ANALYTICAL PROBLEM SOLVING APPROACH TO LAYOUT DESIGN OF AN INGREDIENT ROOM

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ABSTRACT

ANALYTICAL PROBLEM SOLVING APPROACH TO
LAYOUT DESIGN OF AN INGREDIENT ROOM

By

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The purpose of this study was to develop an ingredient room layout in the form of a construction algorithm for the Dietetics Department of University Hospital, Ann Arbor, Michigan. The systematic, logical plan for analyses of functions and elements of the systems as well as subsystems was completed through the development of a form of a PERT network diagram. The network diagram included identification of materials (ingredients) and detailed analyses of their volume, routing, environment and processing time to determine equipment and space requirements.

Industrial engineering principles were applied to eliminate unnecessary activities, combine like activities and develop simplified processes. Other analytical techniques included time study and travel charting as a quantitative measure for minimization of materials flow. To maintain food quality, hourly deliveries were scheduled from the ingredient room to production areas as materials were needed for production; also, principles of food science and sanitation were incorporated into developed procedures. Flexibility was incorporated by

selection of portable equipment whenever possible as well as equipment to perform diversified processes. Integration of all facets of the Dietetics Department was considered. Samples of all forms developed for the study are included along with examples of the analyses.

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By

Patricia J. Sayed

A PROBLEM

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To my parents, family and the world

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INTRODUCTION

Mass production in industry has been accomplished through scientifically designed plant layouts and equipment thereby permitting effective use of men, materials and machines. However, application of similar scientific industrial engineering principles, techniques and/or analytical tools has penetrated food service systems layout planning only to a limited extent (32, 35, 42, 56). Scarcity of skilled personnel and high labor costs emphasize the urgent need for investigating different organizational methods and systems and hence, application to layouts for food service (14, 20, 22, 35, 53). The ingredient room concept has been suggested as a means of "fighting spiraling costs" (14, 15, 16, 17, 21, 22, 34).

The ingredient room concept involves a separate room or area for pre-preparative procedures such as weighing, measuring, cleaning, chopping, slicing, and peeling of ingredients for all recipes. The ingredients are then issued to the production area(s) by recipe and preparation time. Such centralization of pre-preparative procedures decreases the amount of time a cook must spend in performing tasks such as transporting food items and utensils to and from the work area thereby freeing his time for tasks commensurate with his skills. Along with increased efficiency in the utilization of skilled personnel and equipment, the ingredient room concept could improve product quality by controlling ingredient amounts and preparation times (22).

Basic to plant layout and design is the utilization of a systematic logical plan for analysis of functions and elements of a work system. Suggested guides developed by industrial engineers (44, 46) and adaptations of these guides to food service (22, 30, 33, 35, 36, 42, 53) are numerous. Through analysis of systems, digital computer simulation has been used as a technique for effective study of cafeteria serving lines (32), dining room seating capacity (31), and other aspects of cafeterias (47). A mathematical technique has been developed for quantitatively determining seating requirements for the dining area of a cafeteria (28). Working with a part of a more complex system, computer programs have been developed for quantitatively determining and evaluating maximum effectiveness of layouts (2, 6, 8, 38). To provide needed information for study of complex systems, time study techniques have also been utilized (4, 11, 19, 25, 26, 41, 46, 50, 51). Collectively or individually, these techniques have not been utilized in planning ingredient room layouts according to available literature.

It was the purpose of this study to demonstrate the application of selected industrial engineering principles and analytical techniques to the development of an ingredient room in the form of a construction algorithm for the Dietetics Department of University Hospital, Ann Arbor, Michigan. A systematic outline of the essential steps in planning an ingredient room was developed following analytical techniques and then, utilizing engineering principles for determining the required equipment and space, a layout was planned.

Because management involvement in the development of a layout is critical to the effectiveness in actual operation, specific objectives were obtained by interviewing management. These were

- minimize storage and trash within production areas,
- minimize materials flow and handling within and beyond the ingredient room,
- maximize efficiency within work areas,
- maintain and/or improve food quality,
- build flexibility within work areas,
- integrate all facets of the facility,
- reduce labor costs by minimizing routine tasks of skilled employees, and
- plan for eventual use of computer time within the Dietetics Department.

REVIEW OF LITERATURE

Ingredient Room Concept

The application of a centralized materials handling concept to issuing and handling of raw materials from storeroom to preparation area is a current trend in food service systems analysis (1, 20, 34). However, only limited reports appear in the literature concerning this concept (14, 15, 16, 17, 21, 22). According to reports in the literature and personal communications (7, 37, 39), most operators indicated improved efficiency with centralized distribution of ingredients to production areas.

Heinemeyer *et al*. (22) compared, in terms of labor time and cost, centralized and conventional methods of food production materials handling in a hospital setting. From their study, they concluded a central ingredient unit could lead to more effective use of manpower resources on the management level as well as for employees.

Industrial Engineering Principles

The systematic approach to layout of industrial facilities developed by Muther (44) has been supported by Montag *et al*. (42) for application to planning and design of kitchen layouts. This approach begins with a detailed analysis identifying two basic elements, materials (products) to be processed and quantities (volume). Routing sequence of materials is explored within their environment and related or supporting services are investigated. These elements are considered in the realm of time. Although accumulation of this information is laborious, the final layout represents a design for those materials being processed rather then non-existing materials assumed to be processed. Furthermore, an analytical definition of procedures, in lieu of established guidelines, enables provision of space for specified products and volume; hence, only equipment required to change or modify known materials is needed. Finally, the equipment requirements are subsequently arranged in an optimized sequence of materials flow.

For realization of an optimal design, certain principles and techniques have been developed and successfully utilized in industry. A compilation of the principles of work analysis and design have been specified by Kazarian (30). These include listings of the principles of work analysis, systems design, layout, materials handling and motion economy. Also considered are principles of human engineering and safety.

Industrial Engineering Analysis Techniques

Network Analysis

Network analysis is a management tool developed in industrial engineering for defining and coordinating a complex set of events, activities, and relationships to successfully accomplish objectives of a project. By using a network diagram, a series of operations which must follow in logical sequence are clearly displayed to management.

Events, or significant points in a project, are represented by geometric figures such as circles or squares, while activities, or performance of the tasks, are indicated by arrows as illustrated in Figure 1.

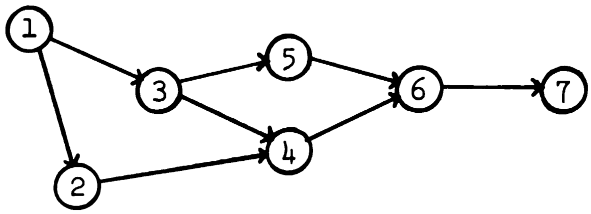

Figure 1. A simplified network diagram.

Listed and numbered in their logical sequence for completion of the objective, events indicate the start or completion of a task. In contrast, activities involve the actual performance of the task; hence, activities require manpower, materials, space, facilities or other resources. Together, events and activities in the network depict definite sequential relationships between and among the basic tasks involved in the program since no event can be reached before the activity immediately preceding it has been completed. Upon completion of the network diagram, time as well as cost for performance of each activity can be calculated.

According to reports, network analysis provides management with a means for specifying how planning is to be done as well as for follow-up to see that it actually has been done and an approach for keeping planning up to date as work is accomplished or as conditions change (12, 13, 48). Further, network analysis permits management to foresee the impact of deviations from the plan and to take corrective action in anticipation rather than after the fact (12).

Network analysis technique is used by engineering managers in construction, product manufacture, military and naval contracting, plant engineering, product and plant design, and many other sequential-type activities requiring careful planning, control, and review (23).

Analysis of a Work System

Within the complex set of events so developed through network analysis, objectives or functions must be identified (30, 46). Functions may be identified for a whole system, but because the whole system may be comprised of many or few subsystems, subfunctions must also be pin-pointed (46). As illustrated by Nadler (46), the highest system level frequently has functions stated in terms of goals, purposes, and objectives of the organization; while the next system level might require functional models related to available resources. Other system levels require appropriate functional models.

As with network analysis, activities to accomplish functions are identified (30, 46). By careful analysis unnecessary activities may be eliminated, like activities combined, or simplified processes may be developed.

Flow of Materials

As a part of the analysis of a work system, determination of material flow patterns or routing is an important step. The value of this step leading to successful completion of a floor plan or layout has been recognized by industrial engineers (44, 46) as well as in guides developed for planning food service layouts (30, 33, 35, 36, 42, 53). Materials flow is determined by analyzing the sequential steps of moving supplies through a process and determining the most effective flow. For an effective flow, supplies or materials should advance toward completion of the process with a minimum of detours and/or backtracking (44).

Industrial engineers have developed numerous techniques for acquiring and/or analyzing the steps and their logical sequence in completion of a process. Examples of the various techniques are product and operation process charts, flow diagrams, and travel charts (44, 46).

Product Process Chart. The product process chart or flow process chart is defined as the symbolic and systematic presentation of the tasks used in modifying and/or developing a product. These charts may be developed for a single product incorporating few or many materials. A similar technique, referred to as multi-product process charting, may be used for analysis of many products (30, 44).

Operation Process Chart. Symbolically shown on an operation process chart, is the total view of a production process separated into the component parts (46). The method a person uses to accomplish a given task at one work place is investigated by charting the fine breakdown of motions used to perform an operation (30). In contrast to product process charting which delineates what is being done, operation process charting specifies how the task is to be done (30). Thus, this technique can also be used to eliminate unnecessary motions, develop job breakdowns and plan procedures for new methods.

Form Process Chart. To facilitate the most effective use and flow of forms necessary for communication within an organization, form process charting can be used (46). The form process chart is the symbolic and systematic representation of a procedure used to develop, modify or handle a form (46). It differs from the product process chart only in the symbols used in charting.

Flow Diagrams. Flow of materials can be schematically depicted by use of a technique described by industrial engineers as flow diagramming. Flow may be diagrammed on scale layout drawings or between functions with directional lines drawn to indicate the sequential movement of materials (35, 45).

Travel or Cross Charting. Travel or cross charting is a quantitative industrial engineering technique indicating backward and forward flow of man or materials as well as distance traveled. According to this technique, the movements essential to completion of a process are listed in their logical sequence. All possible combinations of paired activities for the process are summed and their frequencies are then entered in a square matrix. From the display of backward and forward movements within the matrix, the optimum flow of man or materials can be calculated. This technique may be used to record and analyze costs, quantities, specific distances, relative importance of materials as well as flow, singly or combined (2, 18, 30). The various uses of this technique have been described by Gottlieb et al. (18) and Muther (44).

Muther (44) has suggested a guide for selection of the appropriate technique for analysis of flow. According to this guide, selection of a technique for analysis of flow is based on the volume and variety of items being produced. The guide follows.

- For one or a few standardized products or items, use operation process chart.
- For several products or items, use multi-product process chart.
- For many products or items, combine them into logical groups and analyze according to one of the above, or select sample products or items and analyze according to one of the above.
- For very many diversified products or items, use the from-to chart.

Muther (44) also had suggestions for logically grouping items to simplify development of materials flow.

> By combining all or certain items which are alike in design we may have a group which will have a common or reasonably distinct routing sequence. Or items which are alike in process equipment frequently follow the same routing. We seek out these groups by classifying like designs in the former case and, in the latter case, by looking for items which begin or end at the same operation or which pass through certain key operations.[1]

Time Study

Muther (44) stated time is the underlying element affecting all facets of layout development because time is a quantitative measure of performance within the system (11, 30, 43). Thus, performance time has been studied through continuous or randomly sampled observations.

Shaw defined time study as "...the analysis of a given operation to determine the elements of work required to perform it, the order in

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[1]Richard Muther, Systematic Layout Planning (Boston: Industrial Education Institute, 1961), p. 4-12.

which these elements occur, and the times which are required to perform them efficiently."[2] Collection of time data requires a familiarity with existing procedures (30, 45, 50). Forms, designated to provide the information needed for stated objectives and tested in preliminary investigations, are essential (25, 30, 45, 50). Application of industrial engineering time study techniques to investigate food production procedures within hospitals was demonstrated by Stumpf (51).

Time standards, or the time required to repeatedly complete a task using standard materials, processes, methods, equipment, and environment, can be used to provide time information needed for layout development (11, 30). Standard times can be formulated through various techniques (24). In the methods-time-measurement (MTM) procedure developed by Maynard et al. (40), tasks are broken down into small units and time as well as performance conditions are determined. MTM is used for highly repetitive tasks performed in short cycles. Universal standard data (USD) is a modification of MTM, but applicable to any type of operation or process (24). Another modification of MTM utilizing a broader breakdown of motion is master standard data (MSD) developed by Crossen et al. (9). Montag et al. (41) demonstrated the use of this procedure by determining times required for preparation of baked pudding and plain yeast rolls.

Ivanicky et al. (26) reported studies involving preparation, panning, and cooking time standards for selected recipes of varying

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[2]A.E. Shaw, "Stop-watch Time Study," in Industrial Engineering Handbook, ed. by H.B. Maynard (2nd ed.; New York: McGraw-Hill Book Company, Inc., 1963), p. 3-23.

quantities. In their study, the suggested application of the time data was scheduling production by use of a computer.

Utilizing the concepts of MTM, USD, and MSD along with a less broad division of tasks than those developed by Ivanicky et al. (26), Brown (4, 5) developed some standard measurements of work to establish time standards. Her study allocated time to "modules" which included a breakdown of specific tasks and/or elements of tasks for a specific step in a procedure. Two classifications of modules were defined by Brown (4). Constant module time never varied because it was not influenced by other factors such as volume changes and because it included one task or groups of sequential or opposite tasks. Variable module time increased as quantitative factors such as batch, size or weight increased, and included one or groups of tasks having the same variable unit.

METHODOLOGY AND/OR RESULTS

The application of selected industrial engineering principles and analytical techniques will be illustrated through the development of an ingredient room for the Dietetics Department of University Hospital, Ann Arbor, Michigan. A systematic outline of the essential steps was developed and through analysis of events, functions and/or activities, a layout and the requisite equipment was determined.

The development of a PERT network diagram provided the methodology by which industrial engineering principles were utilized for accomplishment of the objective. The complete network diagram is shown in Figure 2. The PERT principles utilized in this study include those involving the development and completion of events, activities, and relationships; however, time for completion of activities was not entered. To demonstrate the use of the methodology, the activities which led to completion of each event for the ingredient room layout will be discussed.

1 Project Started

The function of the ingredient room was defined as preparation of "as purchased" food materials for issue to preparation areas in the quantities, shape and/or state needed for production of menu items or products. To facilitate planning the following assumptions and/or restrictions were made.

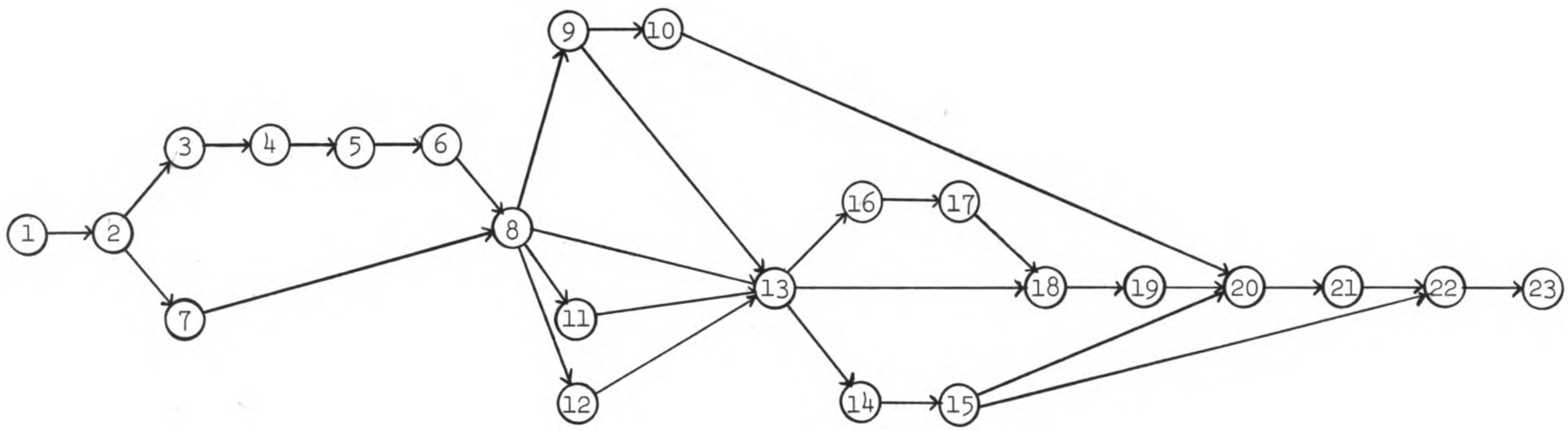


Figure 2. PERT network diagram for development of ingredient room layout.

Figure 2 (cont'd.)

<u>Key to Events</u>

1. Project started
2. Menus and production sheets obtained
3. Historical production data obtained
4. Number of servings per menu item determined
5. Products determined
6. Projected number of servings for devised menu pattern determined
7. Recipes obtained
8. Materials determined
9. Quantity of materials determined
10. Material dimensions obtained
11. Functions within ingredient room specified
12. Related functions outside ingredient room specified
13. Procedures developed
14. Materials and paper flow between functions developed
15. Arrangement of functions determined
16. Equipment needs determined
17. Equipment dimensions obtained
18. Time for performing procedure tasks completed
19. Peak production load within ingredient room selected
20. Space requirements determined
21. Templates of work centers developed
22. Arrangement of work centers within functions determined
23. Layout drawn to scale

- The menu pattern used for the study was based on current University Hospital menus. Only general selective diet patient menu items were considered.
- Daily non-changing menu items, such as juices, dry cereals, breakfast eggs (other than scrambled), bread, butter pats, crackers, beverages, and ice cream, were not considered in the study assuming these items would be issued under the currently followed system, in which these items are delivered to unit kitchens as requested to maintain a constant supply.
- Materials purchased in suitable containers for transporting to production areas and having the content weight specified, will not be re-weighed in the ingredient room.
- With the exception of liquids, materials will be weighed unless only measure is stated in the recipe. Water, as specified in the recipes, will be measured within the production areas.
- Materials will be available from the Dietetics Department Storeroom as needed.
- Recipes will be issued to the ingredient room having all calculations for specific quantities/production needs calculated.
- The ingredient room will be planned as a construction algorithm or with no preconceived layouts or dimensions.
- The ingredient room will be planned to incorporate the existing systems preceding and following the ingredient room.

2 Menus and Production Sheets Obtained

To determine the materials or foods requiring preparation or processing within the ingredient room, a complete set of the 21-day menu cycle was obtained from the University Hospital Dietetics Department. Corresponding production sheets which included items commonly selected by patients in lieu of listed menu items were also obtained to facilitate analysis of the materials. The menu items listed on the production sheets were printed with codes to correspond to recipes and grouped alphabetically by production areas. A sample of a menu and a production sheet can be seen in the Appendix, pages 89 and 90, respectively.

3 Historical Production Data Obtained and

4 Number of Servings per Menu Item Determined

At University Hospital the number of servings prepared per menu item is recorded daily on a form corresponding to the pre-printed production sheets. These historical records were utilized to determine the average number of servings per day of each menu item which had been prepared for the past five rotations of the menu cycle.

5 Products Determined

Examination of the menus revealed no consistent daily pattern in processes (activities) performed on ingredients. Thus, rather than analyze the complete set of menus, the decision was made to develop a menu pattern based on preparation processes to be performed in the ingredient room as well as ingredients (materials) which were representative in composition and purchase specifications of all 21 days of the cycle.

Using the production sheets and the suggestions of Muther (44), menu items (products) were grouped according to the class of food each menu item represented such as fruit, vegetable, entree, or soup. Within each group, purchase form, denoted as fresh, frozen, or canned, as well as number of ingredients required for preparation of the menu item, denoted as single or multiple, were designated. Then, the number of times a menu item was served within each of the designated groups was tallied or recorded in the appropriate columns for each of the 21 days.

The data were then summarized. Referring back to the number of servings per menu item, all items receiving less than two orders from patients were omitted. Means of tallied menu items were then calculated. If the average was less than 0.5, the class of food was omitted from further consideration in the developing menu pattern. Products averaging more than 0.5 servings were included in the menu pattern, Figure 3, to be used throughout the study.

Products containing multiple materials (MM) were further analyzed and grouped according to similarity of materials. For example, fruit pie-, cobbler-, and crisp-fillings were grouped and considered as one product because all contained the same materials. Mixed entrees containing similar materials were also grouped and considered as one product, denoted in the menu pattern as "multiple material entree."

6 Projected Number of Servings for Devised Menu Pattern Determined

As a step in determining the quantities of food needed for each product listed on the devised menu pattern, specific menu items were grouped under the appropriate product along with the average number of servings of each item as calculated in Event 4. Data obtained from historical production records for the number of servings was then averaged to determine a quantity for each product on the devised menu pattern. These averages were then used to calculate amounts of materials needed for the study.

BREAKFAST	
Canned & Frozen Fruit	Bacon
Muffin, Doughnut or Fried Cake (MM)[a]	Flavored Gelatin
Cooked Cereal	Bouillon
Scrambled Eggs	Lemon Wedge

LUNCH	SUPPER
Soup:	Soup:
Bouillon or Consomme	Bouillon or Consomme
Cream (MM)[a]	Stock (MM)[a]
Entrees:	Entrees:
Roast Meat, Beef Gravy (MM)[a]	Roast Meat, Chicken Gravy (MM)[a]
Frankfurter on Bun	Frankfurter on Bun
Hamburger on Bun	Hamburger on Bun
Ground Round Steak	Ground Round Steak
Multiple-material Entree (MM)[a]	Multiple-material Entree (MM)[a]
Chops or Chicken	
Vegetables:	Vegetables:
Baked, French Fried & Whipped (MM)[a] Potatoes	Baked, French Fried, Whipped & Multiple-material Potatoes
Frozen & Canned	Frozen & Canned
Salads:	Salads:
Lettuce Wedge	Lettuce Wedge
Sliced Tomatoes	Sliced Tomatoes
Cottage Cheese	Cottage Cheese
Combination (MM)[a]	Vegetable (MM)[a]
Fruit (MM)[a]	Molded (MM)[a]
Salad Dressings:[b]	Salad Dressings:[b]
Types A, B & C	Types D, E & F
Sandwiches:[c]	Sandwiches:[c]
Bologna	Roast Beef
American Cheese	Ham
Ham	
Leaf Lettuce	
Lemon Wedge	Lemon Wedge
Desserts:	Desserts:
Fresh & Canned Fruit	Fresh & Canned Fruit
Flavored Gelatin & Whipped Cream (MM)[a]	Flavored Gelatin
	Fruit Filling (MM)[a]
Pie (MM)[a]	Cream Filling (MM)[a]
Frosted Cake or Cookies (MM)[a]	Dinner Roll (MM)[a]

[a]Multiple-materials (MM): More than one ingredient or material required to prepare the product, such as beef stew.

[b]Purchased, pre-portioned in assorted varieties or types.

[c]Materials sent to unit kitchens in bulk, not made into sandwich.

Figure 3. Devised Menu Pattern used for development of an ingredient room.

7 Recipes Obtained

A complete set of recipes was obtained from University Hospital. These were used to calculate the quantities of materials needed for the established menu pattern.

8 Materials Determined

To facilitate the analysis of determining materials needed for products prepared from multiple ingredients or materials, the form shown in Figure 4 was developed. In addition to materials, the preparation activities to be performed on each material within the ingredient room were identified and recorded on the form.

From all recipes, quantities as well as purchase form and preparation activities of each ingredient were extended across the form. Analysis of the compiled data involved calculating the mean of the number of times each activity was used based on the total number of multiple-material products recorded. Averages were rounded to the nearest whole number. These figures were then used to select materials which were representative of the mean number of activities. All activities performed on materials were included.

Materials having similiar characteristics such as storage place, purchase unit, consistency, and/or quantity were then grouped (e.g., baking powder, cream of tartar, baking soda became "baking powder"; all spices became "spice"; tomato paste, puree, tomatoes became "#10 can, not drained"). Thus, this grouping included representative samples of materials or ingredients which were similar in nature.

Product / Material	Specifications: 1Fsh 2Fzn 3Can	Specifications: Unit Size	Specifications: Form	Quantity: No. serv/ prod	Quantity: Batch per meal	Quantity: Amt need	Activities: Portion: Weigh	Activities: Portion: Meas-ure	Activities: Portion: Count	Activities: Clean: Peel	Activities: Clean: Trim	Activities: Clean: Wash	Activities: Change Shape: Chop	Activities: Change Shape: Dice	Activities: Change Shape: Slice	Activities: Open Container: Cs.	Activities: Open Container: Cans: Drain	Activities: Open Container: Cans: NoDr.	Activities: Open Container: Pkg	Activities: Open Container: Jar
Braised Beef Cubes:				300	1															
Beef Cubes	1	1 lb	cube			105#	105#													
Mushroom	3	1 lb				6			6								6			
Tom.Puree	3	#10				3			3									3		
Carrots	1		chop			15#	✓			✓		✓	15#							
Celery	1	24/cs	chop			15#	✓				✓	✓	15#							
Onions	1	50#	chop			15#	✓			✓		✓	15#							
Parsley	1	bch	chop			3#	✓				✓	✓	3#							
Beef Base	1	30# can				6#	6#											1		
Summary:																				
Total no. of products: 10																				
Total no. of times activity occured:							63.0	25.0	42.0	8.0	8.0	16.0	23.0		1.0	11.0	8.0	10.0	29.0	4.0
Mean:							6.3	2.5	4.2	0.8	0.8	1.6	2.3		0.1	1.1	0.8	1.0	2.9	0.4
Rounded:							6.0	3.0	4.0	1.0	1.0	2.0	2.0		0.0	1.0	1.0	1.0	3.0	0.0

Figure 4. Example of analysis of multiple-material products to determine types and quantities of materials needed.

9 Quantity of Materials Determined

Using the "Quantity" information from the form illustrated in Figure 4, averages were calculated for each of the materials. For example, quantities of items which had been grouped as "baking powder" were averaged based on the number of items which had been grouped into the "baking powder" category.

Products of both single and multiple-materials were then summarized on a form as shown in Figure 5. Information on specifications, quantity per number of servings, and activities for single-material products was obtained from historical production records and corresponding recipes.

10 Materials Dimensions Obtained

After determining the specific foods or materials which would require processing, it was necessary to analyze the space requirements of these materials. Therefore, the materials were grouped according to packaging media (PM) in which they were received and the place of storage after receipt. Packaging media were listed as case, crate, box, carton, or sack while storage places were identified as refrigeration, freezer, or dry stores.

Using a standard steel tape measure, the height, width, and depth dimensions of all PM were physically obtained at University Hospital. For spices, baking powder, flavorings, and similar materials packaged in containers of varying sizes, the length of shelving containing the 29 items used in the production areas was measured. Two

		Specifications			Quantity			Activities					
								Portion			Clean		
Product	Materials	1Fsh 2Fzn 3Can	Unit size	Form	No. serv/ prod	Batch per meal	Amt. need	Weigh	Meas- ure	Count	Peel	Trim	Wash
LUNCH:													
Potato, Baked	Idaho Potato	1	80-100		2	1	2			2			2
	Vegetable Short.	3	50# cube				1/2 oz	1/2 oz					
French Fried Potato	French Fr.	2	5#-6/cs	reg. cut	40	1	10#			2 pkg			
Whipped Potato	Margarine	1	1#		300	2	4#			4			
	Whole Milk Powder	3	#10 (4#)				6#	6#					
	Salt	3	1#				12 oz	12 oz					
	Inst.Msh. Potato	3	#10 (6#)				9#	9#					

Activities									
Change Shape				Open Container					
					Cans				
Chop	Dice	Crack	Pan	Case/ sack	Drain	No Drain	Pkg Ctn.	Jar	

Figure 5. Example of comprehensive listing of devised menu pattern per day.

average height restrictions of 5 and 9 in. were defined as well as two average depth restrictions of 3.5 and 6 in. by measuring the containers of maximum height and depth.

11 Functions within Ingredient Room Specified

To outline the sequence of operations in the processing of materials within the ingredient room, it was necessary to delineate specific functions. The over-all function of the whole system or ingredient room was to provide materials as specified in the recipe to production areas. Sub-functions were identified from the activities specified in Figure 5. One sub-system was designated as materials processing. The identified functions for this sub-system are shown in Figure 6.

A second sub-system within the ingredient room concerned materials distribution. Within this sub-system, certain functions were identified as shown in Figure 7.

12 Related Functions Outside Ingredient Room Specified

Functions within the Dietetics Department which were related to the ingredient room were identified. These are listed in Figure 8 with the relationship to the ingredient room specified.

13 Procedures Developed

As a preliminary step in the analysis of materials flow and use of travel charting, the sequence of activities for processing materials to accomplish the functions listed in Figure 6 were developed. All materials included in the comprehensive menu pattern (Fig. 5) were

FUNCTIONS	ACTIVITIES
Portioning	Weigh Measure Count
Cleaning Materials	Peel Trim Wash
Changing Shape	Chop Dice Crack (eggs) Slice Grate
Panning and Breading	Separate Dip (bread) Pan
Opening Cans	Wash lids Open cans Drain

Figure 6. Ingredient room functions concerned with material processing.

FUNCTIONS	ACTIVITIES
Packaging	Package Seal or close package
Assembling Materials	Assemble materials (products)
Dry Storage	Store dry materials which include opened unused materials in original containers as well as ingredient bins containing 50-100 lb of dry materials
Refrigerated Storage	Temporary storage of materials requiring processing and/or ready to be delivered to production areas
Storing for Assembly	Storage of delivery carts
Washing Utensils	Wash utensils
Delivering Materials	Deliver assembled materials to production areas
Accumulated Trash Holding	Deposit accumulated trash

Figure 7. Ingredient room functions concerned with materials distribution.

grouped according to the functions and activities within each function. The groupings were further refined by combining materials requiring the same activities of pre-preparation.

FUNCTION	RELATIONSHIP
Pot and Pan Washing	Wash soiled re-usable containers and mobile carts
Storeroom	Supply "as purchased" materials
Clerical	Supply communication of material needs
Cooks production area (C)	Product preparation
Vegetable production area (V)	Product preparation
Salad production area (S)	Product preparation
Area portioning of salads and desserts (A)	Assembly of materials (products) for serving areas
Bakeshop production area (BS)	Product preparation

Figure 8. Functions related to the ingredient room.

General procedures were developed for each activity within the specific function. All procedures were based on volume of materials processed as well as principles of food quality, sanitation, materials handling, human engineering, and safety. An investigation of types of containers and means of transporting materials was made by contacting organizations maintaining ingredient rooms (7, 37, 39). Also, since quality of food materials is maintained with minimal handling, containers in which materials would be placed during processing in the production areas were selected as transportation containers (TC) when possible (e.g., potatoes for the product, Baked Potato, were placed in 18x26x1 in. sheet pans). Mobile carts (MC) were planned for the delivery of materials from the ingredient room to the production areas. After utilizing the materials, empty re-usable and disposable TC were to be returned to the MC. The existing Pot and Pan Washing Area within University Hospital Dietetics Department was planned for washing carts and re-usable TC as well as dispensing with disposable TC.

As an example of a procedure, the washing activity within the Cleaning Materials Function, may be accomplished by using sinks of varying depths (35). However, spray-washing is a more effective method for washing fruits and vegetables (3). Therefore, the latter method was selected. The procedure is graphically presented in Figure 9.

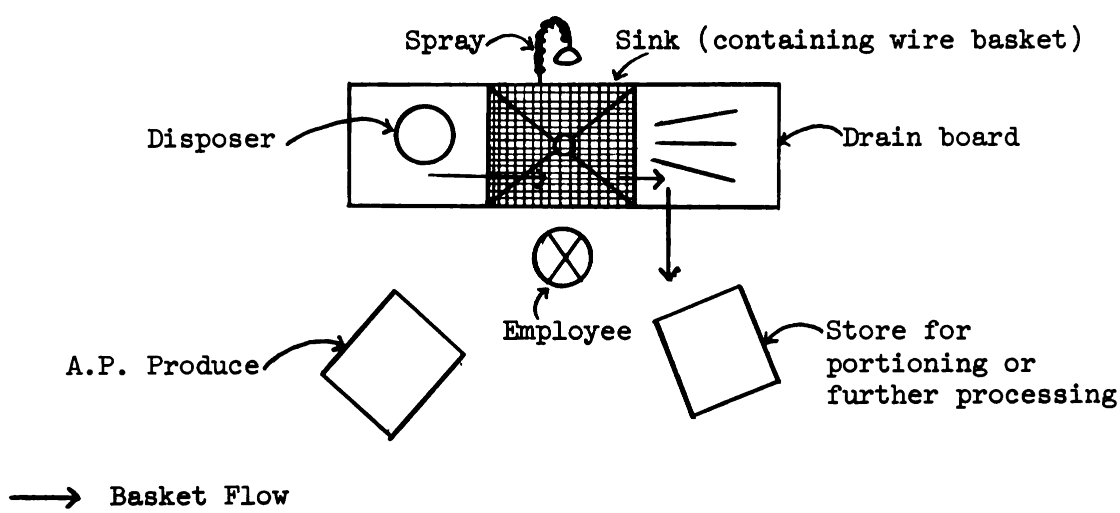


Figure 9. Example of a procedure diagram in which fruits and vegetables are washed.

The sequence of activities performed on each material within each function was next diagramed indicating related equipment needed and activities as shown for washing cucumbers in Figure 10. All grouped material flows within each function were diagramed to provide a comprehensive picture of the work being performed and show flow between related functions within and outside of the ingredient room. An example is given in Figure 11.

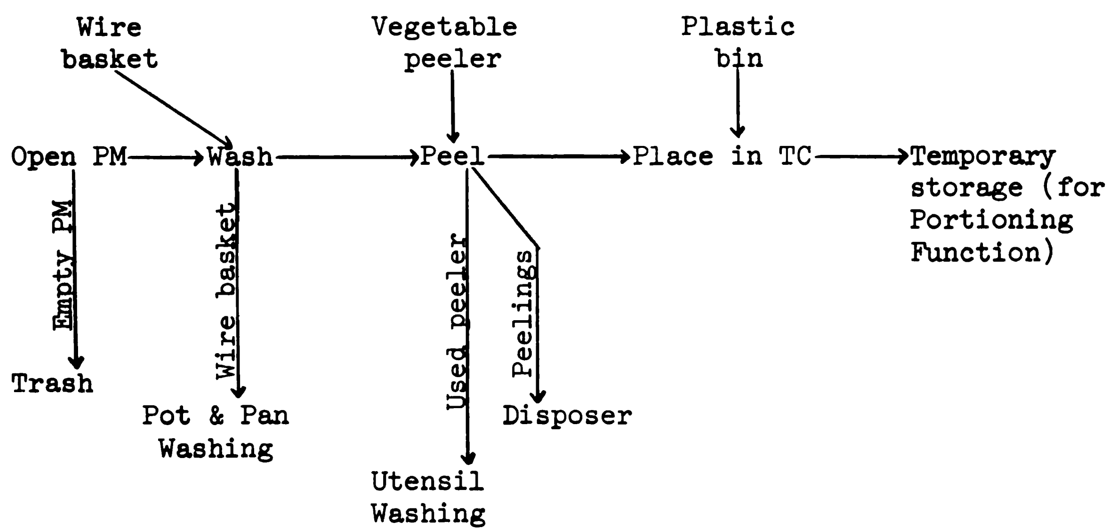
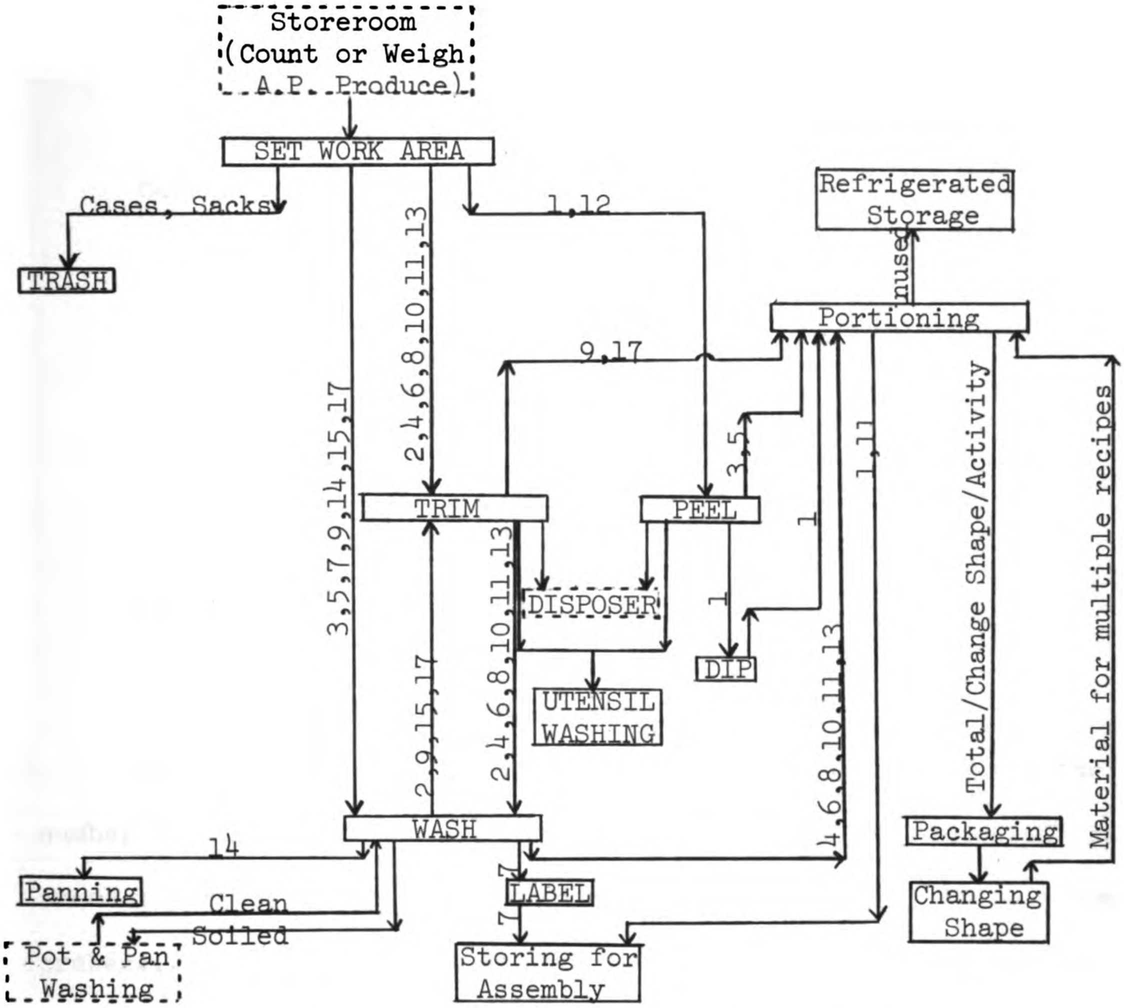


Figure 10. Flow diagram of cucumbers through Cleaning Materials Function.

14 Materials and Paper Flow between Functions Developed

After establishing the sequence of activities for processing materials within each function, the materials flow between functions was developed. Specified functions as shown in Figures 6 and 7 were classified into three categories: (1) those through which all materials traveled, (2) those through which more than one, but not necessarily all materials traveled, (3) those which evolved as a result of materials flow. Functions within Category 2 were assigned a number. The categories and functions, with the numerical identification where applicable, were listed.



Numerical Code of Materials:

1	Bananas	9	Lemons
2	Cabbage	10	Lettuce, Head
3	Carrots	11	Lettuce, Leaf
4	Celery	12	Onions
5	Cucumbers	13	Parsley
6	Escarole	14	Potatoes, Idaho
7	Fresh Fruit	15	Radishes
8	Green Pepper	16	Romaine
17	Tomatoes		

Symbolic Code:

CAPS Activities within Cleaning Function

Lower case Related Functions within ingredient room

Lower case Related Functions outside ingredient room

CAPS Major Equipment required

⟶ Routing of specified materials &/or described information

Figure 11. Comprehensive materials flow for the Cleaning Materials Function.

Category 1:

Assembling Materials
Delivering Materials

Category 2:

1 Opening Cans
2 Dry Storage
3 Cleaning Materials
4 Portioning
5 Packaging
6 Changing Shape
7 Panning
8 Breading
9 Storing for Assembly
10 Refrigerated Storage

Category 3:

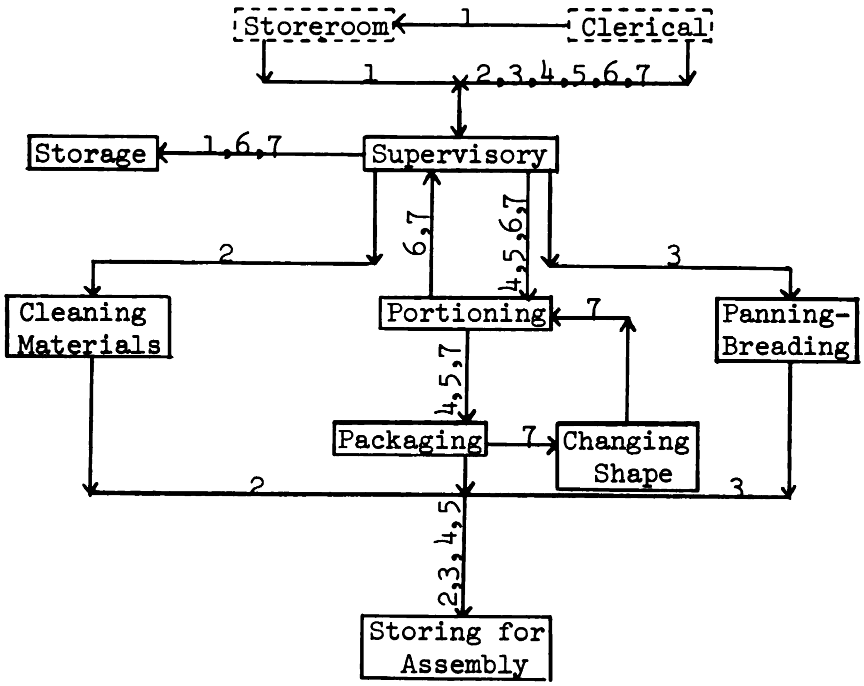
Utensil Washing
Accumulated Trash Holding

All materials were next listed in alphabetical order and the number of times each material was to be portioned (or processed) per product for the entire day's production was tabulated. Using a comprehensive materials flow for each function as shown in Figure 11; the sequence of material movements between each function was summarized. An example of the tabulation can be seen in Figure 12.

After the procedures and materials flow between functions were identified, a paper system was developed to communicate material requirements from the related clerical function to the ingredient room functions. Figure 13 presents the complete flow diagram of the paper system for clerical, storeroom, and ingredient room functions. Two forms of printed information were planned to be distributed to the point of use, pre-printed labels and computer print-out of processes and recipes in requisite volume as enumerated in Figure 13.

Material	Frequency of portioning/ product/day	Sequence of movements between functions 1 through 10	Frequency of sequence
Lettuce, Leaf	1	3-10	1
	3	10-4$^{\nearrow 10}$-5-9	3
Margarine	6	4-5$^{\nearrow 10}$-9	6
Meat: Chops or Chicken	1	8-7-10	1
Milk: Dry	5	1-4$^{\nearrow 10}$-5-9	5
Milk: Fresh	1	4-5$^{\nearrow 10}$-9	1
Onions: Fresh	1	3-4-5$^{\nearrow 10}$-6-10	1
	3	10-4-5-9	4

Figure 12. Examples of sequence of material movements between functions.



Numerical Code of Paper:

1 List of total material needs per delivery time

2 Gummed labels for fresh fruit menu items + vol

3 Gummed labels for panned &/or breaded menu items + vol

4 Pre-printed roll of labels with material title for those materials not readily identified by visual inspection (e.g., salt and sugar)

5 Recipes converted for no. of servings required

6 Priority listing: Developed and explained in sequence of its creation, pp. 49-50

7 Change shape labels of materials requiring the same shape, but for more than one product (e.g., chopped green pepper for soup, salad, & MM Entree)

Symbolic Code:

Functions within ingredient room

Related functions outside ingredient room

Routing of specified paper

Figure 13. Paper system flow diagram from clerical to ingredient room.

15 Arrangement of Functions Determined

From the sequence of material movements between functions, a portion of which is shown in Figure 12, all combinations of pairs were tallied to isolate the movement of materials between functions or pairs. The pairs where movement was found were listed, accompanied by the sum of the tally to identify the frequency of movement between pairs as shown in Table 1.

Table 1. Frequency of Material Movements between Functions.

Functions		
From	To	Frequency
1 (Opening Cans)	4	14
1	9 (Storing for Assembly)	12
2 (Dry Storage)	4	35
3 (Cleaning Materials)	4	14
3	7	2
3	10	3
4 (Portioning)	2	39
4	3	1
4	5	119
4	10	47
5 (Packaging)	6	13
5	9	115
5	10	28
6 (Changing Shape)	10	15
7 (Panning)	10	13
8 (Breading)	7	1
10 (Refrigerated Storage)	4	24
10	6	2

As suggested by Muther (44) for travel charting, the forward and backward movement or intensity of flow between two pairs of functions was summed and ranked. By ranking, the order of most important relationships was indicated. These results appear in Table 2.

Table 2. Ranked total movement between functions.

Rank	Pair	Movement Forward	Movement Backward	Total (Intensity of flow)
1	4,5	119	0	119
2	5,9	115	0	115
3	2,4	35	39	74
4	10,4	47	24	71
5	10,5	28	0	28
6	6,10	15	2	17
7	3,4	14	1	15
8	1,4	14	0	14
9	5,6	13	0	13
10	7,10	13	0	13
11	1,9	12	0	12
12	3,10	3	0	3
13	3,7	2	0	2
14	8,7	0	1	1

The logic for diagramming relationships in space,[3] described by Muther (44) was next employed to locate the ranked numerically coded functions as illustrated in Figure 14.

1	2	7	8
3	4	10	6
	5	9	

Figure 14. Diagram of ranked numerically coded functions in space.

To utilize the distance factor travel chart for the arrangement of two parallel rows described in the Appendix, pages 91 through 94, the spatial placement of the functions was further evaluated. Because

[3]The logic relates to Activities Relationship charting which aided in selecting a beginning arrangement for travel charting. This method resulted in an arrangement allied with the travel charting solution.

the Function pair of 4 (Portioning) and 5 (Packaging) obtained the highest priority and because in reality they were considered to be inseparable; they were combined. Since 7 (Panning) and 8 (Breading) were also considered inseparable, they too were combined. Furthermore, since Function 9 (Storing for Assembly), was a function critical to all but refrigerated materials, it was omitted for this part of the analysis. This resulted in the following two parallel rows (Fig. 15).

1	2	7-8	0
3	4-5	10	6

Figure 15. Diagram of two parallel rows of functions.

Formulating this configuration altered the movement between pairs. The effects have been summarized in Table 3.

Table 3. Affects upon pairs resulting with elimination of Function 9 and combination of Functions 4-5 and 7-8.

Function (Pair)	Total intensity of flow	Change	Results			
			Pair	Movement		Intensity of flow
				Forward	Backward	
4,5	119	Eliminate	--	--	--	--
5,9	115	Eliminate	--	--	--	--
2,4	74	Function no.	2,4-5	35	39	74
4,10	71	Sum: 4,10				
5,10	28	& 10,5	4-5,10	75	24	99
10,6	17	No change	10,6	15	2	17
3,4	15	Function no.	3,4-5	14	1	15
1,4	14	Function no.	1,4-5	14	0	14
5,6	13	No change	5,6	13	0	13
7,10	13	Function no.	7-8,10	13	0	13
1,9	12	Eliminate	--	--	--	--
3,10	3	No change	3,10	3	0	3
3,7	2	Function no.	3,7-8	2	0	2
7,8	1	Eliminate	--	--	--	--

Using the distance factor travel chart in the Appendix, page 91, the spatial arrangement of two parallel rows of functions (Fig. 15), and the revised backward and forward movement figures (Table 3); arrangements were constructed and compared to obtain the "good" solution for minimizing materials flow. The arrangement having the lowest resulting index factor is shown in Figure 16.

From \ To	1	3	2	4-5	7-8	10	0	6
1				14				
3				14	2	3		
2				35				
4-5		1	39			75		13
7-8						13		
10				24				15
0								
6						2		

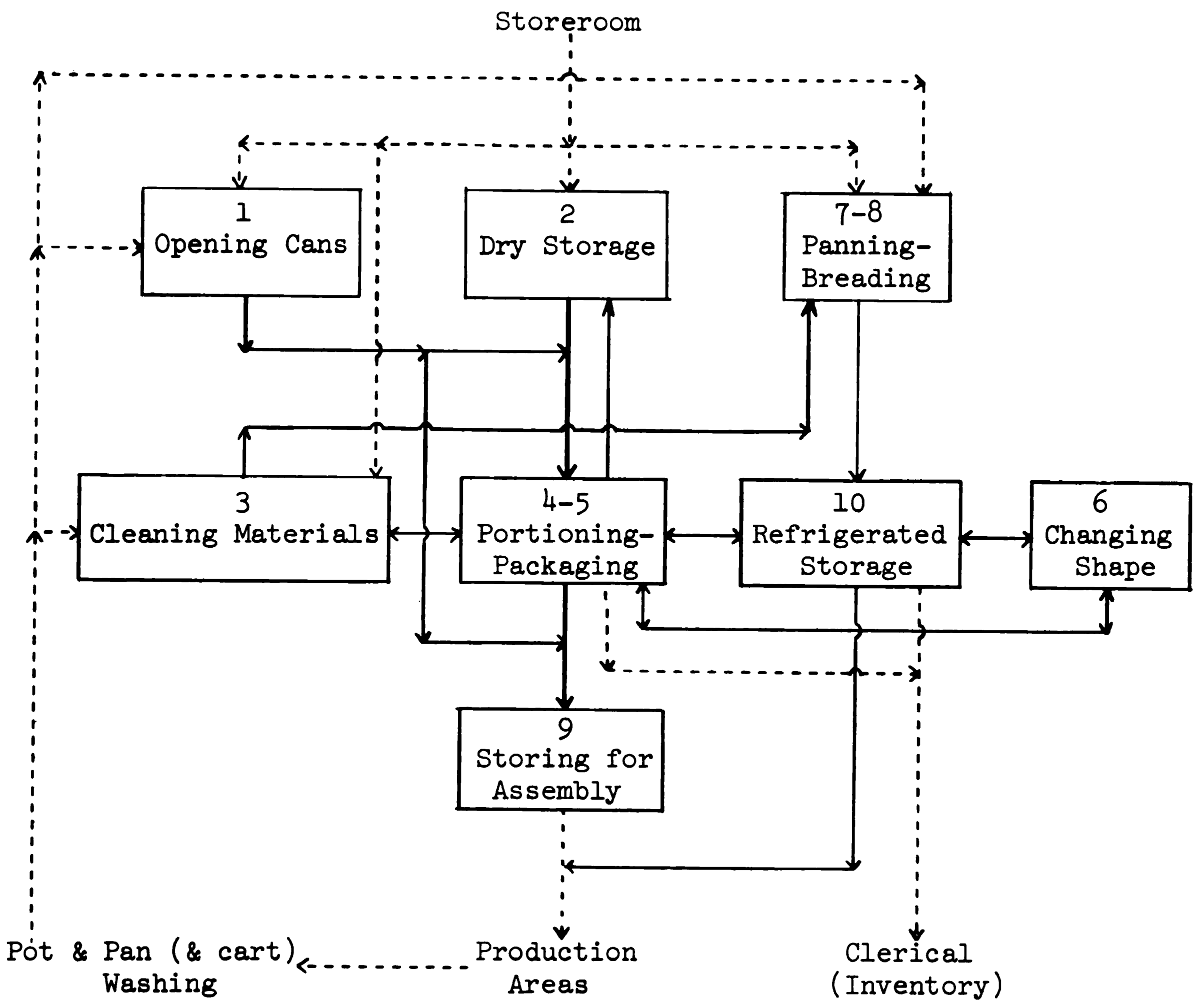
Figure 16. Final travel chart of least distance traveled.

It can be seen in Figure 16, for example, that the lateral movement from Function pair 4-5 (Portioning-Packaging) to Function 2 (Dry Storage) as well as the backward movement from Function 10 (Refrigerated Storage) to Function pair 4-5 was indicated because it resulted from storing materials which had been opened and not totally utilized, such as a 30 lb can of beef base from which 1 lb was weighed. Since the greatest majority of materials traveled in a forward direction, backtracking as well as material flow was minimized with the arrangement shown in Figure 15 accompanying the travel chart solution (Fig. 16).

This numerically coded arrangement (Fig. 15) was then placed in the traditional Function Flow Diagram illustrated in Figure 17. Function 9 (Storing for Assembly) was added as well as the related functions outside the ingredient room. The directional arrows indicating interrelationships were drawn from the travel chart constructed from the information in Table 1. Relationships shown between related functions were drawn from the flow diagrams similiar to Figure 11, but specific for the procedure developed for the function being illustrated.

16 Equipment Needs Determined and
17 Equipment Dimensions Obtained

Procedure development enabled the identification of minor and major equipment required to change or modify materials. Examples of minor equipment included utensils such as knives, measuring spoons, cups, quarts, gallons as well as transportation containers (TC) such as pans, bins, plastic bags. Major equipment included machinery to change the shape of materials and mobile carts (MC) to transport materials between functions. Catalogues for minor equipment were obtained from institution kitchen equipment distributing companies. Major equipment was investigated by observation and/or use of machinery in operation and through discussion with manufacturing company representatives. All equipment was evaluated in terms of composition, ease of operation and cleaning, National Sanitation Foundation (NSF) approval, ability to perform one or many material modifications, speed, and cost.



Directional flow of materials between functions within the ingredient room.

Directional flow of materials and/or paper between related functions outside the ingredient room, but within the Dietetics Department.

Figure 17. Flow diagram showing functional relationships as a result of travel charting.

Major equipment which directly affected procedure time was selected. Enough information was obtained to enable selection of the type of equipment; however, capacity was determined during space requirement investigation (Event 20). The list of equipment which follows is accompanied with the reasons for selection.

Equipment	Reason for Selection
Vertical Cutter/Mixer (VCM) Hobart Manufacturing Company	Quality of material produced. Potential for future use: Chop rather than shread cabbage. Combine certain materials within the ingredient room. Ease of operation. Ease of cleaning. Speed and safety. NSF approval.
Automatic Meat Slicer, Hobart Manufacturing Company	Large opening chute and fence attachments, providing diversification and material quality. Ease of operation. Ease of cleaning. Speed and safety. NSF approval.
Heat Sealer, Sentinal Heat-Sealer, Packaging Industries	Complete seal, thus preventing spillage potential. Closure which prevented use of tape or staples or any other means of sealing the container which potentially could become extraneous foreign matter in the product. Ease of operation: Both hands of employee free to hold package since sealer was foot operated.
Electric Scale, Toledo Manufacturing Company	Weight in decimal part of a lb. Accuracy for quality control. Reduction in calculations throughout the paper system. Ease of operation. NSF approval.

Using the material and equipment dimensions along with the portion size specified in the recipes, capacity per pan was next determined. For example, the number of heads of lettuce that would fit in the basket during the washing activity and the number of lettuce wedges that would fit in an 18x26x1 in. sheet pan were calculated.

18 Time for Performing Procedure Tasks Completed

Establishing the time required to perform each activity was necessary to schedule processing of materials through functions to meet production deadlines. From this information the peak preparation load within the ingredient room as well as the amount of equipment needed was determined. To obtain this information limited time studies were performed in the Dietary Department at W.A. Foote Memorial Hospital in Jackson, Michigan. The average bed capacity was 275 during the observation period from November 20 to December 5, 1969. The existing menus were concurrent with the 21-day menu cycle used at University Hospital; hence, the times for the required activities were easily obtained. Management approval as well as employee cooperation and understanding were obtained through scheduled meetings. It was established that no changes would be made in the existing preparation procedures; also production deadlines would not be interrupted during the collection of time data.

As the first step, tasks required for completion of the activities of the procedures described within each ingredient room function were specified. Since work involves a general breakdown of get ready, change or modify materials, and clean-up, this division was used to categorically list the specified tasks as shown in the Appendix, 95 and 96.

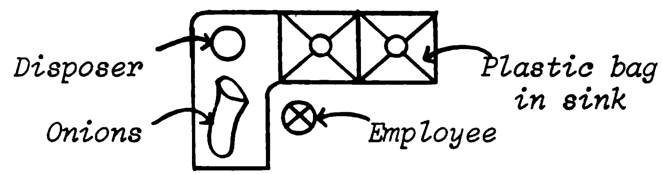
Having identified the tasks, pertinent information desired for this study was isolated. Inspection as well as operations at one work place which did not add value to the material and/or operations which directly modified the material were timed. Recalling the assumption that the layout sought was a construction algorithm, movement and temporary or controlled storage were omitted. These were recognized as existing; however, they were considered variables which changed as physical arrangement and storage systems changed.

Directly related to time was the quantity of materials handled and the equipment and utensils used; therefore, this information was desired. To determine the length of time required to perform each task, a common denominator of quantity units was defined. For example, the common unit of "1 lb" was established for the task of weighing dry materials. The final time determined could then be stated in time per unit or, in view of the cited example, minutes per pound.

The beginning and ending points for timing each task were established. For example, timing the task of opening cans began when the can was placed at the opener and stopped when it was removed from the work table. A stopwatch was used for collecting continuous time to the nearest whole second. The form appearing in Figure 18 was developed to record the desired information and for analysis of the collected data. A sketch of the work area was included to define limitations for data collection, thus avoiding recording time spent in travel. Because only operations and inspections were observed, the symbol for "inspections" was recorded while a blank space denoted

Date: 11/21/69

Work Area Sketch



Symbol (1)	Description-Notes (2)	Quantity Amt (3)	Quantity Unit (4)	Time min (5)	Time sec (6)	Equipment (7)	Storage Container (8)	Elapsed Time, sec (9)	Sum/Reps[a] (10)	Time/Unit, sec (11)
	Spanish Onions:									
	Peel, etc.	1	each		26	Paring knife	Plas bag	26		
	Peel, etc.	1			51			25		
	Peel, etc.	1		1	15			24	75	25
	Peel, etc.	1			46			31		
	Peel, etc.	1		2	20			34		
	Peel, etc.	1			36			16	87	27
	Peel, etc.	1			55			19		
	Peel, etc.	1		3	25			30		
	Peel, etc.	1			51			26	83	27.6→28
	Peel, etc.	1		4	37			46		
	Peel, etc.	1		5	05			28		
	Peel, etc.			5	14			[illegible]	83	27.6→28

[a]Replications

Figure 18. Time data collection form showing an example of recording and partially analyzing data.

the "operations" symbol in the first column of the form. Specific operations or inspections were noted as observed in col 2. Quantities of materials (col 3 and 4) were recorded as seen and confirmed verbally with an employee. Time change of operations for the defined tasks were recorded on the appropriate line of the form without stopping the watch. Using the cumulative record, the elapsed time for each operation was derived by subtraction during analysis. The size and quantity of equipment, utensils, and/or containers used for material modification were recorded during observation.

The task of peeling was used to show the method of analysis following collection of data. The sequence of operations included picking up one unit of material, peeling the unit, dropping the peel into the disposer and placing the peeled unit in a sink filled with water or in a storage container. The recorded data and analysis for peeling of onions is shown in Figure 18.

To reduce human errors as well as differences among units of materials, the time required for handling three units was averaged. The average was then considered as one replication of the time required to perform the specific task on one unit of material. For example, the total time required for peeling three onions, or 75 sec, was entered in col 10 and the average time for each replication, or 25 sec, was entered in col 11 (Fig. 18). Time for each replication or unit was then entered on a form as seen in Figure 19.

Because of the wide range of times required for peeling various materials, two divisions of time were established. A "high" time was needed to peel materials such as onions while a "low" time was required for materials such as carrots, bananas, and cucumbers. The number of replications required for validity was determined using a nomograph described by Nadler (45). When feasible within the limitations of this study, the minimum number of observations was made. Data were averaged and the mean used in this study.[4] Time factors were established for all tasks listed in the Appendix, pages 95 and 96. For selected equipment not used at W.A. Foote Memorial Hospital, time factors were assumed based on the manufacturers' specifications.

Function: Cleaning Materials		Activity: Peeling, High time		
Date	Rep	Material	Unit	Time, sec
11/20	1	Spanish Onion	1 each	34
11/20	2	" "	"	35
11/20	3	" "	"	29
11/20	4	" "	"	25
11/21	5	" "	"	25
11/21	6	" "	"	25
11/21	7	" "	"	27
11/21	8	" "	"	28
11/2				
			Sum:	322
			Range:	25-38 (13)
			Mean:	28.8→29

Figure 19. Example of form used to summarize time data.

Established time factors for the specific tasks were then used to determine relative times for performing the procedures defined in Event 13. Relative times were used because no allowances were made for distance traveled, storage, or performance delays. Each procedure

[4]Time factors derived for this study are based on limited observations; hence, they should not be considered as time standards.

per function was then charted as illustrated on the form shown in Figure 20 using a modification of multi-product process charting as presented by Muther (44).

Based on the time modules described by Brown (4), time factors were sorted into four categories. For the first, constant time was defined as that which was not changed by the volume of material handled. For example, placing a paring knife on a work table was a constant time. Variable time, the second category, was considered as the time which increased as volume increased. For example, 0.10 min was required to measure 1 qt of dry material while 0.3 min was needed to measure 3 qt of the same material. A third time was that which changed as the ratio of material to equipment capacity changed. One roasting pan, for example, was needed for four 10 lb roasts while an 18x26x1 in. sheet pan, was used for fifty 4x2x2 in. baking potatoes. The sum of these three times as charted provided the length of time required to perform each procedure per unit. The fourth category of time noted included the time involved in cleaning the work area and equipment. These times were isolated since the tasks would not necessarily be performed after processing each material, but rather after processing numerous materials.

19 Peak Production Load within Ingredient Room Selected

A decision to deliver materials to the production areas on an hourly basis beginning at 8:00 A.M. was made to minimize storage of processed materials within the ingredient room. Using the comprehensive listing of the established menu pattern (Fig. 5), the food production manager of the Dietetics Department at University Hospital was

Tasks	Time/ Unit, min	FUNCTION: Opening Cans				FUNCTION: Portioning-Packaging			
		MATERIAL GROUP: Dry milk powder, Instant mashed potatoes, Jelly, Orange juice				MATERIAL GROUP: Dry milk powder, Instant msh pot., Dry eggs, Spice, Bk pwd, Cocoa, Salt			
		Sum	C	V	Sum	Sum	C	V	Sum
GET READY:									
Check/confirm amt needed	0.10	x1	1			x1	1		
Open PM: Case/Sack	0.18								
Bin (assume)	0.08								
Package/Carton: High	0.50								
Low	0.13								
Cans: #10/48 oz/4 lb/32 oz	0.17			5					
#303/#2-1/2	0.13								
Lidded (assume)	0.20							6	
Jars: Gallon	0.15								
qt/pt	0.07								
Place material on/at WT/Equipment	0.12	x1	2			x1	2		
Place utensil on/at WT/Equipment	0.13	x1	3			x2	3	(frame, scoop)	
Place TC on/at WT/Equipment	0.13					x1	4	(plas bag)	
Set/Adjust: Scale	0.22					x1	5		
Meat slicer	0.60								
Food cutter—add H_2O (assume)	1.25								
TOTAL:		0.35				0.96			
CHANGE OR MODIFY MATERIAL:									
Weigh dry material	0.20							7	

Note: / = "or" in list of tasks
WT = Work table
C = Constant time
V = Variable time

Figure 20. Example of charting procedures per function per task in reference to time.

interviewed to obtain specific times necessary to deliver materials per product per meal to each production area. This information was recorded on a form as shown in Figure 21.

Meal	Production Area	Product	Serv/ Meal	Time materials/product needed in production area							
				5	6	7	8	9	10	11	12
Breakfast	Salad (S)	Fruit:									
		Canned	10		✓						
		Frozen	10		✓						
	Bakeshop (BS)	Muffin or	200	✓							
		Doughnut or									
		Fried Cake									
	S	Gelatin	25								
	Cooks (C)	Cooked cereal	300	✓							
	C	Scrambled eggs	300	✓							
	C	Bouillon	40		✓						
	Assembly (A)	Lemon wedge	40			✓					
Lunch	C	Gravy	300					✓			
	C	Bouillon	60					✓			

Figure 21. Example of form used to tabulate delivery times to production areas.

The materials were then grouped according to production areas and the designated delivery times. Using a form as shown in Figure 22, material amounts were entered after pound weights had been converted to decimal parts of a pound (52). Place of storage, refrigerator, freezer, or dry storage, immediately prior to delivery to the ingredient room was also indicated.

Using the alphabetized listing of all materials and the information recorded as shown in Figure 22, the quantities of each material were recorded per hour as shown in Figure 23. The sum of the total number of materials requiring portioning and packaging through the

Time	Prod Area	Serv/ Meal	Batches	Product	Material	Amt[a]	1 Ref 2 Fzn 3 Dry	Order of prep[b]
1:00 P.M.	V	625	1	Baked potato	Idaho potato	625	1	23
					Veg. shortening	3.125	3	5
		300	2	Whipped potato	Margarine	4.000	1	25
					Whole milk pwd.	9.000	3	4
					Salt	0.750	3	7
					Ins msh potato	21.000	3	6
1:00 P.M.	C	250	1	Chicken gravy	Chicken base	0.563	1	27
					Cooked Roux	3.500	1	26
					Egg shade	3/4 t	3	10
				Bouillon	Beef base	1.000	1	

[a]Amount in decimal part of pound unless otherwise specified.
[b]Specified order of preparation in Portioning Function.

Figure 22. Example of materials categorized by time needed within production areas.

Delivery time	Numerically coded listing of alphabetized materials								Summary of materials	
	1	2	80	81	82	83	96	97	Total number	Number of kinds
9:00 A.M.			0.063		1/2 c				28	25
10:00 A.M.			0.375 0.375 0.563						25	18
1:00 P.M.			0.594 0.375 0.375	3.125	2T 1/2 c	100 e			49	35
2:00 P.M.									20	8
3:00 P.M.										

Figure 23. Example of quantities of materials required within production areas per hour.

ingredient room per hour were determined. Within this total, like materials were combined and a total number of kinds of materials was calculated. For example, three quantities of salt (material No. 80) were required at 1:00 P.M. All three of these entries were considered for the total number of materials; however, salt was counted only once for the total number of kinds of materials.

The criteria for selecting the peak load of production within the ingredient room was based on the time period having the largest total number and kinds of materials. However, the period was examined to insure that all activities within all functions would be performed. Also, the highest volume to be processed per material was required for the period. The time period of 1:00 P.M. met these requirements. Therefore, the materials and quantity processed during this period were used to determine space requirements of the ingredient room.

20 Space Requirements Determined

To determine space requirements, the events: Material 10 and equipment dimensions 17, peak production load 19, and arrangements of functions 15 were summarized. Also, a priority listing for performing the activities within the ingredient room function of Portioning was developed in view of food quality, sanitation, and materials handling principles. Because of possible microbial growth and quality deterioration, processing of refrigerated foods was scheduled following processing of non-refrigerated foods. The sequence of weighing, measuring, and finally counting was determined for orderly processing rather than, for example, measuring followed by weighing and then back to measuring for a third material. The sequence of what to weigh or measure was also established to avoid repetition of having to process the same material within a small time span, for example, weigh flour then weigh baking powder for the same product, followed by weighing flour for the next product. The completed priority in decending order of preparation can be seen in Figure 24.

Storage Place	Process	Preparation
Dry	Weigh	Large bulk containers Small containers Cans
	Measure	Teaspoons or tablespoons Cups or quarts or gallons
	Count	As required
Refrigerated	Weigh	As required
	Measure	Teaspoons or tablespoons Cups or quarts or gallons
	Count	As required

Figure 24. Priority listing for processes in Portioning Function.

Using the data entered for materials categorized by time needed within the production areas, the order for processing materials within the Portioning Function during the 1:00 P.M. peak production period was established. All products were assigned a number to facilitate analysis. The priority information (Fig. 24) was then used to record the order of processing materials in numerical sequence. An example in the "Order of prep" column is shown in Figure 22. Materials of the same kind were given the same processing number, for example, every time flour appeared it was given a "1".

The accumulated and/or calculated data on material and equipment dimensions, time, and materials flow were entered on the Space Requirements Analysis Form, illustrated in Figure 25. Material dimensions (Event 10) were used to calculate cubic and square inches occupied by specified quantities of materials. Time and procedure data, shown in Figure 20 were also used as demonstrated in the example cited below. For this example, the material, whole milk powder for the product, Whipped Potatoes will be traced and the results summarized in Figure 25.

Entries in columns one to 13 were directly transferred from the source indicated.

Column	Entry	Source of Entry
1	Production area of main kitchen denoted by a letter symbol.	Production sheets
2	Product number.	Fig. 22, Materials categorized by time needed within the production areas.
3	Product name.	
4	Material number.	Alphabetical listing of materials.
5	Material name.	Fig. 22
6	Market specification of material (i.e., fresh, frozen or canned)	Fig. 5, Comprehensive listing of devised menu pattern per day.
7	Unit size.	Fig. 5
8	Form required in production area.	Fig. 5
9	Number of servings per product.	Fig. 5
10	Batch(es) per meal.	Fig. 5
11	Material amount needed.	Fig. 22

Production Area (1)	Product No. (2)	Product Name (3)	Material No. (4)	Material Name (5)	Specifications 1 Fsh 2 Fzn 3 Can (6)	Specifications Unit Size (7)	Specifications Form (8)	Quantity No. Serv/Product (9)	Quantity Batch/Meal (10)	Quantity Material Amt Needed (11)	Time Needed in Prod (12)	Material Flow between Functions (13)	Time Procedure/Function, min (14)	Time Preparation Function, min (15)	Storeroom Delivery to Function Quantity, Size No. or lb cu in. (16)	Transportation Container Kind (17)	Transportation Container Size, in. cu in. (18)	Transportation Container Quant (19)
V	19	Whipped Potatoes	60	Whole Milk Powder	3	#10 4 lb	Weigh	300	2	9.0 lb	1:00PM	1	1.59		3-#10 / 756	#10 w/ Plas lid		3/1
												4	2.52			Plas bag 14x11 in.	180 / 180	2
												10				#10 w/ Plas lid		1/1
												5						
												9						

Utensils (20)	Equipment: Work Table Time, min (21)	Work Table Space, sq in. (22)	Sink Time, min (23)	Sink Space, sq in. (24)	Can Opener Time, min (25)	Can Opener WT Space, sq in. (26)	Scale Time, min (27)	Scale WT Space, sq in. (28)	Vertical Food Cutter Time, min (29)	Vertical Food Cutter Cart Space, sq in. (30)	Meat Slicer Time, min (31)	Meat Slicer WT Space, sq in. (32)	Trash Time, min (33)	Trash Space, cu in. (34)	Transportation Equipment of Preprocessed, weighed, measured & packaged material: Wire Bskt (35)	Plas Bin (36)	Shelf (37)	Mobil Frame Time, min Product No. (38)	Mobil Cart Time, min Product No. (39)	Unused Material Shelving 1 Ref 2 Dry (40)	Unused Material Shelving sq in. cu in. (41)
			0.14		1.35	36-7							0.10	108							
Frame Scoop	0.28	36					2.03	108					0.10	504							
																				1	36-7 / 252
																P 19			0.10 / 19		

Figure 25. Space Requirements Analysis Form showing an example of the material, whole milk powder.

Column	Entry	Source of Entry
12	Time material needed in production area.	Event 19, Peak production load within ingredient room selected.
13	Material flow between functions.	Fig. 12, Sequence of material movements between functions.

Columns 14 to 34 are discussed for entries made adjacent to Function 1, Opening Cans.

Column	Entry	Source of Entry
14	Discussed following columns 16, 17, 18, 19, & 20.	
15	Discussed following column 41.	
16	Storeroom delivery to function. Quantity: 3-#10 cans containing 4 lb each were delivered. Thus, 3-#10 was entered.	Fig. 25, col 7, 10, 11
	Size: 1-#10 can measures 6x6x7 in. or 252 cu in. Cans were assumed to be square; thus, 756 cu in. (3 x 252) was entered.	Fig. 25, col 7 & Event 10, Material (unit) dimensions obtained.
17	A plastic lid was required to cover the #10 can enroute from Functions 1 to 4. Thus, #10 w/plas lid was entered	Fig. 20, Charting procedures per function per task in reference to time.
18	None.	
19	The entry, 3/1 represented 3 cans & 1 plastic lid. Since 2 cans would be emptied after portioning & 1 can would be stored, only 1 plastic lid was required.	Fig. 20 & Fig. 25, col 16.
20	None.	
14	The constant times for: "Confirm the amt need", "Place material at equip (can opener)", "Place TC (plastic lid) at equip", & "Clear trash" were summed & noted. The variable times for: "Wash material (lid of can): Low", "Open #10	Fig. 20

Column	Entry	Source of Entry
14 (cont'd)	can", "Cover TC", & "Place TC on cart" were summed & multiplied by three. The constant & variable time sums were added. The result, 1.59 min was entered.	
21	Time & space entries for specified equipment were made where applicable.	Time: Fig. 20; Space: Events 10 & 17
22	None.	
23	Sink time: 0.14 min required to wash lids of 3 cans.	Fig. 20
24	None.	
25	Can opener time: 1.35 min spent opening 3 cans.	Fig. 20
26	Can opener space: Each #10 can occupied 6x6 in. with height of 7 in. Thus, 36-7 was entered.	Event 10
27-32	None.	
33	Trash time: 0.10 min was spent disposing of the 3 lids removed from the cans.	Fig. 20
34	Trash space (calculated in cu in.): The amount of trash accumulated by 3 lids was 108 cu in. Since depth was minimal, only length & width were considered.	Event 10

The next functions specified in col 13 for the material flow of whole milk powder were 4 (Portioning) & 5 (Packaging). Function 10 (Refrigerated Storage) was specified as the storage place for the unused material. Entries made in appropriate col 16 to 32 as well as col 40 & 41 will be discussed for Functions 4, 5, & 10. As previously done, col 14 will be discussed following col 20.

Column	Entry	Source of Entry
17	TC Kind: A plastic bag was specified as the TC to be used from Function 5 for delivery to the production area. In Function 10 a #10 can with a plastic lid would be stored.	Fig. 20, FUNCTION: Portioning-Packaging MATERIAL GROUP which contained dry milk powder.

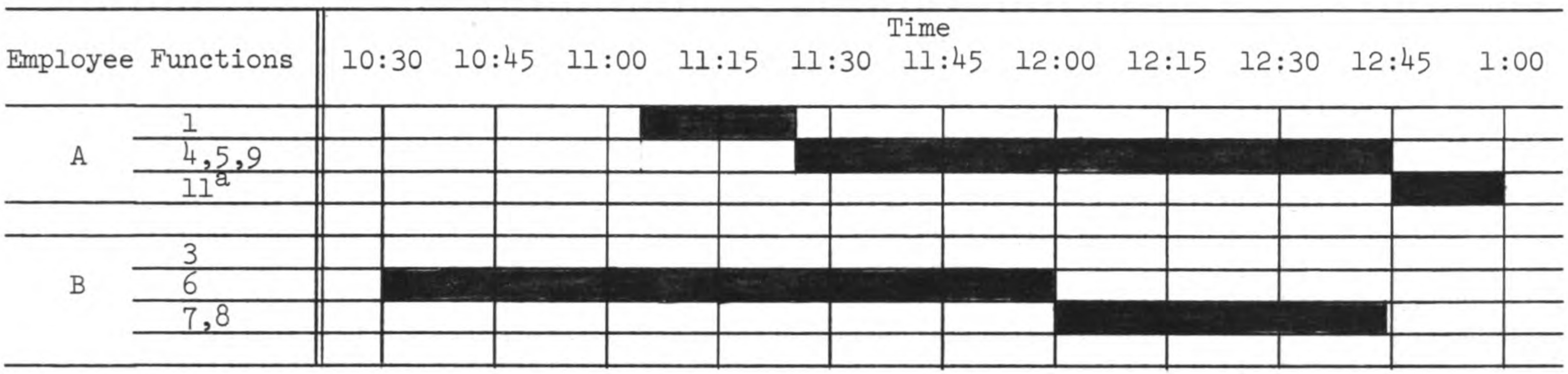
Column	Entry	Source of Entry
18	TC Size: The amount of material needed for 2 batches was calculated to be 180 cu in. each. A double entry was made of 180. The TC (plastic bag) required to accommodate 180 cu in. was specified as 14x11 in.	Fig. 25, col 10, 11 and Event 17 ; Minor equipment catalogue & weight-measure equivalents (10, 55).
19	TC Quantity: Since 2 batches were to be delivered, 2 plastic bags were required in Functions 4 & 5. Since 1 can would be stored with 1 plastic lid, an entry of 1/1 was made adjacent to Function 10. It was noted that the "1" representing the plastic lid was the same obtained in Function 1.	
20	Utensils: A frame to place a plastic bag into during weighing and a scoop with which to dip the milk powder, were the utensils required.	Fig. 20
14	The constant times were summed & noted (i.e., "Check amt needed", "Place material on WT", "Place utensil (frame) on equip (scale)", "Place utensil (scoop) on WT", "Place TC (plastic bag in frame) on equip", "Set scale", "Close lidded can", "Clear work area of unused material, utensils, and trash". The variable time of weighing was next calculated and noted for the specified weight required (i.e., 4.5 lb per batch). The third time of "Closing TC (Heat seal plastic bag)", "Attach label", & "Place on cart" were summed & multiplied by two. These three times were added & the results entered in column 14. It was noted that this time represented Functions 4, 5, & 10.	Fig. 20
21	Work table time: The time spent was 0.28 min.	Fig. 20

Column	Entry	Source of Entry
22	Work table space: 36 sq in. of space was required to accommodate the TC of milk powder for labeling.	Event (10)
27	Scale time: The amount of time calculated to weigh 9.0 lb of milk powder in 2 batches of 4.5 lb each, was calculated to 2.03 min & this time was entered.	Fig. 20
28	Scale space: 3-#10 cans placed at the scale required 108 sq in. of space.	Event (10)
29-32	None.	
33	Trash time: Disposing of 2 cans required 0.10 min.	Fig 20
34	Trash space: 2 cans were emptied & required 504 cu in. of space. (6 x 6 x 7 = 252 x 2 = 504)	Event (10)
35-37	Containers to be inserted in or on mobile carts (MC) for material transportation. The product number, P no. associated with the material being processed or material number, M no. was entered adjacent to the function from which transportation was required.	Fig. 25, col 2 & 13
38-39	Type of cart suitable for the container identified. Entries included: $\frac{\text{Time, min}}{\text{Product No.}}$	Fig. 25, col 35 to 37 & Fig. 20
40	Unused material shelving space required was either refrigerated, 1 or dry, 2. Unused whole milk powder was to be stored under refrigeration, thus the No. 1 was entered adjacent to Function 10.	Principles of quality retention & sanitation.
41	Unused material shelving space: $\frac{36\text{-}7}{252}$ was entered where, 36-7 indicated sq in. & the height restriction; 252 indicated cu in. of 1 #10 can.	Event (10)

Column	Entry	Source of Entry
15	Summarizing procedure time data in col 14 & scheduling of employee(s) within the ingredient room was determined for the peak load period of 1:00 P.M. Because no deliveries to the production areas were required between 10:00 A.M. and 1:00 P.M., the approximate 6 hr work load of peak ingredient room preparation was divided between 2 employees. Functions were then grouped for work distribution according to relativity and total preparation time per function. The scheduling results can be seen in Figure 26.	Fig. 25, col 14

Mobile cart (MC) analysis was next performed for three types of deliveries: (1) storeroom to the ingredient room, (2) function to function within the ingredient room, (3) ingredient room to production areas within the main kitchen. Cart requirements from the storeroom to the ingredient room were calculated by summing the cubic inches of space noted for each material per function (Fig. 25, col 16) according to the material storage requirement; dry or refrigerated. The results are summarized in Figure 27.

Height restrictions were entered based on the most common purchase unit of materials delivered to each function. The cubic inches were converted by dividing cubic inches by the height restriction. A square root table was then used to convert the resulting figure to length and width requirements. Appropriate carts were selected from equipment catalogues as indicated in Figure 27. A modified equipment layout form shown by Muther (44) was then used to draw the selected carts to scale and provide the needed equipment information as illustrated in the Appendix, page 97.



[a]Assembling Materials (according to products)

Figure 26. Time schedule and work distribution of peak preparation within ingredient room.

From Storeroom Storage	To Function	A.P.[a] Material Required, cu in.	A.P.[a] Material LxWxH, in.	MC Summary Type	MC Summary Size, in.	MC Summary Quant	MC Summary Capacity, lb
Dry	1	9,399	36x36x7	Cart, Star p. 152 2 shelf, 21 in. clearance	22-3/4x39x 37-1/4	1	1000
	4	2,772	20x19x8	Tubular Utility cart, Star p. 151 3 shelf, 11 in. clearance	22x40-1/2x 37-1/4	1	400
Refrigera-ted	4	3,780	25x25x6	Same as in Function 4, above		1	
	3	86,246	60x60x24	Shelf Rack, Crescor 270 Series 3 shelf without top shelf	48-1/4x24-1/2x 69-1/2	1	400
Freezer	7	252	7x6x6	None: Bring with refrigerated materials for Function 4. Remove 252 cu in. materials at Function 7. Deliver remaining materials with cart to Function 4.			

[a]As purchased materials

Figure 27. Mobile cart analysis for storeroom delivery during peak ingredient room preparation.

Transportation of materials between functions were found to be from $1 \rightarrow 4$, $\begin{tikzcd} 3 \arrow[r] & 4 \arrow[r] & 6 \arrow[r] \arrow[dr] & 4 \\ & & & 10 \end{tikzcd}$, $3 \rightarrow 7$, and from 3 to the Assembly Production Area. The same cart could be used for transportation between Functions 1 (Opening Cans) and 4 (Portioning). Analysis of the transportation of other materials was accomplished by using information from the Space Requirements Analysis Form (Fig. 25) and summarizing it on the Mobile Cart Analysis between Functions Form (Fig. 28). The use of this form is described as follows.

Column	Entry	Source of Entry
1	Product identification number.	Fig. 25, col 2
2	Material identification number allowing one line per material.	Fig. 25, col 4
3	Direct routing of materials between functions. A ✓ mark indicated that the material traveled the specified route as opposed to any other routing specified.	Fig. 25, col 13
4	Number of containers required per material.	Fig. 25, col 17
5-8	Size of containers in which materials were to be transported.	Fig. 25, col 17 & 18
9	Container height.	Fig. 28, col 5-8
10	Total height required for the containers specified obtained by multiplying the container quantity by the container height restriction.	Fig. 28, col 4 & 9
11	The number of containers was determined based on the maximum space allowance of a sheet pan (shelf), 18x26 in.	Fig. 28, col 4-8

MC Analysis between												
			Containers for Cart						Summary			
Product Number (1)	Material Number (2)	Function 3→4 (3)	Quantity (4)	Perforated Pan (5)	Wire Basket (6)	Plastic Bin (7)	Sheet Pan (8)	Height Restriction (9)	Height, in. (10)	Shelves, in. (11)	Function 4→6→4 (12)	Quantity (13
4,20	55	✓	2	—	18x26x2.5	—	—	2.5	5.0	2	—	—
4	11	✓	1	—	18x24x4	—	—	4.0	4.0	1	✓	2
7,12	63	✓	2	—	—	20x15x5	—	5.0	10.0	2	✓	1
7	12	✓	1	20x12x2.5	—	—	—	2.5	2.5	1	✓	—
12	13	✓	1	—	18x26x4	—	—	4.0	4.0	1	✓	1

a. Total:	33.0	9	
Cart(s) required:			
b. Corrugated, 1.5 in. centers			
c. Angle Ledge, 5-1/8 in. centers	1-9 ledge, 36 in. high		

Figure 28. Example of mobile cart analysis between functions.

Column		Entry	Source of Entry
12-end		Repetition of the information described for col 3-11, but for different routings.	
Row	Col		
a	10	Total height required by summing col 10.	Fig. 28
b	11	Total number of shelves required by summing col 11.	Fig. 28
b,c	--	Kinds of carts required.	Event 10, Equipment catalogues
b or c	10 11	Cart specified to accommodate needs	

Upon completion of the Analysis between Functions Form, the total number and type of carts required within the ingredient room were determined. As done for the storeroom delivery carts, an Equipment Layout Data Form, including the plan view scale drawing, was completed for each size and type of cart required.

A similar analysis of cart requirements to transport materials from the ingredient room to production areas was made. Because one of the objectives of the ingredient room was to deliver materials per recipe to the production areas, all products from which materials had been separated in processing were assembled. When no assembling was necessary for such products as baked potatoes, materials moved directly to production areas using carts which had accommodated the materials as they moved between functions (i.e., Functions 3, Cleaning Materials and 6, Changing Shape) in the ingredient room. Other materials were assembled following processing within Functions 5 (Packaging) and 7 (Panning). Following analysis, types of carts were specified based on needs and availability.

Utensils required for Functions 4 (Portioning) and 5 were summarized using Figure 25, col 13 and 20. Measurements indicated in equipment catalogues or obtained by physically measuring the items provided the necessary information for determining space requirements. Since no drawers were desired within the ingredient room, a vertical suspension storage arrangement was selected. Configurations of possible arrangements were drawn. The arrangement requiring the least amount of space or 28 in. in length and 18 in. in height with a maximum projection of 7 in. to accommodate the 1 gal measure, was selected.

The analysis of trash accumulation was next determined using the data recorded on the Space Requirements Analysis Form (Fig. 25). Trash was created in Functions 1 (Opening Cans), 3 (Cleaning Materials), 4-5 (Portioning-Packaging), 7 (Panning), and 8 (Breading). According to an engineering principle of materials handling (30), trash should be eliminated at the point of creation; therefore, the cubic inches of trash accummulated per function denoted in col 34, Figure 25 were summed per function. Equipment catalogues were then used to select the appropriate trash container(s) based on the existing system of trash disposal at University Hospital, Dietetics Department in which polyethylene-lined paper bags are utilized. Each trash bin liner is 23x17x48 in. or 18,768 cu in. in size. Hence, the sum of trash accumulated per function was divided by 18,768 cu in. to determine the number of liners required per function. Knowing the dimensions of the trash bin liners, the amount of floor space required per function was next calculated and denoted in length, width, and height as well as square feet. These results are shown in Table 4.

Table 4. Calculations to determine space requirements for total trash accumulation.

Functions:		1	3	4-5	7
cu in. trash:		3,425	84,686	2,192.5	4,250
no. of liners: (23x17x48 in.)		1	4	1	1
Floor space required	ft:	2x1.5	4x3	2x1.5	2x1.5
	sq ft:	3.0	12.0	3.0	3.0

A summary was made of re-usable transportation containers such as plastic bins, sheet pans, and stainless steel pans, per function from Figure 25, col 13, 17, 18, and 19. The totals provided the dimensions of space required for all containers within each function. To facilitate weighing, the suggestion was made that each container be etched with its own weight.

Columns 40 and 41 of the Space Requirements Analysis Form (Fig. 25) were used to determine refrigerated and dry storage space. The sum of the refrigerated material entries, 14,206.5 cu in. or 9 cu ft, indicated shelving requirements. From the MC analyses, three carts (1.83x2.25 ft) needed refrigeration while the remaining carts were in use or circulating between one or more functions. Thus, 24.7 sq ft of refrigerated cart space was required.

Dry storage within the ingredient room was of three types: (1) shelving for spices, flavorings, and similar opened-unused materials, (2) ingredient bins for flour, sugar, and starch, (3) a dolly for a 50 lb container of shortening. The sum of dry storage shelving requirements (col 41) for opened-unused materials was 181 sq in. with a height restriction of 7 in. As determined in Event (10) a length of 105 in. was required for the 29 items commonly used in processing with two height restrictions of 5 and 9 in. Thus, 286 sq in. of dry storage shelving was required with height restrictions of 5, 7, and 9 in. For dimensions of ingredient bins the amount of material used per day and per week were summed and calculated. Based on the volume and purchase unit, the appropriate bin sizes (half and full size) were selected from the equipment catalogues.

The major equipment needs chosen at the completion of Event (16) and dimensions from corresponding specification sheets (Event (17)) were listed for each function (i.e., 3, 4-5, 6, and 7-8). The maximum dimension of material and/or re-usable containers placed on or at the equipment was selected from the appropriate function row and equipment column on the Space Requirements Analysis Form (Fig. 25) to provide sufficient work space. Sketches including dimensions were then drawn per function in an arrangement employing the procedures developed at the completion of Event (13) and the principles of motion economy, human physical normality, layout, and materials handling as discussed by Kazarian (30). Utensil, re-usable container, and dry storage summaries of space requirements were used to arrange the items in the available space above and below work surfaces as illustrated in the following figures.

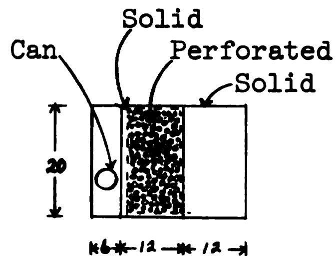
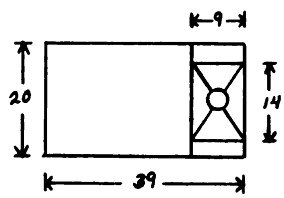
Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
	Wash top of cans: Sink	9x14x8	
1-#10 can material space required at one time, Fig. 25, col 22	Open cans: Electric can opener		
SS pans (Fig. 25, col 18 & 19): 1-12x20 perforated 2-12x20 solid	Drain cans: Work table  		
	Summary: Work table-sink  		
	Adjusted space required:		3.5x2.0 (template)
Other space required: Re-usable container storage: 24x20x12 in. vertical storage			Ample space under WT
Trash accumulation summary: 3,425 cu in.	1 liner	2x1.5x4 ft	2.0x1.5 (template)

Figure 29. Summary of Function 1, Opening Cans.

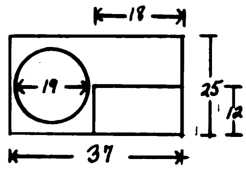
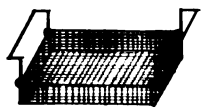
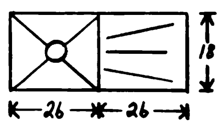
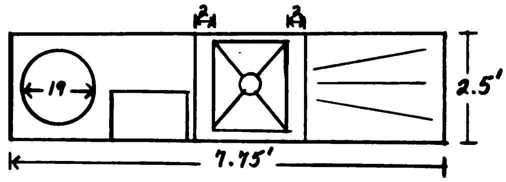
Maximum dimension of material &/or re-usable container, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
	Trim & peel:		
	Disposer	5 hp, Table opening: 19 in. diameter Drain outlet, based on 34 in. height table, 14.5 in.	
12x18 chopping board	Work table 		
	Adjusted space required:		3.5x2.5
	Wash:		
18x26 basket constructed with flexible handles on sides to lower & lift; 3 in. above bottom of sink so as not to recontaminate the clean produce; but low enough to prevent employee from getting wet while spraying.	Sink	18x26x14	
	Basket: 		
	Spray	Wall attachment above sink	
	Drain board 	1/8 minimum slope toward sink (NSF)	
	Adjusted space required:		3.5x5.25
	<u>Summary</u>:		
	Work table-sink 		7.75x2.5 (template)

Figure 30. Summary of Function 3, Cleaning Materials.

Figure 30 (cont'd.)

Maximum dimension of material &/or re-usable container, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
Other space required:			
Re-usable container storage:			
Pans: 33x26x18			Space to be provided
Baskets: 12x16 vertical or 18x26x29 horisontal			Ample space under WT section
Dishmachine (for utensil washing):		24x25x34	Ample space under drain board section
Trash accumulation summary:			
84,686 cu in.	4 liners	2x1.5x4 ft	4.0x3.0 (template)

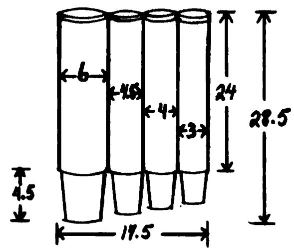
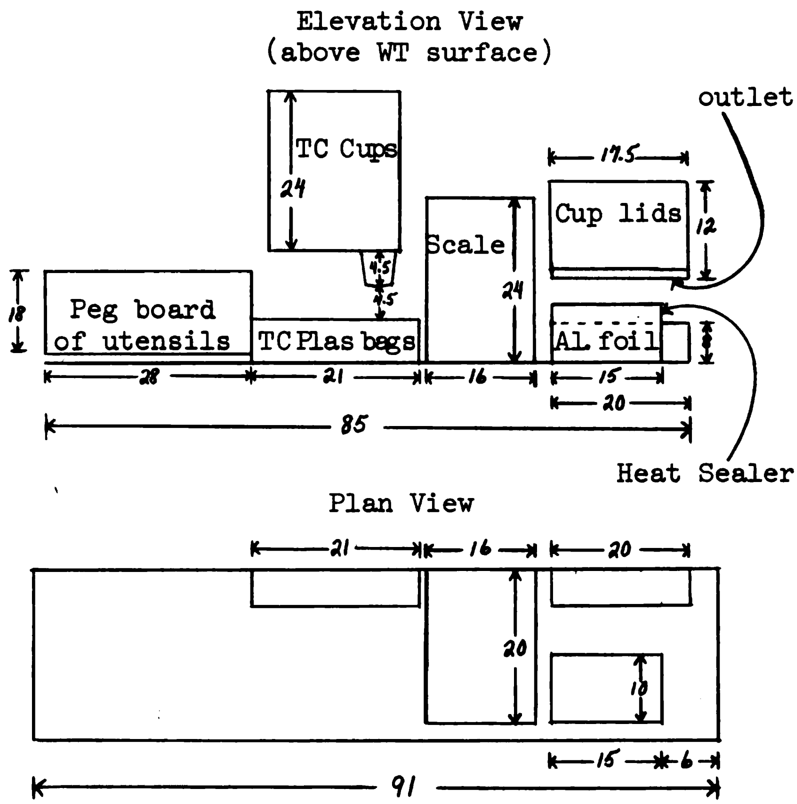
Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
Prepeeled potatoes, 18.5x14x5.5 in. material space required as well as a plastic bin, 20x15x5 in., Fig. 25, col 16.	Open PM: Work table	43x20	
4 sizes of cylinder cups were required, Fig. 25, col 17 & 18. Diameters, in.: 6.0 4.5 4.0 3.0 Maximum height: 6.0 in.	Portion: TC cup dispenser (closed cylinder sleeves required by Public Health) 	17.5x6x28.5	
2 sizes of plastic bags were required, Fig. 25, col 17: 14x11 & 8.25x7	TC plastic bag dispenser	21x8x8	
15 lb celery maximum material batch weight required, Fig. 25, col 11.	Scale, 0.01 lb gradation, 15 lb	16x20.6x24	
	Utensil storage (determined in utensil analysis)	28x7x18	

Figure 31. Summary of Function pair 4-5, Portioning-Packaging.

Figure 31 (cont'd.)

Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
	Package:		
Maximum plastic bag opening: 11 in., Fig. 25, col 17	Heat sealer	15x10x9	
	Aluminum foil dispenser	20x8x8	
Same diameters as cylinder cups (relatively).	TC cup-lid dispenser	17.5x6x12	
	Work table space (to set down cups to close)	6x6x6	

Summary:



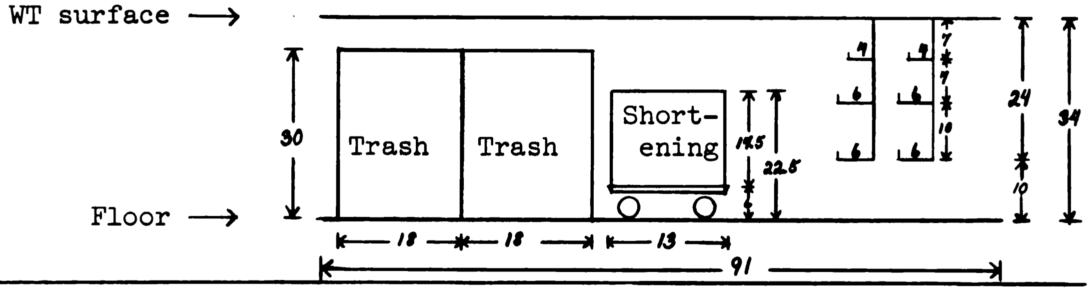
Adjusted space required: 7.5x2.0 (template)

Figure 31 (cont'd.)

Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
Other required space:			
Trash accumulation summary:			
2,192.5 cu in.	2 liners	2x3 ft	Since trash containers were to be stored under WT, 34 in. high, 2 containers folded down required.
Dry stroage summary:			
PM of shortening, 12x12x17.5	Dolly: 13x13x6	13x13x22.5 (under WT)	
Shelving, 181 sq in., 7 in. height restriction, 5x6x7			
29 items, Event 10, 105x 3.5x5 / 6.0x9	Shelving: (6 shelves on sliding track suspended beneath WT. Public Health restriction: Non-portable storage of food should be a minimum of 10 in. from the floor.)	18x24x24	
Re-usable container storage: 42x26x18			Space to be provided

Summary:

Elevation View
(below WT surface)



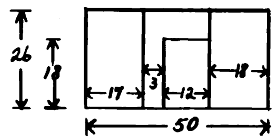
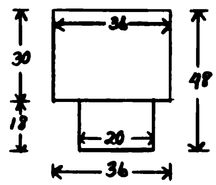
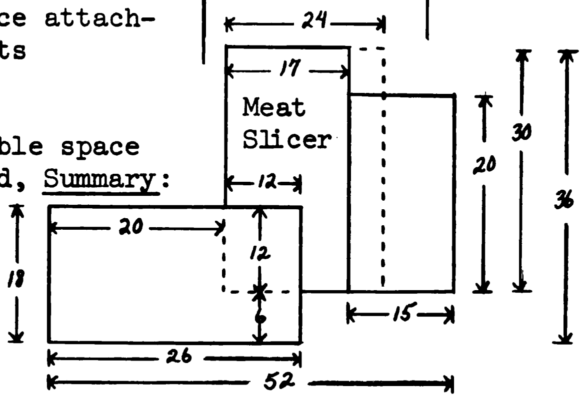
Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
12x18 chopping board, 26x17 plastic bin, & 26x18 sheet pan, Fig. 25, col 17 & 18.	Manual chop & dice: 	50x26	
	Adjusted space required:		4.5x2.5 (template)
27 qt onions maximum amt of material to be chopped, Fig. 25, col 30.	Machine chop: Vertical cutter/ mixer, 30 qt capacity, Hobart model #: VCM-25	36.24x48.5 (bowl turned down)	
20x18 pan, Fig. 25, col 30.	Cart beneath VCM spout to empty content into TC 	20x18x8	
	Adjusted space required:		3.0x4.0 (template)
37 lb cabbage maximum amt of material to be sliced (shredded), Fig. 25, col 34.	Machine slice: Automatic meat slicer; chute attachment	29-3/16x24 or 29-3/16x 17 (below carriage)	
72 lb prepeeled potatoes maximum amt to be sliced.	2 fence attachments		
20x15x5 plastic bin 26x18x1 sheet pan, Fig. 25, col 22.	Work table space required, Summary: 		
	Adjusted space required:		4.5x3.0 (template)

Figure 32. Summary of Function 6, Changing Shape.

Figure 32 (cont'd.)

Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
Other required space: Re-usable container storage: Sheet pans: 9x26x18 vertical			Ample space under WT

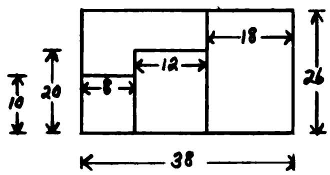
Maximum dimension of material &/or re-usable containers, in.	Equipment required per activity, in.	Dimensions, in.	Summary, ft
10x8 material space required, Fig. 25, col 22. 26x18 sheet pan 20x12 pan (breading mix), Fig. 25, col 22.	Pan &/or bread: Work table 		
	Adjusted space required:		3.5x2.5 (template)
Other required space: Re-usable container storage: Sheet pans: 15x26x18 vertical			Ample space under WT
Trash accumulation summary: 4,250 cu in.	1 liner	2x1.5x4 ft	2.0x1.5 (template)

Figure 33. Summary of Function pair 7-8, Panning-Breading.

Function Space Required, in.	Equipment	Dimensions, in.	Summary, ft
Function 3: 33x26x18	Mobile cart: Cres-Cor model #: 270-40-4823 3 corrugated shelves	48-1/4x24-3/8x 69-1/2	4.0x2.0 (template)
Functions 4-5: 42x26x18	Same MC	Same MC	Same MC

Figure 34. Summary of re-usable container space to be provided for Functions 3 and 4-5.

21 Templates of Work Centers Developed

The necessary templates were determined from the mobile cart analyses, refrigeration and ingredient bin space analyses, and sketches with function summaries (Fig. 29, 30, 31, 32, 33, and 34). The most common scale used for layouts is 1/4 in. per ft. Thus, 1/4 in. scale, color-coded templates were made from construction paper.

22 Arrangement of Work Centers within Functions Determined

The templates were arranged on 1/4 in. graph paper according to the functional flow diagram (Fig. 17) which resulted from travel charting (Event 15). Because all work centers were not equal in dimension and because aisle space requirements were not yet determined; arrangement modifications were performed by manipulating the templates directly on the graph paper.

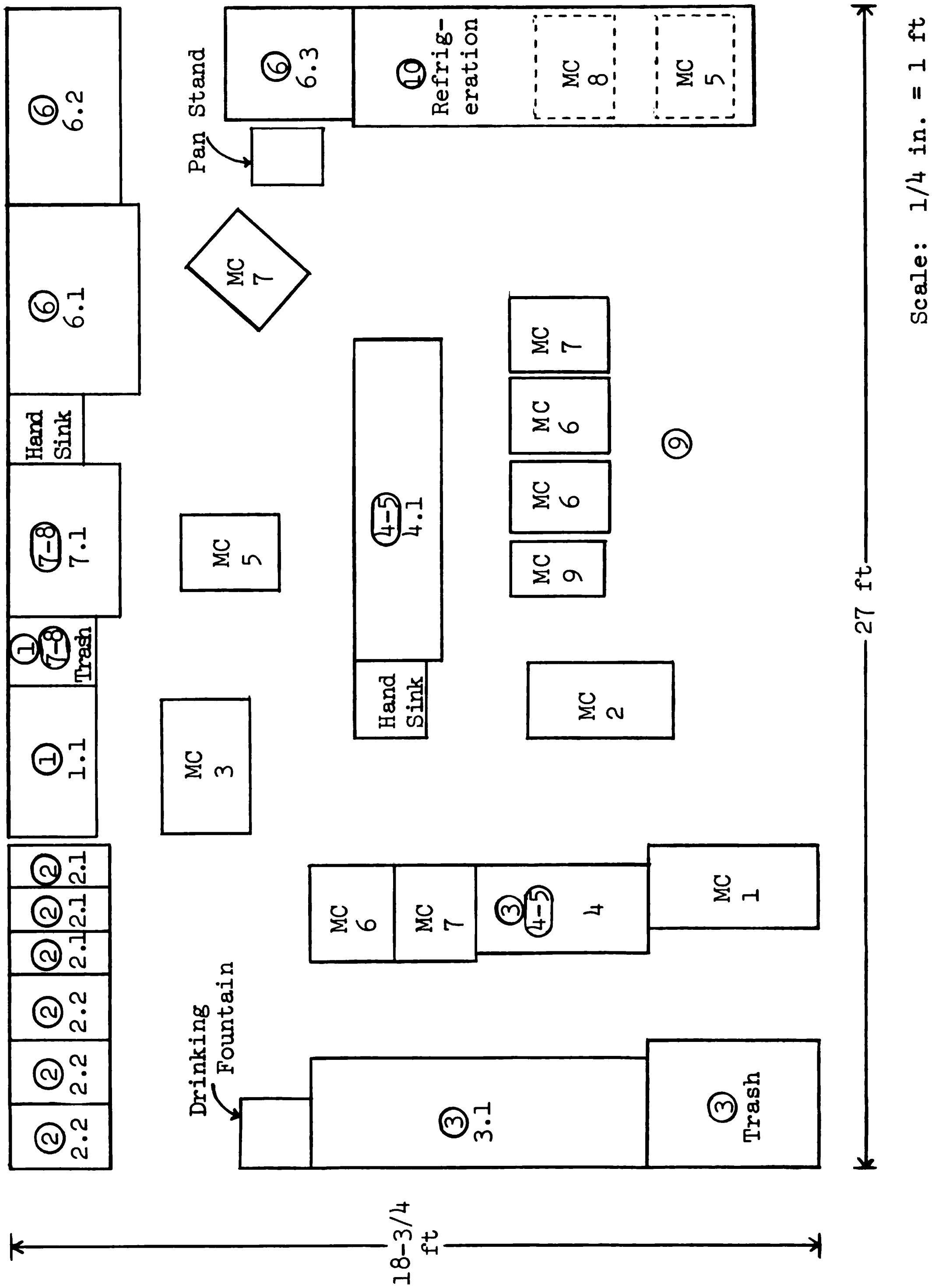
Function 2 (Dry Storage of the ingredient bins) was exchanged with Function 1 (Opening Cans work center) for the following reasons. The recorded frequency of material flow between Function 2 and 4 (Portioning) included shelving as well as ingredient bins. The greater frequency of movement was due to shelving whereas the ingredient bin movement was relatively restricted to one delivery time per day. Since shelving was included in the work center of Function pair 4-5 (Portioning-Packaging), obviously the distance for the more frequent movement was minimized. Another advantage to the change was that ingredient bins were more accessible to the storeroom for refilling. On the other hand Function 1 (Opening Cans) resulted in a straight line to Function 4 (Portioning). Furthermore, as a result of this change, trash space was decreased and became centrally located for Functions 1 (Opening Cans) and 7-8 (Panning-Breading). Since the total space for Functions 1, 2 (Dry Storage), and 7-8 was less than Functions 3 (Cleaning Materials) and 4-5, enough space was available to place Function 6 (Changing Shape) opposite Function 10 (Refrigerated Storage) and adjacent to Function 7-8. The change provided better access to Function 10 as well as totally, a rectangular configuration of the ingredient room and a reduction in distance to travel.

One cart was eliminated by simulating the material movement and performance of activities between Functions 3 and 4-5. Rather than having two independent carts from Function 4-5 for Function 6, it was assumed that when one of the two carts from Function 3 was emptied, it could be filled with portioned materials for Function 6 routing.

Having developed a relative arrangement of the work center templates in space, aisle space requirements were next determined. Recommendations for aisle space have been provided as described in the Appendix, pages 98 and 99. These recommendations as well as maneuvering MC templates through their routing sequence in relation to time, determined aisle space dimensions. Adjustments were made in the placement of work center templates to allow for the necessary aisle space.

23 Layout Drawn to Scale

Having established the arrangement to accommodate all necessary space requirements, the layout (Fig. 35) was drawn to scale from the template layout. As a construction algorithm the presentation of the layout for this study was done as a sketch to scale rather than a final blueprint for bidding purposes. It is drawn on a 1/4 in. scale and is accompanied by a schedule of major equipment (Fig. 36). Minimal specifications were identified in accord with the request of University Hospital, Dietetics Department management.



6
6.2
6
6.1
Hand Sink
7-8
7.1
1
7-8
Trash
1
1.1
2
2.1
2
2.1
2
2.1
2
2.2
2
2.2
2
2.2
Pan Stand
6
6.3
10
Refrig-
eration
MC 8
MC 5
MC 7
MC 5
MC 3
4-5
4.1
Hand Sink
MC 7
MC 6
MC 6
MC 9
9
MC 2
Drinking Fountain
MC 6
MC 7
3
4-5
4
MC 1
3
3.1
3
Trash
27 ft
18-3/4 ft
Scale: 1/4 in. = 1 ft

Key to Ingredient Room Layout

Function		Equipment		
Code	Title	Code	Description	
1	Opening Cans	1.1	Work table detailed in Figure 29	
		MC 3	Canned materials, storeroom delivery	
2	Dry Storage	2.1	Ingredient bins, full size	
		2.2	Ingredient bins, half size	
3	Cleaning Materials	3.1	Work table-sink detailed in Figure 30	
		MC 1	Mobile cart for produce storeroom delivery	
		MC 6 & 7	Mobile carts for clean produce	
3 4-5	Cleaning Materials & Portioning-Packaging	MC 4	Re-usable container storage	
4-5	Portioning-Packaging	4.1	Work table detailed in Figure 31	
		MC 2	Dry or refrigerated storeroom delivery (Change as time needs change)	
6	Changing Shape	6.1	Work table described in Figure 32 for manual chop & dice	
		6.2	Work table described in Figure 32 for machine slice & shread	
		6.3	Vertical Cutter/Mixer described in Figure 32 for chop & grate	
		MC 7	Mobile cart for change of shape materials	
7-8	Panning-Breading	7.1	Work table detailed in Figure 33	
		MC 5	Mobile cart for panned &/or breaded materials	
9	Storing for Assembly	MC 9	Area portioning of salads & desserts	Specified for peak preparation needs. Destinations change as volume & delivery times change.
		MC 6	Vegetable Production Area	
		MC 6	Salad Production Area	
		MC 7	Cooks Production Area	
10	Refrigerated Storage	MC 5 & 8	Mobile carts for panned, cleaned, &/or changed shape materials (Content change as needs change with delivery times)	

Note: MC 5 through 9 were indicated to show space allocation rather than ramifications during during preparation.

Figure 35. Layout of ingredient room drawn to scale.

Function		Equipment (all NSF approved)		
Layout code	Title	Layout code	Quantity	Description
1	Opening Cans	1.1	1	Work table-sink: 42x24x34 in. including a single compartment sink, 9x14x8 in.; SS top, solid construction. Removable SS corrugated shelving, 10 in. from floor.
	(on work table)	--	1	Can opener: Electric, heavy duty.
2	Dry Storage	2.1	3	Ingredient bin: 18x29x28 in. w/sliding lid; S or E[a] to: Rubbermaid, model # 3634.
		2.2	3	Ingredient bin: 12x29x28 in. w/sliding lid; S or E to: Rubbermaid, model # 3627.
3	Cleaning Materials	3.1	1	Work table-sink: 93x30x36 in. including 19 in. diameter opening for disposer, 18x26x14 in. sink, and 26x 18 in. drain board w/1/8 in. minimum slope toward sink; removable corrugated SS shelving between disposer and sink, 10 in. from floor.
	(under work table-sink)	--	1	Dishwasher: 24x25x34 in. S or E to: Hobart, model # UMP-4D, minus top.
	(installed in work table)	--	1	Disposer: 5 hp, cone adapter.
4-5	Portioning-Packaging	4.1	1	Work table: 93x24x34 in. SS top; 2 vertical shelf assemblies suspended beneath surface on sliding track, 10 in. from floor; portable.

[a]S or E: Similar or Equivalent

Figure 36. Schedule of major equipment.

Figure 36 (cont'd.)

Function		Equipment (all NSF approved)		
Layout code	Title	Layout code	Quantity	Description
4-5 cont'd.	(on work table)	--	1	Scale: 0.01 lb gradations; 15 lb minimum capacity; S or E to: Toledo, model # 1070.
	(on work table)	--	1	Heat sealer: 15x10x9 in.; S or E to: Sentinal Heat-Sealer, model # 12TP.
	(under work table)	--	1	Dolly: 13x13x6 in., 5 in. wheels.
6	Changing Shape	6.1	1	Work table: 54x36x34 in.; SS top; removable SS corrugated shelving, 10 in. from floor; portable.
	(on work table)	--	1	Automatic meat slicer: 29-3/16x24 in., w/one 7-1/2 in. diameter chute and 2 fence attachments; S or E to: Hobart, model # 1712.
		6.2	1	Work table: 54x30x34 in.; SS top.
		6.3	1	Vertical cutter/mixer: 36-1/4x18-1/2x46-1/2 in.; S or E to: Hobart, model # VCM-25.
7-8	Panning-Breading	7.1	1	Work table: 42x30x34 in.; SS top; removable SS corrugated shelving, 10 in. from floor; portable.
MC	Storeroom Delivery carts: (Produce)	1	1	Shelf rack mobile cart: 48-1/4x24-3/8x69-1/2 in.; wire rod shelving w/handle; S or E to: Cres-Cor, model # 270-43-3623 minus top shelf.

Figure 36 (cont'd.)

Function		Equipment (all NSF approved)		
Layout code	Title	Layout code	Quantity	Description
MC cont'd.	Storeroom Delivery (Dry & Refrigerated materials)	2	2	Tubular utility cart: 40-1/4x22x37-1/2 in.; 400 lb capacity; 3 shelf, 11 in. clearance; S or E to: Lakeside, model # 493.
	(Canned materials)	3	1	All-purpose cart: 39x22-3/4x 37-1/4 in.; 1000 lb capacity; 2 shelf, 21 in. clearance; S or E to: Delux Imperial Carts, model # 152K943.
3 4-5	Re-usable container storage	4	1	Shelf rack: 48-1/4x24-3/8x 69-1/2 in.; 3 corrugated shelves; S or E to: Cres-Cor, model # 270-40-4823.
MC	Mobile Cart	5	2	Corrugated rack mobil cart: 21-9/16x26-3/4x69-9/16 in.; 39 corrugations, 1-1/2 in. centers; S or E to: Cres-Cor, model # 200-1841.
MC	Mobile Cart	6	3	Angle ledge rack mobile cart: 22-1/8x26-3/4x42 in.; 6 ledges, 5-1/8 in. centers; 18x26 in. pan capacity; S or E to: Cres-Cor, model # 201-186.
MC	Mobile Cart	7	3	Angle ledge rack mobile cart: 22-1/8x26-3/4x57-9/16 in.; 9 ledges, 5-1/8 in. centers; 18x26 in. pan capacity; S or E to: Cres-Cor, model # 201-1810.
MC	Mobile Cart	8	1	Corrugated rack mobile cart: 21-9/16x26-3/4x42 in.; 22 corrugations, 1-1/2 in. centers; 18x26 in. pan capacity; S or E to: Cres-Cor, model # 200-1822.
MC	Mobile Cart	9	1	Utility truck: 27-1/4x15-1/2x 31-1/2 in.; 3 shelves, 13 in. clearance, 24x15-1/2 in.; 300 lb capacity; S or E to: Star, model # SP188.

SUMMARY AND CONCLUSIONS

The purpose of this study was to develop an ingredient room layout in the form of a construction algorithm for the Dietetics Department of University Hospital, Ann Arbor, Michigan. The systematic, logical plan for analyses of functions and elements of the systems as well as subsystems was completed through the development of a form of a PERT network diagram. The network diagram included identification of materials (ingredients) and detailed analyses of their volume, routing, environment, and processing time to determine equipment and space requirements.

Industrial engineering principles were applied to eliminate unnecessary activities, combine like activities such as the Portioning and Packaging functions as well as the Panning and Breading functions, and develop simplified processes such as spray-washing for fruits and vegetables. Other analytical techniques included time study and travel charting as a quantitative measure for minimization of materials flow and backtracking.

To maintain food quality, hourly deliveries were scheduled from the ingredient room to production areas as materials were needed for production; also, principles of food science and sanitation were incorporated into developed procedures. To minimize trash within production areas, disposal of packaging media was accomplished within the ingredient room and disposable transportation containers were collected in the Pot and Pan Washing Area from the mobile carts used for delivery of materials. Flexibility was incorporated by selection of portable equipment whenever possible as well as equipment to perform diversified processes. Integration of all facets of the Dietetics Department was considered. The paper system developed for communication of material requirements to the ingredient room was planned for eventual use of computer time within University Hospital Dietetics Department.

The author recommends computer programming of the methodology developed for the following reasons: (1) a great deal of time was involved in analysis of the data, (2) the data required was in numerical terms or could be reduced to numerical terms. Thus, computer programming would aid in the analyses and accommodate the total material and volume needs of University Hospital. Another recommendation is that time standards be developed and used in the proposed computer program. These time standards would be used for allocation of the time required for processing materials throughout food production, scheduling the processing times, and determining the peak load of production.

LITERATURE CITED

1. Blaker, Gertrude and Donaldson, Beatrice. "System Analysis-- A Tool for Management." Journal of the American Dietetic Association, 55 (August, 1969), 121-126.

2. Bloetjes, M.K. and Gottlieb, R. "Determining Layout Efficiency in the Kitchen." Journal of the American Dietetic Association, 34 (August, 1958), 829-35.

3. Borgstrom, Georg. Principles of Food Science. Vol. I. New York: The Macmillan Company, 1968.

4. Brown, Robin M. "Estimating Dietary Labor by Use of Work Modules." Hospitals, Journal of the American Hospital Association, 43 (October 16, 1969), 103-06.

5. Brown, Robin M. Personal communication, December 4, 1969. (Assistant Director, Dietary Service, Shands Teaching Hospital and Clinics, University of Florida, Gainesville, Fla.)

6. Buffa, Elwood S.; Armour, Gordon C.; and Vollmann, Thomas E. "Allocating Facilities with CRAFT," Harvard Business Review, 42 (March, April, 1964), 136-58.

7. Caccese, Esther K. Personal communication, November 25, 1969. (Director-Department of Dietetics, Community General Hospital, Reading, Pa.)

8. Conrad, George R. "Program Layout." Handout of travel charting program for Facilities Programming course at Michigan State University, East Lansing, Michigan, 1969.

9. Crossan, R.M. and Nance, H.W. Master Standard Data. New York: McGraw-Hill Book Co., Inc., 1962.

10. Dahl, J.O. and Breland, J.H. Food Standards Handbook for Quantity Cookery. Stamford, Conn.: Dahl Publishing Co., 1945.

11. Deegan, Wayne J. "Uses of Time Standards." Industrial Engineering Handbook. Edited by H.B. Maynard. 2nd ed. New York: McGraw-Hill Book Company, Inc., 1963.

12. Dooley, Arch R.; McGarrah, Robert E.; McKenney, James L.; Rosenbloom, Richard S.; Skinner, C. Wickham; and Thurston, Philip H. Operations Planning and Control. New York: John Wiley & Sons, Inc., 1964.

13. Federal Electric Corporation. A Programmed Introduction to PERT. New York: John Wiley & Sons, Inc., 1963.

14. Flack, Katherine E. "A Realistic Approach to Kitchen Production Methods." The Cornell Hotel and Restaurant Administration Quarterly, 3 (November, 1962), 95-98.

15. Flack, Katherine E. "Central Ingredient Room." Hospitals, Journal of the American Hospital Association, 33 (September 1, 1959), 125, 128, 132.

16. Flack, Katherine E. "Ingredient Room: Labor Savor." Volume Feeding Management, 23 (September, 1964), 38-41.

17. Flack, Katherine E. "Model Food Program." Institutions Magazine, Part 1, May, 1959, pp. 186-88; Part 2, August, 1959, pp. 136-38; Part 3, September, 1959, pp. 10, 38-40.

18. Gottlieb, Regina and Couch, Mary A. "Using the Cross Chart in Planning Kitchen Layouts." Journal of the American Dietetic Association, 36 (June, 1960), 585-92.

19. Green, Howard C. "A Method for Labor Time Analyses of a Specific Work Task." Unpublished M.S. Problem, Michigan State University, 1964.

20. Gue, Ronald L. "An Introduction to the Systems Approach in the Dietary Department." Hospitals, Journal of the American Hospital Association, 43 (September 1, 1969), 100-01.

21. Hartman, Jane. "Central Ingredient Room Improves Food Production." Modern Hospital, 110 (March, 1968), 100.

22. Heinemeyer, Jane M. and Ostenso, Grace L. "Food Production Materials Handling." Journal of the American Dietetic Association, 52 (June, 1968), 490-97.

23. Hicks, Tyler G. Successful Engineering Management. New York: McGraw-Hill Book Company, 1966.

24. Hodson, William K. and Mattern, William J. "Universal Standard Data." Industrial Engineering Handbook. Edited by H.B. Maynard. 2nd ed. New York: McGraw-Hill Book Company, Inc., 1963.

25. Institution Management Personnel. Methodology Manual for Work Sampling Productivity of Dietary Personnel. Unpublished manual, University of Wisconsin, 1967.

26. Ivanicky, Mary C.; Mason, Helmi A.; and Vierow, Susan C. "Food Preparation: Labor Time Versus Production Quantity." Hospitals, Journal of the American Hospital Association, 43 (October 16, 1969), 99-103.

27. Kazarian, Edward A. "Aisle Space Guidelines." Lecture notes presented in Layout and Design course, College of Hotel, Restaurant, and Institutional Management at Michigan State University, East Lansing, Michigan, January 24, 1968.

28. Kazarian, Edward A. "Graphic Method Analyzes Cafeteria Operation." College and University Business, 37 (December, 1964), 55-57.

29. Kazarian, Edward A. "Travel Charting." Lecture notes presented in Work Methods in Volume Feeding and Housing course, College of Hotel, Restaurant, and Institutional Management at Michigan State University, East Lansing, Michigan, October 30, 1968.

30. Kazarian, Edward A. Work Analysis and Design for Hotels, Restaurants and Institutions. Westport: The AVI Publishing Company, Inc., 1969.

31. Knickrehm, Marie E. "Digital Computer Simulation in Determining Dining Room Seating Capacity." Journal of the American Dietetic Association, 38 (March, 1966), 199-203.

32. Knickrehm, Marie E.; Hoffmann, Thomas R.; and Donaldson, Beatrice. "Digital Computer Simulation of a Cafeteria Service Line." Journal of the American Dietetic Association, 43 (September, 1963), 203-08.

33. Knight, Gladys. "Food Service Facilities Planning Seminar," Michigan State University, East Lansing, 1968. (Mimeographed).

34. Konnersman, Paul M. "The Dietary Department as a Logistics System." Hospitals, Journal of the American Hospital Association, 43 (September 1, 1969), 104-09.

35. Kotschevar, Lendal H. and Terrell, Margaret E. Food Service Layout and Equipment Planning. New York: John Wiley and Sons, Inc., 1961.

36. Liberty, Jean B. "A System Approach to Redesigning a Canadian Military Food Service Facility." Unpublished M.S. Problem, Michigan State University, 1969.

37. Ludwig, Charlotte E. Personal communication, June 23, 1969. (Director-Nutrition Service Internship, State of New York, Department of Mental Hygiene, Poughkeepsie, N.Y.)

38. Maas, Albert. "Mathematical Programming in the Fruit and Vegetable Processing Industry." Food Technology, 19 (March, 1965), 61-65.

39. Manchester, Katherine E. Personal communication, September 12 and November 18, 1969. (Col. AMSC, Chief, Food Service Division, Walter Reed Army Medical Center, Washington, D.C.)

40. Maynard, H.B.; Stegemerten, G.J.; and Schwab, J.L. Methods-Time Measurement. New York: McGraw-Hill Book Company, Inc., 1948.

41. Montag, Geraldine M; McKinley, Marjorie M.; and Klinschmidt, Arthur C. "Predetermined Motion Times--A Tool in Food Production Management." Journal of the American Dietetic Association, 45 (September, 1964), 206-11.

42. Montag, Geraldine M. and Tamashunas, Victor M. "Engineered Kitchen Layout Planning and Design." Journal of the American Dietetic Association, 55 (August, 1969), 127-32.

43. Muther, Richard. "Production-Line Techniques." Industrial Engineering Handbook. Edited by H.B. Maynard. 2nd ed. New York: McGraw-Hill Book Company, Inc., 1963.

44. Muther, Richard. Systematic Layout Planning. Boston: Industrial Education Institute, 1961.

45. Nadler, Gerald. Motion and Time Study. New York: McGraw-Hill Company, Inc., 1955.

46. Nadler, Gerald. Work Design. Chicago: Richard D. Irwin, Inc., 1963.

47. Ostenso, Grace Laudon; Moy, William A.; and Donaldson, Beatrice. "Developing a Generalized Cafeteria Simulator." Journal of the American Dietetic Association, 46 (May, 1965), 379-83.

48. Pilcher, Roy. Principles of Construction Management. London: McGraw-Hill Publishing Company Limited, 1966.

49. Schwab, John L. "Methods-Time Measurement." Industrial Engineering Handbook. Edited by H.B. Maynard. 2nd ed. New York: McGraw-Hill Book Company, Inc., 1963.

50. Shaw, A. E. "Stop-Watch Time Study." Industrial Engineering Handbook. Edited by H.B. Maynard. 2nd ed. New York: McGraw-Hill Book Company, Inc., 1963.

51. Stumpf, Grace L. "Adapting Some Time Study Techniques and Cost Control Methods of Industry to Food Production in Hospital." Unpublished M.S. Thesis, University of Wisconsin, 1956.

52. The American Dietetic Association. Bulletin of the Association. Standardizing Recipes for Institutional Use. Chicago, Ill.: The American Dietetic Association, 1967.

53. Thomas, Orpha Mae Huffman. "A Scientific Basis of the Design of Institution Kitchens." Columbia University, New York, 1947. (Printed privately by author. Out of print.)

54. University of Michigan. Bulletin of Food Service, Food Service Bulletin. University of Michigan Food Service, 1969.

55. U.S. Department of Agriculture. Agricultural Research Service. Food Yields Summarized by Different Stages of Preparation. Agriculture Handbook No. 102. Washington, D.C.: Government Printing Office, 1956.

56. West, Bessie Brooks; Wood, Levelle; and Harger, Virginia F. Food Service in Institutions. New York: John Wiley & Sons, Inc., 1966.

APPENDIX

BREAKFAST — FRIDAY 3

NAME ____________ ROOM ______

DIET ____________

USE SPECIAL PENCIL ONLY TO MAKE MENU SELECTIONS MARK AS DARK AS POSSIBLE WITH AN X WITHIN BOX ONLY

3 ☐ *ORANGE JUICE, 1/2 Cup — • ☐ Peach Preserves
4 ☐ ORANGE JUICE, 1 Cup
5 ☐ PINEAPPLE JUICE, 1/2 Cup
6 ☐ PINEAPPLE JUICE, 1 Cup
-----
7 ☐ *RICE KRISPIES
8 ☐ OATMEAL
9 ☐ CORNMEAL
10 ☐ FARINA
-----
11 ☐ *SCRAMBLED EGGS
12 ☐ SOFT COOKED EGG
-----
13 ☐ *BUTTERED WHITE TOAST
14 ☐ BUTTERED WHOLE WHEAT TOAST
15 ☐ DRY WHITE TOAST
16 ☐ DRY WHOLE WHEAT TOAST
17 ☐ GLAZED DOUGHNUT
18 ☐
19 ☐
20 ☐

☐ Butter
☐ White Bread
☐ Whole Wheat Bread
☐ • Milk
☐ Skim Milk
☐ Chocolate Milk
☐ • Coffee
☐ Tea
☐ • Cream
☐ Lemon
☐ • Sugar

LUNCH — FRIDAY 3

NAME ____________ ROOM ______

DIET ____________

1 ☐ NEW ENGLAND CLAM CHOWDER
-----
2 ☐ *FILET OF SOLE
With
3 ☐ *TARTAR SAUCE
4 ☐ MACARONI AND CHEESE
5 ☐ VEAL SCALLOPINI
6 ☐ GROUND ROUND STEAK
-----
7 ☐ *ROAST POTATO
8 ☐ WHIPPED POTATOES
9 ☐ BEEF GRAVY
10 ☐ *SPINACH
11 ☐ BRAISED CELERY
-----
12 ☐ *GARDEN SALAD
13 ☐ *FRENCH DRESSING
14 ☐ FRUIT MARSHMALLOW SALAD
15 ☐ COTTAGE CHEESE
-----
16 ☐ *CANNED PEARS
17 ☐ BANANA CAKE With Vanilla Butter Icing
18 ☐ FRESH FRUIT
19 ☐
20 ☐

☐ Vanilla Ice Cream
☐ • Crackers
☐ • White Bread
☐ Whole Wheat Bread
☐ • Butter
☐ Milk
☐ Skim Milk
☐ Chocolate Milk
☐ • Coffee
☐ Tea
☐ • Cream
☐ Lemon
☐ • Sugar

SUPPER — FRIDAY 3

NAME ____________ ROOM ______

DIET ____________

1 ☐ TOMATO RICE SOUP
-----
2 ☐ *BAKED HAM
3 ☐ HALIBUT STEAK
With
4 ☐ LEMON WEDGE
5 ☐ GROUND ROUND STEAK
-----
6 ☐ *CANDIED SWEET POTATO
7 ☐ WHIPPED POTATOES
8 ☐ BEEF GRAVY
9 ☐ *MIXED VEGETABLES
10 ☐ SLICED BEETS
-----
11 ☐ *CUCUMBER SLICES IN VINEGAR
12 ☐ HARD COOKED EGG SALAD
13 ☐ COTTAGE CHEESE
-----
14 ☐ *RAINBOW JELLO
15 ☐ CANNED FIGS
16 ☐ FRESH FRUIT
-----
17 ☐ *DINNER ROLL
18 ☐
19 ☐
20 ☐

☐ Vanilla Ice Cream
☐ Crackers
☐ White Bread
☐ Whole Wheat Bread
☐ • Butter
☐ • Milk
☐ Skim Milk
☐ Chocolate Milk
☐ • Coffee
☐ Tea
☐ • Cream
☐ Lemon
☐ • Sugar

LUNCH, FRIDAY—3 GRAVIES & SOUPS	Level TOTAL	SUPPER, FRIDAY—3 GRAVIES & SOUPS
Gravy (Beef) G TH Children		Gravy (Beef) G TH Children
Gravy (Beef) US		Gravy (Beef) US
Soup		Soup
Clam Chowder, New England G		Tomato, Cream of TH
		Tomato Rice G
Bouillon G TH		
Bouillon US		Bouillon G TH
Consomme G TH		Bouillon US
Consomme US		Consomme G TH
Corn, Cream of TH		Consomme US

LUNCH, FRIDAY—3 ENTREES	Level TOTAL	SUPPER, FRIDAY—3 ENTREES
Filet of Sole G TH		Beef, Minced TH US
Filet of Sole US		Fish Sticks, French Fried Children
Macaroni & Cheese G TH		Halibut Steak G TH
Macaroni & Cheese US		Halibut Steak US
Macaroni & Cheese Children		Ham, Baked G TH
Veal Chop, Baked TH		Lamb Cubes (Baked) AL
Veal Chop, Baked US		Meat Loaf TH
Veal, Minced TH US		Meat Loaf US
Veal Scallopini G		
Beef, Roast, Sliced G TH US		Beef, Roast, Sliced G TH US
Frankfurter on Bun G TH		Frankfurter on Bun G TH
Hamburger on Bun G TH		Hamubrger on Bun G TH
Hamburger on US Bun US		Hamburger on US Bun US
Lamb Chop (Broiled) AL		Lamb Chop (Broiled) AL
Steak, Ground, Round G TH US		Steak, Ground, Round G TH US
Steak, Strip G TH US		Steak, Strip G TH US
Turkey, Sliced G TH US		Turkey, Sliced G TH US

LUNCH, FRIDAY—3 VEGETABLES & POTATO SUBSTITUTES	Level TOTAL	SUPPER, FRIDAY—3 VEGETABLES & POTATO SUBSTITUTES
Bean, Green, Puree TH		Beet Puree TH
Bean, Green, Puree US		Beet Puree US
Beans, Green US		Beets, Diced TH
Celery, Braised G TH		Beets, Diced Children
Spinach G TH		Beets, Sliced G TH
Spinach US		Beets, Sliced US
Spinach, Chopped TH		Carrots, Sliced (no bu) AL
Spinach, Chopped Children		Vegetables, Mixed G TH
		Vegetables, Mixed US
Potatoes		Potatoes
Potato, Roast G TH		Potato, Sweet, Candied G
Potato, Roast US		Potato, Sweet, Mashed TH
		Potato, Sweet, Mashed US
		Potatoes, French Fried Children
Baked G TH US		Baked G TH US
French Fried G TH		French Fried G TH
French Fried US		French Fried US
Whipped G TH		Whipped G TH
Whipped US		Whipped US
Whipped Children		Whipped Children
Whipped (no milk) TH		Whipped (no milk) TH
Whipped (no milk) US		Whipped (no milk) US
Rice (no bu) US		Rice (no bu) US
Rice, Steamed (no bu) AL		Rice, Steamed (no bu) AL

<u>Distance Factor Travel Chart for Two Parallel Rows of Equipment</u>

A travel chart containing inherent distance factors for an arrangement of two parallel rows of equipment as described by Kazarian (29) is shown in Figure 37.

To

From

	1	1	$\sqrt{2}$	2	$\sqrt{5}$	3	$\sqrt{10}$
1		$\sqrt{2}$	1	$\sqrt{5}$	2	$\sqrt{10}$	3
1	$\sqrt{2}$		1	1	$\sqrt{2}$	2	$\sqrt{5}$
$\sqrt{2}$	1	1		$\sqrt{2}$	1	$\sqrt{5}$	2
2	$\sqrt{5}$	1	$\sqrt{2}$		1	1	$\sqrt{2}$
$\sqrt{5}$	2	$\sqrt{2}$	1	1		$\sqrt{2}$	1
3	$\sqrt{10}$	2	$\sqrt{5}$	1	$\sqrt{2}$		1
$\sqrt{10}$	3	$\sqrt{5}$	2	$\sqrt{2}$	1	1	

Figure 37. Distance-factor travel chart for arrangement of two parallel rows of equipment.

Considering one block,

x	✓
✓	x

the upper right and lower left quadrants indicate movements across the aisle (✓) whereas upper left and lower right quadrants indicate movements along one row (x). The distance factors contained in the matrix were calculated from the formula for the hypotenuse of a right-angled triangle, $c = \sqrt{a^2 + b^2}$ where a = base, b = side, and c = hypotenuse. To illustrate, consider the hypothetical arrangement of two parallel rows of equipment coded A through H as shown in Figure 38. A triangle is depicted by the connecting lines between the pieces of equipment coded F, H, and D. To apply the above formula, a = the travel distance between 2 non-adjacent pieces of equipment coded F and H while b = the travel distance directly across the aisle to a piece of equipment coded D; therefore, $c = \sqrt{2^2 + 1^2}$ or $\sqrt{5}$.

<u>Two Parallel Row Travel Chart</u> (cont'd.)

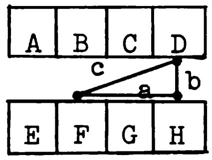


Figure 38. Hypothetical arrangement of two parallel rows of equipment used to calculate distance-factor for travel charting.

With the distance-factor travel chart remaining constant, the pieces of equipment become the variables of a frequency chart. Looking at the hypothetical arrangement of equipment (Fig. 38) and a table of the frequency of material movement between pairs of equipment (Table 5), the equipment is then arranged to enable the greatest frequencies to be entered in the quadrants of the matrix closest to the diagonal line (Fig. 39). In construction of the frequency chart, opposite pieces of equipment are considered one unit (i.e., CA, EB, DH, and FG) and surround the matrix as specified in Figure 40. The frequency of movement is then entered in the appropriate quadrants of the matrix.

In a travel chart containing data for a single, continuous-line arrangement of equipment; the entries above the diagonal line indicate forward movement whereas those below the diagonal line indicate backward movement. This is also true of a travel chart containing data for a two, parallel-row configuration, but with one exception. The entries in the upper right and lower left quadrants along the diagonal line indicate lateral movements rather than either backward or forward movement.

Two Parallel Row Travel Chart (cont'd.)

Table 5. Frequency of movement between pairs of equipment.

Frequency of Movement		
From	To	Frequency
A	B	5
A	C	2
A	D	1
B	C	2
B	D	2
C	D	1
D	E	7
D	F	6
D	H	1
E	F	2
F	G	3
G	H	7

C	E	D	F

A	B	H	G

Figure 39. Rearranged equipment based on frequency of movement between pairs of equipment.

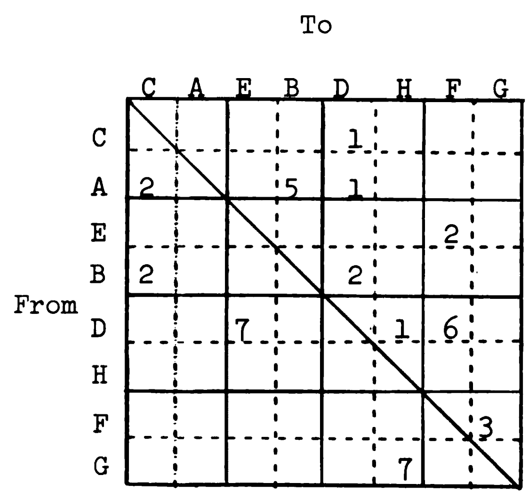


Figure 40. Frequency chart used for determining the index factor.

Two Parallel Row Travel Chart (cont'd.)

Using the distance chart (Fig. 37) and the frequency chart (Fig. 40) corresponding quadrants of each matrix were multiplied to obtain a total factor of distance traveled or index factor. The computation follows in Table 6.

Table 6. Results of multiplying distance-factor and frequency charts to determine an index factor.

Equipment Pair	Distance Chart	x	Frequency Chart	=	Distance Traveled
CD	2		1		2.00
AC	1		2		2.00
AB	1		5		5.00
AD	$\sqrt{5}$		1		2.24
EF	2		2		4.00
BC	$\sqrt{2}$		2		2.82
BD	$\sqrt{2}$		2		2.82
DE	1		7		7.00
DH	1		1		1.00
DF	1		6		6.00
FG	1		3		3.00
GH	1		7		7.00
			Index factor:		44.88

The optimum solution to the problem can be obtained by selecting the lowest index factor after repeating the above procedure 40,320 times (i.e., 8! possible arrangements existing for 8 pieces of equipment). However, the closer the highest frequency data is placed to the diagonal line, the lower the distance traveled is inherent in the distance chart. Therefore, a "good", but not necessarily the "best" or optimal solution can be obtained by repeating the process with other arrangements of equipment allowing the high frequency data to be entered as close to the diagonal line as possible. The arrangement resulting with the lowest total distance factor is then selected as a "good" solution.

Tasks for Performing Activities of Defined Procedures

GET READY:
- Check/confirm amount needed
- Open PM: Case/Sack
  - Bin
  - Package/Carton
  - Cans: #10/48 oz/4 lb/32 oz
    - #303/#2-1/2
    - Lidded
  - Jars: gal
    - qt/pt
- Place material on/at WT/Equipment
- Place utensil on/at WT/Equipment
- Place TC on/at WT/Equipment
- Set/Adjust: Scale
  - Meat Slicer
  - Food Cutter--add H_2O

CHANGE OR MODIFY MATERIAL:
- Weigh dry
- Weigh liquid
- Weigh solid
- Measure t/T dry
- Measure c/qt/gal dry
- Measure t/T liquid
- Measure c/qt/gal solid
- Count
- Peel
- Trim
- Wash
- Cut: One cut
  - Wedges
- Chop: Manual
  - Machine
- Slice: Machine
- Feed into slicing machine attachment:
  - Chute
  - Fence
- Dice
- Crack (fresh eggs)
- Separate (frozen/sliced meat)
- Dip (i.e., breading meats and dipping peeled bananas in anti-oxidant)
- Drain: #10 can/gal/jars
  - #303 can
  - Produce (in basket after washing)
- Pour/Transfer into TC/Equipment
- Empty material with utensil to TC
- Arrange in TC (i.e., panning)
- Close/Cover TC
- Attach label to TC
- Place TC on MC

<u>Activity tasks</u> (cont'd.)

CLEAN-UP:
- Close PM of un-used material:
  - Case/Sack
  - Bin
  - Package/Carton
  - "Tin" Can
  - Lidded Can
  - Jars: gal
    - qt/pt
- Clear work area of:
  - Material in TC/on MC
  - Un-used material
  - Used utensils
  - Used re-usable containers
  - Trash
  - Trim to disposer
  - Water in food cutter
- Clean:
  - Work table
  - Sink
  - Equipment: Food Cutter
    - Meat Slicer
    - Scale
    - Can Opener
  - Wash utensils

Equipment Layout Data Form

EQUIPMENT LAYOUT DATA

Institution *University Hosp.*
Project no. *39*
Date *May 10, 1970*
Utilities:

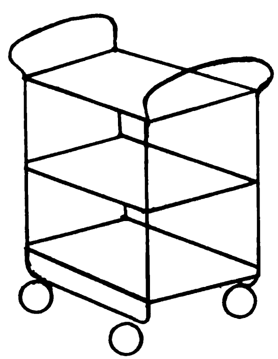
Electrical Power drive:

hp	v	Cycle	Phase	amp
-	-	-	-	-

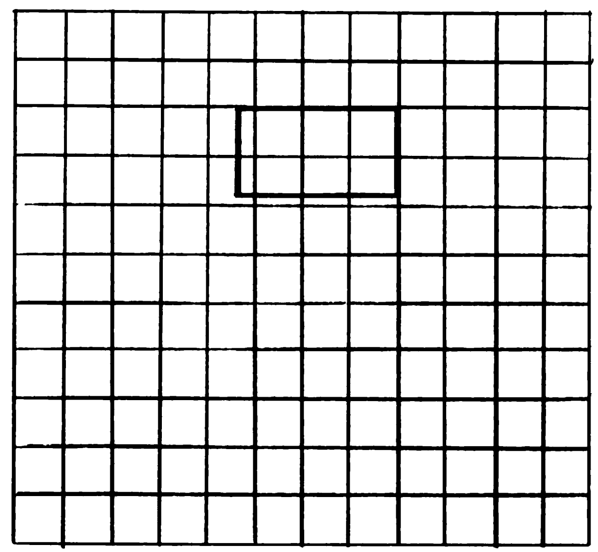
Water	Steam	Drains
-	-	-

Name, type *Tubular Utility Cart*
Manufacturer *Lakeside*
Capacity *400 lb*
Left-right *40-1/4 in.*
Front-back *22 in.*
Height *37-1/2 in.*
Net floor area *3.33 ft x 1.83 ft*

File *Hospital*
Size/Model *493*
Area for aisle *24 in.*
Serving/Other *3 shelf, 11 in. clearance*
Gross area (for plan) *6 sq ft*



Perspective drawing or photo



Plan view Scale *1/4* in. = 1 ft

Source *Star distributor catalogue, p. 151*
Approx. cost *$90.00*
No. required *2*

Figure 41. Equipment Layout Data form with a mobile cart illustrated.

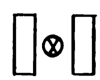
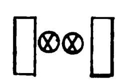
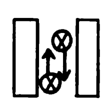
Aisle Space Recommendations

Kotschevar and Terrell (35) make the following general recommendations. Less than 30% of the total space in a satisfactory layout is utilized by equipment while 70% or more may be allocated to work aisles, traffic lanes, and space around the equipment. This is done for easy operation and cleaning purposes. Specific recommendations are as follows:

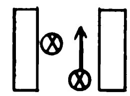
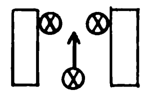
Type of Aisle Space	Space Required
Between equipment, 1 person working	36 in.
Between equipment, 2 persons working	42 in.
Mobile equipment	48 to 54 in.
Mobile equipment, main traffic lane	60 in.
Workers or equipment standing in lane while working	appropriate amount
Doors opening into an aisle	appropriate amount
Handling large pieces of equipment (e.g., roasting pans, baking sheets)	appropriate amount

Additional specific recommendations are: (1) main thoroughfares should not pass through work centers, (2) compactness is essential for step saving, (3) work centers at right angles to traffic lanes are efficient.

Kazarian (27) made the following recommendations concerning aisle space allowances. Work aisles and traffic aisles are considered separately.

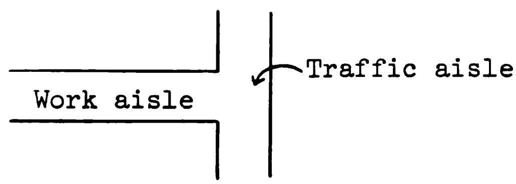
Type of Aisle Space	Space Required	
Work Aisle:		
One person	36 in.	
Two persons, back to back	42 in., if little or no traffic	
Traffic Aisle:		
Two persons passing, without equipment or carts	30 in.	
1 cart passing 1 person	24 in. plus cart width	

Aisle Space Recommendations (cont'd.)

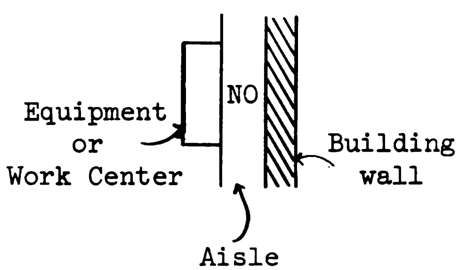
Type of Aisle Space	Space Required	
Combined Aisles:		
1 person passing 1 person at work	42 in.	
1 person passing 2 persons back to back	48 in.	
Cart passing 2 persons working back to back	60 in. plus cart width	

In addition, two general statements were made concerning traffic aisles.

First, traffic aisles should be perpendicular to work aisles.



Second, no aisle should be adjacent to a building wall. It usually maximizes rather than minimizes space.



Recommendation: