount to $225 per month.

Table 18. Cost of Utilities for Plant C, Method 2

Item	Total horse-power	Average kilowatt hours per hour	Hours of operation per day	Maximum usage in a 15 minute period (K.W.H.)	Total monthly energy usage (K.W.H.)
	(1)	(2)	(3)	(4)	(5)
Conveyor	35	35	12	8.75	10,955
Refrigeration units	9	7.83	24	2.25	5.716
	Total billing demand			11.00	16,671
	Price per K.W.H.			$ 1.10	$ .007
	Monthly cost			$12.10	$116.70

Sources: Col. (1): Table 4, p. 27, gives the refrigeration horsepower and Table 6, p. 28, gives the horsepower of the conveyor or drive units. Col. (2): Based on one K.W.H. per H.P. for conveyor and .87 K.W.H. per H.P. for refrigeration. Col. (3): Based on plant observations. Col. (4): Total H.P. divided by 4. Col. (5): Based on 12 hours per day, 313 days per year for conveyor and 24 hours per day, 365 days per year for refrigeration.

Description of Method 3, Plant C

In this method the individual loads are not preformed. The milk is merely stacked in the cold room with all of the half-gallons in one area, half-pints of buttermilk in another place, etc. When a driver arrives at the loading dock, he hands his shipping order to the load out crew. The load out crew takes the shipping order into the cold room, selects the appropriate items in the desired number and sends them out on the conveyor. When the products reach the truck, the driver pulls the milk into the truck. The layout for this method is illustrated in Figure 4.

Building, Equipment and Labor Cost

Initial building costs and annual fixed building cost are given in Tables 19 and 20. It will be noted that annual building costs are lower than for the other two methods because of a higher utilization of floor space.

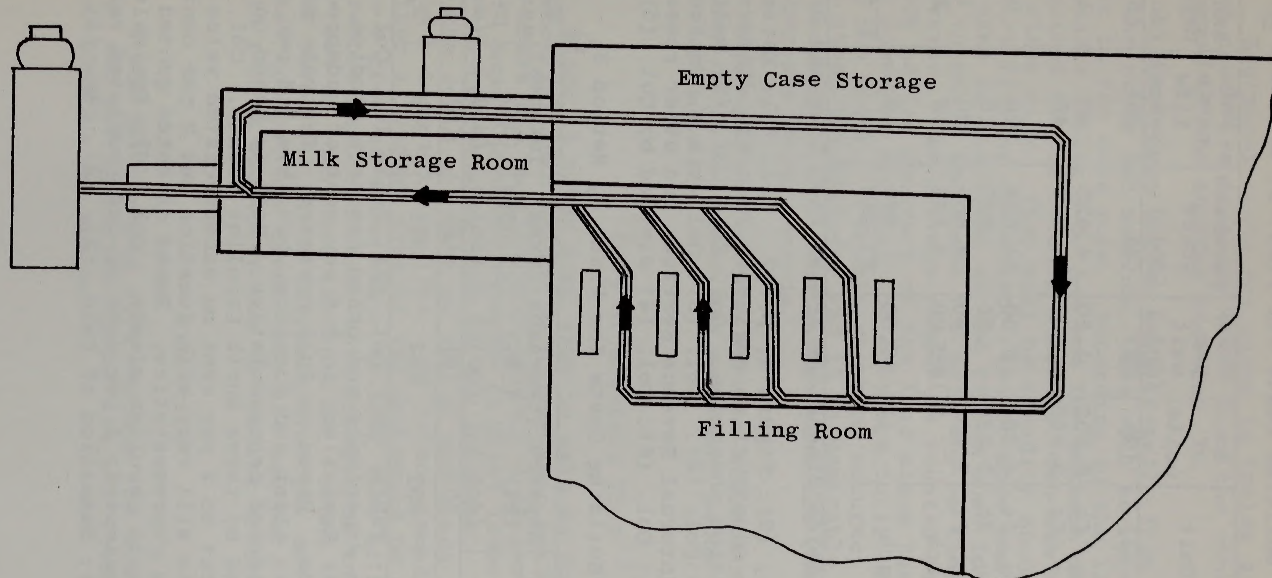


Figure 4. Building Design and Conveyor Layout for Plant C, Method 3

Table 19. Initial Building Costs for Plant C, Method 3 a/

Item	Unit	No. of units	Price per unit (dol.)	Purchase price (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Foundation	sq. ft.	2,952	1.50	4,428	40	111
Floor	sq. ft.	2,952	.67	1,978	40	49
Ceiling and walls	sq. ft.	4,264	3.50	14,924	20	746
Roofing	sq. ft.	3,280	.25	820	15	55
Diamond tread	sq. ft.	2,952	.90	2,657	20	133
Refrigeration	each	3	1625.00	4,875	15	325
Electric wiring	each	12	20.00	240	10	24
Total				31,547		1,443

a/ Building inside dimensions are 82 feet long and 27 feet wide.

Sources: Col. (1), (2): Figure 4, p. 47. Col. (3): Estimates from two construction engineers from two different construction companies. Col. (4): Col. (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research studies. Col. (6): Col. (4) divided by Col. (5).

Table 20. Annual Building Costs for Plant C, Method 3

Initial cost (dol.)	Annual depreciation (dol.)	Repairs (2%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
31,547	1,443	631	252	331	946	3,603

Sources: Col. (1): Table 19. Col. (2): Table 19. Col. (3): Based on experience and other research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The rate will vary with plant and location, but this 1.6 per cent is considered representative. Rate is based on data submitted by three North Carolina plants. Col. (5): Equivalent to 2 per cent on undepreciated value. This rate will vary with location but 2 per cent is taken as representative. Based on rates quoted to three North Carolina plants. Col. (6): Equivalent to approximately 5 per cent of undepreciated value. Col. (7): Summation of Cols. (2), (3), (4), (5) and (6).

Equipment costs are given in Tables 21 and 22. Equipment costs are slightly lower than the other two methods because of the shorter conveyor.

Labor crews differ significantly from the requirements of the other two methods. Men will be required to stack the milk in the cold room. According to the labor standards in Appendix Tables A-3, A-4 and the maximum rate of work required by the filling schedule, two men will be required to stack milk. They will be steadily occupied during the entire filling operation. Two or more men will be required to make up the loads as the trucks come in. Another man has to check the loads for accuracy as they come down the conveyor. The drivers cannot be counted on to make a reliable check on the accuracy of the load since the milk comes down the conveyor too fast and they are fully occupied with loading the truck. A double check on accuracy was provided in the other two methods, and it is desirable to keep the degree of product control constant so that the costs will be more comparable among methods.

The remainder of the work is accomplished in the same manner as in the other two methods. Labor costs are summarized in Table 23.

Cost of Salesman Time

Since it takes some time to make up loads, the rate of loadout for this method is slower than method 2 unless loadout crews are sufficiently large. A larger loadout crew would mean increased expense in plant labor but would decrease the cost of waiting time of the salesman. It is clear that one man could not make up all of the loads fast enough to avoid a long waiting line. It is not immediately clear whether a loadout crew of two men would be more economic than a crew of three men. Waiting time of salesmen was therefore analyzed under both situations and the total salesman cost is indicated in Table 24. Since the loadout crew of three saves $41.27 of salesman time per day, and the additional loadout man costs only $14 per day, it appears that it would pay to use three men to loadout trucks.

Utilities

Since this method uses exactly the same number of power units and refrigeration costs, the utilities cost is the same--$353.80 per month.

Table 21. Initial Equipment Cost for Plant C, Method 3

Item	Unit	No. of units	Price per unit (dol.)	Total cost (dol.)
	(1)	(2)	(3)	(4)
Infloor conveyor, straight double chain	ft.	336	27	9,072
Above floor conveyor, straight single chain	ft.	288	18	5,184
90° turn, infloor conveyor	each	2	360	720
90° turn, above floor conveyor	each	3	255	765
45° turn, infloor	each	1	180	180
45° turn, above floor	each	4	120	480
45° Y junction infloor	each	3	325	975
90° Y junction above floor	each	3	350	1,050
90° Y double junction	each	1	750	750
5 H.P. drive units	each	4	1,500	6,000
3 H.P. drive units	each	5	1,250	6,250
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	10	300	3,000
Lubricators	each	10	100	1,000
Traffic controls	each	6	220	1,320
Unstacker	each	1	3,000	3,000
				40,898
	Installation (20%)			8,180
	Total price			49,078
	Freight			800
				49,878

Sources: Col. (1), (2): Estimated by sales engineers of several major dairy plant equipment manufacturers. Col. (3): Price lists supplied by dairy plant equipment manufacturers. Col. (4): Col. (2) multiplied by Col. (3).

Table 22. Annual Cost of Equipment for Plant C, Method 3

Item	Initial price installed (dol.)	Est. life (yrs.)	Annual depreciation (dol.)	Repairs (4%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual cost (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Infloor conveyor, straight double chain	8,551	5	1,710	342	68	90	257	2,467
Other conveyor equip.	37,727	12	3,144	1,509	302	396	1,132	6,503
Unstacker	3,600	7	514	144	29	38	108	833
Total								9,803

Sources: Col. (1): Table 21, p. 50. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies and estimates from major dairy plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those assumed in other research studies. Col. (5): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 1.6 per cent on undepreciated value. Col. (6): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 2 per cent of value on undepreciated balance. Col. (7): Equivalent to 5 per cent interest on the average amortized value.

Table 23. Labor Costs for Plant C, Method 3

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
(1)	(2)	(3)	(4)	(5)	(6)
Receive milk from conveyor and stack in cold room	14.1 cases per min. per man	20 cases per min.a/	--	2	24
Make up loads when trucks come in	--	--	--	3 e/	42
Check loads for accuracy as loads come from conveyor	--	--	--	1	14
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	10.9 cases per min.b/	370 min.c/	1	12
Check in returned milk	rtl.-.52 min. per truck		18 min.	--	
	whsl.-1.27 min. per truck		33 min.	--	
Supply empty cases to fillers	30 cases/min.	--	190 min.d/	1/2	6
			Total per day		98

Table 23 (continued)

Sources: Col. (1): pp. 26-36. Col. (2): Appendix Tables A-3, A-4. Col. (3): a/ Table 9. b/ Average rate at which cases are returned on heaviest day during unloading hours of 11:00 a.m. and 5:50 p.m. Col. (4): c/ Total number of cases unloaded on heaviest day (5,600 cases) divided by labor standard. d/ Performed intermittently in alternate half hours from 5:00 a.m. until 1:00 p.m. during filling. Col. (5): e/ Determined in Table 24. Col. (6): Based on wage rates used by two representative plants. Actual wage rates were inflated 25 per cent to allow for fringe costs and additional labor for replacement in case of illness.

Table 24. Cost of Salesman Time, Plant C, Method 3, Loadout Crew of Two and Three

Size crew	Type truck	Unload (min.)	Load (min.)	Wait (min.)	Total time per truck (min.)	No. of trucks	Total time (min.)	Cost per min. (dol.)	Total daily cost (dol.)
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
2	rtl.	5.12	4.94	17.5	27.56	34	937.0	.035	32.80
-	whsl.	11.49	8.28	17.5	37.27	26	969.0	.040	38.76
3	rtl.	5.12	4.94	2.2	12.26	34	416.8	.035	14.59
-	whsl.	11.49	8.28	2.2	21.97	26	571.2	.040	22.85

Sources: Col. (1): Assumed 35 case load for retail trucks and 110 case load for wholesale. Labor standards of .1463 minutes per case for retail trucks and .1045 for wholesale trucks. Col. (2): Labor standards of .1411 minutes per case for retail trucks and .0753 for wholesale trucks. Col. (3): Estimated with the procedure outlined in Appendix B. Col. (4): Summation of Cols. (1)-(3). Col. (5): Page 21 of text. Col. (6): Col. (4) multiplied by Col. (5). Col. (7): Assumed to be representative of wage rates in North Carolina. Col. (8): Col. (6) multiplied by Col. (7).

Description of Method 4 for Plant C

Method 4 is probably the most common in North Carolina at the present time. The primary reason for the selection of this method was to compare it with the others.

The primary difference between this method and the previous ones is that this method uses an above-floor conveyor. Normally the cases are handled singly instead of in stacks of five. Although case sizes are larger with an above floor conveyor (resulting in a smaller number of cases), labor costs are increased substantially when cases are handled one at a time.

The layout is indicated in Figure 5. In this system the drivers back the truck up to the unloading dock to unload, then move the truck to the loading dock, hand the shipping clerk the shipping order and pull the cases onto the truck one at a time as they come down the conveyor. It is possible to expand the plant by adding additional loading stalls. The analysis is carried through only for a cold room having three loading stalls.1/

Building, Equipment and Labor Costs

Initial building costs and annual fixed building costs are given in Tables 25 and 26.

Since above floor conveyor equipment is priced somewhat lower than in the other methods, the initial equipment costs and annual fixed equipment costs are somewhat less as in seen in Tables 27 and 28.

Labor costs are given in Table 29.

Cost of Salesman Time

The cost of salesman time is given in Table 30. Waiting time with the use of three loading conveyors averaged less than a minute per truck. Waiting time with only two loading conveyors averaged about 8 minutes, with some trucks waiting as much as 35 minutes. The decrease in the cost of waiting time with the use of three loading conveyors more than offsets the cost of adding another loading conveyor, so the analysis for three loading conveyors was used.

Utilities

Electricity costs are given in Table 31. Lubrication costs for the conveyor are $25 per lubrication unit for

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1/ A preliminary analysis indicated that a cold room having three loading stalls saved $19 per day in salesman waiting time. This saving more than offsets the cost of an additional load out man at $14 per day plus negligible annual building and equipment costs.

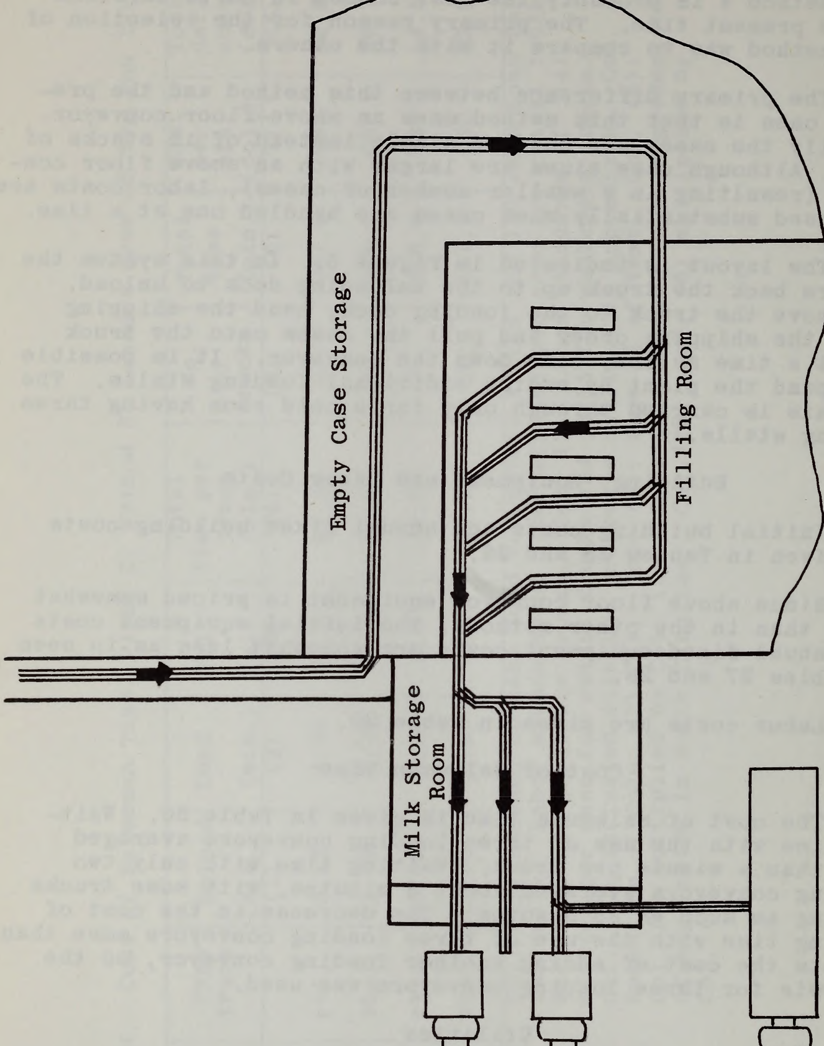

Figure 5. Building Design and Conveyor Layout for Plant C, Method 4

Table 25. Initial Building Costs for Plant C, Method 4 a/

Building with three loading stalls	Unit	No. of units	Price per unit (dol.)	Total cost (dol.)	Est. life (yrs.)	Annual depreciation (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Foundation	sq. ft.	3,740	1.50	5,610	40	140
Floor	sq. ft.	3,740	.67	2,506	40	63
Diamond plate	sq. ft.	3,300	.90	2,970	20	149
Walls and ceiling	sq. ft.	6,060	3.50	21,210	20	1,060
Roof	sq. ft.	3,300	.25	825	15	55
Refrigeration	each	3	1625.00	4,875	15	325
Wiring	each	12	20.00	240	10	24
Total				38,236		1,816

a/ Building 55 feet wide, 60 feet long, dock 8 feet wide across front.

Sources: Col. (1), (2): Figure 5, p. 56. Col. (3): Estimates from two construction engineers from two different construction companies. Col. (4): Col (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research studies. Col. (6): Col. (4) divided by Col. (5).

Table 26. Annual Building Costs, Plant C, Method 4

Purchase cost (dol.)	Annual depreciation (dol.)	Repairs (2%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total (dol.)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
38,236	1,816	1,765	306	401	1147	4,435

Sources: Col. (1): Table 25. Col. (2): Table 25. Col. (3): Based on experience and other research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The rate will vary with plant and location, but this 1.6 per cent is considered representative. Rate is based on data submitted by three North Carolina plants. Col. (5): Equivalent to 2 per cent on undepreciated value. This rate will vary with location but 2 per cent is taken as representative. Based on rates quoted to three North Carolina plants. Col. (6): Equivalent to approximately 5 per cent of undepreciated value. Col. (7): Summation of Cols. (2), (3), (4), (5) and (6).

Table 27. Initial Equipment Cost for Plant C, Method 4

Item	Unit	No. of units	Price per unit (dol.)	Total cost (dol.)
	(1)	(2)	(3)	(4)
Above floor conveyor, straight single chain	ft.	700	18	12,600
90° turns	each	5	255	1,275
90° Y junction	each	5	350	1,750
45° turns	each	5	120	600
45° Y junction	each	3	250	750
3 H. P. drive units	each	11	1,250	13,750
Take up units	each	12	300	3,600
Lubricators	each	12	100	1,200
Case pass doors, insulated	each	4	187	748
Case pass doors, uninsulated	each	1	146	146
Case pass frame	each	1	87	87
	Total purchase price			36,506
	Installation			7,301
				43,807
	Freight			800
				44,607

Sources: Col. (1), (2): Estimates by sales engineers of several major dairy plant equipment manufacturers. Col. (3): Price lists supplied by dairy plant equipment manufacturers. Col. (4): Col. (2) multiplied by Col. (3).

Table 28. Annual Equipment Cost for Plant C, Method 4

Item	Initial price installed (dol.)	Est. life (yrs.)	Annual depreciation (dol.)	Repairs (4%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Conveyor	7,560	5	1,512	302	60	79	227	2,180
All other conveyor equip.	37,047	12	3,085	1,481	296	389	1,111	6,362
Total								8,542

Sources: Col. (1): Table 27, p. 58. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies and estimates from major dairy plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those assumed in other research studies. Col. (5): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 1.6 per cent on undepreciated value. Col. (6): Estimated on basis of data submitted by three North Carolina plants. Equivalent to 2 per cent of value on undepreciated balance. Col. (7): Equivalent to 5 per cent interest on the average amortized value.

Table 29. Labor Requirements and Costs for Plant C, Method 4

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
(1)	(2)	(3)	(4)	(5)	(6)
Receive cases from above floor conveyor and place in storage	5.9 cases per min. per man	16.7 cases per min.	--	3	36
Make up loads when trucks come in	--	--	--	3	42
Receive empty cases from conveyor and place in case storage	9 cases per min. per man	--	--	2	24
Supply filler with empty cases	10 cases per min. per man	16.7 cases per min.	--	2	24
			Total per day		126

Sources: Col. (1): Text, pp. 26-36. Col. (2): Appendix Tables A-3, A-4. Col. (3): Table 9. Col. (5): Part time jobs involving 4 hours or less per day were lumped together into one man where the jobs dovetailed in terms of time of performance. Col. (6): Based on wage rates used by two representative plants. Actual wage rates were inflated 25 per cent to allow for fringe costs and additional labor for replacement in case of illness.

Table 30. Cost of Salesman Time, Plant C, Method 4

Type truck	Unload (min.)	Change docks (min.)	Load (min.)	Wait (min.)	Total time per truck (min.)	No. of trucks	Total waiting time (min.)	Cost per min. (dol.)	Total daily cost (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Retail	3.80	2.00	6.44	.67	12.91	34	438.94	.035	15.36
Wholesale	8.15	2.00	11.90	1.00	23.05	26	599.30	.04	23.97
									39.33

Sources: Col. (1): Assumed 25 cases per retail load and 78 cases per wholesale load. Labor standards of .1463 minutes per case for retail loads and .1045 minutes per case for wholesale trucks were used. Col. (2): Assumed time required to walk from dock to truck, enter truck, drive to loading dock, dismount from truck and walk to conveyor. Col. (3): Labor standards of .2576 minutes per case for retail trucks and .1525 minutes per case for wholesale trucks were used. Col. (4): Estimated with the procedure outlined in Appendix B. Col. (5): Summation of Cols. (1)-(4). Col. (6): Page 21 of text. Col. (7): Col. (5) multiplied by Col. (6). Col. (8): Assumed to be representative of wage rates in North Carolina. Col. (9): Col. (7) multiplied by Col. (8).

Table 31. Electricity Cost for Plant C, Method 4

Item	Total H.P.	Average K.W.H. per hour	Hours of operation per day	Maximum energy used	Total monthly usage
	(1)	(2)	(3)	(4)	(5)
Conveyor	33	3333	12	8.25	10,329
Refrigeration units	9	7.83	24	2.50	5,716
				10.75	16,045
			Price	$ 1.10	$ .007
			Monthly cost	$11.83	$112.32

Sources: Col. (1): Table 4, p. 27, gives the refrigeration horsepower and Table 6, p. 28, gives the horsepower of the conveyor or drive units. Col. (2): Based on one K.W.H. per H.P. for conveyor and .87 K.W.H. per H.P. for refrigeration. Col. (3): Based on plant observations. Col. (4): Total H.P. divided by 4. Col. (5): Based on 12 hours per day, 313 days per year for conveyor and 24 hours per day, 365 days per year for refrigeration.

12 lubricators for a total monthly cost of $300 for a system having three loading stalls. The monthly cost is $25 less for a system of two loading stalls.

Summary and Conclusions for Plant C

The summary of costs under the four methods is given in Table 32. Method 2 is the least cost method followed by method 1, method 3 and method 4 in that order. Method 2 costs $17,700 less per year than method 4. Method 4 is quite commonly used in North Carolina and is one of the older technologies. The prevalence of method 4 indicates that the adoption of new technologies has lagged somewhat. The causes for this lag may include lack of adequate cost information, lack of investment capital or many other reasons. A reason frequently extended for not changing over to the more modern method is that the old equipment has been completely depreciated out in terms of book value with the equipment still in good repair so that it is profitable to use the equipment since it is nearly "free" to the plant. However, this position is shown in Table 32 to be very tenuous. The savings to be realized with method 2 over method 4 exceed the total annual fixed costs of the buildings and equipment of method 4. This means that even if the users of method 4 imputed a cost

Table 32. Summary of Costs for Plant C, Methods 1, 2, 3 and 4

Method	Annual building costs (dol.)	Annual equipment costs (dol.)	Annual labor costs (dol.)	Annual cost of salesman time (dol.)	Annual utility costs (dol.)	Totals (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
1	6,599	12,013	18,154	13,634	6,996	57,396
2	4,745	10,287	21,910	10,926	4,246	52,115
3	3,603	9,803	30,674	11,719	4,246	60,045
4	4,435	8,542	39,438	12,310	5,090	69,815

Sources: Col. (1): Tables 5, 13, 20, 25. Col. (2): Tables 7, 15, 22, 27. Col. (3): Tables 9, 16, 23, 28. Col. (4): Tables 10, 19, 27, 29. Col. (5): Tables 11, 18, 24, 30. Col. (6): Summation of Cols. (1), (2), (3), (4) and (5).

of zero for their building and equipment, it would still pay to change to method 2. This would be true even if the plant had just been constructed 1/ and the equipment was new. The high cost of method 4 is due primarily to the high labor cost of handling single cases.

The analysis probably underestimates the cost savings obtainable by adopting method 2 over method 4. Under method 4 the trucks must move from the unloading dock to the loading dock. This additional driving within the restricted area of the loading docks increases the probability of minor truck accidents. Also, method 2 (as well as the other methods using the infloor conveyor) involves less strenuous work. Cases are slid along the floor instead of being lifted. Also, a plant with an infloor conveyor system is in a more flexible position to adopt innovations such as automatic casers and stackers.

The high cost of method 1 relative to method 2 is due to two factors. First, the loss of cold air through the loading doors requires expensive refrigeration. Refrigeration requirements are estimated on the basis of peak usage. In estimating peak usage it was assumed that as many as five doors would be open at a given time. Actually, refrigeration

1/ Assuming that the cost of tearing out the old equipment did not exceed the salvage value.

costs can be cut considerably by requiring drivers to keep the doors closed as much as possible. The second factor causing a high cost is the high loading time required of drivers. The drivers must drag the milk a considerably further distance in method 1 than the other methods.

Method 3 has the disadvantage of loading only one truck at a time plus the disadvantage of assembling the loads after the drivers arrive for loading. When many trucks arrive at close intervals a long waiting line may develop. Loading time per truck can be decreased by larger loading crews up to a certain maximum sized crew. However, increasing the loadout crew beyond this limit will merely result in the workers' getting in each other's way.

SUMMARY FOR PLANT B

Since the procedure for estimating costs for Plant B is similar to that just described for Plant C, only the summary for Plant B is given here. The detailed tables from which the costs are estimated are given in Appendix Tables C-1 to C-7.

Model Plant B bottles an average of two million pounds of fluid milk per month, operates 17 retail routes, 14 wholesale routes and sends one transport load to a branch sales plant.1/ The cost summary for Plant B is given in Table 33. Method 2 is the lowest cost case handling method with method 3, method 1 and method 4 following in that order. Labor costs constitute the largest single cost category. This factor alone accounts for much of the cost advantage of method 2 over method 4. This savings in labor costs is partially offset by higher building and equipment costs, but the cost advantage is still substantial. The high labor costs of handling cases one at a time makes method 4 particularly disadvantageous even though the number of cases can be reduced by using a larger sized case.

Although method 1 uses a relatively small amount of labor, the high building and refrigeration costs incurred by the use of individual loading doors increases the cost of this method as compared to method 2. The high refrigeration requirement is reflected in the utilities costs as well as the building costs.

1/ The product mix and retail-wholesale-transport proportion of total sales is estimated from sales data from several North Carolina plants of this approximate size.

Table 33. Summary of Four Case Handling Methods for Plant B

Method	Annual building costs (dol.)	Annual equipment costs (dol.)	Annual labor costs (dol.)	Annual salesman costs (dol.)	Annual utilities costs (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
1	3,717	9,584	14,398	7,121	5,152	39,972
2	2,642	8,543	14,398	5,584	3,895	35,062
3	2,006	8,148	18,154	7,136	3,300	38,744
4	1,641	6,609	23,788	7,302	4,167	43,507

Sources: Col. (1): Appendix Table C-2. Col. (2): Appendix Table C-4. Col. (3): Appendix Table C-5. Col. (4): Appendix Table C-6. Col. (5): Appendix Table C-7. Col. (6): Summation of Cols. (1)-(5).

As far as methods 1 and 2 are concerned, the cold room labor is inefficiently utilized. Plant B is slightly too large to accomplish preforming of loads with one man and considerably too small to use two men efficiently. It might be possible for some plants to lower labor costs in methods 1 and 2 still further by using only one man full time to preform loads with part time supplementary labor from some other jobs used in times of peak work requirements. This possibility was not analyzed.

SUMMARY FOR PLANT A

Table 34 gives the summary of the cost analysis for Plant A. The costs are developed in detail in Appendix Tables D-1 to D-7.

Plant A bottles an average of one million pounds of fluid milk per month, operates nine retail routes, seven wholesale routes and sends a small transport load to a branch sales plant.1/

The cost summary indicates that case handling method 2 is still the least cost method. However, the differences

1/ The product mix and retail-wholesale-transport distribution of total sales is estimated from sales data of several North Carolina plants of this approximate size.

Table 34. Summary of Four Case Handling Methods for Plant A

Method	Annual building costs (dol.)	Annual equipment costs (dol.)	Annual labor costs (dol.)	Annual salesman time (dol.)	Annual utilities costs (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
1	2,291	6,608	10,016	3,687	3,388	25,990
2	1,840	5,787	10,016	2,720	2,662	23,025
3	1,375	5,325	13,772	3,660	1,995	26,127
4	1,321	4,079	15,650	4,069	2,263	27,382

Sources: Col. (1): Appendix Table D-2. Col (2): Appendix Table D-4. Col. (3): Appendix Table D-5. Col. (4): Appendix Table D-6. Col. (5): Appendix Table D-7. Col. (6): Summation of Cols. (1)-(5).

between the four methods for a plant of this size are small. Method 2 offers an annual saving of $4,357 over method 4. Reduction of the labor payroll for plants as small as Plant A is difficult because there are few jobs requiring more than one man each, yet these jobs must be performed simultaneously and require the full time attention of one man. This fact accounts for the small differences between the four methods. However, this cost savings of over $4,000 per year must not be de-emphasized. This represents the annual saving which could be realized each year over the full life of the equipment.

SUMMARY FOR PLANT D

Plant D bottles an average of eight million pounds of fluid milk per month, operates 44 retail routes, 26 wholesale routes and sends 9 transport loads to branch sales plants.1/ The cost summary for Plant D is given in Table 35. Table 35 is developed from Appendix Tables E-1 to E-7.

Cost estimates for Plant D were developed in the same manner as with other plants. One factor which required special

1/ These plant characteristics correspond roughly to plants of similar size in the Southeast.

consideration was the organization of work crews to allow for the large proportion of total volume going out in transports. Much of this milk must be handled twice. Since the transports can not load all of the milk directly off the fillers, much of the milk must be previously filled and placed in storage. When the transports come in for loading, the milk will have to be replaced on the conveyor to be conveyed to the loading dock. However, the four men allotted to the cold room case handling can accomplish the preforming of retail and wholesale loads with enough spare time to handle transport loading as well.

Table 35. Summary of Four Case Handling Methods for Plant D

Method	Annual building costs (dol.)	Annual equipment costs (dol.)	Annual labor costs (dol.)	Annual salesman costs (dol.)	Annual utilities costs (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
1	8,245	16,715	36,308	14,079	9,486	84,833
2	6,371	14,653	40,064	12,601	6,932	80,621
3	5,275	14,436	43,820	13,227	6,932	83,690
4	6,002	15,610	60,096	16,611	8,681	107,000

Sources: Col. (1): Appendix Table E-2. Col. (2): Appendix Table E-4. Col. (3): Appendix Table E-5. Col. (4): Appendix Table E-6. Col. (5): Appendix Table E-7. Col. (6): Summation of Cols. (1)-(5).

Method 2 is still the least cost method, costing nearly $26,000 less than method 4. Differences between method 2 and methods 3 and 4 are less significant. Labor costs in the cold room account for much of the cost differential between methods 2 and 4. Largely the same conclusions regarding the case handling methods can be drawn for Plant D as for the other plants. However, the magnitude of the cost savings seems to increase as the size of the plant increases.

SUMMARY AND GENERAL CONCLUSIONS

The objective of this study was to analyze four case handling methods currently available for use in North Carolina milk plants and indicate which method seemed most economical in terms of monetary cost. The four methods analyzed were:

Method 1 - Infloor conveyor, preformed loads, loadout through multiple loading doors.

Method 2 - Infloor conveyor, preformed loads, loadout by a common conveyor and loading dock.

Method 3 - Infloor conveyor, loads made up on arrival of trucks, loadout on a common conveyor and loading dock.

Method 4 - Above-floor conveyor, loads made up on arrival of trucks, loadout on multiple conveyor spurs.

The analysis was carried through for plants of four different sizes in order to determine the effects of volume on the selection of the case handling method. In each case a complete list of the inputs and services necessary to accomplish the case handling function was made. Physical inputs and input prices were listed separately to allow adaptation of the results to different price situations. Costs were divided into building costs, equipment costs, labor costs, cost of salesman time at the loading docks, and utilities costs.

The analysis indicated that substantial cost savings can be realized with the use of infloor conveyor as opposed to the older method of above-floor conveyor. Much of the savings is attributable to decreased labor costs in the cold room. Cases can be easily handled in stacks of five with an infloor conveyor instead of one at a time with the above-floor conveyor. The stacking of cases for use on an infloor conveyor can be accomplished in the filling room in several ways. The case-off men can manually stack the cases while casing-off. The stacking can be expedited by the use of an inexpensive stacking aid at each filler.

Labor costs can be further reduced with an infloor conveyor by preforming loads directly from the filler-conveyor. With this procedure the cases are handled a lesser number of times than with the procedure of first stacking the cases in storage and then making up the loads. The successful preforming of loads depends largely on the effective coordination of the filling operation with the cold room case handling. Cold room work requirements vary considerably with the number and type of products being filled at any given time. Thus cold room work can be lightened by using two or more fillers on one product. Although this procedure increased the number of product and size changes on the fillers, it does not greatly affect the efficiency of the filling operation and has the advantage of lightening cold room work in preforming loads.

Once the loads are preformed, the trucks may be loaded out through individual loading doors, as in method 1, or on a common conveyor and dock as in method 2. Method 1 has the advantage of giving the driver more freedom to load at will and eliminates the annoying problem of waiting in line for space at the dock. However, method 1 has the disadvantages of higher building, equipment and electricity costs. Also it takes the drivers more time to load since the milk must be dragged a longer distance. These disadvantages cause method 1 to be slightly more expensive than method 2 for all sizes of plants considered.

Methods 3 and 4 have lower building and equipment costs than methods 1 and 2 but have the disadvantage of making up the loads after the trucks arrive for loading. Loading times for each truck are therefore increased and long waiting lines may develop for plants having a large number of trucks to load. The waiting problem can be somewhat alleviated by increasing the size of shipping crews and reducing the loading time per truck. Increased shipping crews add to annual payroll costs.

The total cost advantage of method 2 over method 4 ranges from $4,700 per year for plants bottling one million pounds of fluid milk per month to $26,000 per year for plants bottling eight million pounds per month. Plants of intermediate size have corresponding savings. The saving in labor cost alone between methods 2 and 4 is of a greater magnitude than the total annual fixed cost of buildings and equipment for method 4. This means that the users of method 4 could save money by changing to method 2 even though they impute a value of zero to their building and equipment.1/

1/ Assuming the salvage value of the old equipment covered the cost of tearing out the old equipment.

Appendix A
Estimation of Labor Requirements

There are two major methods of estimating labor standards. One is called "work sampling" and the other is the continuous stop watch method.

The work sampling method consists simply of observing the workers' activities briefly at random intervals during an extended period, noting the particular work activity being performed at each observation and inferring from these random observations the proportion of time which the workers spend on particular tasks. The output of the worker during the period of observation is also recorded. The procedure is illustrated in Table A-1.

Appendix Table A-1. An Illustration of the Method of Estimating Time Requirements

Type of job - preforming retail loads
Begin 8:30 End 10:20 Total time 110 minutes Number of cases 200

Job elements	Number of observations
1. Read load sheet	12
2. Drag and place milk	20
3. Break down cases	18
4. Miscellaneous work	5
5. Wait, non-work	27
Total	82

The researcher must have clearly in mind the beginning and ending points for each of the work elements so there will be no uncertainty as to which work element is being performed at the time of observation. These decisions should be worked out in advance if possible. The analysis of the sample is carried on as shown in Table A-2.

Appendix Table A-2. Sample Analysis of Work Sampling Sheets

Job element	No. of obs.	Per cent of total obs.	Time spent (min.)	No. of cases	Minutes per case
Read load sheet	12	14.6	16.1	200	.0803
Drag and place milk	20	24.4	26.8	200	.1342
Break down cases	18	21.9	24.1	200	.1204
Miscellaneous work	5	6.1	6.7	200	.0336
Wait, non-work	27	33.0	36.3	200	--
			Total		.3685

This process should be repeated for a number of different workers and at a number of plants if possible. Confidence in the results is increased as the sample size increases.

The other method is the "continuous stop watch" method. With this method, as the name implies, the workers are under constant observation. As the workers perform their activities, the observer keeps a running account of the worker with a stop watch. The work may be broken down into a number of job elements with separate observations for each. The total working time is divided by the output of the worker to estimate labor standards.

There are advantages and disadvantages with each of the two methods. The continuous stop watch method may be more accurate for observing a small number of workers for short periods. As the number of workers to be observed increases, the task of keeping all of the workers under constant surveillance becomes extremely difficult. The work sampling method is more appropriate where many workers are to be observed simultaneously. However, since work sampling involves the observation of each worker during only a small proportion of his working time, the sample size must be increased substantially in order to obtain confidence in the estimated labor requirements.

The labor standards in Appendix Tables A-1 and A-2 were estimated by using both methods. In each case the particular method of estimation was selected which appeared easiest to apply with satisfactory results.

With unlimited research inputs and many different plants to observe, it is possible to estimate the labor standards as accurately as may be desired. However, research inputs for this study were not unlimited so that the sample size was small. Even so, the limiting factor in extending the sample size did not arise from the limited research inputs available but from the paucity of plants using the particular labor techniques under investigation. In some cases the estimation of labor standards is based on the observation of only one plant. In such a situation, the estimates should not be interpreted as "labor standards" but more realistically should be considered as "possibilities." However, the measurements obtained do represent actual situations which may be duplicated by other plants.

Appendix Table A-3. Time Standard for Case Handling Jobs with Infloor Conveyor

Job description	Time standard (min./case) a/		Condition surrounding work
Position cases in cold room - worker walks to conveyor, hooks onto a 5-high stack and slides it to the appropriate place	Walk to get milk	.0070	Worker covered approximately 100 linear feet of storage space and was concerned with 3 different products
	Drag milk from conveyor and position in storage	.0641	
	Total	.0711	
Loading out milk for tractor-trailer - load out man consults load sheet, walks to appropriate stack of milk, selects required number of items and pulls them on the conveyor in 5-high stacks	Read load sheet	.0049	Storage area was 200 feet long
	Walk to get milk	.0066	
	Drag milk to conveyor	.0523	
	Total	.0638	
Loading retail truck from conveyor - truck driver drags milk from conveyor to dock beside truck and places milk inside truck		.1411	Conveyor was approximately truck door height and about 2 feet in horizontal distance from the truck door
Loading retail truck through individual loading door - truck driver opens door, goes into storage room, checks milk, pulls milk out door onto loading dock, puts milk in truck	Check milk	.0606	Milk was dragged from the cold room across a 4 foot platform and into the truck
	Drag milk to truck	.1121	
	Arrange milk in truck	.1160	
	Total	.2887	
		(.0232) b/	
Loading wholesale truck from individual loading door with hand truck in stacks 5-high	Check milk	.0273	Milk was dragged from the cold room across a 4 foot platform and into the truck
	Drag milk in truck	.0907	
	Total	.1180	
		(.0035)	

Appendix Table A-3 (continued)

Job description	Time standard (min./case) a/	Condition surrounding work
Load wholesale truck from conveyor - truck driver pulls milk from conveyor into truck	.0753 c/ (.0019)	Conveyor was approximately truck door height and about 2 feet in horizontal distance from the truck door
Loading out wholesale trucks - 1 man crew - the loadout man takes the load sheet, goes into the cold room, alternately reads the load sheet & places items on conveyor	.1156 (.0082)	Storage area was approximately 200 feet long
Loading out retail trucks - one man crew	.2680 (.0297)	Storage area covered was approximately 200 feet long
Loading out wholesale trucks - two man crew	.0731 (.0046)	Storage area was approximately 75 feet long
Loading out retail trucks - two man crew	.1157 (.0058)	Storage area was approximately 75 feet long
Loading out wholesale trucks - three man crew	.0435 d/	Storage area was approximately 75 feet long
Loading out retail - three man crew	.0600 d/	Storage area was approximately 75 feet long
Loading tractor trailer - pull milk from conveyor and place in tractor trailer in 5-high stacks	.0504	Transport 35 feet long loaded through side door
Preforming retail loads - reads load sheet, walks to conveyor, drags milk to appropriate place, breaks down cases	Read load sheet .0456 Drag milk .0552 Break down cases .0499 .1507	Cold storage area approximately 27 feet wide

Appendix Table A-3 (continued)

Job description	Time standard (min./case)a/	Condition surrounding work
Preforming wholesale loads - reads load sheet, drags milk to appropriate place and breaks down cases if necessary	Read load sheet .0071 Drag and place .0552 Break down cases .0082 .0705	Cold storage area approximately 27 feet wide
Unload wholesale truck - place empty cases on conveyor through rear door of truck	.1045 (.0064)	Conveyor was approximately truck door height and about 2 feet in horizontal distance from truck door
Unload retail truck - place empty cases on conveyor through rear door of truck	.1463 (.0051)	Conveyor was approximately truck door height and about 2 feet in horizontal distance from truck door
Setting preformed loads onto conveyor - pulls stacks of milk onto conveyor	.0427	Cold room 27 feet wide
Receive empty cases from conveyor, stack to 6-high and place in storage	.0680	Cases are usually received already stacked 3 or 4 high, worker increases stack to 6
Pull stacks of empty cases onto conveyor for case unstacker to supply fillers	.0333	
Check in returned milk from trucks	Retail .52 per truck	Less than one case per truck is normally returned from refrigerated trucks

Sources on following page.

Appendix Table A-3 (continued)

a/ Measured in minutes per case except as otherwise noted.

b/ Figures in parentheses are standard errors of the estimate of the mean.

c/ Time requirements for this job seemed to be related to load size. The following regression equation describes the relationship:

$$T = -\ .96\ X^{.88} \qquad (R^2 = .74) \quad (N = 38)$$

where T = minutes required to load; X = number of cases.

d/ No observations were obtained for a crew of this size. These estimates were merely extrapolated from the preceding figures for one and two men crews.

Appendix Table A-4. Time Standards for Off-floor Conveyor

Job description	Time standard (min. per case)	
Loading out wholesale trucks - cold room crew takes shipping order into cold room, selects the appropriate items and sends them out on the conveyor		.1525
Loading out retail trucks - cold room crew takes shipping order into cold room, selects the appropriate items and sends them out on the conveyor		.2576 (.0312)a/
Placing milk in cold room - cold room worker receives milk from conveyor, stacks the milk on the floor beside the conveyor, moves the stack over to the wall by hand truck	Stack case on floor	.035
	Secure stack to move	.020
	Position stack and turn	.014
	Move hand truck 15 ft. and return	.032
	Miscellaneous	.070
		.171b/
Loading tractor trailer - cold room crew takes shipping order into cold room, selects the appropriate items and sends them out on the conveyor		.0900
Unload wholesale truck - place empty cases through rear door of truck onto case conveyor		.1045 (.0064)
Unload retail truck - place empty cases through rear door of truck onto case conveyor		.1463 (.0051)
Receive empty cases from conveyor, stack 5-high and place in storage		.1111c/
Take stacks of cases from conveyor, unstack cases and place cases one at a time on conveyor		.1000c/

a/ Numbers in parentheses represent the standard error of the estimated mean of the observations.

b/ Obtained from Charles E. French and Harry R. Varney, Jr., "Labor Utilization in Cold Storage and Empty Bottle Rooms," Purdue Research Bulletin No. 677, Lafayette, Indiana, April, 1959, and Fred H. H. Calhoun, Jr., "Standard Cycle Times Applied to Milk Bottle Case Handling in Dairy Plants," Unpublished thesis submitted in partial fulfillment of the degree, Master of Dairy Manufacturing, North Carolina State College, 1956, pp.28-40.

c/ Estimates taken from Calhoun, loc. cit.

Appendix B

Queuing Theory and the Determination of Waiting Time for Trucks

To use queuing theory in the determination of waiting time at a service facility such as a loading dock, the following types of information are required:

(1) the probability distribution of truck arrivals at the loading dock;

(2) the mean arrival rate;

(3) the probability distribution of loading times;

(4) the average loading time;

(5) the queue discipline or priority system, such as "first come-first served."

Solutions regarding the behavior of the queue differ with the type of probability distributions which characterize the truck arrivals and loading times. A particular arrival distribution which frequently occurs in practical problems is the Poisson distribution. The sample of truck arrivals obtained in the study was tested in Appendix Table B-1 by chi-square to see if it could have come from a population with a Poisson distribution. The hypothesis that the sample was obtained from a population with a Poisson distribution could not be rejected at the 95 per cent level of confidence. Consequently, the mathematical procedures developed here are applicable to queues in which the truck arrivals have a Poisson distribution.

A necessary assumption in the development that follows is that the mean arrival rate and the mean servicing rate are constant over time. The solution is given only for a loading facility which loads one truck at a time. The solution for K loading lines follows the same procedure.

Appendix Table B-1. A Chi-Square Test to Determine if a Sample of Truck Arrivals Could Have Come from a Poisson Distribution

(1) No. of arrivals in 15 min.	(2) Frequency of occurrence (f_o)	(3) Probabilities of occurrence ($\overline{\lambda} = 1.5$)	(4) Expected no. of intervals (f_c)	(5) $\frac{(f_c - f_o)^2}{f_c} = X^2$
0	36	.223	30.0	1.156
1	42	.335	45.2	.227
2	25	.251	33.9	2.337
3	22	.125	16.9	1.539
4	8	.047	6.3	.439
5 or more	1	.018	2.4	.817
				6.515

$(\bar{f}_o = 1.5$ per 15 minutes$)$ $\quad \left(11.07 = X^2_{.95}\right)$

Sources: Col. (1): The hours from 11:00 a.m. to 5:30 p.m. were divided up into fifteen minute periods and the number of trucks arriving within these periods were counted. Col. (2): Taken from a sample in which the truck arrivals were recorded for a week at a North Carolina plant. The first number (36) means that during the week there were 36 fifteen minute periods during which there were no truck arrivals. Col. (3): Probabilities from a Poisson distribution with mean 1.5 of the number of intervals during which 0, 1, 2, 3, 4, 5, 6, 7 trucks arrived. Col. (4): Expected value of the number of intervals during which 0, 1,...7 trucks arrived. Obtained by multiplying the number of total arrivals by Col. (3). Col. (5): The square of the deviation of Col. (2) - Col. (3). Since the $X^2 = 6.5$ is less than the tabled value of 11.07, the hypothesis that the sample came from a universe with a Poisson distribution cannot be rejected at the 95 per cent level of confidence. Since the number of intervals during which 5 or more trucks arrived was small, these intervals were combined into the single category "5 or more."

The following notation will be used:

n = number of units in waiting line at time t

λ = mean arrival rate

μ = mean loading time

$P_n(t)$ = probability of n units in the queue at time t

λdt = the probability of a new truck entering the queue in the time interval dt

μdt = the probability of a truck being loaded in the time interval dt

The solution involves the formulation of two differential equations which are to be solved simultaneously. One equation represents the probability of n trucks in the queue at time (t + dt) and the other equation represents the probability of no trucks in the queue at time (t+dt). The equations are as follows:

$$(1)\quad P_n(t + dt) = P_n(t)\left[1 - (\lambda+\mu)dt\right] + P_{n-1}(t)\,\lambda dt + P_{n+1}(t)\mu dt$$

$$(2)\quad P_o(t+dt) = P_n(t)\,(1 - \lambda dt) + P_1(t)\mu dt$$

The first equation states that the probability of n trucks in the system at time (t + dt) equals the probability of n trucks in the system at time t multiplied by the probability of no arrivals and no departures plus the probability of (n-1) trucks in the system at time t multiplied by the probability of one arrival and no departures plus the probability of (n + 1) trucks in the system at time t multiplied by the probability of one departure and no arrivals. These represent an enumeration and summation of all ways in which there might result in (n) trucks in the system at time (t + dt).

Expanding these two equations and passing to the derivative we get:

$$(3)\quad \frac{P_n(t + dt) - P_n(t)}{dt} = -\lambda P_n(t) - \mu P_n(t) + \mu P_{n+1}(t) + \lambda P_{n-1}(t)$$

and

$$(4)\quad \frac{dP_o(t + dt) - P_o(t)}{dt} = \lambda P_o(t) + \mu P_1(t)$$

In setting these derivatives to zero and transposing terms, there results:

(5) $(\lambda + \mu) P_n = \lambda P_{n-1} + \mu P_{n+1}$

(6) $\lambda P_o = \mu P_1$

Solving equation (2) for P_1

(7) $P_1 = \frac{\lambda}{\mu} P_o$

For n = 1 we substitute in equation (5),

(8) $(\lambda + \mu) P_1 = \lambda P_o + \mu P_2$

And solve for P_2

(9) $P_2 = (\frac{\lambda}{\mu})^2 P_o$

Repetition of this process for all n gives:

(10) $P_n = (\frac{\lambda}{\mu})^n P_o$

Using the relationship of $\sum_{n=o}^{\infty} P_n = 1$ enables us to obtain a solution involving only the parameters λ and μ, as follows:

(11) $\sum_{n=o}^{\infty} P_n = 1$ but $P_n = (\frac{\lambda}{\mu})^n P_o$ so $\sum_{n=o}^{\infty} (\frac{\lambda}{\mu})^n P_o = 1$

Using the formula for the sum of an infinite geometric progression, namely

(12) $\sum_{n=o}^{\infty} ar^n = \frac{a}{1-r}$

our equation becomes:

(13) $\sum_{n=o}^{\infty} P_o (\frac{\lambda}{\mu})^n = \frac{P_o}{1 - \frac{\lambda}{\mu}} = 1$ or $P_o = 1 - \frac{\lambda}{\mu}$ hence

$P_n = (\frac{\lambda}{\mu})^n (1 - \frac{\lambda}{\mu})$

Now we have a formula for the estimation of the probabilities of any number of trucks in the system expressed only in terms of our parameters λ and μ.

An estimate of the actual number of trucks in the system at any time is given by:

(14) $L = \sum_{n=o}^{\infty} nP_n = (1 - \frac{\lambda}{\mu}) \sum_{n=o}^{\infty} n(\frac{\lambda}{\mu})^n = \frac{\frac{\lambda}{\mu}}{1 - \frac{\lambda}{\mu}}$

Note that L is an expected value with variance:

$$\sum_{n=o}^{\infty} (n - L)^2 P_n = \sum_{n=o}^{\infty} n^2 P_n - \left\{ \frac{\frac{\lambda}{\mu}}{1 - \frac{\lambda}{\mu}} \right\}^2$$

Other formulas can be derived for estimates of the average waiting time, average idle time of the loading facility, etc.

Direct algebraic computation of queuing characteristics for this problem is simple. However, the relaxation of the assumption that the mean arrival rate or the mean service rate are constant over time changes the method of solution. A. B. Clarke1/ has shown that when the mean arrival rate is dependent on time, the solution of queue characteristics can be found by the evaluation of a (complicated) Bessel function.

The mean arrival rate of milk delivery trucks at the loading dock is dependent on time. This fact seems obvious in Figure B-1, which shows the mean arrival rate per hour as a function of time during the entire loading period of a sample plant. Since the mean arrival rate cannot be considered independent of time, a simple algebraic solution of queue characteristics is not available. Fortunately, however, the solution can be accomplished in a simple non-mathematical manner by a Monte Carlo simulation procedure. This procedure involves (1) setting up (on paper) a series of random truck arrivals characterized by a Poisson distribution, (2) assigning the trucks to loading facilities on a first come-first serve basis and (3) keeping a running account of dock occupancy and waiting time.

Simulated truck arrival times are obtained from a table of random numbers. A group of random numbers are drawn and certain numbers are specified as being "arrivals" and some as "non-arrivals." The specification of numbers is done in such a way that the expected value of the total number of "arrivals" in the group of random numbers equals the estimated mean arrival rate and in such a way that the frequency distribution of arrivals corresponds to a Poisson distribution. In a group of two digit numbers, the occurrence of a double digit number (such as 99) has a Poisson frequency distribution. By specifying the 99 as an "arrival" and all other numbers as non-arrivals, the corresponding series of truck arrivals should be distributed in accordance with the Poisson distribution. Furthermore, since the occurrence of a 99 can be assigned a probability of .01, the appropriate

1/ A. B. Clarke, "A Waiting-Line Process of Markov Type," Annals of Mathematical Statistics, Volume 27, 1956, Waverly Press, Inc., Baltimore, Maryland.

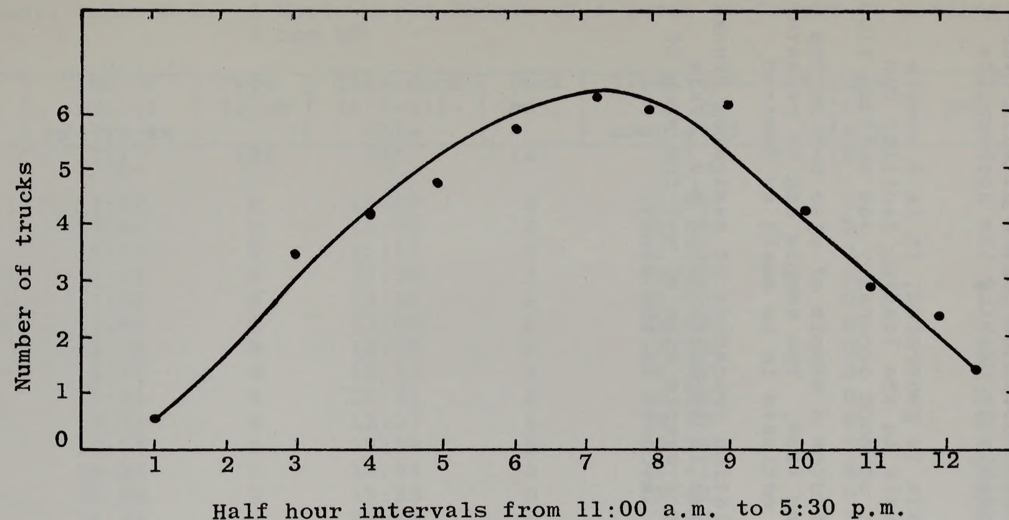

Figure B-1. Distribution of Truck Arrivals for Loading during an Afternoon Loading Period

Source: Sample at a North Carolina plant.

mean arrival rate can be approximated by specifying the number of random numbers drawn. If the specified mean arrival rate is 3.5 trucks per half hour, it would be necessary to draw 350 random numbers. Each random number would correspond to a time interval of 30/350 = .0857 minutes. Consequently, if the sampling procedure is considered as starting at 11:00 a.m., and the number 99 occurred on the 30th, 67th and 220th trial, trucks could be said to have arrived at 11:00.2, 11:05.7 and 11:18.9 a.m. The arrival rate could be varied at will over consecutive time periods merely by drawing the appropriate number of random numbers.

Once a list of arrivals is generated, it is a simple matter to assign the arrivals to the loading facility and maintain a running account of dock occupancy and waiting time.

This procedure constitutes a sample of size n=1 in the estimation of total waiting time. The sample can be repeated until the variance of the estimate is as small as desired.

A sample of the simulation procedure of assigning trucks to the loading dock is given in Appendix Table B-2. This procedure was repeated for a sample size of n=7 for each of the waiting time problems involved in the study.

Appendix Table B-2. A Monte Carlo Sample of a Queue of Trucks at Loading Docks A and B[a]

No.	Time of arrival of trucks	Type truck	Time dock is available	Dock sel.	Time loading is completed	Waiting time (min.)	λw per hr.	λr per hour
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	11:02	R	11:02	A	11:09	0	.6	4.6
2	11:02	R	11:02	B	11:09	0	.6	4.6
3	11:17	W	11:17	A	11:30	0	.6	4.6
4	11:35	W	11:35	A	11:48	0	.6	4.6
5	11:53	R	11:53	A	12:00	0	.6	4.6
6	11:59	R	11:58	B	12:05	0	.6	4.6
7	12:05	R	12:05	A	12:12	0	2.2	8.8
8	12:14	W	12:14	A	12:27	0	2.2	8.8
9	12:21	R	12:21	B	12:28	0	2.2	8.8
10	12:21	R	12:27	A	12:34	6	2.2	8.8
11	12:25	R	12:28	B	12:35	3	2.2	8.8
12	12:28	R	12:34	A	12:41	6	2.2	8.8
13	12:35	R	12:35	B	12:42	0	2.2	8.8
14	12:43	R	12:43	A	12:50	0	2.2	8.8
15	12:51	R	12:51	A	12:58	0	2.2	8.8
16	12:53	R	12:53	B	1:00	0	2.2	8.8
17	12:57	W	12:58	A	1:11	1	2.2	8.8
18	1:07	R	1:07	B	1:13	0	5.4	9.7
19	1:09	W	1:11	A	1:24	2	5.4	9.7
20	1:13	W	1:13	B	1:26	0	5.4	9.7
21	1:14	R	1:24	A	1:31	10	5.4	9.7
22	1:23	R	1:26	B	1:33	3	5.4	9.7
23	1:23	R	1:31	A	1:38	8	5.4	9.7
24	1:26	R	1:33	B	1:40	7	5.4	9.7
25	1:26	R	1:38	A	1:45	12	5.4	9.7
26	1:33	W	1:40	B	1:53	7	5.4	9.7

Appendix Table B-2 (continued)

No.	Time of arrival of trucks	Type truck	Time dock is available	Dock sel.	Time loading is completed	Waiting time (min.)	λw per hr.	λr per hour
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
27	1:38	W	1:45	A	1:58	7	5.4	9.7
28	1:40	R	1:53	B	2:00	13	5.4	9.7
29	1:44	R	1:58	A	2:05	14	5.4	9.7
30	1:48	R	2:00	B	2:07	12	5.4	9.7
31	2:01	W	2:05	A	2:18	4	10.1	6.2
32	2:02	W	2:07	B	2:20	5	10.1	6.2
33	2:03	W	2:18	A	2:31	15	10.1	6.2
34	2:10	R	2:20	B	2:29	10	10.1	6.2
35	2:19	R	2:29	B	2:34	8	10.1	6.2
36	2:25	R	2:31	A	2:34	6	10.1	6.2
37	2:30	R	2:34	A	2:41	4	10.1	6.2
38	2:31	R	2:34	B	2:41	3	10.1	6.2
39	2:32	W	2:46	A	2:54	9	10.1	6.2
40	2:41	W	2:41	B	2:54	0	10.1	6.2
41	2:44	W	2:54	A	3:07	10	10.1	6.2
42	2:45	W	2:54	B	3:07	9	10.1	6.2
43	2:50	W	3:07	A	3:20	17	10.1	6.2
44	2:51	W	3:07	B	3:20	15	10.1	6.2
45	2:55	W	3:20	A	3:33	25	10.1	6.2
46	2:58	W	3:20	B	3:33	22	10.1	6.2
47	2:58	W	3:33	A	3:46	35	10.1	6.2
48	3:19	W	3:33	B	3:46	16	4.1	3.4
49	3:25	W	3:46	A	3:59	21	4.1	3.4
50	3:29	R	3:46	B	3:53	17	4.1	3.4
51	3:37	W	3:53	B	4:00	16	4.1	3.4
52	3:43	R	3:59	A	4:06	16	4.1	3.4
53	3:49	R	4:00	B	4:07	11	4.1	3.4

Appendix Table B-2 (continued)

No.	Time of arrival of trucks	Type truck	Time dock is available	Dock sel.	Time loading is completed	Waiting time (min.)	λw per hr.	λr per hour
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
54	3:52	R	4:06	A	4:13	14	4.1	3.4
55	3:59	W	4:07	B	4:20	8	4.1	3.4
56	4:00	R	4:13	A	4:20	13	3.5	1.2
57	4:05	W	4:20	B	4:33	15	3.5	1.2
58	4:16	W	4:20	A	4:33	4	3.5	1.2
59	4:25	R	4:33	A	4:40	8	3.5	1.2
60	4:25	R	4:33	B	4:40	8	3.5	1.2
						475		

Sources: Col. (1): At each time period a two digit number was drawn from a table of random numbers. If the number was under 99, no arrivals were made. Numbers 99 and over constituted an arrival. Col. (2): Separate drawings were made for wholesale trucks and retail trucks. Col. (3): Same as Col. (1) if no trucks are in line. If trucks are in line, this column represents the time at which a dock is freed. Col. (4): Any dock that happens to be empty. Col. (5): Col. (3) plus the loading time. Col. (6): Col. (3) - Col. (1). Col. (7), (8): Arrival rates used to simulate dock occupancy.

a/ The chi-square test to determine whether the truck arrivals were characterized by a Poisson distribution was accomplished by aggregating the individual hourly arrival data. Yet the Monte Carlo simulation separated the data into individual hours. Unfortunately there was an insufficient number of observations to accomplish separate chi-square tests for each hour. Hence the assumption was made that the individual hourly components possessed the same distribution characteristics as the aggregated hourly data.

Appendix Table C-1. Initial Building Costs for Plant B, Four Case Handling Methods

Item	Unit	No. of units	Price per unit (dol.)	Initial cost (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 1 a/						
Foundation	sq. ft.	2197	1.50	3,295	40	82
Floor	sq. ft.	2197	.67	1,472	40	37
Wall and ceiling panels	sq. ft.	3861	3.50	13,513	20	675
Steel plate on floor	sq. ft.	2197	.90	1,977	20	99
Roofing	sq. ft.	2760	.25	690	15	48
Individual loading doors	each	7	250.00	1,750	20	88
Refrig. units (4 ton)	each	5	1625.00	8,125	15	542
Electric outlets	each	12	20.00	240	10	24
				31,012		1,593
Method 2 b/						
Foundation	sq. ft.	1952	1.50	2,928	40	73
Floor	sq. ft.	1952	.67	1,308	40	33
Wall and ceiling panels	sq. ft.	3606	3.50	12,621	20	631
Steel plate on floor	sq. ft.	1952	.90	1,756	20	88
Roofing	sq. ft.	2480	.25	620	15	41
Refrig. units (3 ton)	each	2	1625.00	3,250	15	216
Electric outlets	each	6	20.00	120	10	12
				22,603		1,094

Appendix Table C-1 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Initial cost (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 3 c/						
Foundation	sq. ft.	1435	1.50	2,153	40	54
Floor	sq. ft.	1435	.67	961	40	24
Wall and ceiling panels	sq. ft.	2668	3.50	9,338	20	467
Steel plate on floor	sq. ft.	1435	.90	1,292	20	65
Roofing	sq. ft.	1760	.25	440	15	30
Refrig. units (2 ton)	each	2	1400.00	2,800	15	186
Electric outlets	each	5	20.00	100	10	10
				17,084		836
Method 4 d/						
Foundation	sq. ft.	1188	1.50	1,782	40	45
Floor	sq. ft.	1188	.67	796	40	20
Wall and ceiling panels	sq. ft.	2052	3.50	7,182	20	359
Steel plate on floor	sq. ft.	972	.90	875	20	44
Roofing	sq. ft.	1386	.25	347	15	23
Refrig. units (2 ton)	each	2	1400.00	2,800	15	186
Electric outlets	each	6	20.00	120	10	12
				13,902		689

Sources: Col. (1), (2): Estimates of floor area were designed to provide adequate space to store cases stacked five high on peak day. Col. (3): Estimates

Appendix Table C-1 (continued)

from construction engineers. Col. (4): Col. (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research reports. Col. (6): Col. (4) divided by Col. (5).

a/ Inside dimensions - 65 feet long by 27 feet wide.
b/ Inside dimensions - 58 feet long by 27 feet wide.
c/ Inside dimensions - 37 feet long by 27 feet wide.
d/ Inside dimensions - 27 feet long by 36 feet wide.

Appendix Table C-2. Annual Building Costs for Plant B, Four Case Handling Methods

Case handling method	Initial cost (dol.)	Annual depreciation (dol.)	Repairs (2%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	31,012	1,593	620	248	326	930	3,717
2	22,603	1,094	452	181	237	678	2,642
3	17,084	836	342	137	179	512	2,006
4	13,902	689	278	111	146	417	1,641

Sources: Col. (1), (2): Appendix Table C-1. Col. (3): Based on experience and research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The exact rate will vary somewhat with plant and location. Col. (5): Equivalent to 2 per cent on undepreciated value. Col. (6): Equivalent to 5 per cent on undepreciated value. Col. (7): Summation of Columns (2) - (6).

Appendix Table C-3. Initial Equipment Costs for Plant B, Four Case Handling Methods

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
Method 1				
Infloor conveyor, straight chain	feet	390	27	10,530
Above floor conveyor, straight chain	feet	232	18	4,176
90° turn, infloor conveyor	each	2	360	720
90° turn, above floor conveyor	each	3	255	765
45° turn, infloor conveyor	each	1	180	180
45° turn, above floor conveyor	each	3	120	360
90° Y junction, infloor conveyor	each	1	450	450
45° Y junction, infloor conveyor	each	2	325	650
90° Y junction, above floor conveyor	each	2	350	700
4 H.P. drive unit	each	5	1,350	6,750
3 H.P. drive unit	each	4	1,250	5,000
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	11	300	3,300
Lubricators	each	11	100	1,100
Traffic controls	each	5	220	1,100
Case unstacker	each	1	3,000	3,000
				39,933
	Installation cost (20%)			7,987
				47,920
			Freight	600
				48,520
Method 2				
Infloor conveyor, straight chain	feet	294	27	7,938
Above floor conveyor, straight chain	feet	232	18	4,176
90° turn, infloor conveyor	each	1	360	360
90° turn, above floor conveyor	each	3	255	765

Appendix Table C-3 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
45^{o} turn, infloor conveyor	each	1	180	180
45^{o} turn, above floor conveyor	each	3	120	360
45^{o} Y junction, infloor	each	2	325	650
90^{o} Y junction, above floor	each	2	350	700
90^{o} Y junction, infloor	each	1	750	750
4 H.P. drive units	each	4	1,350	5,400
3 H.P. drive units	each	5	1,250	6,250
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	8	300	2,400
Lubricators	each	8	100	800
Traffic controls	each	4	220	880
Automatic case unstacker	each	1	3,000	3,000
				35,761
	Installation cost (20%)			7,152
				42,913
			Freight	600
				43,513
Method 3				
Infloor conveyor, straight chain	feet	270	27	7,290
Above floor conveyor, straight chain	feet	232	18	4,176
90^{o} turn, infloor conveyor	each	1	360	360
90^{o} turn, above floor conveyor	each	3	255	765
45^{o} turn, infloor conveyor	each	1	180	180
45^{o} turn, above floor conveyor	each	3	120	360
45^{o} Y junction, infloor	each	2	325	650
90^{o} Y junction, above floor	each	2	350	700
90^{o} YY junction, infloor	each	1	750	750

Appendix Table C-3 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
4 H.P. drive units	each	4	1,350	5,400
3 H.P. drive units	each	4	1,250	5,000
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	8	300	2,400
Lubricators	each	8	100	800
Traffic control	each	5	220	1,100
Automatic case unstacker	each	1	3,000	3,000
				34,083
	Installation cost (20%)			6,817
				40,900
		Freight		600
				41,500
Method 4				
Above floor conveyor, straight chain	feet	505	18	9,090
90^{o} turn	each	5	255	1,275
90^{o} Y junction	each	3	350	1,050
45^{o} turn	each	3	120	360
45^{o} Y junction	each	2	250	500
3 H.P. drive units	each	9	1,250	11,250
Take up units	each	10	300	3,000
Lubricators	each	10	100	1,000
Case pass doors, insulated	each	3	187	561
Case pass doors, uninsulated	each	2	146	292
Case pass frame	each	1	87	87
				28,158
	Installation cost (20%)			5,693
				34,158
		Freight		600
				34,758

Sources: Col. (1), (2): Estimates by sales engineers of several major plant equipment companies. Col. (3): Price lists supplied by dairy plant equipment companies. Col. (4): Col. (2) multiplied by Col. (3).

Appendix Table C-4. Annual Equipment Costs for Plant B, Four Case Handling Methods

Item	Initial price installed (dol.)	Estimated life (years)	Annual depreciation (dol.)	Repairs (4%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Method 1								
Conveyor chain	8,823	5	1,765	353	71	93	265	2,547
Other conveyor equip.	36,097	12	3,008	1,444	289	379	1,084	6,204
Case unstacker	3,600	7	514	144	29	38	108	833
								9,584
Method 2								
Conveyor chain	7,268	5	1,454	291	58	76	218	2,097
Other conveyor equip.	32,645	12	2,722	1,307	261	343	980	5,613
Case unstacker	3,600	7	514	144	29	38	108	833
								8,543
Method 3								
Conveyor chain	6,880	5	1,376	275	55	72	206	1,984
Other conveyor equip.	31,020	12	2,585	1,241	248	326	931	5,331
Case unstacker	3,600	7	514	144	29	38	108	833
								8,148
Method 4								
Conveyor chain	5,454	5	1,091	218	44	57	164	1,574
Other conveyor equip.	29,304	12	2,442	1,172	234	308	879	5,035
								6,609

Sources: Col. (1): Appendix Table C-3. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies, and estimates from milk plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those used in other research studies. Col. (5): Estimated on the basis of data submitted by three North Carolina

Appendix Table C-4 (continued)

plants. Equivalent to 1.6 per cent of undepreciated value. Col. (6): Estimated on the basis of data submitted by three North Carolina plants. Equivalent to 2 per cent on undepreciated value. Col. (7): Equivalent to 5 per cent interest on the average undepreciated balance. Col. (8): Summation of Cols. (3) - (7).

Appendix Table C-5. Labor Costs for Plant B, Four Case Handling Methods

Job Description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Method 1					
Receive major items from conveyor and preform loads	14.1 cases per min. per man	6.19 cases per min. a/	--	1	14
Receive minor items from conveyor and preform loads	6.6 cases per min. per man	5.5 cases per min. a/		1	14
Make up odd items and preform loads	2.25 min./load	--	70 min. c/		
Check loads for accuracy	3 min./ load		90 min. d/		
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	6.36 cases per min. b/		1	12
Check returns from trucks	rtl.-.52 min. per truck whsl.-1.27 min.		9 min. e/ 18 min.		
Supply empty cases to fillers	30 cases per min. per man	11.98 cases per min. a/	--	1/2	6
					46
Method 2					
Receive major items from conveyor and preform loads	14.1 cases per min. per man	6.19 cases per min. a/	--	1	14
Receive minor items from conveyor and preform loads	6.6 cases per min. per man	5.5 cases per min. a/		1	14
Make up odd items and preform loads	2.25 min./load		70 min. c/		

Appendix Table C-5 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Check loads for accuracy	3 min./load		90 min. d/		
Pull preformed loads onto conveyor	23.4 cases per min. per man				
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	6.36 cases per min. b/		1	12
Check returns from truck	rtl.-.52 min. per truck whsl.-1.27 min.		9 min. e/ 18 min.		
Supply empty cases to fillers	30 cases per min. per man	12 cases per min. a/		1/2	6
					46
Method 3					
Receive cases from conveyor and place in storage	14.8 cases per min. per man	12 cases per min. a/		1	12
Make up loads when trucks come in				2	28
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	6.4 cases per min. b/		1	12
Check returns from trucks	rtl.-.52 min. per truck whsl.-1.27 min.		9 min. e/ 18 min. e/		

Appendix Table C-5 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Supply empty cases to fillers	30 cases per min. per man	12 cases per min. a/		1/2	6
					58
Method 4					
Receive cases from conveyor and place in storage	5.85 cases per min. per man	7.5 cases per min. a/		2	24
Make up loads when trucks come in				2	28
Receive empty cases from conveyor and place in storage	9 cases per min. per man	4.8 cases per min. b/		1	12
Check returns from truck	rtl.-.52 min. per truck		9 min. e/		
	whsl.-1.27 min.		18 min. e/		
Supply empty cases to fillers	10 cases per min. per man	7.5 cases per min. a/		1	12
					76

Sources: Col. (1): Appendix Tables A-3, A-4. Col. (2): a/ Based on output rates from two Model Q fillers, 1 Model N filler and 1 Model S filler. b/ Average rate at which cases are returned on heaviest day during unloading hours of 11:00 a.m. and 5:30 p.m. Col. (3): c/ This job performed from 9:00 a.m. until 11:40 a.m. d/ This job performed from 11:40 a.m. until 5:30 p.m. e/ This job performed in conjunction with receiving empty cases. Col. (4): Part time jobs involving 4 hours or less per day were lumped together where the jobs dovetailed in terms of time of performance. Col. (5): Based on wage rates used by two representative milk plants in North Carolina. Actual wage rates were inflated 25 per cent to allow for fringe benefits and replacement labor.

Appendix Table C-6. Cost of Salesman Time for Plant B, Four Case Handling Methods

Type truck	Unload (min.) (1)	Load (min.) (2)	Wait (min.) (3)	Time for each truck (min.) (4)	Total time all trucks (min.) (5)	Total daily cost (dollars) (6)
Method 1						
Retail	5.1	10.1	0	15.2	258	9.03
Whsl.	11.5	13.0	0	24.5	343	13.72
					Total	22.75
Method 2						
Retail	5.1	4.9	1.0	11.0	170	6.20
Whsl.	11.5	8.3	1.0	20.8	291	11.64
					Total	17.84
Method 3a/						
Retail	5.1	4.9	4.9	14.9	253	8.86
Whsl.	11.5	8.3	4.9	24.7	346	13.84
					Total	22.70
Method 4b/						
Retail	3.8	8.4	3.2	15.4	262	9.17
Whsl.	8.1	14.0	3.2	25.3	354	14.16
					Total	23.33

a/ Shipping clerk crew comprised of two loadout men and one checker.
b/ Two loading conveyor spurs are used.

Sources: Col. (1), (2): Methods 1, 2 and 3 are assumed to involve average load sizes of 35 cases for retail trucks and 110 cases for wholesale trucks. Method 4 involves case loads of 26 cases for retail and 76 cases for wholesale. Labor standards are given in Appendix Tables A-3, A-4. Col. (3): Based on the application of queuing theory to known arrival rates and loading times as explained in Appendix B. Col. (4): Summation of Cols. (1) - (3). Col. (5): Col. (4) expanded to allow for 17 retail and 14 wholesale trucks. Col. (6): Based on $.035 per minute for retail drivers and $.04 per minute for wholesale drivers.

Appendix Table C-7. Utilities Cost for Plant B, Four Case Handling Methods

Power item	Total horse-power	Average kilowatt hours per hour	Hours of operation per day	Maximum usage in a 15 min. period (K.W.H.)	Total monthly energy usage (K.W.H.)
	(1)	(2)	(3)	(4)	(5)
Method 1					
Conveyor	32	32.00	12	8	10,016
Refrigeration	12	10.44	24	3	7,621
				11	17,637
			Price	$ 1.20	$ .008
			Cost	$13.20	$141.10
Method 2					
Conveyor	31	31.00	12	7.75	9,703
Refrigeration	6	5.22	24	6.00	3,811
				13.75	13,514
			Price	$ 1.20	$ .008
			Cost	$16.50	$108.11
Method 3					
Conveyor	28	28.00	12	7	8,764
Refrigeration	4	3.48	24	1	2,540
				8	11,304
			Price	$ 1.20	$ .008
			Cost	$ 9.60	$ 90.43
Method 4					
Conveyor	27	27.00	12	6.75	8,451
Refrigeration	4	3.48	24	1.00	2,540
				7.75	10,991
			Price	$ 1.20	$ .008
			Cost	$ 9.30	$ 87.93

Sources on following page.

Appendix Table C-7 (continued)

Sources: Col. (1): Appendix Tables C-1, C-3. Col. (2): Based on 1 K.W.H. per H.P. for conveyor and .87 K.W.H. per H.P. for refrigeration units. Col. (3): Based on plant observation. Col. (4): Col. (1) divided by 4. Col. (5): Based on 12 hours per day, 313 days per year for conveyor, and 24 hours per day, 365 days per year for refrigeration.

Appendix Table D-1. Initial Building Costs for Plant A, Four Case Handling Methods

Item	Unit	No. of units	Price per unit (dol.)	Initial cost (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 1 a/						
Foundation	sq. ft.	1368	1.50	2052	40	51
Floor	sq. ft.	1368	.67	917	40	23
Walls, ceiling	sq. ft.	2464	3.50	8624	20	431
Steel plate on floor	sq. ft.	1368	.90	1231	20	62
Doors	each	4	250.00	1000	20	50
Roofing	sq. ft.	1440	.25	360	15	24
Refrig. units(3 ton)	each	3	1625.00	4875	15	325
Electric outlets	each	6	20.00	120	10	12
				19,179		978
Method 2 b/						
Foundation	sq. ft.	1330	1.50	1995	40	50
Floor	sq. ft.	1330	.67	891	40	22
Walls, ceiling	sq. ft.	2382	3.50	8337	20	417
Steel plate on floor	sq. ft.	1330	.90	1197	20	60
Roofing	sq. ft.	1440	.25	360	15	24
Refrig. units (2 ton)	each	2	1400.00	2800	15	187
Electric outlets	each	4	20.00	80	10	8
				15,660		768
Method 3 c/						
Foundation	sq. ft.	840	1.50	1260	40	31
Floor	sq. ft.	840	.67	563	40	14
Walls, ceiling	sq. ft.	1668	3.50	5838	20	292
Steel plate on floor	sq. ft.	840	.90	756	20	38
Roofing	sq. ft.	980	.25	245	15	16
Refrig. units (2 ton)	each	2	1400.00	2800	15	187
Electric outlets	each	4	20.00	80	10	8
				11,542		586

Appendix Table D-1 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Initial cost (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 4 d/						
Foundation	sq. ft.	729	1.50	1094	90	27
Floor	sq. ft.	729	.67	488	40	12
Walls, ceiling	sq. ft.	1668	3.50	5838	20	292
Steel plate on floor	sq. ft.	540	.90	486	20	24
Roofing	sq. ft.	945	.25	236	15	16
Refrig. units (2 ton)	each	2	1400.00	2800	15	187
Electric outlets	each	4	20.00	80	10	8
				11,022		566

a/ Inside dimensions 36 feet long by 27 feet wide.
b/ Inside dimensions 34 feet long by 27 feet wide.
c/ Inside dimensions 20 feet long by 27 feet wide.
d/ Inside dimensions 20 feet long by 27 feet wide.

Sources: Col. (1), (2): Estimates of floor area were designed to provide adequate space to store cases stacked five high on peak day. Col. (3): Estimates from construction engineers. Col. (4): Col. (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research reports. Col. (6): Col. (4) divided by Col. (5).

Appendix Table D-2. Annual Building Costs for Plant A, Four Case Handling Methods

Case handling method	Initial cost (dol.)	Annual depreciation (dol.)	Repairs (2%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	19,179	978	384	153	201	575	2,291
2	15,660	768	313	125	164	470	1,840
3	11,542	586	230	92	121	346	1,375
4	11,022	566	220	88	116	331	1,321

Sources: Col. (1), (2): Appendix Table D-1. Col. (3): Based on experience and other research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The exact rate will vary somewhat with plant and location. Col. (5): Equivalent to 2 per cent on undepreciated value. Col. (6): Equivalent to 5 per cent on undepreciated value. Col. (7): Summary of columns (2) - (6).

Appendix Table D-3. Initial Equipment **Costs** for Plant A, Four Case Handling Methods

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
Method 1				
Infloor conveyor, straight chain	feet	240	27	6,480
Above floor conveyor, straight chain	feet	186	18	3,348
90^o turns, infloor conveyor	each	2	360	720
90^o turns, above floor conveyor	each	3	255	765
45^o turns, infloor conveyor	each	1	180	180
45^o turns, above floor conveyor	each	2	12	240
90^o Y junction, infloor conveyor	each	1	450	450
45^o Y junction, infloor conveyor	each	1	325	325
90^o Y junction, above floor conveyor	each	1	350	350
5 H.P. drive unit	each	3	1,500	4,500
3 H.P. drive unit	each	2	1,250	2,500
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	7	300	2,100
Lubricators	each	7	100	700
Traffic controls	each	2	220	440
Case unstacker	each	1	3,000	3,000
				27,250
		Installation cost (20%)		5,450
				32,700
		Freight		500
				33,200
Method 2				
Infloor conveyor, straight chain	feet	188	27	5,076
Above floor conveyor, straight chain	feet	186	18	3,348
90^o turn, infloor	each	2	360	720
90^o turn, above floor	each	3	255	765

Appendix Table D-3 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
45° turn, infloor	each	1	180	180
45° turn, above floor	each	2	120	240
45° Y junction	each	1	325	325
90° Y junction, above floor	each	1	350	350
5 H.P. drive units	each	3	1,500	4,500
3 H.P. drive units	each	1	1,250	1,250
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	6	300	1,800
Lubricators	each	6	100	600
Traffic controls	each	2	220	440
Case unstacker	each	1	3,000	3,000
				23,746
		Installation cost (20%)		4,749
				28,495
		Freight		500
				28,995
Method 3				
Infloor conveyor, straight chain	feet	144	27	3,888
Above floor conveyor, straight chain	feet	186	18	3,348
90° turn, infloor conveyor	each	2	360	720
90° turn, above floor conveyor	each	3	255	765
45° turn, infloor conveyor	each	1	180	180
45° turn, above floor conveyor	each	2	120	240
45° Y junction, infloor conveyor	each	1	325	325
90° Y junction, above floor	each	1	350	350
5 H.P. drive unit	each	2	1,500	3,000
3.H.P. drive unit	each	2	1,250	2,500

Appendix Table D-3 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	5	300	1,500
Lubricators	each	5	100	500
Traffic controls	each	2	220	440
Case unstacker	each	1	3,000	3,000
				21,908
		Installation cost (20%)		4,382
				26,290
		Freight		500
				26,790
Method 4				
Above floor conveyor, straight chain	feet	296	18	5,328
90^{o} turns, above floor conveyor	each	4	255	1,420
45^{o} turn, above floor conveyor	each	3	120	360
45^{o} Y junction, above floor	each	1	250	250
90^{o} Y junction, above floor	each	1	350	350
3 H.P. drive unit	each	5	1,250	6,250
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	5	300	1,500
Lubricators	each	5	100	500
Traffic controls	each	2	220	440
				17,550
		Installation cost (20%)		3,510
				21,060
		Freight		500
				21,560

Sources: Col. (1), (2): Estimates by sales engineers of several major plant equipment companies. Col. (3): Price lists supplied by dairy plant equipment companies. Col. (4): Col. (2) multiplied by Col. (3).

Appendix Table D-4. Annual Equipment Cost for Plant A, Four Case Handling Methods

Item	Initial price installed (dol.)	Estimated life (years)	Annual depreciation (dol.)	Repairs (4%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Method 1								
Conveyor chain	5,897	5	1,180	236	47	62	177	1,702
Other conveyor equip.	23,703	12	1,975	948	190	249	711	4,073
Case unstacker	3,600	7	514	144	29	38	108	833
								6,608
Method 2								
Conveyor chain	5,052	5	1,011	202	40	53	152	1,458
Other conveyor equip.	20,343	12	1,695	814	163	214	610	3,496
Case unstacker	3,600	7	514	144	29	38	108	833
								5,787
Method 3								
Conveyor chain	4,341	5	868	174	35	46	130	1,253
Other conveyor equip.	18,849	12	1,571	754	151	198	565	3,239
Case unstacker	3,600	7	514	144	29	38	108	833
								5,325
Method 4								
Conveyor chain	3,197	5	639	128	26	34	96	923
Other conveyor equip.	18,363	12	1,530	735	147	193	551	3,156
								4,079

Sources: Col. (1): Appendix Table D-3. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies, and estimates from milk plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those used in other research studies. Col. (5): Estimated on the basis of data submitted by three North Carolina plants. Equivalent to 1.6 per cent of undepreciated value. Col. (6): Estimated on the basis of data submitted by three North Carolina plants. Equivalent to 2 per cent on undepreciated value. Col. (7): Equivalent to 5 per cent interest on the average undepreciated balance. Col. (8): Summation of Columns (3) - (7).

Appendix Table D-5. Labor Costs for Plant A, Four Case Handling Methods

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Method 1					
Receive major items from conveyor and preform loads	14.1 cases per min. per man				
Receive minor items from conveyor and preform loads		6.5 cases per min. a/ (total major and minor)		1	14
Make up odd items and preform loads	2.25 min. per load		36 minutes c/		
Check loads for accuracy	3 min./load		48 minutes d/		
Receive empty cases from conveyor and place in storage	14.7 cases per min.	6 cases per min. b/		1	12
Supply empty cases to fillers	30 cases per min.	6.5 cases per min.		1/2	6
					32
Method 2					
Receive major items from conveyor and preform loads	14.1 cases per min. per man	6.5 cases per min. a/ (total major and minor)		1	14
Receive minor items from conveyor and preform loads	6.6 cases per min. per man				
Make up odd items and preform loads	2.25 min./load		36 minutes c/		
Check loads for accuracy	3 min./load		48 minutes d/		

Appendix Table D-5 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Pull preformed loads onto conveyor	23.4 cases per min. per man		64 minutes	1	12
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	6 cases per min. b/			
Supply empty cases to fillers	30 cases per min. per man	6.5 cases per min. a/		1/2	6
					32
Method 3					
Receive cases from conveyor and place in storage	14.1 cases per min. per man	6.5 cases per min. a/		1	12
Make up loads when trucks come in				1	14
Receive empty cases from conveyor and place in storage	14.7 cases per min.	6 cases per min. b/		1	12
Supply empty cases to fillers	30 cases per min. per man	6.5 cases per min. a/		1/2	6
					44
Method 4					
Receive cases from conveyor and place in storage	5.85 cases per min. per man	4.84 cases per min. a/		1	12
Make up loads when trucks come in				1	14

Appendix Table D-5 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Receive empty cases from conveyor and place in storage	9 cases per min. per man	5 cases per min. b/		1	12
Supply empty cases to fillers	10 cases per min. per man	4.84 cases per min. a/		1	12
					50

Sources: Col. (1): Appendix Tables D-3, D-4. Col. (2): a/ Based on output rates from two Model Q fillers, one Model N filler and one Model S filler. b/ Average rate at which cases are returned on heaviest day during unloading hours of 11:00 a.m. and 5:30 p.m. Col. (3): c/ This job performed from 9:00 a.m. until 11:40 a.m. d/ This job performed from 11:40 a.m. until 5:30 p.m. e/ This job performed in conjunction with receiving empty cases. Col. (4): Part-time jobs involving 4 hours or less per day were lumped together where the jobs dovetailed in terms of time of performance. Col. (5): Based on wage rates used by two representative milk plants in North Carolina. Actual wage rates were inflated 25 per cent to allow for fringe benefits and replacement labor.

Appendix Table D-6. Cost of Salesman Time for Plant A, Four Case Handling Methods

Type truck	Unload (min.)	Load (min.)	Wait (min.)	Time for each truck (min.)	Total time all trucks (min.)	Total daily cost (dollars)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 1						
Retail	5.1	10.1	0	15.6	140	4.90
Whsl.	11.5	13.0	0	24.5	172	6.88
					Total	11.78
Method 2						
Retail	5.1	4.9	0	10.0	90	3.15
Whsl.	11.5	8.3	0	19.8	138.6	5.54
					Total	8.69
Method 3a/						
Retail	5.1	4.9	5	15.0	135	4.73
Whsl.	11.5	8.3	5	24.8	174	6.96
					Total	11.69
Method 4b/						
Retail	3.8	8.4	5	17.2	155	5.43
Whsl.	8.1	14.0	5	27.1	190	7.60
					Total	13.03

a/ One man loading out.
b/ One loading conveyor.

Sources: Col. (1), (2): Methods 1, 2 and 3 are assumed to involve average load sizes of 35 cases for retail trucks and 110 cases for wholesale trucks. Method 4 involves case loads of 26 cases for retail and 76 cases for wholesale. Labor standards are given in Appendix Tables D-3, D-4. Col. (3): Based on the application of queuing theory to known arrival rates and loading times as explained in Appendix B. Col. (4): Summation of Columns (1) - (3). Col. (5): Col. (4) expanded to allow for 9 retail trucks and 7 wholesale trucks. Col. (6): Based on $ .035 per minute for retail drivers and $ .04 per minute for wholesale drivers.

Appendix Table D-7. Utilities Cost for Plant A, Four Case Handling Methods

Power item	Total horse-power	Average kilowatt hours per hour	Hours of operation per day	Maximum usage in a 15 min. period (K.W.H.)	Total monthly energy usage (K.W.H.)
	(1)	(2)	(3)	(4)	(5)
Method 1					
Conveyor	21	21.00	12	5.25	6,573
Refrigeration	9	7.83	24	2.25	5,716
				7.50	12,289 K.W.H.
			Price	$ 1.20	$ .008
			Cost	$ 9.00	$ 98.31
Method 2					
Conveyor	18	18.00	12	4.5	5,634
Refrigeration	4	3.48	24	.87	2,540
				5.37	8,174 K.W.H.
			Price	$ 1.20	$ .008
			Cost	$ 6.47	$ 65.39
Method 3					
Conveyor	16	16.00	12	4.00	5,008
Refrigeration	4	3.48	24	.87	2,540
				4.87	7,548 K.W.H.
			Price	$ 1.20	$ .008
			Cost	$ 5.84	$ 60.38
Method 4					
Conveyor	15	15.00	12	3.75	4,695
Refrigeration	4	3.48	24	1.00	2,540
				4.75	7,235 K.W.H.
			Price	$ 1.20	$ .008
			Cost	$ 5.70	$ 57.88

Sources: Col. (1): Appendix Tables D-1, D-3. Col. (2): Based on one K.W.H. per H.P. for conveyor and .87 K.W.H. per H.P. for refrigeration units. Col. (3): Based on plant observation. Col. (4): Col. (1) divided by 4. Col. (5): Based on 12 hours per day, 313 days per year for conveyor, and 24 hours per day, 365 days per year for refrigeration.

Appendix Table E-1. Initial Building Costs for Plant D, Four Case Handling Methods

Item	Unit	No. of units	Price per unit (dol.)	Initial cost (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 1 a/						
Foundation	sq. ft.	5460	1.50	8190	40	205
Floor	sq. ft.	5460	.67	3658	40	91
Walls, ceiling	sq. ft.	8808	3.50	30,828	20	1,541
Steel plate on floor	sq. ft.	5460	.90	4914	20	246
Roofing	sq. ft.	6600	.25	1650	15	110
Indiv. loading doors	each	14	250.00	3500	20	175
Refrig. units (4 ton)	each	10	1625.00	16,250	15	1,083
Electric outlets	each	20	20.00	400	10	40
				69,390		3,491
Method 2 b/						
Foundation	sq. ft.	5390	1.50	8085	40	202
Floor	sq. ft.	5390	.67	3611	40	90
Walls, ceiling	sq. ft.	8298	3.50	29,043	20	1,452
Steel plate on floor	sq. ft.	5390	.90	4851	20	242
Roofing	sq. ft.	6160	.25	1540	15	103
Refrig. units (4 ton)	each	4	1625.00	7500	15	500
Electric outlets	each	12	20.00	240	10	24
				54,870		2,613
Method 3 c/						
Foundation	sq. ft.	4515	1.50	6773	40	169
Floor	sq. ft.	4515	.67	3025	40	76
Walls, ceiling	sq. ft.	6375	3.50	22,313	20	1,116
Steel plate on floor	sq. ft.	4515	.90	4064	20	203
Roofing	sq. ft.	5200	.25	1300	15	90
Refrig. units (4 ton)	each	4	1625.00	7500	15	500
Electric outlets	each	12	20.00	240	10	24
				45,215		2,178

Appendix Table E-1 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Initial cost (dol.)	Est. useful life (years)	Annual deprec. (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 4 d/						
Foundation	sq. ft.	5016	1.50	7524	40	188
Floor	sq. ft.	5016	.67	3361	40	84
Walls, ceiling	sq. ft.	7848	3.50	27,468	20	1,373
Steel plate on floor	sq. ft.	4560	.90	4104	20	205
Roofing	sq. ft.	5600	.25	1400	15	93
Refrig. units (4 ton)	each	4	1625.00	7500	15	500
Electric outlets	each	12	20.00	240	10	24
				51,597		2,467

a/ Inside dimensions 160 feet long by 27 feet wide.
b/ Inside dimensions 150 feet long by 27 feet wide.
c/ Inside dimensions 125 feet long by 27 feet wide.
d/ Inside dimensions 80 feet long by 57 feet wide.

Sources: Col. (1), (2): Estimates of floor area were designed to provide adequate space to store cases stacked five high on peak day. Col. (3): Estimates from construction engineers. Col. (4): Col. (2) multiplied by Col. (3). Col. (5): Bulletin F, United States Internal Revenue Service, and other research reports. Col. (6): Col. (4) divided by Col. (5).

Appendix Table E-2. Annual Building Costs for Plant D, Four Case Handling Methods

Case handling method	Initial cost (dol.)	Annual depreciation (dol.)	Repairs (2%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	69,390	3,491	1,388	555	729	2,082	8,245
2	54,870	2,613	1,097	439	576	1,646	6,371
3	45,215	2,178	904	362	475	1,356	5,275
4	51,597	2,467	1,032	413	542	1,548	6,002

Sources: Col. (1), (2): Appendix Table E-1. Col. (3): Based on experience and other research studies. Col. (4): Equivalent to 1.6 per cent of undepreciated value. Based on full coverage. The exact rate will vary somewhat with plant and location. Col. (5): Equivalent to 2 per cent on undepreciated value. Col. (6): Equivalent to 5 per cent on undepreciated value. Col. (7): Summation of Columns (2) - (6).

Appendix Table E-3. Initial Equipment Costs for Plant D, Four Case Handling Methods

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
Method 1				
Infloor conveyor, straight chain	feet	723	27	19,521
Above floor conveyor, straight chain	feet	470	18	8,460
90° turn, infloor conveyor	each	2	360	720
90° turn, above floor conveyor	each	3	255	765
45° turns, infloor conveyor	each	1	180	180
45° turns, above floor conveyor	each	7	120	840
90° Y junction, infloor conveyor	each	1	450	450
90° double Y junction, infloor	each	1	750	750
45° Y junction, infloor	each	6	325	1,950
90° Y junction, above floor	each	6	350	2,100
7 1/2 H.P. drive units	each	3	1,750	5,250
5 H.P. drive units	each	3	1,500	4,500
3 H.P. drive units	each	8	1,250	10,000
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	18	300	5,400
Lubricators	each	18	100	1,800
Traffic controls	each	13	220	2,860
Case unstacker	each	1	3,000	3,000
				69,698
		Installation cost (20%)		13,939
				83,637
		Freight		1,000
				84,637
Method 2				
Infloor conveyor, straight chain	feet	581	27	15,687
Above floor conveyor, straight chain	feet	470	18	8,460
90° turn, infloor conveyor	each	2	360	720
90° turn, above floor conveyor	each	3	255	765

Appendix Table E-3 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
45^o turn, infloor conveyor	each	1	180	180
45^o turn, above floor conveyor	each	7	120	840
90^o Y junction, above floor conveyor	each	6	450	2,700
45^o Y junction, infloor conveyor	each	6	325	1,950
7 1/2 H.P. drive units	each	2	1,750	3,500
5 H.P. drive units	each	2	1,500	3,000
3 H.P. drive units	each	8	1,250	10,000
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	16	300	4,800
Lubricators	each	16	100	1,600
Traffic controls	each	12	220	2,640
Case unstacker	each	1	3,000	3,000
				60,994
	Installation cost (20%)			12,199
				73,193
	Freight			1,000
				74,193
Method 3				
Infloor conveyor, straight chain	feet	571	27	14,337
Above floor conveyor, straight chain	feet	470	18	8,460
90^o turn, infloor conveyor	each	2	360	720
90^o turn, above floor conveyor	each	3	255	765
45^o turn, infloor conveyor	each	1	180	180
45^o turn, above floor conveyor	each	7	120	840
90^o Y junction, above floor	each	6	450	2,700
90^o double Y junction	each	1	750	750
45^o Y junction, infloor	each	6	325	1,950
7 1/2 H.P. drive units	each	2	1,750	3,500

Appendix Table E-3 (continued)

Item	Unit	No. of units	Price per unit (dol.)	Total costs (dol.)
	(1)	(2)	(3)	(4)
5 H.P. drive units	each	2	1,500	3,000
3 H.P. drive units	each	8	1,250	10,000
Case pass doors, insulated	each	2	336	672
Case pass doors, uninsulated	each	2	240	480
Take up units	each	16	300	4,800
Lubricators	each	16	100	1,600
Traffic controls	each	12	220	2,640
Unstacker	each	1	3,000	3,000
				60,394
		Installation cost (20%)		12,079
				72,473
		Freight		1,000
				73,473
Method 4				
Above floor conveyor, straight chain	feet	1,277	18	22,986
90^{o} turns, above floor conveyor	each	9	255	2,295
90^{o} junctions, above floor conveyor	each	6	350	2,100
45^{o} junctions, above floor conveyor	each	4	250	1,000
45^{o} turns, above floor conveyor	each	8	120	960
3 H.P. drive units	each	20	1,250	25,000
Take up units	each	20	300	6,000
Lubricators	each	20	100	2,000
Traffic controls	each	11	220	2,420
Case pass doors, insulated	each	4	336	1,344
Case pass doors, uninsulated	each	4	240	960
				67,065
		Installation cost (20%)		13,413
				80,478
		Freight		1,000
				81,478

Sources: Col. (1), (2): Estimates by sales engineers of several major plant equipment companies. Col. (3): Price lists supplied by dairy plant equipment companies. Col. (4): Col. (2) multiplied by Col. (3).

Appendix Table E-4. Annual Equipment Costs for Plant D, Four Case Handling Methods

Item	Initial price installed (dol.)	Estimated life (years)	Annual depreciation (dol.)	Repairs (4%) (dol.)	Insurance (.8%) (dol.)	Taxes (1.05%) (dol.)	Interest (3%) (dol.)	Total annual costs (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Method 1								
Conveyor chain	16,789	5	3,358	672	134	176	504	4,844
Other conveyor equip.	64,248	12	5,352	2,570	514	675	1,927	11,038
Case unstacker	3,600	7	514	144	29	38	108	833
								16,715
Method 2								
Conveyor chain	14,488	5	2,898	580	116	152	434	4,180
Other conveyor equip.	56,105	12	4,675	2,244	449	589	1,683	9,640
Case unstacker	3,600	7	514	144	29	38	108	833
								14,653
Method 3								
Conveyor chain	13,679	5	2,736	547	109	144	410	3,946
Other conveyor equip.	56,194	12	4,683	2,248	450	590	1,686	9,657
Case unstacker	3,600	7	514	144	29	38	108	833
								14,436
Method 4								
Conveyor chain	13,791	5	2,758	552	110	145	414	3,979
Other conveyor equip.	67,687	12	5,641	2,707	541	711	2,031	11,631
								15,610

Sources: Col. (1): Appendix Table E-3. Col. (2): Schedule F, United States Internal Revenue Service, estimates from other research studies, and estimates from milk plant equipment manufacturers. Col. (3): Col. (1) divided by Col. (2). Col. (4): Rates are comparable to those used in other research studies. Col. (5): Estimated on the basis of data submitted by three North Carolina plants. Equivalent to 1.6 per cent of undepreciated value. Col. (6): Estimated on the basis of data submitted by three North Carolina plants. Equivalent to 2 per cent on undepreciated value. Col. (7): Equivalent to 5 per cent interest on the average undepreciated balance. Col. (8): Summation of Columns (3) - (7).

Appendix Table E-5. Labor Costs for Plant D, Four Case Handling Methods

Job Description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Method 1					
Receive major items from conveyor and preform loads	14.1 cases per man per min.	23.8 cases per min. a/	--	2	28
Receive minor items from conveyor and preform loads	6.6 cases per min. per man	9.9 cases per min. a/	--	2	28
Make up odd items and preform loads	2.25 min./load		158 min. c/	1	12
Check loads for accuracy	3 min./load		210 min. d/		
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	31 cases per min. b/			
Check returns from trucks	rtl.-.52 min. per truck whsl.-1.27 min.		23 min. e/ 23 min. e/	2	24
Supply empty cases to fillers	30 cases per min. per man	33.9 cases per min. a/		2	24
					116
Method 2					
Receive major items from conveyor and preform loads	14.1 cases per min. per man	23.8 cases per min. a/		2	28
Receive minor items from conveyor and preform loads	6.6 cases per min. per man	9.4 cases per min. a/		2	28
Make up odd items and preform loads	2.25 min./load		158 min. c/		

Appendix Table E-5 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Check loads for accuracy	3 min./load		210 min. d/	1	12
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	31 cases per min. b/		2	24
Check returns from trucks	rtl.-.52 min. per truck whsl.-1.27 min.		23 min. e/ 23 min. e/		
Supply empty cases to fillers	30 cases per min.	33.9 cases per min. a/		2	24
Pull preformed loads onto conveyor	23.4 cases per min. per man	23.4 cases per min.		1	12
					128
Method 3					
Receive cases from conveyor and place in storage	14.1 cases per min. per man	33.9 cases per min. a/		3	36
Make up loads when trucks come in				3	42
Check loads for accuracy				1	14
Receive empty cases from conveyor and place in storage	14.7 cases per min. per man	31 cases per min. b/		2	24
Check returns from trucks	rtl.-.52 min. per truck whsl.-1.27 min.		23 min. e/ 23 min. e/		
Supply empty cases to fillers	30 cases per min. per man	33.9 cases per min. a/		2	24
					140

Appendix Table E-5 (continued)

Job description	Time standard	Maximum rate required	Total work required per day	No. of men required	Daily labor cost (dol.)
	(1)	(2)	(3)	(4)	(5)
Method 4					
Receive cases from conveyor and place in storage	5.85 cases per min. per man	33.9 cases per min. a/		6	72
Make up loads when trucks come in				3	42
Receive empty cases from conveyor and place in storage	9 cases per min. per man	31 cases per min. b/		3 1/2	42
Check returns from trucks	rtl.-.52 min. per truck whsl.-1.27 min.		23 min. e/ 23 min. e/		
Supply empty cases to fillers	10 cases per min. per man	33.9 cases per min. a/		3	36
					192

Sources: Col. (1): Appendix Tables E-3, E-4. Col. (2): a/ Based on output rates from two Model Q fillers, one Model N filler and one Model 5 filler. b/ Average rate at which cases are returned on heaviest day during unloading hours of 11:00 a.m. and 5:30 p.m. Col. (3): c/ This job performed from 9:00 a.m. until 11:40 a.m. d/ This job performed from 11:40 a.m. until 5:30 p.m. e/ This job performed in conjunction with receiving empty cases. Col. (4): Part-time jobs involving 4 hours or less per day were lumped together where the jobs dovetailed in terms of time of performance. Col. (5): Based on wage rates used by two representative milk plants in North Carolina. Actual wage rates were inflated 25 per cent to allow for fringe benefits and replacement labor.

Appendix Table E-6. Cost of Salesman Time for Plant D, Four Case Handling Methods

Type truck	Unload (min.)	Load (min.)	Wait (min.)	Time for each truck (min.)	Total time all trucks (min.)	Total daily cost (dol.)
	(1)	(2)	(3)	(4)	(5)	(6)
Method 1						
Retail	5.1	10.10	0	15.2	669	23.42
Whsl.	11.5	12.98	0	24.5	539	21.56
					Total	44.98
Method 2						
Retail	5.1	4.9	2.1	12.1	532	18.62
Whsl.	11.5	8.3	1.0	20.8	541	21.64
					Total	40.26
Method 3						
Retail	5.1	4.9	3.0	13	572	20.02
Whsl.	11.5	8.3	1.6	21.4	556	22.24
					Total	42.26
Method 4						
Retail	3.8	8.4	5.3	17.5	770	26.95
Whsl.	8.1	14.0	3.0	25.1	653	26.12
					Total	53.07

Sources: Col. (1), (2): Methods 1, 2 and 3 are assumed to involve average load sizes of 35 cases for retail trucks and 110 cases for wholesale trucks. Method 4 involves case loads of 26 cases for retail and 76 cases for wholesale. Labor standards are given in Appendix Tables E-3, E-4. Col. (3): Based on the application of queuing theory to known arrival rates and loading times as explained in Appendix B. Col. (4): Summation of Columns (1) - (3). Col. (5): Col. (4) expanded to allow for 44 retail trucks and 26 wholesale trucks. Col. (6): Based on $ .035 per minute for retail drivers and $ .04 per minute for wholesale drivers.

Appendix Table E-7. Utilities Cost for Plant B, Four Case Handling Methods

Power item	Total horse-power	Average kilowatt hours per hour	Hours of operation per day	Maximum usage in a 15 min. period (K.W.H.)	Total monthly energy usage (K.W.H.)
	(1)	(2)	(3)	(4)	(5)
Method 1					
Conveyor	61.5	61.5	12	15.4	19,250
Refrigeration	40.0	34.8	24	10.0	25,404
				25.4	44,654
			Price	$ 1.10	$ .007
			Cost	$ 27.94	$ 312.58
Method 2					
Conveyor	49.0	49.0	12	12.25	15,337
Refrigeration	12.0	10.44	24	3.00	7,621
				15.25	22,958
			Price	$ 1.10	$ .007
			Cost	$ 16.78	$ 160.85
Method 3					
Conveyor	49.0	49.0	12	12.25	15,337
Refrigeration	12.0	10.44	24	3.00	7,621
				15.25	22,958
			Price	$ 1.10	$ .007
			Cost	$ 16.78	$ 160.85
Method 4					
Conveyor	60.0	60.0	12	15.0	18,780
Refrigeration	16.0	13.9	24	4.0	10,147
				19.0	28,927
			Price	$ 1.10	$ .007
			Cost	$ 20.90	$ 202.49

Sources on following page.

Appendix Table E-7 (continued)

Sources: Col. (1): Appendix Tables E-1, E-3. Col. (2): Based on one K.W.H. per H.P. for conveyor and .87 K.W.H. per H.P. for refrigeration. Col. (3): Based on plant observation. Col. (4): Col. (1) divided by 4. Col. (5): Based on 12 hours per day, 313 days per year for conveyor, and 24 hours per day, 365 days per year for refrigeration.

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