ABSTRACT

THE APPLICATION OF INDUSTRIAL ENGINEERING
PRINCIPLES TO THE DESIGN AND LAYOUT
OF A FOOD SERVICE FACILITY

By

Sister Josita Prokosch

Integrated systems of men, materials and equipment are fundamental to the nature of industrial activity. Food service facility planning has incorporated industrial engineering concepts, yet the principles involved are not always evident in the interpretations and applications.

On the assumption that food service is a composite of diversified processes and activities, it is suggested that a clarification of industrial engineering principles of design and layout will be an effective aid in analysis and decision making for food service facility planning in an era of advancing technology.

Relative to design, Richard Muther suggests four guiding fundamentals; (1) plan the ideal and from it the practical, (2) plan the process and the equipment around the product requirements, (3) plan the layout around the process and (4) plan for the satisfaction and safety of the workers.

The IDEALS system concept developed by Gerald Nadler is a design strategy incorporating these principles. The

ideal system concept uses as a guide the ideal and best in developing a recommended system in contrast to the conventional attempt to use present and past models as bases for design decisions. Restrictions and constraints on the ideal are defined in terms of function, output, input, process and environment.

The basic objectives or principles in plant layout are: (1) integration of all facets of the facility, (2) reduction of material movement to a minimum, (3) arrangement of effective work flow, (4) effective utilization of space and (5) flexibility in the arrangement.

A specific design and layout is examined in the light of the concepts discussed. A rationale for the layout is presented.

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By

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A PROBLEM

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INTRODUCTION

A cursory review of food service literature reveals an abundance of checklists, formulas, rules of thumb and procedures for logical calculations purported to aid in planning efficient kitchen layouts. However, layouts coming off drawing boards frequently are outdated, inefficient and ineffective. These shortcomings may well relate less to the actual arrangement of equipment within a given setting than to the preliminary planning and decisions that precede the detailed layout.

Concepts of design and layout are commonly used interchangeably to mean the designation of space and the arrangement of equipment for a particular function. Moore, an industrial engineer, underscores a significant distinction in these two concepts (12). He defines plant design as the panoramic view, the broad functions which include the overall plan of the enterprise. Design incorporates the decisions about men, machines, and materials that must precede layout considerations. Plant layout is a limited function, the plan of an optimum arrangement of a facility in accord with the preliminary design decisions. Layout is the arrangement of men, machines and materials.

The role of industrial engineering is clarified by Sizelove (21). He speaks of integrated systems of men, materials and equipment as fundamental to the nature of industrial activity. The design and installation of these systems are the concern of industrial engineering. The design of the systems becomes the basis of managerial decisions for the effective conduct of the enterprise.

Food service facility planning has relied on industrial engineering concepts. Yet the principles involved are not always evident in the interpretations and applications. A clarification of these principles may improve food service facility planning and aid in the appraisal of opportunities provided by technological advances.

The following assumptions aid in establishing the appropriate application of industrial engineering principles to the design and layout of food service operations:

1. Food service is a composite of diversified processes and activities which requires optimum analysis and planning in the design and layout of facilities.

2. Production and service are components of a whole; effective total operation calls for their integration.

3. Though it is theoretically accepted that menu pattern is the central determining factor for layout engineering, it is a system within itself and as such should be viewed and approached in its elemental components of input, output and process.

4. A food service operation is a complex system utilizing men, materials and equipment as chief resource components which are an essential and integral part of the design and layout.

5. An intimate relationship exists between the planning of a food service unit and the organization of the work to be done in the facility after construction. Optimum realization of this relationship demands that management make the necessary decisions to make available the kind of information needed by the architect and that the architect reiterate the design to management upon completion of the layout.

This paper will identify industrial engineering principles applicable to design and layout of food service facilities, illustrate the application of the principles selected by reviewing the design for a food production and service unit for the College of St. Benedict student activity center and formulate a rationale for a proposed layout with the intent of providing a decision-making tool for the administrators, consultants and architects for the College.

INDUSTRIAL ENGINEERING PRINCIPLES

The writings of Richard Muther (13, 14) enumerate principles which guide industrial engineers in plant layout planning. Several of these principles apply most aptly to the design of the operation while others pertain directly to layout.

Design

Relative to design, Muther (13, 14) suggests four guiding fundamentals: (1) plan the ideal and from it the practical, (2) plan the process and the equipment around the product requirements, (3) plan the layout around the process and (4) provide for the satisfaction and safety of workers. The IDEALS system concept developed by Nadler (18) is a design strategy incorporating these principles. In addition it is a system approach which gives cognizance to the reality of interactions and provides a framework wherein decisions relating to any element or component are seen as significantly affecting the whole (20). It provides a graphic model which will substitute for mental containment which is difficult or impossible with the diverse and numerous elements and relationships characteristic of complex enterprises (21). Finally, it is a design model which suggests an ongoing evolutionary character to cope with continual technological developments.

IDEALS concept

IDEALS is an acronym for "ideal design for effective and logical systems". The IDEALS concept involves the systematic investigation of contemplated and present work systems with the intent of formulating the easiest and most effective system for achieving necessary functions. Work system refers to the arrangement of resources required to achieve a purpose. Effectiveness adds a qualifying element to that of efficiency in the accomplishment of a result. Necessity of function may appear to state the obvious, yet systems are designed where no required function other than "this is the way we've always done it" exists.

The reasons for planning and designing systems are to increase productivity and to develop manpower effectiveness. Increased productivity shows in increased profits and/or decreased costs. Manpower effectiveness involves a less routine organizational objective, that of enhancing human dignity and encouraging advancement toward the limits of ability. It is this objective that appears to be of special significance in the food service industry faced with decisions to introduce or to reject technological nuances.

The ideal system concept uses as a guide the ideal and best in developing a recommended system. This approach is in contrast to the conventional attempt to use present and past models as bases for design decisions. Nadler (18) has developed a triangular figure to illustrate this concept (Exhibit 1). The distance between the sides of the triangle represent total cost (or time or energy), per unit of output at each system level. The apex represents the theoretical ideal system, a system which involves no cost, no time, no energy per unit for an infinite amount of output. It is thus equivalent to the concept of infinity in mathematics. This level is defined in order to provide limitlessness for thought processes in designing the system. It is an ideal intended to be increasingly approached without ever being absolutely reached. An ultimate ideal system is a long-range design needing research and development to make it feasible. Technologically workable ideal systems may be several in number, utilize already available knowledge and components, and could be installed if there were no real life restrictions. One technologically workable system is selected as the target and guide in developing the recommended solution.

Avery (3) applies the ideal system to food service operations. He suggests that only when yesterday's systems, facilities and equipment are abandoned when designing for the future will the challenge of a dynamic society be met. He poses instantaneous food production at no cost or effort as the theoretically ideal system. Completely automated food services represent the ultimate ideal. The

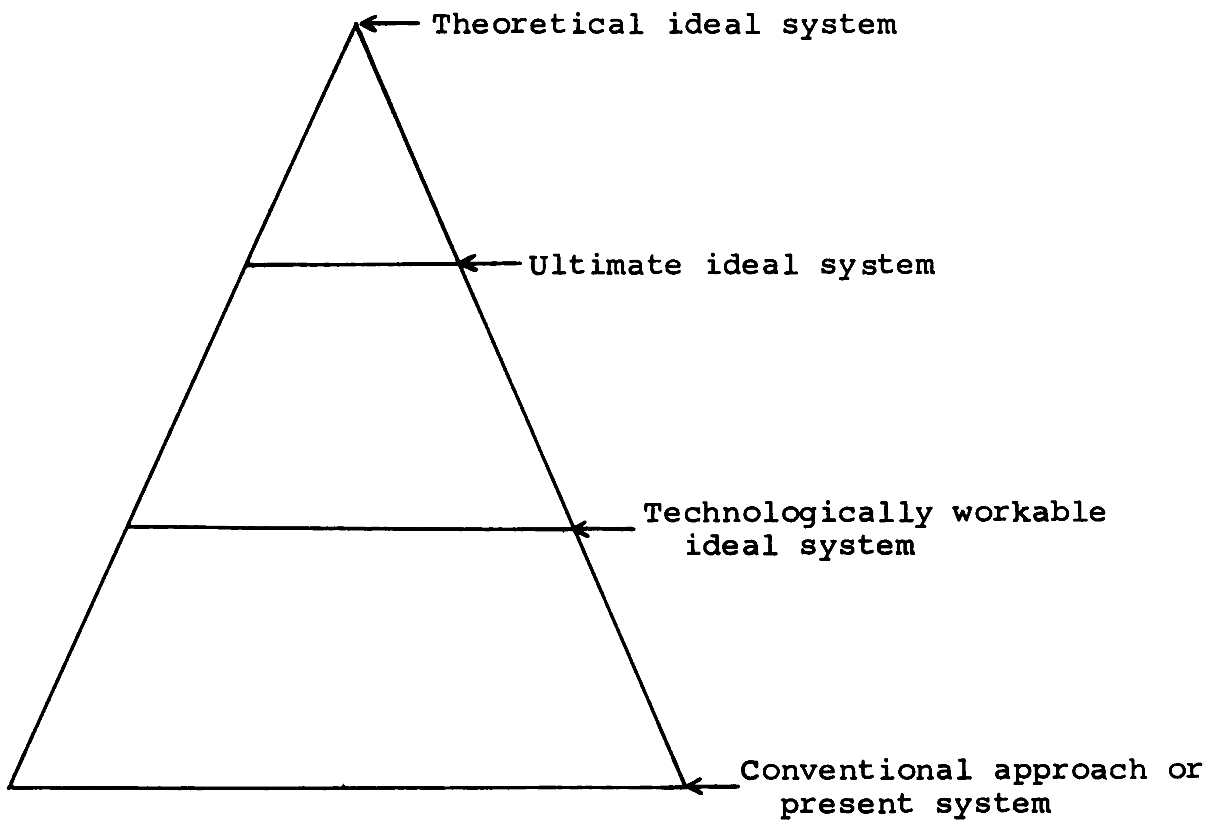

EXHIBIT 1. Levels of IDEALS systems.[a]

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[a]Gerald Nadler, Work Systems Design: The IDEALS Concept (Homewood, Illinois: Richard D. Irwin, Inc., 1967), Figure 3-1, p. 26.

technologically workable ideal system may incorporate a high degree of automation, mechanization and computer control.

Another application of the IDEALS system model lies in its making visual the distribution of costs in the various resource components within the system. The major resource components are men, materials and machines. Recall that the theoretically ideal system is instantaneous, infinite production with no cost for manpower, materials or equipment. With this theoretically ideal concept in mind questions can be raised and alternatives weighed: will a ready-to-serve item be purchased for automatic vending, a ready-to-serve item be purchased and served, a partially prepared item purchased, assembled and/or processed and served, raw materials purchased, processed and served. Each of the above involve a different mix of the three major components. Each of the resource components is interdependent upon every other. An effective system optimizes the various components with the ideal system suggestions and with the definition and/or recognition of restrictions and constraints. These restrictions and constraints are established and/or imposed by functions, output needs, input specifications and availability, process decisions and environment desired. These design elements characterize the second phase of systems design.

Design elements

It is not feasible to apply a universal design which will serve all needs, nor to plan for every eventuality. The necessary restrictions and constraints may be imposed or formulated according to five elements of the IDEALS design strategy (18). The series of decisions involving these elements constitute the preliminary planning or design of an enterprise.

The first of these elements is function. Function is the mission, aim, or primary concern of a system. Function is used as distinct from goal which Nadler defines as the desired state within which the achievement of the purpose is to take place. The irreducible, minimum function in terms of results desired for a college food service might be to satisfy the daily physical, psychological and social food needs of the students, faculty, staff and guests.

The second element or step is to describe how the function is to be accomplished; that is to specify the output desired. In food service the menu pattern formulates a major part of the output specifications. It includes product design and product mix. Establishing the quantity required, quality desired and service to be provided complete the output specifications. The budgetary and financial framework within which this is to be accomplished is the goal of the enterprise.

The input to the process refers to any physical items, information or feedback which enter into processing to arrive at the desired output. It is the defining of the input which has received the least amount of consideration in food service layout planning. This may be due to the relatively few alternatives of input available prior to the 1960's. With the industry now in the midst of advancing technological achievements it is mandatory that decisions about input precede the completion of the design and the initiation of the layout. The prime question may be, "to what extent can pre-processed or partially prepared foods be utilized to achieve the function with optimal satisfaction of output specifications".

The state of preparedness of the input determines in large part the fourth element, process. Process includes not only the sequence of operations necessary but also the equipment and human agents required to change the input to output.

The final element, one gaining in significance, is environment. In Nadler's scheme environment includes sociological, psychological as well as the physical climate within which the process occurs to accomplish the function. A basic consideration for food service that has ramifications in the physical, sociological and psychological aspects of working conditions lies in conceiving the wholeness or integralness of production and service.

These restrictions and constraints when adequately defined form an essential part of the final specifications and interpretation of a system.

Layout

Plant layout refers to the optimum arrangement of a facility in accord with preliminary design decisions. It is the arrangement of men, equipment and materials (12). Layout includes the space needed for operating equipment and personnel, for material movement and storage and all other supporting activities and services (14).

Historically, the earliest principles called for grouping similar machines and processes together, for providing adequate room around each machine, for lining up work areas in orderly rows, specifying aisle-ways and keeping them clean, and for bringing material in at one end and moving it in one direction toward the other end of the plant (14). In retrospect it is obvious that these principles were incomplete and not wholly valid. It is from these few details, however, that concepts of effective layout are still evolving.

The basic objectives or principles in plant layout are: (1) integration of all facets of the facility, (2) reduction of material movement to a minimum, (3) arrangement of effective work flow, (4) effective utilization of space, and (5) flexibility in the arrangement (13, 14).

Principle of overall integration

The achievement of one overall working unit is a desirable aim in layout. Integration of all facets of an operation assumes that relationships are considered and/or established. It is suggested that the importance of relative closeness required or desired between each pair of activities be rated and supported with reasons (15, 16). See Exhibit 2.

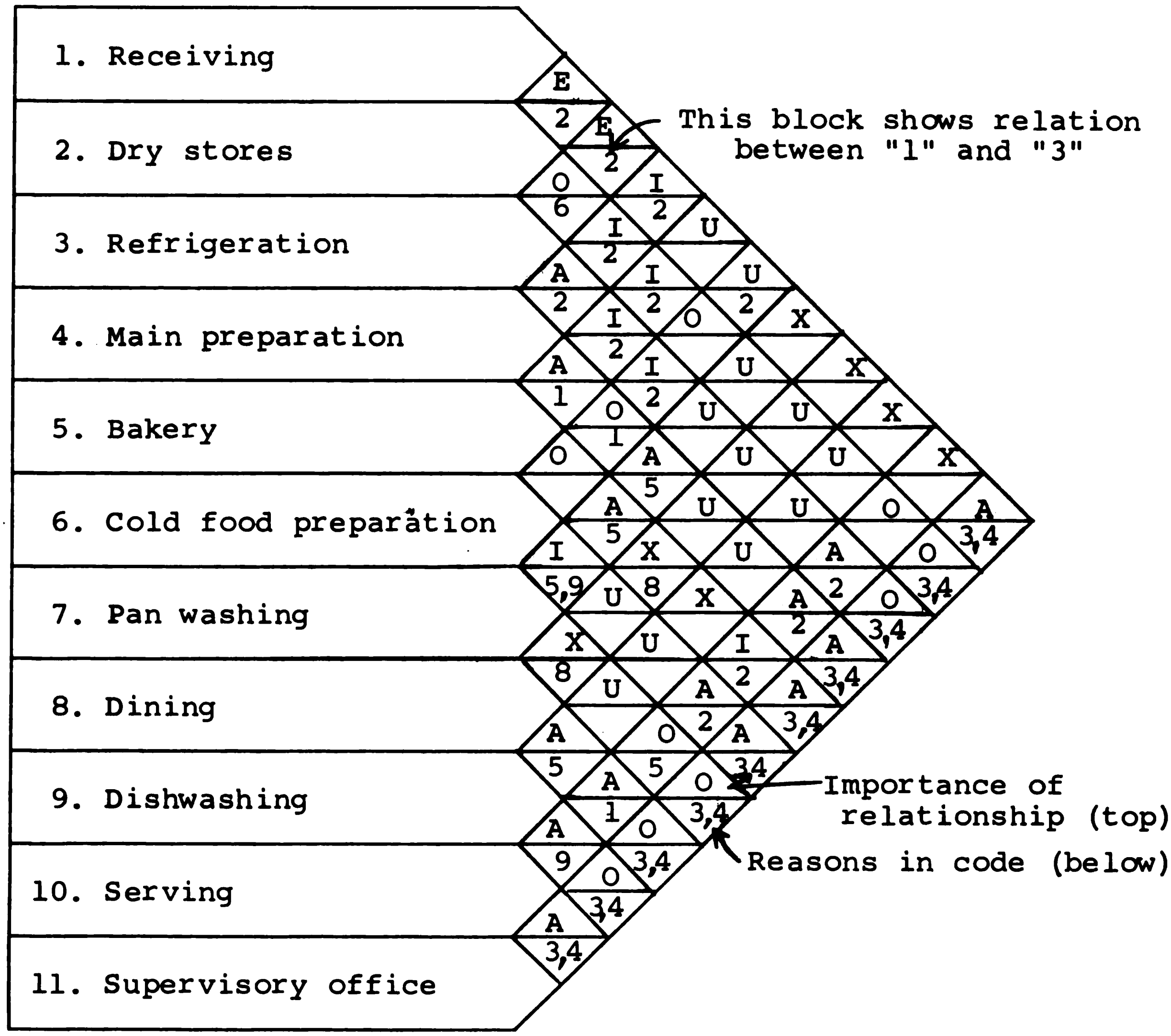
Principle of minimum distance

Movement as such adds to the cost of the product without adding to the value of a product. If materials in production are moved minimum distances production time is shortened, employee effort and fatigue are decreased, labor costs are lowered and supervision is simplified (7).

Transportation between operations can be minimized by placing subsequent operations adjacent to previous ones and by having pick-up for one operation coincide with discharge from the previous operation.

Principle of flow

The concept of flow is one of constant progress toward completion with a minimum of backtracking, interruption, interference or congestion. This is not necessarily a straight line or single direction. Zigzag or circular flows may be effective (14). Muther suggests that in arranging flow lines, it is usually effective to work backward from the end point.



Value	Closeness
A	Absolutely necessary
E	Especially necessary
I	Important
O	Ordinary closeness
U	Unimportant
X	Undesirable

Code	Reason
1	Use same equipment
2	Flow of materials
3	Supervision
4	Flow of information
5	Flow of soiled dishes/pans
6	Same receiving dock
7	Convenience
8	Noise
9	Flow of clean dishes

EXHIBIT 2. Relationship chart.

Principle of space utilization

Layout is basically the arrangement of space or "spaces" occupied by men, materials, equipment and supporting services. Space has both vertical and horizontal dimensions. Effective layout utilizes cubic space as well as floor area. Too little space and too much space are liabilities felt in the initial investment and in the daily operation of the facility.

Principle of flexibility

In a climate of varying needs, increasing demands and changing operational constraints and restrictions, flexibility is one characteristic that can strengthen the coping power of an operation. Provision for adjustment and rearrangement wherever possible will be an asset to an enterprise.

A SPECIFIC PROPOSAL

Having outlined the principles deemed applicable to food service, a design and general layout will be examined in the light of the concepts discussed.

The plan under consideration is a food service unit which is one section of a layout for a total student activity center for a college.

Design

The design of an operation includes a statement of function and the basic decisions that will guide layout considerations. The format of this review is the elements of Nadler's design strategy.

Function

The primary aim of this system will be the satisfaction of the physical, psychological and social food needs of the college community and guests insofar as this is possible and feasible.

Output

The accomplishment of this function will vary in accord with specific situations and groups within the community. The most regularly occurring need for the largest group represented will be three daily meals for approximately one thousand students.

It is assumed from experience and observation that students' daily food needs can be effectively satisfied by high quality food served attractively with some selection and with minimum or no waiting time for service.

As an initial specification of output, in terms of product, the following menu pattern is suggested.

Menu Pattern

	Food Item	Number of Choices
Breakfast:	Juice	1
	Fruit	1
	Entree'	1
	Quick bread	1
	Toast	2
	Cereal	Assorted
	Accompaniments	Assorted
	Beverage	4-6
Lunch:	Appetizer	1
	Entree'	2
	Salad	2-3
	Dessert	3
	Bread	2-3
	Accompaniments	Assorted
	Condiments	Assorted
	Beverage	4-6
Dinner:	Appetizer	1
	Entree'	2
	Vegetable	2
	Potato or substitute	1
	Salad	2-3
	Dessert	3
	Bread	2-3
	Accompaniments	Assorted
	Condiments	Assorted
	Beverage	4-6

In addition to product output, demands in terms of service must also be met. It is estimated that service and dining area capacity should be of such size and arrangement as to accommodate 75 to 80 percent of the patrons within one hour for the regularly occurring daily needs.

Non-regular output demands occasioned by special events and social and psychological needs of the regular patrons as well as guests will require specific consideration in production and service.

Input

It is assumed that the developing trends in food technology will continue and intensify. Therefore it appears advisable and feasible to establish that labor-saving food items be incorporated as input whenever availability and quality justify their use. These may include pre-portioned meat, fish and poultry; frozen, canned and otherwise preserved vegetables, fruits and juices; mixes; raw-frozen bread items and other partially prepared products.

Process

Following from the state of preparedness of input described above, process will be relatively simple with the elimination of many pre-preparation steps. Emphasis will be on assembling, mixing, applying heat, and finishing.

Selection of equipment will be governed to a degree by capacity required for high product turnover demanded in quick service and by batch and to-order preparation where advisable for quality and quantity control.

The labor force will be smaller than in a traditional operation and skills or qualifications will also vary with the input requirements.

Environment

Considerations that will improve the physical, sociological and psychological climate for the worker and the patron include both functional and aesthetical values.

Heat and humidity control are essential to worker comfort as is consideration of human engineering factors in equipment and work area design (2).

It is suggested that the elimination of interior wall structures may serve several purposes. It facilitates supervision and in turn makes management more accessible to the worker. It makes possible closer quantity control particularly for batch or to-order production. It may provide an incentive for higher standards of sanitation and orderliness. A general appearance of wholeness or integralness between production and service may raise morale among the workers and also encourage immediate feedback about products to promote greater customer satisfaction.

Layout Rationale

The layout (Exhibit 4, pocket inside back cover) includes the food production, service and dining areas of a college student activity center. The exterior wall structure and the supporting pillars are shown as they appear in the original plan for the entire building. An attempt was made to leave these walls intact. However, as it became apparent that more space was desirable in the dining area and less in the production area it seemed advisable to suggest a new exterior wall structure in two areas that do not adjoin the remainder of the building.

The prime criteria for judgment of adequacy of a layout is the degree to which the facility will accomplish the function for which it is designed and the extent to which it incorporates the principles of layout.

The design of the facility can be summarized as the efficient and effective service of quality food.

The focal point for supply and demand or production and service is the serving area. To effect the quick service desirable for the routine daily needs, the hollow square or shopping center type of service area is suggested. It is an open system that allows random selection of items desired with no specific sequence or line pattern. It allows large groups to be served in a short period of time.

Laschober (9) recommends a space allowance of five square feet per person for the heaviest hour-load of service.

This recommendation suggests that over seven hundred persons could be served per hour in the approximate thirty-six hundred square feet allowed in this layout for service area.[1]

Integration is primarily a matter of recognizing and/or establishing relationships. The relationships evident in the proposed layout are recorded on Muther's relationship chart. See Exhibit 2, page 13.

The "A" relationships include:

Refrigeration to main preparation
Main preparation to bakery
Main preparation and bakery to panwashing

Main preparation to service
Cold food preparation to service
Refrigeration to service

Service to dining
Dining to dishwashing
Dishwashing to service

Office to receiving
Office to main preparation and bakery
Office to cold food preparation
Office to service.

The list represents a significant number of "absolutely necessary relationships". A contributing factor to this high degree of integration is the "L" shaped production area contiguous to the serving area via pass-through refrigerated and heated holding units. The main dining area immediately adjoins the serving area with the dishwashing strategically

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[1] In a similarly sized and arranged serving area in operation at Holden Hall, Michigan State University, the manager states that 100 persons per five minute intervals can be served at peak capacity.

located to form the desirable triangle. The office area is located as to allow adequate supervision of and ready accessibility to receiving, preparation and service areas.

The principle of minimum movement has been incorporated through the close proximity of storage to preparation to service. This principle is epitomized in the combination dairy storage and dispensing unit which allows immediate point-of-use delivery.

The flow pattern is a symbolic representation of the general arrangement of areas and the movement of supplies, food, service, dishes and pans as shown in Exhibit 3. The schematic diagram gives evidence that the flow is direct with minimum backtracking, interruption or congestion.

Floor space has been effectively utilized. The back to back arrangement of the heat-application equipment results in a consolidated bank economizing on floor and ventilation area. The integration of bakeshop with main preparation allows optimum use of equipment thus reducing floor space requirements. Aisles have been planned to concentrate and facilitate movement in main traffic lanes and to give sufficient space yet reduce unnecessary movements in the working areas.

There has been an attempt to utilize cubic space in the refrigerated and dry storage areas, in pan storage on shelves and under tables and in staple bins under the work table.

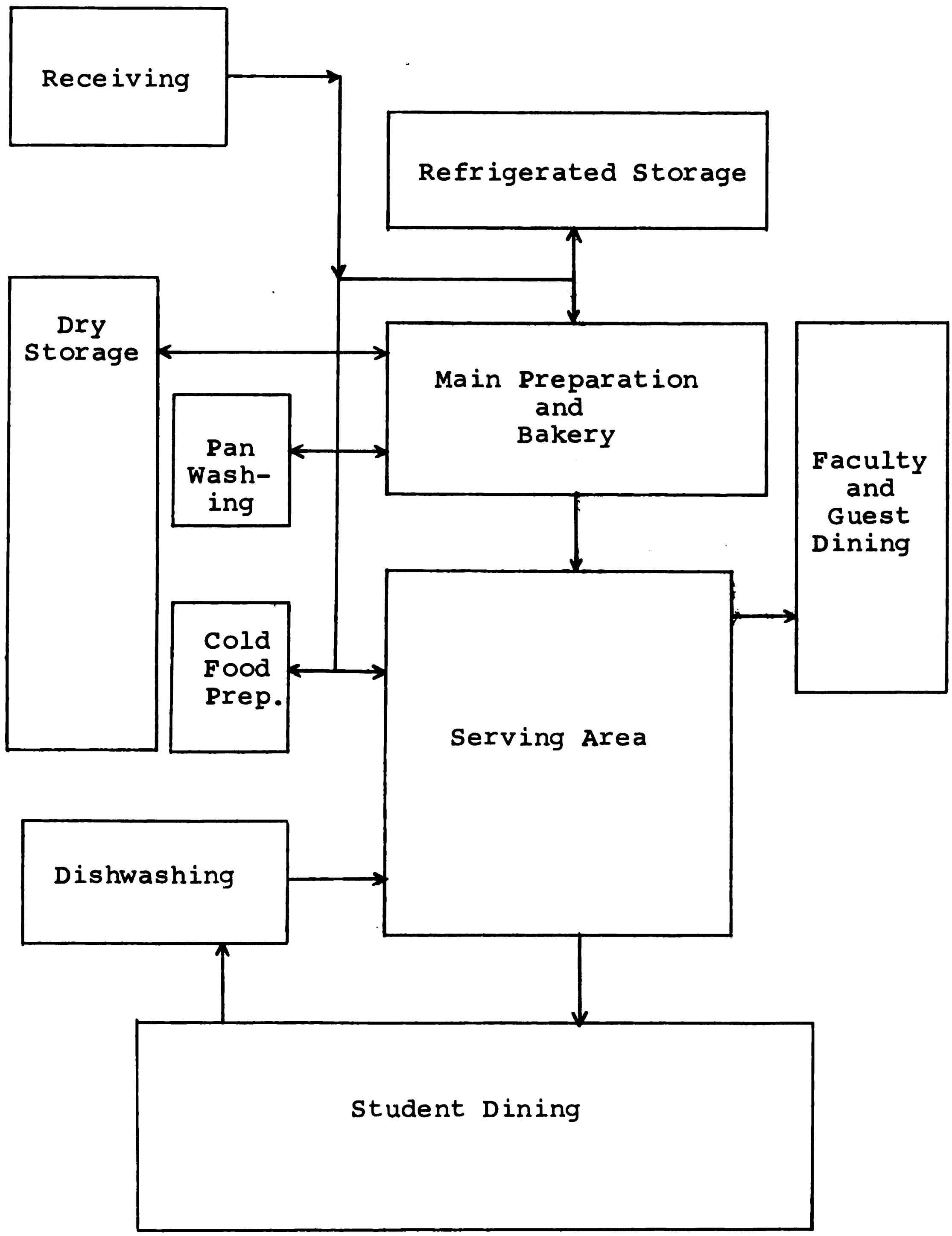

EXHIBIT 3. Flow diagram showing functional relationships.

Undoubtedly careful study would reveal more possibilities for effective use of cubic space.

Flexibility is essential in planning for the varied needs of the present and the possible demands of the future. The production area has been planned to cope with daily and special requirements. Flexibility is also proposed for the dining areas. This is accomplished through the use of folding partitions to adjust to varying group sizes. The recommended increase in size and change in shape in the main dining area permits use as a banquet room for the college community and for catered events.[2] The hollow square serving area with moveable tables will allow for rearrangement for buffet service. Mobility in material handling and production is incorporated throughout the plan.

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[2]The recommendation is that the main dining room be increased in size to 120' x 94' or 11,250 square feet. At 15 square feet per person necessary for round tables, 750 persons could be seated. This would reduce the dining room turnover ratio and allow more leisurely dining. If on occasion banquet tables are used in this same setting with an allowance of 10 square feet per person, the entire student body and faculty could be accommodated at the same time.

CONCLUSION

This has been an attempt to record the principles of industrial engineering that appear applicable to the design and layout of food service facilities and to review a design and present a rationale for a general layout for a specific operation.

It is hoped that the identification of principles will provide a framework for the appraisal of technological advances as they are made available to the food service industry.

It is also hoped that the formulation of a design and the preliminary planning for the general layout will provoke further discussion, analysis and decisions by the organizational and food service administrators, architect and consultants and ultimately lead to the construction of an efficient and effective operation that will accomplish the function for which it is intended.

BIBLIOGRAPHY

BIBLIOGRAPHY

1. Apple, James M. Plant Layout and Materials Handling. New York: Ronald Press Company, 1963.

2. Avery, Arthur C. "Maximizing Performance Through Human Engineering." Paper presented at the Food Administration Conference, Ames, Iowa, July 20-23, 1966. (Mimeographed.)

3. Avery, Arthur C. "Work Design--A New Approach to Food Service Facilities." Paper presented at the Food Administration Conference, Ames, Iowa, July 20-23, 1966. (Mimeographed.)

4. Bloetjes, M. K., and Gottlieb, Regina. "Determining Layout Efficiency in the Kitchen." Jour. Am. Diet. Assn., XXXIV (August, 1958), 829-835.

5. Dana, Arthur. Kitchen Planning for Quantity Food Service. New York: Harper & Brothers, 1949.

6. Folts, Franklin E. Introduction to Industrial Management. New York: McGraw-Hill, 1963.

7. Gottlieb, Regina, and Couch, Mary A. "Using the Cross Chart in Planning Kitchen Layouts." Jour. Am. Diet. Assn., XXXVI (June, 1960), 585-592.

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

9. Laschober, Joseph. A Short Course in Kitchen Design. Chicago: Domestic Engineering Co., 1960.

10. Manchester, Colonel Katherine E. "Quantity and Quality Production in Patient Feeding." Paper presented at the 18th Conference of the Society for the Advancement of Food Service Research. Boston, Massachusettes, April 22-23, 1968. (Mimeographed.)

11. Montag, Geraldine. "Development of Overall and Detailed Layout." Paper presented at the Food Administration Conference, Ames, Iowa, July 20-23, 1966. (Mimeographed.)

12. Moore, James M. Plant Layout and Design. New York: Macmillan Company, 1962.

13. Muther, Richard. "Plant Layout." Industrial Engineering Handbook. Edited by H. B. Maynard. New York: McGraw Hill Co. Inc., 1963.

14. Muther, Richard. Practical Plant Layout. New York: McGraw Hill Co. Inc., 1955.

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

16. Muther, Richard, and Wheeler, John D. Simplified Systematic Layout Planning. Kansas City, Missouri: Management and Industrial Research Publications, 1962.

17. Nadler, Gerald. Work Design. Homewood, Illinois: Richard D. Irwin, Inc., 1963.

18. Nadler, Gerald. Work Systems Design: The Ideals Concept. Homewood, Illinois: Richard D. Irwin, Inc., 1967.

19. Reed, Ruddell. Plant Layout Factors, Principles and Techniques. Homewood, Illinois: Richard D. Irwin, Inc., 1961.

20. Reed, Ruddell, Plant Location, Layout and Maintenance. Homewood, Illinois: Richard D. Irwin, Inc., 1967.

21. Sizelove, Oliver J. "Systems Design." Industrial Engineering Handbook. Edited by H. B. Maynard. New York: McGraw-Hill Co. Inc., 1963.

22. Tamashunas, Victor M. "Space Determination." Paper presented at the Food Administration Conference, Ames, Iowa, July 20-23, 1966. (Mimeographed.)

23. Thomas, Orpha Mae Huffman. A Scientific Basis for the Design of Institution Kitchens. New York: Orpha Mae Huffman Thomas, 1947.

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