3-1979

# A Computerized Scheduling Model for Analyzing Cook Freeze Food Production Plans

Carolyn Unklesbay Lambert
*University of Tennessee, Knoxville*

To the Graduate Council:

I am submitting herewith a dissertation written by Carolyn Unklesbay Lambert entitled "A Computerized Scheduling Model for Analyzing Cook Freeze Food Production Plans." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Human Ecology.

Betty L. Beach, Major Professor

We have read this dissertation and recommend its acceptance:

Mary Jo Hitchcock, Russell Buchan, Roy E. Beauchene

Accepted for the Council:

Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Carolyn Unklesbay Lambert entitled "A Computerized Scheduling Model for Analyzing Cook Freeze Food Production Plans." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Home Economics.

Betty L. Beach

Betty L. Beach, Major Professor

We have read this dissertation and recommend its acceptance:

Mary J. Hitchcock

Roy E. Beauchene

Accepted for the Council:

L. Evans Roth

Vice Chancellor
Graduate Studies and Research

# A COMPUTERIZED SCHEDULING MODEL FOR ANALYZING COOK FREEZE FOOD PRODUCTION PLANS

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Carolyn Unklesbay Lambert

March 1979

## ACKNOWLEDGMENTS

The author wishes to express her appreciation and gratitude to Betty L. Beach, Ph.D., Associate Professor of Food Systems Administration, for her guidance and encouragement during the development and completion of this study and to J. Russell Buchan, M.S., Associate Professor of Industrial Engineering, for his guidance and consultation in the development of the material requirements planning model. Appreciation is expressed also to Mary Jo Hitchcock, Ph.D., Professor of Food Systems Administration, and to Roy E. Beauchene, Ph.D., Professor of Nutrition, for their suggestions in the development of the study.

This research was supported by a General Foods Fellowship and a Special Improvement Grant from the Health Resources Administration, Department of Health, Education, and Welfare, for the Coordinated Undergraduate Program in Dietetics at the University of Tennessee, Knoxville.

Appreciation is expressed to the University of Tennessee, Knoxville, Computing Center, and specifically to Mr. Don Broach, who provided much technical guidance.

The author wishes to extend special appreciation to her husband, Joe, for his encouragement, technical assistance, and support throughout the study.

ABSTRACT

Costs of food service system resources are steadily increasing, with labor being cited as the most costly resource. A management tool is needed in the food service industry to schedule production personnel and equipment to minimize forced delay time and decrease total labor costs. Material requirements planning was adapted to generate production data for two nine-day menu cycles in a hypothetical cook freeze production system. Data for the total production plan; master food product schedule, a record of specific entree requirements by time period; and bill of materials, consisting of a standardized formula, list of production activities, and an arrow-on-node flow diagram of the preparation process for each entree, were obtained from a hypothetical food production system serving 1,000 meals for noon and supper as defined by Beach (1974). Three categories of labor: cook, assistant cook, and food service worker, and eight major kinds of equipment were utilized to produce the 42 different entrees. Ten hours were available for scheduling necessary production activities. One seven-day and three five-day production plans, an original and two alternatives, were developed from the master production schedule, a summary of master food product schedules. The five-day production plan—Alternative 1 was used as a basis for a production system employing one labor category.

The COST-ARREST program was used to generate daily production sheets for one week for each of the four production plans. Labor time requirements, forced delay time, and labor cost were analyzed for each of the production plans. Results showed that the five-day production plan—Alternative 2 minimized the day-to-day fluctuation in labor time requirements. Overtime was minimized when one labor category was utilized with four production cooks. Total forced delay time was less in the five-day production plans than in the seven-day production plan. The lowest percentage of forced delay time and lowest labor cost occurred when one labor category was employed with three production cooks.

Comparison of total production duration time needed to complete work activities revealed that more time was required to prepare entree items in the seven-day production plan than in the five-day plans. Total daily labor demand varied by as much as 24 hours in the five-day production plan—Original. Flexibility in the scheduling of entree items within the week allowed a balancing of labor demand. Labor utilization was limited by job descriptions as supported by analysis of overtime, forced delay and labor cost. Implementation of a flexitime plan could decrease the amount of overtime if employees could adjust work schedules to handle fluctuating work loads. The sequencing of activities influenced production duration. Daily labor requirements increased in all production plans by approximately 40% to reflect forced delay time.

Material requirements planning, coupled with the COST-ARREST technique, could provide food service managers with relevant, accurate, and timely data for a feasible and effective method of allocating and scheduling resources.

TABLE OF CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

FIGURE PAGE

# CHAPTER 1

# INTRODUCTION

The economic utilization of system resources in the attainment of departmental objectives is a major goal of all food service managers. As the costs of personnel, equipment, food, and space continue to rise, this goal is becoming more expensive to attain.

Labor has been cited as the most costly resource (Matthews, 1975; Brown, 1969; Stoneham, 1970; Waldvogel and Ostenso, 1977a; 1977b). Innovative systems which have been designed to decrease the use of on-premise labor include ready prepared foods and production commissaries (Doyon, 1970). The ready prepared or cook freeze system prepares large quantities of food on a five-day production schedule. The items are then portioned, blast frozen, and stored for reheating (American Hospital Association, 1976).

Cook freeze systems have been reported to reduce labor requirements (Rinke, 1976; Ellis, 1976). In a school lunch commissary producing 1,650 meals daily, the time spent in the preparation of food was reduced using the cook freeze system. Total personnel time required to produce 100 meals under the conventional school lunch system was 503 minutes while the cook freeze system required 380 minutes. An additional 70 minutes was needed in the cook freeze system for handling menu items during freezing and storage (Millross and Glew, 1974). After converting to a ready foods system, Beyer (1971) reported that in a 275-bed hospital the number of employees was decreased from 53 to 42. Labor costs in a conventional food system were found to be higher than projected labor costs of ready foods and convenience food systems. Labor costs were calculated by developing actual staffing charts (Goldberg and Kohlligian, 1974).

The cook freeze system separates production from service by a period of frozen storage. Structural and textural changes occur while food is frozen; however, this damage can be minimized by using more stable ingredients and controlling storage time, temperature, and packaging (Hill and Glew, 1974). Nutritional and microbiological changes during the freezing process are also of concern.

Retention of ascorbic acid was significantly greater in frozen samples of Chicken a la King and Broccoli in Cream Sauce than in chilled samples after equivalent storage periods (Kossovitsas et al., 1973). Thiamine and riboflavin losses in foods prepared using the cook freeze system were not significantly different from losses found in foods prepared by conventional methods (Millross et al., 1974).

In cook freeze systems food may be exposed to temperatures between 40°F. (4°C.) and 140°F. (60°C.) for long periods of time. Cooked foods should be frozen as rapidly as possible to prevent multiplication of bacterial organisms. Salmonella organisms were found in samples of Chicken a la King and Codfish in Cream Sauce after 15 and 30 days of storage at -9°F. (-23°C.) (Kossovitsas et al., 1973). Low counts of aerobic bacteria were observed in cooked beef loaves after three different handling treatments. Following cooking, loaves were either refrigerated immediately, pasteurized and refrigerated, or frozen and thawed. The different handling treatments did not influence the microbial growth pattern in the end product (Zallen et al., 1975).

Hazard Analysis Critical Control Point (HACCP) models were developed for quality control of entree production in cook freeze food service systems. Critical control points are components in a process that reduce or eliminate a microbiological hazard. The four critical control points identified for HACCP food service models were ingredient control and storage, equipment sanitation, personnel sanitation, and time-temperature. The authors recommended that standards and monitors for control of critical control points be established for food service operations (Bobeng and David, 1977; 1978).

The nutrient and microbiological contents of prepared food products in the cook freeze food production system were not found to differ greatly from prepared food products in conventional food production systems, provided proper handling techniques were utilized. The reported decrease in labor required in the cook freeze food production system becomes a major advantage of the system. Therefore, in a cook freeze system, management can place emphasis on the development of methods to control labor utilization within established, acceptable handling techniques.

## Identification of the Problem

The successful development of innovative methods for food service operations requires a systems approach. A systems approach to production and inventory management relies on the coordination of all personnel, materials, and equipment within a food service unit (David, 1973). Operational activities, such as allocation of resources, production processes, and control must be integrated. Decisions on the jobs to be completed, equipment and ingredients to be used, and personnel to be utilized must consider influences on all operational resources and activities. Feedback should provide management with information necessary to make appropriate decisions regarding production and inventory systems (Hopeman, 1976).

A formal production and inventory system which assimilates information to develop workable plans has not existed (Wight, 1974). Informal systems arise which try to compensate for the ineffective formal system. Too often, decisions on resource allocation are made using crisis management techniques. A multidisciplinary approach towards finding methods to improve resource utilization and scheduling has been recommended (David, 1973).

## Purpose of Study

Food service managers currently make resource scheduling decisions based on experience. A management tool which would schedule production personnel and equipment to minimize avoidable idle time and decrease labor cost is needed. The purpose of this research was to develop a computerized production scheduling model to be used as a tool for analyzing production plans for labor and equipment utilization in a hypothetical cook freeze production system.

# CHAPTER 2

# REVIEW OF LITERATURE

The effective allocation of system resources depends on a logical and feasible production scheduling technique. Current analytical and computer techniques used in production industries could provide food service facilities with methods to predetermine resource requirements for production and effects of changes in system resources on the scheduling of production. Material requirements planning (MRP), a technique used in industries to plan and control production and material flow, is applicable to industries where product demand can be identified (Wight, 1974). The RESource-Time (REST) scheduling algorithm has been successfully utilized in the construction industry to allocate resources according to availability. Food production facilities should compile sufficient quantitative data to design, verify, and utilize models for resource allocation and scheduling.

## Scheduling

Scheduling is the assignment of specific times for projected activities. Schedules provide the basis for coordinating the flow of materials from receiving through production (Niland, 1970). The design of a scheduling system must include provisions for the following functions:

1. Allocating necessary resources to specific work areas
2. Initiating performance of scheduled work through dispatch sheets
3. Reviewing status of projects as they progress through the system
4. Expediting late and/or critical orders
5. Determining the sequence of projects
6. Revising the schedule in view of system changes (Chase and Aquilano, 1977).

Scheduling can become complicated when sequencing problems occur. If a decision is required regarding the order in which tasks should be completed a sequencing problem exists. Normally, activities may be sequenced automatically if rules have been previously established. Complex sequencing problems deserve managerial consideration but are many times solved by default, rather than by design (Conway et al., 1967).

The four types of information needed prior to allocation of specific resources are:

1. the work activities to be completed
2. the quantity and type of equipment and personnel resources available for work
3. the policies and procedures which govern the production process
4. the criteria for evaluation of the schedule (Conway et al., 1967).

With these data, a scheduling method can be designed to achieve the unique objectives of the user.

The length of time required to complete each work task provides the basic data for the scheduling process. Several industrial engineering techniques have been applied in food service operations to determine production time standards.

## Quantitative Methods for Deriving Data

Work measurement techniques are used to determine time standards after work methods have been defined. Stopwatch time study, predetermined time standards, and work sampling are most frequently used in food service operations to establish production standards.

### Stopwatch Time Study

Stopwatch time study may involve continuous observation to obtain a chronological record of the type of activities performed by individual workers, tasks completed in one work center, or the time a piece of equipment is used. Collected data are used to develop standards for elements, short-cycle work, or long-cycle work (David, 1978). Direct labor costs of ready prepared foods and conventionally prepared foods were compared using continuous time study. The average of three replications was used to calculate an average labor time. The use of time study techniques to determine labor time and cost was recommended; however, the authors suggested that the method needed further testing and revision (Quam et al., 1967).

Continuous stopwatch techniques were used to ascertain whether a central ingredient room would decrease cook labor demands (Heinemeyer and Ostenso, 1968). Time studies to determine the quantity of time required to prepare five different amounts of fifteen specific amounts were conducted by Ivanicky et al., (1969). Data were analyzed to find the time relationship involved in preparation of the various amounts. Elements were categorized according to the relationship between production time and volume. The elements exhibited a production time proportional to production volume, such as individual handling; independent of production volume, such as blending and adding ingredients; or not proportional to production volume, such as hand mixing and pouring ingredients. These elements provided a basis for determining the time required to produce that recipe. The authors concluded that the method could be utilized to predict the time required to prepare any product.

Standard labor times for specific production activities using time studies were established by Brown (1969). Daily labor requirements could be predicted using standard labor times so that personnel or recipes could be adjusted in advance.

## Predetermined Time Standards

Master Standard Data (MSD) was applied to bakeshop activities by Montag et al., (1964). Results suggested that MSD was feasible for developing coded standard data elements in food service operations. Master Standard Data was adapted to standardize production times of different volumes of four specific entrees (Ruf and Matthews, 1973). The authors concluded that MSD could be used to establish time standards for all production items.

Production times for various quantities of three single-item entrees were calculated using MSD and compared with stopwatch time studies (Waldvogel and Ostenso, 1977a). Results indicated that MSD was a valid and reliable technique for determining production times. In a related study, Waldvogel and Ostenso (1977b) utilized MSD to estimate production time for 100, 200, and 500 portions of an entree. A hypothetical system capacity of 250 or 500 portions was set. Batches of 250 or 500 portions were produced to determine the effect of a system capacity less than the volume required and a system capacity equal to the volume required. Two batches of 250 portions each were required when the system capacity was less than the volume required, while one batch of 500 portions was produced to simulate a system capacity equal to the volume required. Labor time per portion decreased as production volume increased. Single production elements were either directly proportional to volume or disproportionate to volume. Total time required per portion decreased exponentially for the two items produced. The authors concluded that optimal production volumes could be determined for current use based on menu item, available production time, system capacity, and personnel.

Using MSD, macro elements of production were developed to determine production labor time for three classifications of entrees (Matthews et al., 1978a). Standardized entree formulas were classified into three classifications: single-item, combination, or roast. Two formulas from each of the three classifications were selected for further study. Procedures for preparing 100 servings of each of the six formulas were grouped into basic elements and the MSD Quantity Food Production Code was applied. Activities which did not have an element code were defined, simulated in a standardized production area, and assigned an element code. Basic elements were grouped and simulated to derive macro elements. The total production time for 100 portions of each formula was calculated using the macro elements. The researchers concluded that the method of predetermining production time was feasible to use as a decision tool to evaluate menu mix, production personnel schedules, and allocation of equipment usage.

The revised MSD Quantity Food Production Code was applied to three quantity levels of the same six entrees used in the previous study (Matthews et al., 1978b). Handling and processing times were combined to determine the total and average production times for each quantity of the three entree classifications. To determine whether various combinations of single-item, combination, and roast could be produced with the equipment and production time available in the simulated food service system, six menu mixes were evaluated. Analysis of total production times for the three classifications of entrees showed production time and/or equipment constraints were violated in five of the six menu mixes. Total production time estimates would be beneficial to management when planning menu mixes, scheduling production personnel, and forecasting labor costs.

## Work Sampling

The technique of work sampling uses random, instantaneous observations to determine the percentage of time devoted to the elements of work, delays, and personal time in a specified time period (Brisley, 1971). Several studies have been conducted which show the relationship of labor time to meals served, and the percentage distribution of all work activities in hospital dietary departments (Schell and Korstad, 1964; Kent and Ostenso, 1965; and Ostenso and Donaldson, 1966).

Work sampling was utilized to analyze work activities of seven selected food service personnel with different job descriptions to improve classification and scheduling in a conventional food service system (Wise and Donaldson, 1961). The two-month study conducted in a 475-bed hospital showed that for the seven selected employees, the majority of time was spent in "food preparation" activities. The average percentage of time the two cooks were involved in food preparation activities was 55. "Food service" activities required an average of 20% of total time.

The activities of food service personnel and labor time per meal in three assembly/serve hospital food systems were compared with eleven conventional hospital food production systems which had similar characteristics to the assembly/serve hospitals. Less total time and direct time were utilized in the assembly/serve systems; however, indirect and delay time were not significantly different. A significant shift in reallocation of work functions did not occur and analyses did not show a direct relationship between the market form of food purchased and time spent in processing.

Delays occur when an employee is available for work, but is not engaged in a work function. When interruptions occur that are beyond the employee's control, a forced delay results. Delays may occur when employees are on allowed personal breaks or are taking unscheduled breaks. The percentage of total direct labor time in conventional food production systems attributed to forced delay has ranged from 1.6% (Institution Management Personnel, 1967) to 13.1% (Williams and Donaldson, 1969). Forced delay for the three assembly/serve hospital food systems ranged from 3.3 to 4.4% (Zolber and Donaldson, 1970). No studies were found on the percentage of forced delay time found in cook freeze food production systems.

## Resource Allocation

The optimal utilization of resources was investigated by Beach (1974). A decision model was developed for a hypothetical food service to determine the most economical market form of food to purchase which would meet the objectives of a food production system. Resource allocation analysis by linear programming determined the maximum savings if the item were produced on-premise rather than purchased ready prepared. The complexity of entree preparation was found to influence the daily demand for direct labor, regardless of market form of food. Results of linear programming formulations showed that daily labor demands could vary by more than one full-time equivalent (FTE) employee. The production of 2,000 portions of entrees per day could be achieved by less than one each FTE cook and assistant cook. A continual food production system would allow the optimal scheduling of labor and equipment. Beach concluded that linear programming could provide objective data for resource allocation and the determination of the optimal market form of food to purchase.

Production activities, however, were not sequenced so realistic resource requirements were not determined. Additional personnel or equipment resources might have been needed to meet set production deadlines and to avoid conflicts in personnel or equipment utilization.

A Resource Allocation Production Scheduling (RAPS) Algorithm was developed by Goodwin (1976) to determine the influence of sequencing of activities on resources. The RAPS Algorithm utilized the CPM method of activity analysis, the Activity-On-Node system of network construction, and a modification of the RESource-Time (REST) Algorithm (Davis and Buchan, 1969) for allocating resources according to availability constraints. The RAPS Algorithm provided a systematic and feasible method of scheduling hot food production. It identified periods of least, greatest, and no activity; showed available resources during specific time periods; and determined optimum workloads for a designated time. Further study was recommended by Goodwin to determine the feasibility of applying the RAPS Algorithm to continuous production systems.

## The Critical Path Method

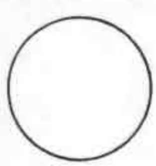
The two best known techniques available for scheduling resources are Program Evaluation and Review Technique (PERT) and Critical Path Method (CPM). Both techniques identify resource requirements by activity and then estimate activity time. The basic difference is that PERT requires that three estimates be obtained for each activity; optimistic, pessimistic, and most likely. The CPM technique uses one estimate, the expected time. Program Evaluation and Review Technique is used to schedule advanced technological projects that are uncertain and CPM's origin is in the scheduling of routine work activities (Chase and Aquilano, 1977). The Critical Path Method is concerned with the relationship between employing more resources to shorten the duration of projects and the increased cost of additional resources (Wiest and Levy, 1977). The CPM technique was determined to be a feasible method of providing objective data for defining time requirements for labor and equipment in food production systems (Beach, 1974; Goodwin, 1976).

## Network Construction

The effectiveness of CPM relies on a sound network construction system. Two systems of network construction have been reported in the literature, the activity-on-arrow (AOA) and the activity-on-node (AON) (Buchan and Davis, 1976; Wiest and Levy, 1977; Moder and Phillips, 1970). The AOA diagram shows the activities as arrows connecting two nodes, with dummy activities required to display specific precedence relationships. An AON diagram is a series of circles or nodes connected by arrows to show specific precedence relationships. The AON diagram has been reported to be easier to draw, more readily understood, and simpler to revise.

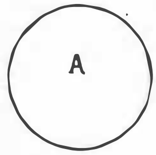
The terms and symbols used in the AON system are:

1. Node



A node is any closed geometric design such as a circle or square.

2. Activity

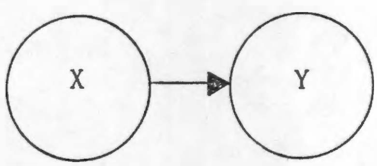



An activity is a time-consuming operation required to complete a part of the project. Each node represents one activity. The operation it represents is indicated by a short description or letter symbol inside the node.

3. Arrow

An arrow is a line connecting two nodes with an arrow head at the front end. The arrow signifies that the activity at the tail must precede the activity at the head (front) of the arrow. Arrow length does not denote time duration of activity.

4. Restriction

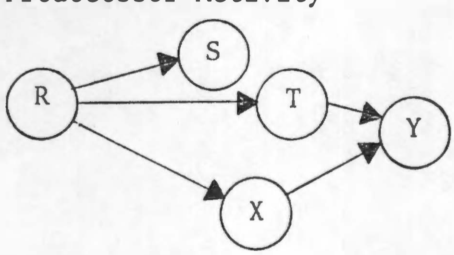



A restriction is a precedence relationship which establishes the sequence of activities. When one activity must be finished prior to the start of a second one, the first is a restraint on the second. In the example, activity X is a restriction on activity Y.

5. Dummy or Milestone

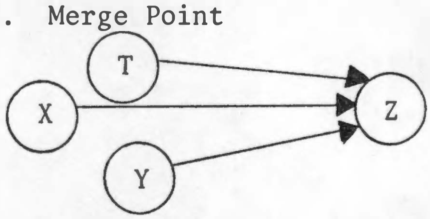
A dummy node indicates a restraint relationship which requires zero time. A dummy is signified by a dashed symbol. Although a dummy is not required in the AON method, it may be used to indicate the start and completion of a project.

6. Predecessor Activity



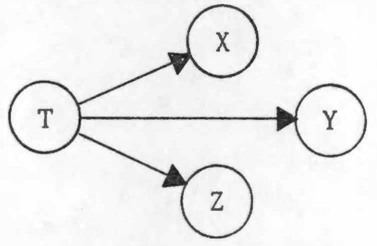

A predecessor activity is one which immediately precedes the one being considered. Activity R is a prerequisite for activities S, T, and X. Activity R is not a predecessor for Y.

7. Merge Point



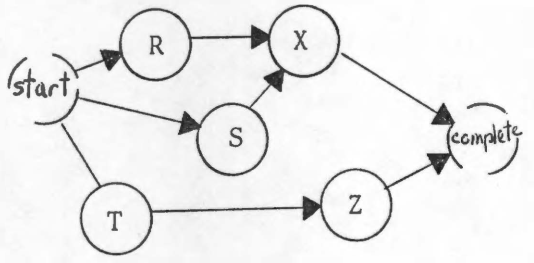

A merge point occurs when two or more activities are predecessors to a single activity. All activities preceding the merge activity must be finished before the merge activity can begin.

8. Burst Point




A burst point occurs when two or more activities have a common predecessor activity. None of the activities succeeding from the burst point activity (Activity T) can be started until the mutual predecessor activity is finished, unless a lag factor is involved.

9. Precedence Diagram




A precedence diagram is a graphical representation of the project activities in the proper sequence required to complete a project. Time is shown proceeding from left to right; however, the length of arrows is not proportional to time.

Data Collection

After the network has been completed, the next concern is the estimation of activity duration and assignment of responsibilities. Time estimates should be as unbiased as possible. Since time data are not always available in absolute and precise terms, techniques which supply information using practical and flexible methods are employed. Either the conference approach or the executive approach may be used to generate data for CPM analysis. In the conference approach, a select group of people decide cooperatively on the sequence and time requirements of activities. The executive approach utilizes only two or three experienced persons to derive data on activities. Time data are accumulated more quickly using the executive approach than the more detailed techniques of predetermined time standards and stopwatch time study (Beach, 1974).

## The REST Algorithm

In the construction industry the RESource-Time (REST) Algorithm (Davis and Buchan, 1969) is a systematic method of allocating resources according to availability. The REST Algorithm offers flexibility for scheduling projects. An appropriate time unit for a particular operation can be selected and the number of time periods for planning projects is unlimited. Resource availability can change from one time period to another.

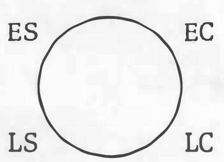
Prior to using the REST Algorithm the quantity and types of resources for each activity must be determined. One activity can simultaneously require as many resource types as necessary. The efficiency of each possible level of resource utilization has to be considered before allocation can occur. A penalty in time units may be designated for each interruption in an activity.

In the resulting schedule a resource may be assigned at different levels during a specific activity. An activity may be segmented instead of being scheduled in consecutive time periods. The REST Algorithm uses the heuristic approach to scheduling and provides a realistic, but nonoptimal production schedule.

The computerized REST Algorithm scheduled activities according to predecessor activities, rather than on a priority basis. The merging of two or more projects was not possible (Faulkner, 1977).

## The RAPS Algorithm

The REST Algorithm was used by Goodwin (1976) to develop the Resource Allocation Production System (RAPS) Algorithm. The RAPS Algorithm consisted of three phases of resource allocation: prescheduling analysis, scheduling, and postscheduling analysis. Prescheduling analysis was composed of eight steps which generated input data. First, an activity analysis was completed for each formula, with time estimates for each activity in minutes being added next using the executive approach (O'Brien, 1971). A network was constructed for each formula using the AON system. Activity duration, content, and number were added to the initial network. The next three steps involved checking the network for advance preparation activities and identifying fixed intervals. The last step in the prescheduling analysis was completion of network time computations. Forward and backward passes were calculated, supplying each activity node with four pieces of time data (Buchan and Davis, 1976) as shown.




where:

ES = Early Start Time
EC = Early Complete Time
LS = Late Start Time
LC = Late Complete Time

The forward pass determined the project duration, using Early Start and Early Complete Times. Each project began at time zero (TO) and each activity began as soon as its predecessor(s) was completed. Forward pass time values were calculated as follows:

$$ES_{ID} + t = EC_{ID}$$

where:

ES = Activity Early Start Time
ID = A specific activity
t = Estimated time duration of the activity
EC = Activity Early Complete Time

The Early Complete Time of one activity became the Early Start Time of the succeeding activity. At merge points, the longest time to that point was carried forward in the computation.

The backward pass provided the Late Complete Time and Late Start Time for each activity. The backward pass began with the project completion node and concluded with the start node. The project duration value was the Late Complete Time for all activities that were immediate predecessors to the completion node. The backward pass time values were calculated as shown:

$$LC_{ID} - t = LS_{ID}$$

where:

LC = Activity Late Complete Time
ID = A specific activity
t = Estimated time duration of the activity
LS = Activity Late Start Time

The LS time of one activity became the LC time of the immediate predecessors. At merge points, the smallest of the LS times to that point was carried backward. The backward pass provided necessary data to compute a criterion value for each activity. The criterion value designated the priority for scheduling each activity and was computed using the formula:

$$CV_{ID} = LS + LC$$

where:

CV = Criterion Value
ID = Specific activity
LS = Late Start of the Activity
LC = Late Complete Time of the Activity

The CV was placed between the LS and LC or ES and EC on the circumference of the activity node.

The Scheduling Phase utilized the basic technique of the REST Algorithm with adaptations as required for the food production system. A Scheduling Worksheet was used to record resource/work content loading decisions. A bar graph was constructed on an activity-by-activity basis to illustrate resource allocation over time. No attempt was made to smooth resource demand.

Postscheduling Analysis was conducted to evaluate the original schedule so adjustments could be made. Resource requirements for each type of resource were totaled for each time interval. Seven smoothing passes were completed to eliminate some of the peaks and valleys of demand, and to lessen the most common excessive demand problems. The resulting schedule provided management with data for improving resource allocation. Computerization and application of the RAPS Algorithm to a continuous production system was suggested (Goodwin, 1976).

## Linear Programming

Linear programming is a mathematical technique which can be used for allocating limited resources among competing activities in order to maximize profit or savings (Hillier and Lieberman, 1974). All mathematical functions in the problem are required to be linear.

A variety of situations exist which meet the necessary criteria, including: the allocation of scarce resources to production areas, the selection of optimal transportation patterns, and the blending of optimal amounts of materials. The optimal solution is one which satisfies the specified goal best or most profitably.

Linear programming models can be used to develop staffing plans to provide the required amount of labor at a minimal cost during a planning horizon (Thompson, 1978; Biegel, 1971; Hillier and Lieberman, 1974). The basis for predicting labor requirements for a production organization is usually the sales forecast. Decisions are made regarding the number of employees, production rate, and net inventory level to be scheduled for a specific time period. Labor standards are used to define the amount of actual labor required to complete one unit of product. When the actual labor requirements are known for a specified time period, total staffing requirements for a set production rate can be determined. Influences on total staffing requirements include vacations, attrition, labor proficiency, long- and short-term illness, absenteeism, and unanticipated production problems. Inventory levels may be increased or decreased according to sales forecasts.

Various costs are considered in the linear programming model. Labor staffing and scheduling plans provide information on costs of hiring, promotions, layoffs, demotions, and overtime. Inventory costs will result because of carrying and/or shortage costs. The linear programming model assumes that each of these costs is proportional to the quantity involved, except that the cost is zero if the quantity is negative. A superscript of + or - on any quantity (q) means the following:

$$q^+ = \begin{cases} q, \text{ if } q > 0 \\ 0, \text{ if } q \leq 0 \end{cases} \qquad q^- = \begin{cases} q, \text{ if } q \geq 0 \\ |q|, \text{ if } q < 0 \end{cases}$$

Thus,

$$q = q^+ - q^-,$$

where either $q^+$ or $q^-$ is zero, depending on whether q is positive or negative. Using the given notation, the possible costs for each pay period are:

1. Regular payroll = rMj
2. Overtime payroll = $s(m\rho_j - M_j)^+$
3. Inventory carrying cost = $iI_j^+$
4. Shortage cost = $hI_j^-$
5. Hiring cost = $a(M_j - M_{j-1})^+$
6. Layoff cost = $f(M_j - M_{j-1})^-$

where:

m = man-hours required/unit

$\rho_j$ = production planned for jth period

$M_j$ = number of man-hours available in jth period

$I_j$ = inventory at the end of the jth period

r = regular time cost per man-hour

a = hiring cost per man-hour

f = layoff cost per man-hour

s = overtime cost per man-hour

i = inventory carrying cost per unit per unit time

h = shortage cost per unit per unit time

The total cost (C) for a planning horizon of n periods is:

$$C(\rho_j, M_j) = \sum_{j=1}^{n} [rM_j + s(m\rho_j - M_j)^+ + iI_j^+ + hI_j^- + a(M_j - M_{j-1})^+ + f(M_j - M_{j-1})^-] \quad \text{(Hillier and Lieberman, 1974)}$$

This formula was used for variable production quantities and work force. When a stable work force is employed, hiring costs, layoff costs, and shortage costs are minimal and may be eliminated from the formula.

## Alternative Work Schedules

The Fair Labor Standards Act of 1938 established the standard work schedule of 5 days and 40 hours. Experimentation with shortened and rearranged workweeks became popular in the 1960's. Shortened work schedules have included the 5-day, 35-hour week; the 4-day, 32-hour week; and the 3-day, 36-hour week. The shortened workweek may provide more leisure time, reduce the number of trips to and from work, and allow employees to arrange personal business outside of work hours (Fleuter, 1975).

Rearranged work schedules have included the 4-day, 40-hour week; flexitour, and flexitime. Under the 4-day, 40-hour week, employees work four, 10-hour days per week. Successful implementation of the 4-day, 40-hour week plan in a dietary department of a 314-bed hospital was reported by Welsh (1975). Flexitour is a work pattern where an employee selects a starting time from an established list of several schedules. Starting time changes may be permitted each month, quarter, or half-year (Swart, 1978). Flexitime, flexible hours scheduling, allows the employee some control over starting and ending work hours in a given day. Numerous variations of flexitime exist but certain basic features and policies normally occur (Kuhne and Blair, 1978). In a typical flexitime system, a "core" time is set from midmorning to midafternoon during which all employees must be present (Owen, 1977). Lunch times may be specified, such as from 12 noon to 1:00 p.m., staggered, or flexible within a 2-hour range. Employees may accumulate daily or weekly credit and debit hours depending on whether employees work over or under the specified number.

## Advantages of Flexitime

Benefits of flexitime occur for employees and employer. Major advantages for the employee include a reduction in conflicts between family needs and job requirements, a reduction in commuting problems, an increase in autonomy, and an increase in freedom to work according to individual physiological and psychological patterns (Swart, 1978). Employers benefit under a flexitime system as time lost through tardiness and unofficial leave is decreased. Idle time and overtime are minimized since employees can adjust work schedules to fluctuating work loads; the result is increased production (Kuhne and Blair, 1978; Fleuter, 1975). Flexitime grants employees increased responsibility which can improve job performance, attitudes toward company objectives, and job satisfaction. Since supervisory personnel and subordinate staff are not always present at the same time, forced delegation of authority occurs to provide continuity during absences of supervisors (Kuhne and Blair, 1978; Anon., 1975). A survey of 2,889 U.S. organizations conducted in June and July of 1977 indicated that 12.8% of all nongovernment organizations with 50 or more employees used flexitime. An additional 9% of all employers nationwide were estimated to be planning or evaluating the use of flexitime. The researchers estimated that 2.5 to 3.5 million workers in the U.S. were on flexitime in 1977 (Nollen and Martin, 1978).

Flexible hour schedules have not been in operation long enough to provide sufficient evidence of the potential of the systems. Current experience has suggested that popularity of flexitime systems will grow as more organizations discover the benefits (Swart, 1978).

## Material Requirements Planning

Material requirements planning (MRP) is a system of planning and controlling production and material flow, which has been rediscovered since the advent of the computer (Miller and Sprague, 1975). Some companies have viewed MRP as a cure-all; however, good manufacturing support systems must be operating before MRP will be successful (Milwaukee Chapter, Inc., APICS, 1977). Material requirements planning depends on a high level of accuracy in inventory records, lead-time information, production records, and personnel and equipment records (Thurston, 1972).

The logic of MRP is based on the fact that the demand for raw materials and product components depends on the demand for an end product (Miller and Sprague, 1975). Requirements for finished products determine the quantity of components needed and delivery dates for raw materials or component parts (Greene, 1974). Orders are based on actual or projected requirements, not economic lot sizes as in traditional inventory management systems. Emphasis is placed on getting the correct raw materials to the right place at the right time.

The planning sequence for an MRP System is shown in Figure 2.1. The production plan is a general plan stated in units, dollars, or hours, established for product groups, not specific items. The estimated quantity of each product group that will be needed during a specified future time period is indicated (Wight, 1974). When future demand is known, production demand can be stabilized. Vacation periods and holidays can be planned into the production period.

The master schedule identifies the specific requirements for each product by time period based on the production plan. Material and resource, or capacity, requirements are determined from the master schedule. The master schedule must be realistic since overstated requirements will cause production scheduling to become distorted and the false demand will result in increased labor hours. As demand changes, the master schedule is revised.

The bill of materials is the basis for the MRP planning process. Traditionally, the bill of materials has been used to define the design of a product. Material requirements planning utilizes the bill of materials for planning purchases of raw materials and scheduling resources. The bill of materials must be accurate and reflect current

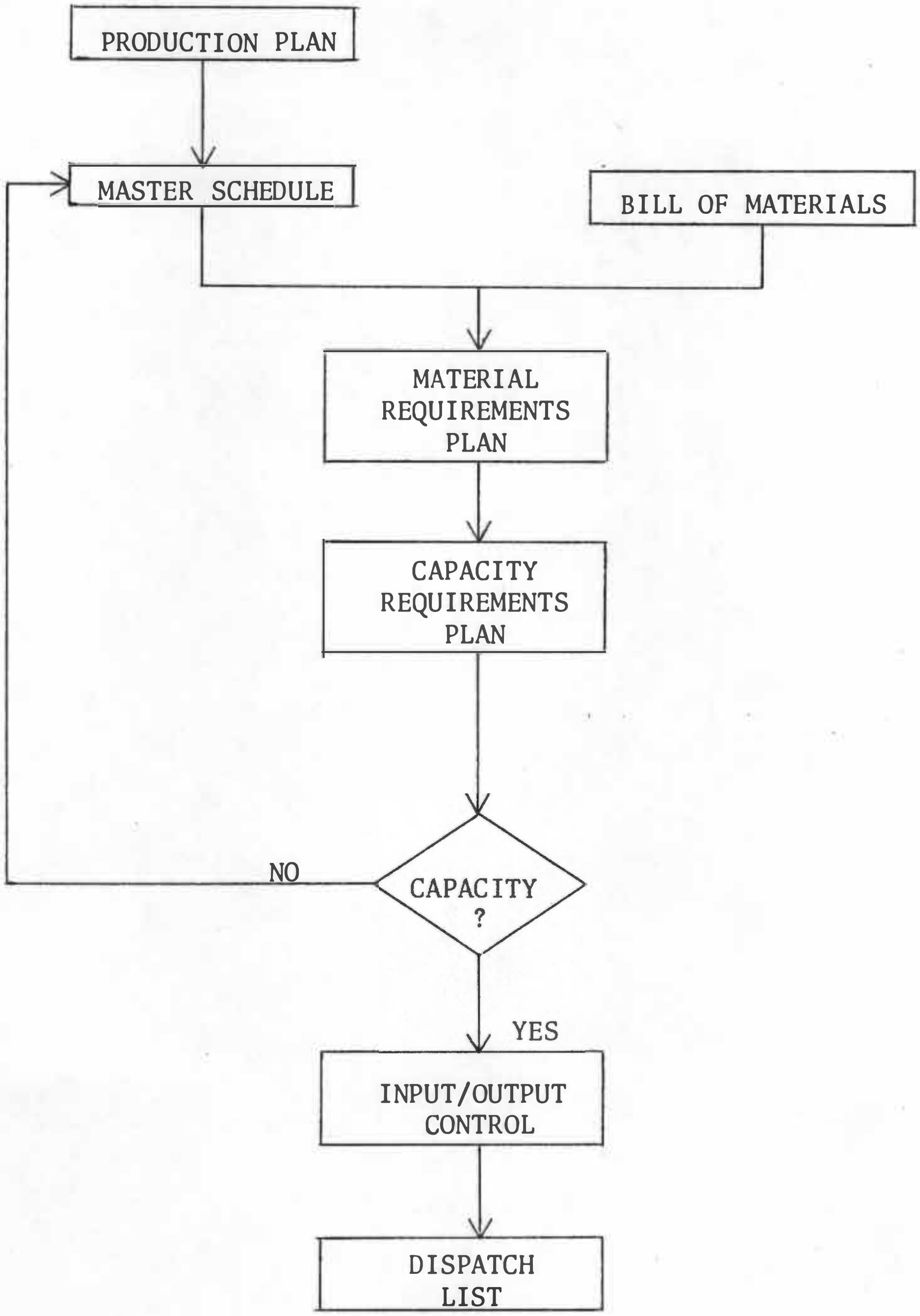



Figure 2.1. Planning sequence for material requirements planning (Adapted from Wight, 1974).

data to ensure valid output. A well-structured and clear bill of materials is necessary for a successful MRP system.

The material requirements plan states the quantity requirements for each component of a product by time period. The mechanics of determining purchase orders using the material requirements plan are illustrated below.

| Master Schedule Bicycles | Weeks 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| | 40 | 0 | 50 | 0 | 0 | 60 | 0 | 60 | 0 |

MRP-Handlebars

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Projected Requirements | | 40 | 0 | 50 | 0 | 0 | 60 | 0 | 60 | 0 |
| Scheduled Receipts | | | | | | | 80 | | 80 | |
| On Hand | 120 | 80 | 80 | 30 | 30 | 30 | 50 | 50 | 70 | 70 |
| Planned Order Release | | | 80 | | 80 | | | | | |

Lead Time = 4; Order Quantity = 80

In the example, the master schedule lists the specific requirements by week for bicycles. The bill of materials is consulted to determine the requirement for all components and the figure is placed in the appropriate column of the projected requirements row for the component part, i.e., handlebars. Scheduled receipts are orders previously placed and scheduled for delivery. The quantity on hand is a running total of receipts minus issues. In the example, a negative balance could occur in week 6 if an order is not released. With a lead time of 4 weeks, an order is scheduled for release in week 2. The order quantity of 80 units is predetermined.

Theoretically, safety stocks are not used. Orders are timed to arrive just prior to stockouts and inventories are kept at the lowest possible levels. In practice, safety stocks are used for items with long lead times and for variations in demand during minimum lead times (New, 1973).

The capacity requirements plan is a tentative plan to show the capacity of resources that is needed. This is compared with the available resources to determine if the master schedule can be met. When resource requirements exceed the available capacity, the master schedule is revised or the system capacity is increased. The final decision must be made at the management level, although the MRP system identifies the alternatives.

Production rates are monitored using an input/output control report. This report measures the flow of work, using standard hours, in and out of work areas. The planned labor hour input and output are obtained from the capacity requirements plan, with deviations from the plan being reported. Control of input/output is achieved by controlling production loads at work centers.

Current priorities are communicated to production areas daily using a dispatch list. As the master schedule is revised, the priorities of jobs may change. The dispatch list provides the foreman with an up-to-date list of requirements so the proper sequence of jobs necessary to meet the objectives of the operation is known.

Data generated by the MRP system, coupled with the fast update capability of computers, provide managers with information necessary to cope with system problems. Priorities can be changed as production orders are cancelled. Vendor deliveries can be rescheduled, required jobs can be finished first, and low levels of finished inventories are maintained (Miller and Sprague, 1975).

When priorities are correct, lead times can be minimized with consequent decreases in parts, in-process, and finished products inventories. Parts are available to enter the production process when necessary. End products which can not meet scheduled deadlines can also be identified through MRP. Demands and system capabilities are known in advance so the feasibility of meeting deadlines are identified. When deadlines cannot be met, alternative plans can be initiated. Because MRP requires accurate data, the technique is used to assist in budgeting and long range planning. Manpower needs, equipment requirements, and major material purchases are anticipated and planned (Miller and Sprague, 1975).

## Application of Material Requirements Planning

The number of MRP systems being implemented in production industries is growing, with many successes being reported (Berry and Whybark, 1975; Fuchs, 1978). Southwire implemented MRP to control work-in-process inventory and production procedures. Ordering was being accomplished by a combination of safety stock and gut feelings. The current work-in-process inventory accuracy was around 69%. The installed MRP system checked the demand against a finished goods inventory with the difference being the net demand. The net demand became input for the MRP module with a Planned Order Report as output. This report showed the product description, order number, amount, order and due date, and lead time. Work-in-process inventory was compared with the net demand requirements to determine what materials must be ordered and when to meet the production requirements. Accuracy of the work-in-process inventory increased to 96% (Boyer, 1977).

Leesona, a textile machinery company, installed a priority scheduling system to improve inventory control. Forecasted material requirements were time-phased by month for a year, and formed the basis for ordering material. Purchase and production orders were completed with delivery or with finished product deadlines determined from the finished material requirements. The priority scheduling system then adjusted production schedules and purchase deliveries to changes in raw material or finished product requirements. Benefits of the priority scheduling system included: lower raw material, work-in-process, and finished product inventories; reduced overtime; reduced back orders; and reduced set ups (Aley, 1976).

A large manufacturer of digital minicomputer products saved two million dollars in raw materials, purchased parts, and work-in-process inventory; inventory turns increased from 1.2 to 3.4 turns per year after implementing a MRP system. A Southwest manufacturer of luggage reduced raw materials and work-in-process inventories, improved accuracy of inventories, and decreased downtime due to waiting by 90% (Fuchs, 1978).

## CHAPTER 3

## PROCEDURE

As costs of materials, equipment, and personnel increase food service managers are seeking new ways to effectively utilize system resources. Personnel has been identified as a key resource which can be utilized more productively. A systematic production scheduling methodology which would be feasible for food production systems would assist management in the improvement of personnel productivity. Materials requirements planning, combined with a computerized scheduling methodology would provide food service managers with accurate and relevant data for making decisions regarding resource scheduling.

Material requirements planning (MRP) was used to generate realistic daily production schedules. A scheduling methodology (REST) and the Resource Allocation Production Scheduling (RAPS) Algorithm were adapted and combined to form COST-ARREST (Computerized Scheduling Technique—using the Algorithms of RAPS and REST). The COST-ARREST program was used to generate resource allocation data for a cook freeze production system.

### The Food Production System

The cook freeze food production system used for this study was based on the ready foods system developed by Beach (1974). Both types of systems use continuous production methods which result in decreased unit costs without significant quality losses. Data derived by Beach (1974) were based on a traditional food production system and analyzed for a cook chill system. The production functions required in cook chill and cook freeze systems are the same, with the cook freeze system allowing an increased flexibility in the duration of storage over the cook chill system. The cook freeze production system was chosen for analysis in the current study.

## Description of System

The hypothetical cook freeze system was based on a traditional food production system. The layout of the production area was considered to be efficient for the preparation of approximately 1,000 entrees for each noon and evening meal. The flow of food from controlled storage areas through the production area is shown in Figure 3.1. The flow of food was considered to be efficient. The main production area was located such that minimal travel between storage and preparation areas was necessary.

Ingredients were assumed to be available in the proper quantity and type in production areas when necessary. Required ingredients were issued daily from controlled storage areas to three day storage areas: dry, refrigerated, and freezer. Canned and staple items were placed in the dry storage area following receiving. Staple ingredients were weighed and measured in the ingredient assembly area according to formula specifications. Meats, fish, and poultry were purchased

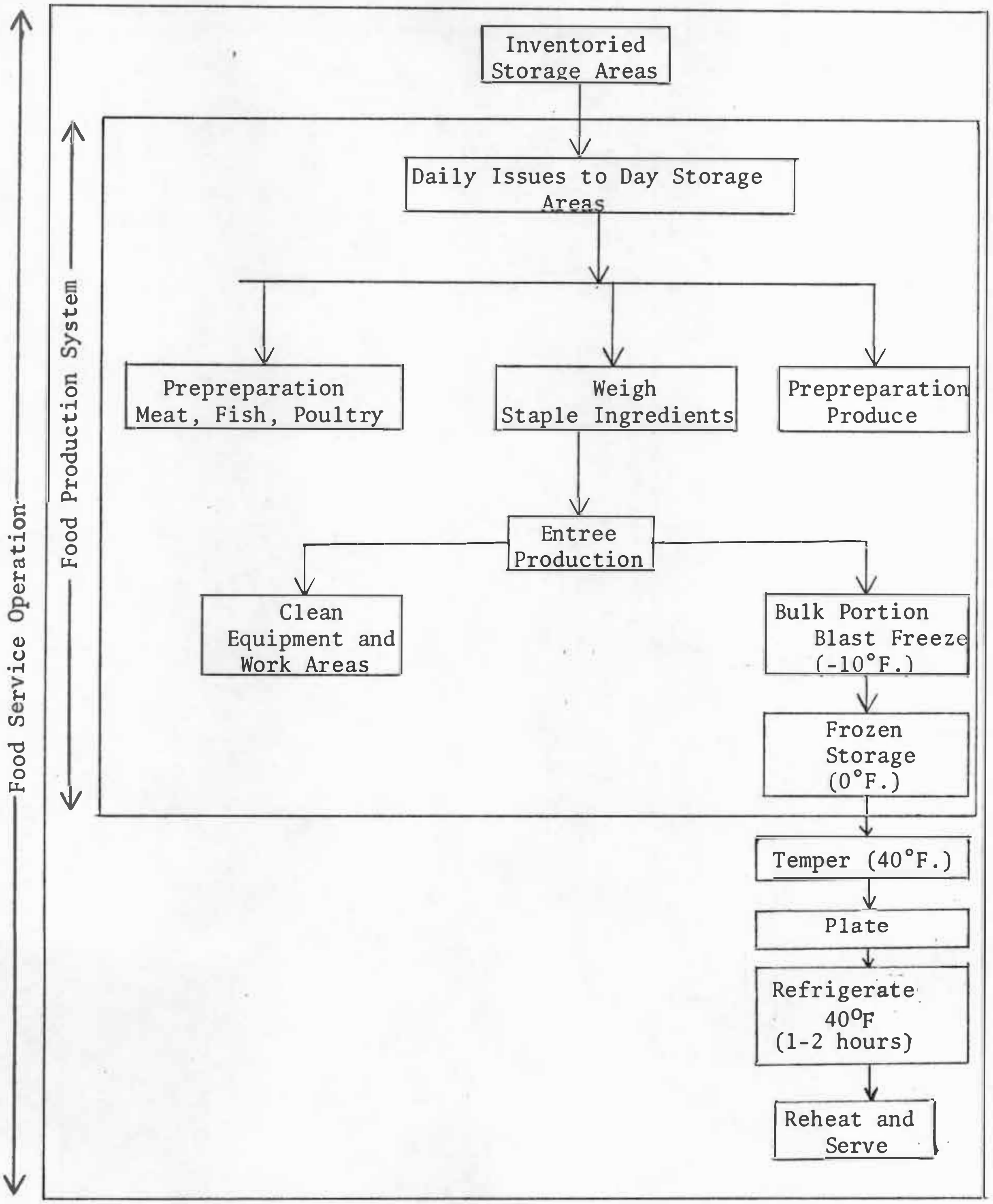



Figure 3.1. Flow of food in a hypothetical food production system for a food service operation using the cook freeze system (Adapted from Beach, 1974).

according to recipe specifications. Fresh meats, fish, and poultry were placed in production refrigerated storage areas until needed. Frozen entree ingredients ready for production were issued to freezer storage. If required, frozen entree ingredients were tempered in the production refrigerators prior to preparation.

Fresh produce was issued daily to either dry or refrigerated storage according to storage requirements. Preprepared produce was placed in refrigerated storage until needed for final preparation of entrees.

Experienced cooks and assistant cooks produced all entrees from preprepared ingredients. The production phase was followed by bulk portioning of 25-30 servings per container and blast freezing (-40°F.). When the item was frozen the containers were moved into a holding freezer (0°F.). Eighteen to twenty-four hours prior to service, the specified number of containers were transferred into a tempering refrigerator (40°F.). Prior to each meal, the required number of entrees were single-portioned on a tray assembly line and placed in refrigerated (40°F.) mobile storage trucks until service, when the entree would be reheated in a microwave oven.

Entrees

Production planning requires detailed data on preparation methods, equipment available and personnel skills available. The seven-day menu developed by Beach (1974) was expanded to a nine-day menu cycle by repeating selected entrees. The reported average patient stay for a sample of hospitals registered by the American Hospital Association (AHA) was 7.1 days (American Hospital Association, 1977; 1978) so a nine-day menu was judged to be suitable. Data were obtained from American Hospital Association reports from May 1977 through March 1978.

The menu reflected considerations of texture, color, flavor, shape, and consistency. Resource requirements were not used in the menu planning. The same standardized formulas analyzed by Beach (1974) were used to maintain a consistent data base. The estimated demand for each entree was the fixed amount for each production batch.

Entree demand. The average percentage of occupancy for hospitals over 500 beds in 1977 was 81% (American Hospital Association, 1977; 1978). Data were obtained from statistics reported by AHA from May 1977 through March 1978. The potential maximum number of entrees served each meal in the hypothetical food service was 1,000; the average number of customers served each meal was 809. The forecasted demand obtained by Beach for each entree item became the popularity index based on 1,000 per meal. Daily demands for each entree item were generated using the random number subroutine of the computerized inventory management system (CIMS) program (Beach and Matthews, 1972). The CIMS program was developed at the University of Wisconsin and adapted for teaching inventory management in the Food Systems Administration major at the University of Tennessee, Knoxville. Random numbers were generated within a range of two standard deviations on either side of the original forecasted demand as calculated from the popularity index.

## Labor

Three skill levels were available for the production of entrees.

Cook. The skilled cook prepared entrees, vegetables, sauces, and gravies. The ability to utilize time and equipment efficiently was required. The cook assumed the major responsibility for menu items which involved baking, broiling, roasting, boiling, or frying, and for the bulk portioning of prepared entrees. The cook supervised other kitchen personnel.

Assistant cook. The assistant cook performed duties assigned by the cook in the preparation of entrees, vegetables, sauces, and gravies. Methods of preparation used included baking, broiling, roasting, boiling, or frying. The bulk portioning of prepared entrees and the cleaning of work areas and specified equipment were additional responsibilities.

Food service worker. The food service worker performed duties as assigned by the cook and included any prepreparation of vegetables, the cleaning of equipment used, work counters, and major cooking equipment such as mixers and steam kettles.

Labor time available. One eight-hour production shift per day was assumed. Ten hours (600 minutes) were made available to allow sufficient time for scheduling necessary production activities. Eight o'clock a.m. was designated to be Time zero (T0) and 6:00 p.m. was T600. Two 15-minute rest breaks (paid) and one 30-minute meal break (unpaid) were included, although these breaks were not scheduled. The assumption was made that personnel would be scheduled to take breaks when production activities did not require attention. Of the 450 paid labor minutes, 360 (80%) were assumed to be devoted to production of main entrees. The 80% figure for entree production was higher than that found in conventional production systems; however, preparing entrees was the major activity of the cook and assistant cook. The food service worker was responsible for cleanup activities related to entree preparation. Vegetable preparation and other assigned duties were assumed to require the remaining 20% of the 8-hour shift. Overtime was paid for each quarter-hour worked beyond the 360-minute production period, provided the employee worked at least 8 of the 15 minutes.

Labor costs. The average hourly wage rates in effect July 15, 1978, in the traditional food production system were used in the current study. Ten percent of the wage rates were added for fringe benefits. The total rates were:

| | |
|---|---|
| Cook | $4.18 per hour |
| Assistant cook | $3.85 per hour |
| Food service worker | $3.68 per hour |

Hiring and firing costs were assumed to be negligible since changes in the number of personnel did not occur in the short run.

### Equipment Constraints

Eight major kinds of equipment were required for production of the 42 different entrees. The layout of the production area is shown in Figure 3.2. A brief description of each piece of equipment utilized is given in Table 3.1. Not all of the equipment shown in the layout was required for production. The equipment was assumed to be the proper size for production quantities to ensure minimal quality losses.

Equipment time available. Each piece of equipment was assumed to be available for the length of time necessary for the production shift. The number of each type of equipment available was recorded in the COST-ARREST file so each piece was scheduled for production separately.

## Material Requirements Planning

Production procedures in food service operations have been recognized as being similar to those in industrial production plants (David, 1973). Material requirements planning, a management technique developed in industry, has been recommended for use when a company produces finished products consisting of an assembly of components (New, 1973). A technique for inventory control and production scheduling, MRP, was adapted and used to compile a master production schedule for a hypothetical cook freeze production system. The necessary conditions for successful implementation of MRP are identical for any production industry.

### Application of MRP to a Food Production System

In applying MRP to a hypothetical cook freeze food production system, the following assumptions were made. Food service management

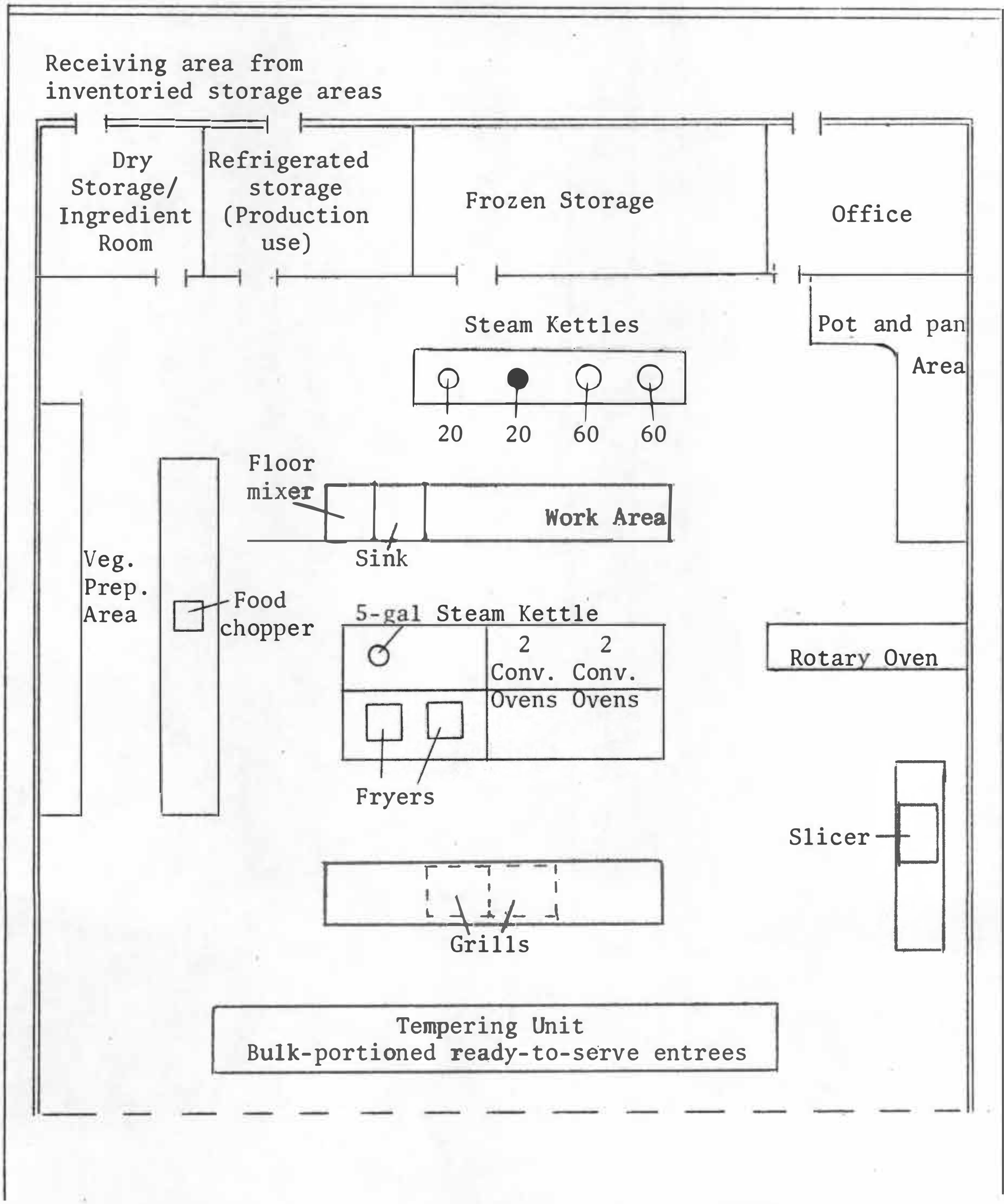



Figure 3.2. Schematic diagram of a hypothetical food production system for a food service operation using the cook freeze system (Adapted from Beach, 1974) (not to scale).

Table 3.1

Major Equipment Used in Entree Production in a Hypothetical Cook Freeze System

| Equipment | COST-ARREST Code | Description |
|---|---|---|
| Floor Mixer | MX | Upright floor mixer with adapter to use various size bowls, multiple speed |
| Steam Kettles | FK | One five-gallon tilting, table mounted, 2/3 jacket height |
| | TK | Two twenty-gallon tilting, floor mounted, 2/3 jacket height |
| | SK | Two sixty-gallon tilting, floor mounted, 2/3 jacket height |
| Convection Oven | OC | Four sections, forced air circulation; capacity per section: six 18" x 26" pans |
| Rotary Oven | OR | One six-shelf unit, with capability to adjust to twelve shelf capacity; capacity per shelf: one 18" x 26" pan |
| Slicer | SL | One table model, automatic, adjustable, positive angle feed, gauge plate to control thickness of slice |
| Grill | GR | Two sections, 18" x 36"; automatic thermostat control per unit |
| Fryer | FR | Two units; conventional instant deep fat fryers, automatic temperature control, quick heat recovery, 10 pounds/fryer capacity under normal conditions |
| Food Chopper | CH | Table model with multiple troughs, including dicer, shredder, horizontal slicer |

within the hypothetical production system utilized sound management principles and communication problems were assumed to be minimal with employees working cooperatively.

Materials were always available when needed for preparation. As a result of explaining the MRP technique to vendors, cooperative relationships existed to ensure delivery of materials on time with no shortages. Employees were trained to follow established record keeping procedures, consisting of a requisition system, used to obtain inventory items, and a perpetual inventory with daily updating by a stock clerk. Raw and finished inventory levels were assumed to be minimal with stockouts occurring.

Forecasting was used to determine the quantity of each entree to produce. The forecasted demand was assumed to be the estimated number of portions required each time the entree was served during a normal nine-day cycle. Formulas were standardized to produce quantities which corresponded to forecasted amounts, rather than the usual multiple of 50 or 100 servings. Weekly forecasts were made each Thursday for the following week, using census figures from the current week and the popularity indexes. When large variations in census occurred, the production plan was revised.

Records of production showed the actual number of portions prepared and served. The popularity indexes were updated regularly to reflect current trends in food preferences.

The capacities of resources, labor and equipment, were identified for each week and compared with the resources required for that week so any necessary adjustments could be made in the production schedule. Vacations, holidays, and sick leave were planned for since the necessary production quantities were known in advance.

Actual standardized formulas from a conventional on-going operation were used as a basis for activity analysis and the establishment of lead times. An activity analysis for each entree had been completed (Beach, 1974) using the executive approach to determine the quantity and skill level of labor needed and the type and quantity of equipment needed.

### Procedure for Implementing MRP in a Cook Freeze System

A list of terms for material requirements planning as defined for industry and food production is shown in Figure 3.3. The standard MRP terms have been adapted to establish a clearer relationship with food production terminology. The essential steps for utilization of MRP in a food production system are shown in Figure 3.4.

Step 1. Total production plan. A total production plan was made to show the estimated total quantity of each product group for a specified future period. The forecasted demand for the hypothetical food production system was 1,000 portions of entrees for each noon and evening meal. The average daily (Monday-Friday) total production plan was for 2,800 portions of entrees. This figure served as a guide for completing the food product requirements plan.

Step 2. Bill of materials. Bill of materials were completed for each entree component and consisted of a list of the ingredients required

| Industry | Food Production System |
| --- | --- |
| **Production Plan** | **Total Production Plan** |
| A general plan which sets the level of manufacturing operations, usually by product group, for future time periods. | A general plan which states the estimated total number of portions required of each product group (entrees, salads, etc.) for a specified time period. |
| **Master Schedule** | **Master Food Product Schedule** |
| Schedule which translates the production plan into specific terms. The master schedule states the required quantity of each item and is used to plan material and capacity requirements. | Schedule which identifies the specific requirements for each food product by time period. |
| **Bill of Materials** | **Bill of Materials** |
| List of components required to manufacture a product, and a diagram of product assembly. | The standardized formula, list of production activities, and flow diagram of the preparation process for each food product. |
| **Material Requirements Plan** | **Food Product Requirements Plan** |
| Plan which states component requirements in detail in specific time periods. These requirements are compared with on-hand and in-process inventories to determine purchase orders. | Plan which compares the food product requirements with on-hand inventories to determine quantity of each food product needed and the day(s) each is to be produced. |
| **Capacity Requirements Plan** | **Labor and Equipment Requirements Plan** |
| Plan which identifies the hours by work center by time period required to produce shop orders. | Plan which identifies labor and equipment time required to produce necessary food products. |

Figure 3.3. Definitions of terms used for material requirements planning.

Input/Output Control Report

Report which measures the flow of work, using standard hours, in and out of work areas.

Master Production Schedule

Collection of master food product schedules for a specified time period.

Weekly Production Plan

Weekly schedule of food production listing food products on day of planned preparation.

Dispatch List

Daily schedule for a work center showing priority sequence of jobs to be completed.

Daily Production Sheet

Daily schedule for a work center showing order in which food products should be prepared. Data are obtained from computerized scheduling program.

Figure 3.3. (Continued)

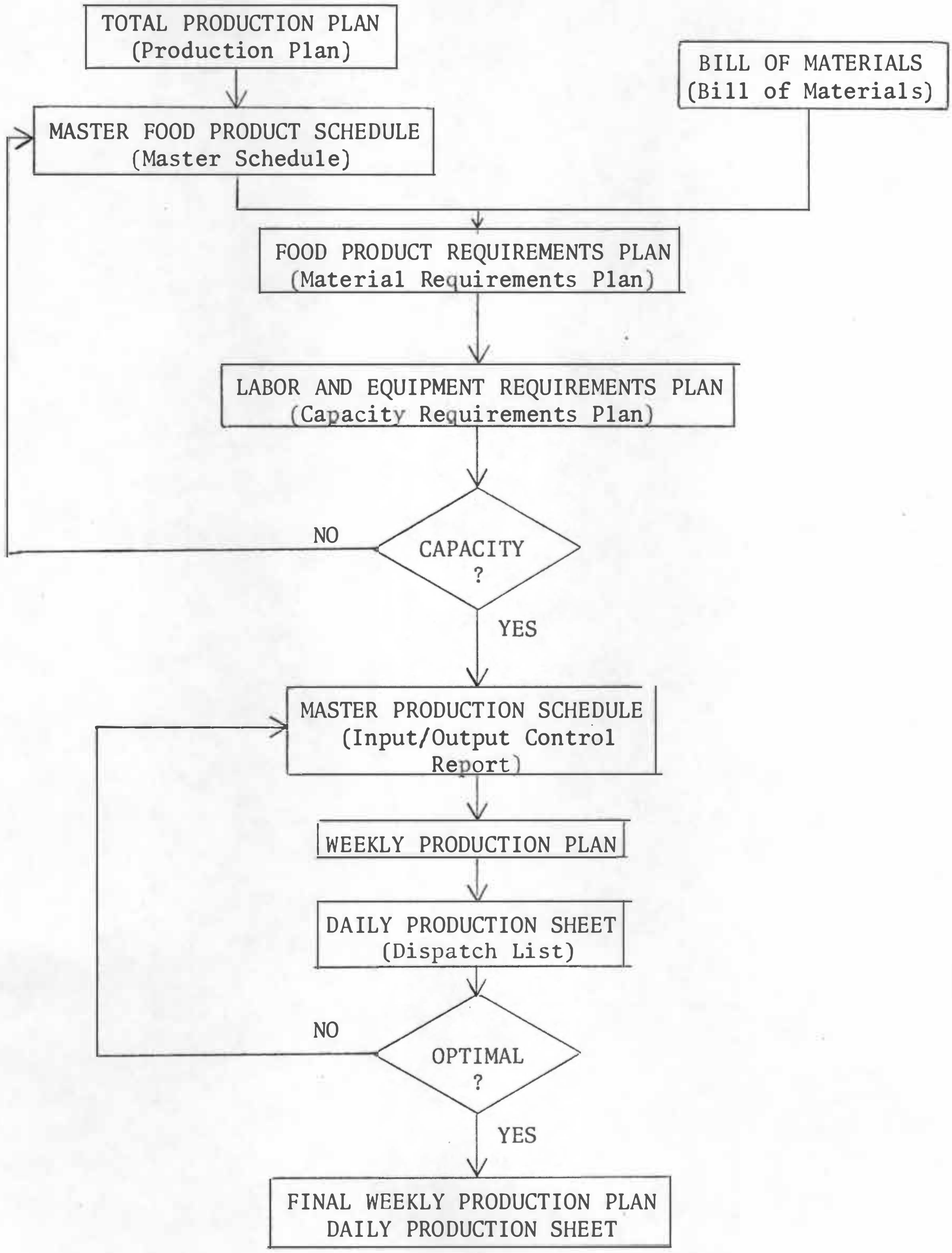



Figure 3.4. Flow chart for utilization of material requirements planning in a food production system.

(the standardized formula), a list of production activities, and a flow diagram of the preparation process. Standardized formulas provided the list of quantities of ingredients required for each menu item. Production quantities were established according to forecasted usage during one normal menu cycle.

Activity analyses completed by Beach (1974) were obtained and reviewed to see if changes would be necessary for application to the cook freeze production system. Two changes were made; some activities were separated to indicate a change in resource utilization, and activity durations were rounded to the nearest five minutes. A five-minute time period was considered to be small enough to provide accuracy and control of data.

The AON method of networking (Buchan and Davis, 1976) was used to construct a flow diagram of preparation activities for each formula. The AON method of networking is described in Chapter 2, under "Quantitative Methods for Deriving Data." Activity duration, content, and number were added to the initial network. Time computations on each formula network were completed using the method described by Buchan and Davis (1976). Forward and backward passes yielded four pieces of time data. The forward pass provided the total estimated project duration. The backward pass provided criterion values which were used to assign each activity a priority for scheduling. The allowed production duration was 9.5 hours so the backward pass began at 570 minutes. Criterion values were checked and adjusted manually when necessary to assure the following three criteria were met:

1. Food was placed in the freezer before cleanup was initiated
2. Ingredients were gathered prior to beginning preparation
3. Unfinished items were scheduled to be produced first the following day

Step 3. Master food product schedule. Data for the master food product schedules for the hypothetical food production system were obtained from the forecasted demand for each entree as generated by the random number subroutine of the CIMS program, and placed on the form shown in Appendix E.1. A period of two menu cycles, 18 days, was chosen for data collection so the master food product schedules reflected an on-going system.

Lead times were assigned to each entree to achieve a realistic production schedule. Lead time was defined to be the elapsed time from when the production order for an entree was placed until the time the entree was placed in the blast freezer. A total of the times required for gathering ingredients, production, transit to the blast freezer, and any waiting occurring prior to production or blast freezing was included in lead time.

The lead time for each entree was designated according to the prepreparation activities required, the market form of food, and the duration of production activities. One day of lead time was added to each formula to allow flexibility in scheduling. For example, Swiss Steak was assigned a lead time of four days since it was received in a frozen state and numerous ingredients for the sauce had to be weighed. The lead time allowed for thawing and the weighing of ingredients was two days. One day was devoted to production and an extra day was added to provide an opportunity to alter the day of production. The list of entrees in the nine-day cycle menu and assigned lead times is given in Table 3.2.

Step 4. Food product requirements plan. The food product requirements plan determined the quantity of each entree component needed to be produced and the day(s) each was required to be prepared. Terms necessary for completion of the food product requirements plan are:

| | |
|---|---|
| Projected requirements | the master food product schedule; the forecasted quantity of entrees to be served on a specific day. |
| Actual requirements | quantity of entrees taken from refrigerator and served. |
| Scheduled product receipts | order quantity received or placed in blast freezer. |
| On hand | quantity of prepared entrees in the freezer. |
| Planned production order | order placed with ingredient room so necessary ingredients are in the right place at the right time in the correct quantity for production. |
| Lead time | period from placement of planned production order until product enters blast freezer. |
| Order quantity | established production quantity based on average usage and equipment size |

The form for the food product requirements plan (Figure E.1) was completed as follows:

Table 3.2

Selected Entrees for a Nine-Day Cycle Menu with Lead Times for a Hypothetical Cook Freeze Production System

| Day | Menu Item | Lead Time (Days) | Menu Item | Lead Time (Days) |
|---|---|---|---|---|
| Sunday | Roast Turkey/Gravy | 5 | Chili con Carne | 4 |
| | Beef Burgundy | 3 | Ham, Macaroni, Cheese Casserole | 3 |
| | Shrimp Marengo | 3 | Grilled Steak/Gravy | 3 |
| Monday | Barbeque Pork Chop | 4 | Flank Steak/Mushroom Gravy | 3 |
| | Oven-Broiled Chicken | 3 | Broiled Flounder | 3 |
| | Sauerbraten | 4 | Turkey Croquette/Gravy | 5 |
| Tuesday | Italian Spaghetti/ Meat Sauce | 3 | Cheese Meat Loaf/ Tomato Sauce | 3 |
| | Oven Grilled Veal Cutlet/ Mushroom Sauce | 4 | Breaded Pork Chop | 4 |
| | Baked Ham/Fruit Sauce | 4 | Seafood Newburg | 3 |
| Wednesday | Swiss Steak | 4 | German Pot Roast | 5 |
| | Roast Pork/Gravy | 4 | Broiled Haddock | 4 |
| | Chicken Chop Suey | 5 | Baked Lasagna | 3 |
| Thursday | Beef Ravioli | 3 | Barbeque Chicken | 3 |
| | Tuna Noodle Casserole | 3 | Grilled Pork Steak | 4 |
| | Cantonese Steak | 4 | Beef Stroganoff | 4 |
| Friday | Sauteed Chicken Livers | 4 | Beef Pot Pie | 3 |
| | Grilled Ham Steak | 3 | Shrimp Newburg | 3 |
| | Italian Steak Parmegiana | 4 | Chicken Cacciatore | 3 |
| Saturday | Chicken and Dumplings | 4 | Chinese Pepper Steak | 4 |
| | Barbeque Spareribs | 4 | Stuffed Flounder | 3 |
| | Beef, Macaroni, Tomato Casserole | 3 | Veal Scallopini | 4 |

Table 3.2 (Cont'd.)

| Day | Menu Item | Lead Time (Days) | Menu Item | Lead Time (Days) |
|---|---|---|---|---|
| Sunday | Swiss Steak | 4 | Broiled Haddock | 4 |
| | Oven-Broiled Chicken | 3 | Italian Spaghetti/ Meat Sauce | 4 |
| | Seafood Newburg | 3 | | |
| | | | Oven-Grilled Veal Cutlet/Mushroom Sauce | 4 |
| Monday | Baked Ham/Fruit Sauce | 4 | Roast Pork/Gravy | 4 |
| | Cantonese Steak | 4 | Beef Pot Pie | 3 |
| | Broiled Flounder | 3 | Chicken Cacciatore | 3 |

1. The projected requirement for the entree was entered on the day the entree was required to be placed in the blast freezer.

2. The quantity on hand was entered for Day 1. Safety stocks were not used so in many cases the inventory level was zero.

3. The projected requirement was compared with the quantity on hand. If the projected number of portions were greater than the amount on hand, an order was placed.

4. The order was placed according to the number of days of lead time required. If an entree had a lead time of three days, the quantity ordered was entered on the fourth day preceding freezing. The ingredient room or production area had the order on the morning of the third day preceding the freezing.

5. The order quantity was entered as scheduled product receipts on the day it entered the freezer and the quantity on hand was updated.

6. The actual requirements on the day of service were completed and the quantity on hand was updated.

Each week projected requirements were made for the following week and the food product requirements plan was updated.

Step 5. Labor and equipment requirements plan. Daily labor and equipment requirements plans were completed by totaling the number of minutes each resource was required. Data were obtained from the activity analyses compiled in the bill of materials, and transferred to the form shown in Appendix E.2. The daily totals for each labor category and piece of equipment were compared with the available labor and equipment time. The scheduling of activities determined if the correct labor and equipment resources were available at the proper time.

Step 6. Master production schedule. The summary of master food product and food product requirements plans for a specific time period for all entrees was the master production schedule (Figure E.3). The master production schedule was the basis for deriving four different production plans.

Step 7. Weekly production plans. Four different weekly production plans were used as input for the COST-ARREST program.

1. A seven-day production plan derived by producing entrees according to minimal lead times. Three days were subtracted from all lead times since the flexibility for scheduling and extra time allowed for prepreparation and weighing of ingredients were not required.

2. A five-day production plan—Original, obtained by using maximum lead times and then shifting the items scheduled for production on Sunday to Monday and the items scheduled for production on Saturday to Friday.

3. A five-day production plan—Alternative 1, obtained by transferring selected items from Monday to Tuesday and from Friday to Thursday.

4. A five-day production plan—Alternative 2, derived by transferring additional entree items from Monday to Tuesday and from Friday to Thursday.

The five-day production plan—Alternative 1 was used as the basis for a production system employing one category of labor, the production cook. Daily production sheets were generated for each weekly production plan using the COST-ARREST program.

## The COST-ARREST Program

The COST-ARREST program was adapted from the REST and RAPS Algorithms, and the computerized REST program. The REST Algorithm provided the basic logic for the allocation of available resources to required activities, the RAPS Algorithm supplied the guidelines for utilizing REST in a food production system and the computerized REST program provided the mechanism for scheduling a large number of activities rapidly.

### Input for COST-ARREST

Input data for the COST-ARREST program were obtained from the bill of materials, master production schedule, and management knowledge. The input consisted of four parts: production sheet information, labor and equipment availability, criterion values, and activity information.

*Daily production sheet.* Data for the daily production sheet obtained from the master production sheet were the specific titles of menu items to be scheduled on a particular day. The total number of labor and equipment categories available and the number of time periods specified for resource allocation were described for the hypothetical cook freeze system in this chapter, under "The Food Production System."

Labor and equipment availability. Initial personnel levels were generated to be sufficient to complete required daily work activities for all production plans within the allotted production period. Five employees—two cooks, two assistant cooks, and one food service worker—were determined to be the level appropriate for analyzing labor utilization in the four different production plans. Equipment availability was described under "The Food Production System."

Activity criterion values. Activity criterion values for each entree were obtained from the AON networks in the bill of materials. The criterion value for each activity within each entree network illustrated the sequence in which activities were to be completed.

Activity information cards. The last part of input data identified and described the content of each activity. Data were obtained from the bill of materials and knowledge of management. The duration of the activity or delay period, predecessor activities, and specific labor and equipment resources required for the activity were identified from the AON network. The length of the activity or delay period was stated in five-minute units. An activity lasting for 25 minutes would require 5 five-minute units.

The preferred, actual, and efficient resource levels were assumed to be identified by management. The preferred resource level was the most desirable level for loading the activity. Activities were scheduled using a ratio of the actual resource units (ARU) and the efficient resource units (ERU). The ARU's identify the possible levels of resource allocation, based on what is normal and practical, and ERU's define the efficiency of the corresponding ARU. Most activities have an ARU/ERU ratio of 1/1, indicating that one resource unit is scheduled and also is the most efficient. When two convection ovens are completely filled the ARU/ERU ratio is 2/2; when the two convections ovens are partially filled, the ARU/ERU ratio is 2/1, indicating that the two ovens have the efficiency of one oven.

## Scheduling Process of COST-ARREST

The COST-ARREST program initially ranked activities in the order of increasing criterion value. Entrees which required longer production periods were initiated first; entrees requiring shorter time periods were started later. Activities were then scheduled according to predecessor activities and resource availability. Predecessors were examined and if completed the activity was available for scheduling. The quantity of resources required was considered next. If the necessary quantity of resource units were available, the activity was scheduled. Activities were not scheduled unless the entire activity could be completed; interruptions in activities were not allowed. One objective of the COST-ARREST program was to schedule all activities in a minimum of time. Each activity was scheduled using the most efficient resource level available. When the level of highest efficiency was not obtainable the next best level of efficiency was assigned.

The COST-ARREST unit of time was five minutes, with the program having the capacity of scheduling activities over a ten-hour period.

### Output of COST-ARREST

Output from the COST-ARREST program, daily production sheets, included a list of the entrees scheduled for production and a summary chart of the resources available and allocated by resource type for each five-minute period. The body of the output below the summary report listed the activity numbers in order of increasing criterion value, and illustrated the resource code and the number of resource units allocated to each activity by five-minute periods.

### The GRACOST Program

The COST-ARREST program was designed to fit a University of Tennessee Computing Center-written procedure, CALPLOT, which plotted program output. CALPLOT is accessed from SAS (Statistical Analysis Systems). The GRACOST (Graph of the Computerized Scheduling Technique) program was used to produce graphs of labor utilization by labor category for each day. The graphs were used to analyze total forced delay time and the duration of forced delay periods.

## Analysis of Results

The technique of material requirements planning was evaluated in terms of its value as a management decision-making tool. The process was analyzed according to the management principles of relevancy, accuracy, and timeliness as applied to the organizational goals.

Daily production sheets obtained as output of the COST-ARREST program were used to determine which of the four different production plans and the five-day production plan—Alternative 1, using one labor category minimized avoidable idle time and labor cost. Each plan was analyzed for the total time and duration of production required for each labor category. Graphs resulting from the GRACOST program were used to analyze the total forced delay time.

Total weekly labor cost was determined for each production plan. Linear programming techniques for calculating labor costs were investigated. Costs for inventory, product shortages, hiring, and firing were not included in labor cost analysis since these costs were not considered relevant to the hypothetical food production system. The two major costs involved in analysis were regular payroll and overtime payroll. The following formula was adapted from the linear programming models.

Let:

DLC = daily labor cost for specific labor category

$P_r$ = personnel category cost for regular time per hour

$P_o$ = personnel category cost for overtime per hour

$W_i$ = number of personnel per category

Thr = number of total hours worked per shift

Hr = number of scheduled hours per shift

$$[\text{Thr} - (\text{Hr})(W_i)]^{+} = Z_1, \text{ where } Z_1 = \begin{Bmatrix} 0 \text{ if } Z_1 \leq 0 \\ Z \text{ if } Z_1 > 0 \end{Bmatrix}$$

$$[\text{Thr} - (\text{Hr})(W_i)]^{-} = Z_2, \text{ where } Z_2 = \begin{Bmatrix} 0 \text{ if } Z_2 \geq 0 \\ |Z| \text{ if } Z_2 < 0 \end{Bmatrix}$$

To find the daily labor cost for a specific labor category:

$$\text{DLC} = (P_o - P_r)\ [\text{Thr} - (\text{Hr})(W_i]^{+} + \text{Pr}\ [\text{Thr} - (\text{Hr})(W_i)]^{-} + \text{Pr}(\text{Thr})$$

Labor cost was used to evaluate the cost of the two legally allowed pay plans. The Fair Labor Standards Act of 1938, as amended by the Fair Labor Standards Amendments of 1974 (Anon., 1974) states that employees may be paid on the basis of a 40-hour work week, with overtime paid for all hours in excess of 40; or employees may be paid for a 14-day period, with overtime paid for hours in excess of 8 hours a day and 80 hours in a 14-day period.

# CHAPTER 4

# RESULTS AND DISCUSSION

A procedure was developed to generate data needed by management for developing daily production sheets using material requirements planning and the COST-ARREST program. The procedure was applied to a hypothetical food production system responsible for continual production of entrees.

## Results of Material Requirements Planning

Material requirements planning was adapted to a cook freeze production system to generate a master production schedule for two menu cycles, 18 days. The master production schedule was the basis for establishing four different weekly production plans. The adapted planning sequence for material requirements planning described in Chapter 3, under "Material Requirements Planning," was followed to obtain the final weekly production plans. Daily production sheets were generated for each weekly production plan using the COST-ARREST program.

### Total Production Plan

The projected number of portions of entrees which was required to be prepared daily in a conventional seven-day production system was 2,000. In the hypothetical five-day cook freeze production system, the projected daily production requirement for entrees was 2,800 portions.

## Bill of Materials

A data file was compiled for each of the 42 entrees and 5 sauces, consisting of the standardized formula, an activity analysis, and a flow diagram using the AON networking method. The data file supplied basic information for the food product requirements plan. An example of the bill of materials for one entree is illustrated in Appendix B.

## Master Food Product Schedule

A master food product schedule was completed for each entree to identify specific portion requirements by day. The projected requirement was reflected on the day the item was placed in the freezer. A completed master food product schedule for Veal Scallopini is shown in Figure 4.1. The projected requirements, based on the popularity index and census figures, were 324 servings on Days 5 and 14.

## Food Product Requirements Plan

The food product requirements plan for each entree was completed after the projected requirements were calculated. The food product requirements plan for Veal Scallopini (Figure 4.1) was completed using the process described in Chapter 3, under "Material Requirements Planning." First, the quantity on hand on Day 1, zero, was entered. The first projected requirement for placement in the freezer, 324 servings for Day 5, was compared with the quantity on hand. Since the projected requirement was greater than the amount on hand, an order was placed. The lead time for Veal Scallopini was determined as four

MASTER FOOD PRODUCT SCHEDULE/FOOD PRODUCT REQUIREMENTS PLAN

ENTREE Veal Scallopini

DAYS

| | Menu Cycle I | | | | | | | | | Menu Cycle II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Master Food Product Schedule | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | 324 | | | | | | | | | 324 | | | | |

Food Product Requirements Plan

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Projected Requirements | | | | | 324 | | | | | | | | | 324 | | | | |
| Actual Requirements | | | | | | | 300 | | | | | | | | | 334 | | |
| Scheduled Product Receipts | | | | | 400 | | | | | | | | | 400 | | | | |
| On Hand | 0 | 0 | 0 | 0 | 400 | 400 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 500 | 500 | 166 | 166 | 166 |
| Planned Production Order | 400 | | | | | | | | | 400 | | | | | | | | |

Lead Time: 4

Order Quantity: 400

Figure 4.1. Completed master food production schedule and food product requirements plan for Veal Scallopini for two menu cycles in a hypothetical cook freeze production system.

days, and the set order quantity was established as 400 servings. An order was placed on Day 1, four days preceding freezing. The order quantity was entered as scheduled receipts on the day it was required to enter the freezer, Day 5. The on hand quantity was updated to reflect the additional freezer inventory. The actual requirement for service on Day 7 was 300 servings, so the final inventory level on Day 7 was 100 servings. The process was continued for the duration of the two menu cycles. The completed schedule illustrates the quantity of each entree component needed and the last day available for scheduling production.

## Labor and Equipment Requirements Plan

Labor and equipment requirement plans were completed for each day in each of the production plans. A completed labor and equipment requirements plan for Wednesday of the five-day production plan—Original is shown in Table 4.1. Data were obtained from the activity analysis of each entree and summed for the daily time requirement for each resource.

The labor and equipment requirements plan provided basic data to determine which specific entrees to transfer from Monday to Tuesday and from Friday to Thursday to generate the two alternative five-day production plans. The total daily time requirements were compared with the time constraints for each resource. The required cook and assistant cook time on Monday in the five-day production plan—Original exceeded the time available (Table 4.2). In an actual operation, the five-day

Table 4.1

Labor and Equipment Requirements Plan in Minutes for Wednesday in Five-Day Production Plan—Original for Hypothetical Cook Freeze Production System

| Entree | Cook | Assistant Cook | Food Service Worker | Mixer | 5-Gal Kettle | 20-Gal Kettle | 60-Gal Kettle | Convect. Oven | Rotary Oven | Slicer | Grill | Fryer | Food Chopper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beef Ravioli | 60 | 10 | 10 | | | 60 | | | | | | | |
| Tuna Noodle Casserole | 90 | 35 | 25 | | 25 | 95 | | 65 | | | | | |
| Cantonese Steak | 55 | 85 | 40 | | | 55 | | | | | 100 | | |
| BBQ Chicken | 35 | 75 | 20 | | | | | 115 | | | | | |
| Grilled Pork Steak | | 40 | 25 | | | | | 60 | | | | | |
| Beef Stroganoff | 75 | 10 | 20 | | | 195 | | | | | | | |
| BBQ Sauce | 30 | 10 | 10 | | | 65 | | | | | | | |
| Tomato Sauce | | 60 | 15 | | 60 | | | | | | | | |
| Total | 345 | 325 | 165 | | 85 | 470 | | 240 | | | 100 | | |

Table 4.2

Required Labor Minutes by Labor Category for Various Five-Day Entree Production Plans

| Production Plan | Labor Category | Monday | Tuesday | Wednesday | Thursday | Friday | Range |
|---|---|---|---|---|---|---|---|
| | | Day | | | | | |
| ORIGINAL | Cook (2) | 790 | 115 | 350 | 275 | 350 | 115-790 |
| | Assistant Cook (2) | 845 | 270 | 325 | 370 | 720 | 270-845 |
| | Food Service Worker (1) | 245 | 50 | 165 | 110 | 220 | 50-245 |
| | Total | 1,880 | 435 | 840 | 755 | 1,290 | 435-1,880 |
| ALTERNATIVE 1 | Cook (2) | 595 | 215 | 445 | 300 | 325 | 215-595 |
| | Assistant Cook (2) | 595 | 495 | 350 | 565 | 525 | 350-595 |
| | Food Service Worker (1) | 180 | 110 | 170 | 125 | 205 | 110-205 |
| | Total | 1,370 | 820 | 965 | 990 | 1,055 | 820-1,370 |
| ALTERNATIVE 2 | Cook (2) | 530 | 280 | 445 | 350 | 275 | 275-530 |
| | Assistant Cook (2) | 585 | 505 | 350 | 580 | 510 | 350-585 |
| | Food Service Worker (1) | 160 | 130 | 170 | 135 | 195 | 130-195 |
| | Total | 1,275 | 915 | 965 | 1,065 | 980 | 915-1,275 |
| ONE LABOR CATEGORY | Production Cook (3, 4) | 1,370 | 820 | 965 | 990 | 1,055 | 820-1,370 |

( ) Number of personnel in category.

production plan—Original would have been revised due to the lack of time available on Monday. In the current study analysis was completed on the five-day production plan—Original since the plan provided the optimal production schedule according to lead times. All equipment was available to satisfy the required production time.

Master Production Schedule

Data from the food product requirements plan were used to make a master production schedule, shown in Figure 4.2. The master production schedule illustrates the quantities of entrees required for production on the day each product was planned to be placed in the blast freezer. The production quantity for Veal Scallopini, 400 portions, appeared on Days 5 and 14, indicating that 400 portions must be placed in the blast freezer on each day. Data from the master production schedule were used to develop four different production plans for the one week period, Day 8 (Sunday) to Day 14 (Saturday).

Weekly Production Plans

Four weekly production plans were developed from the master production schedule and are shown in Figure 4.3. The number of entree portions required for production daily varied in all plans. In the seven-day production plan, the number of entree portions prepared each day varied by 1,006 portions. The range of entree portions prepared daily in the Original five-day production plan was 3,169. The Original five-day production plan was modified by transferring

| LEAD TIME (DAYS) | ENTREE | DAYS: Menu Cycle I | | | | | | | | | DAYS: Menu Cycle II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| (5) | Roast Turkey | | | | | | | | 360 | | | | | | | | | 360 | |
| (3) | Beef Burgundy | | | | | | | | 350 | | | | | | | | | 350 | |
| (3) | Shrimp Marengo | | | | | | | | 300 | | | | | | | | | 300 | |
| (4) | Chili con Carne | | | | | | | | 300 | | | | | | | | | 300 | |
| (3) | Ham, Mac. Cheese | | | | | | | | 230 | | | | | | | | | 230 | |
| (3) | Gr. Steak | | | | | | | | 480 | | | | | | | | | 480 | |
| (4) | BBQ Pork Chop | | | | | | | | | 336 | | | | | | | | | 336 |
| (3) | Broil. Chicken | | | | | | 500 | | | 500 | | | | | | | | | 500 |
| (4) | Sauerbraten | | | | | | | | | 200 | | | | | | | | | 200 |
| (3) | Flank Steak | | | | | | | | | 450 | | | | | | | | | 450 |
| (3) | Broil Flounder | | | | | | | 300 | | 300 | | | | | | | 300 | | 300 |
| (5) | Turkey Croq. | | | | | | | | | 240 | | | | | | | | | 240 |
| (3) | Ital. Spaghetti | 576 | | | | | 576 | | | | 576 | | | | | 576 | | | |
| (4) | Gr. Veal Cutlet | 240 | | | | | 240 | | | | 240 | | | | | 240 | | | |
| (4) | Baked Ham | 200 | | | | | | 200 | | | | | | | | | 200 | | |
| (3) | Cheese Meat Loaf | 230 | | | | | | | | | 230 | | | | | | | | |
| (4) | Br. Pork Chop | 450 | | | | | | | | | 450 | | | | | | | | |
| (3) | Seafood Newburg | 336 | | | 336 | | | | | | | | | 336 | | | | | |
| (4) | Swiss Steak | | 440 | | | | 440 | | | | | | | | | 440 | | | |
| (4) | Roast Pork | | 315 | | | | | 315 | | | | 315 | | | | | 315 | | |
| (5) | Chick. Chop Suey | | 268 | | | | | | | | | 268 | | | | | | | |
| (5) | German Pot Rst. | | 300 | | | | | | | | | 300 | | | | | | | |
| (4) | Broil. Haddock | | 160 | | | | | | | | | 160 | | | | 160 | | | |
| (3) | Baked Lasagna | | 540 | | | | | | | | | 540 | | | | | | | |
| (3) | Beef Ravioli | | | 324 | | | | | | | | | 324 | | | | | | |
| (3) | Tuna Casserole | | | 200 | | | | | | | | | 200 | | | | | | |
| (4) | Cantonese Steak | | | 480 | | | | 480 | | | | | 480 | | | | 480 | | |
| (3) | BBQ Chicken | | 500 | | | | | | | | | | 500 | | | | | | |
| (4) | Gr. Pork Steak | | | 300 | | | | | | | | | 300 | | | | | | |
| (4) | Beef Stroganoff | | | 200 | | | | | | | | | 200 | | | | | | |
| (4) | Chicken Livers | | | | 260 | | | | | | | | | 260 | | | | | |
| (3) | Gr. Ham Steak | | | | 432 | | | | | | | | | 432 | | | | | |
| (4) | Ital. Stk. Parm. | | | | 308 | | | | | | | | | 308 | | | | | |
| (3) | Beef Pot Pie | | | | 252 | | | 252 | | | | | | 252 | | | 252 | | |
| (3) | Shrimp Newburg | | | | 392 | | | | | | | | | 392 | | | | | |
| (3) | Chicken Cacciat. | | | | 384 | | | 384 | | | | | | | | | 384 | | |
| (4) | Chicken/Dumpling | | | | | 300 | | | | | | | | | 300 | | | | |
| (4) | BBQ Spareribs | | | | | 400 | | | | | | | | | 400 | | | | |
| (3) | Beef, Mac. Tomato | | | | | 288 | | | | | | | | | 288 | | | | |
| (4) | Chinese Pepper | | | | | 400 | | | | | | | | | 400 | | | | |
| (3) | Stuffed Flounder | | | | | 216 | | | | | | | | | 216 | | | | |
| (4) | Veal Scallopini | | | | | 400 | | | | | | | | | 400 | | | | |
| (3) | Gravy | | 400 | | | | | 400 | | 400 | | | | | | | 400 | 400 | |
| (3) | BBQ Sauce | | | 528 | | | | | | 528 | | | 528 | | | | | | 528 |
| (3) | Meat Sauce | 576 | 576 | | | | 576 | | | | 576 | | | | | 576 | | | |
| (3) | Mushroom Sauce | 240 | | | | | 240 | | | 240 | 240 | | | | | 240 | | | 240 |
| (3) | Tomato Sauce | 230 | | 230 | | | | | | | 230 | | 230 | | | | | | |

Figure 4.2. Master production schedule for two menu cycles in a hypothetical cook freeze production system.

| Day | Seven-day | Five-day Original | Five-day Alternative 1 | Five-day Alternative 2 |
|---|---|---|---|---|
| Sunday | Shrimp Marengo<br>Ham, Macaroni and Cheese<br>Grilled Steak<br>BBQ Sauce<br>Beef Burgundy<br>BBQ Pork Chop<br>Sauerbraten, Day 1<br>Turkey Croquettes<br>Gravy | | | |
| Monday | Oven-grilled Veal Cutlet<br>Flank Steak<br>Broiled Flounder<br>Chicken Chop Suey<br>Mushroom Sauce (2 batches)<br>Oven-broiled Chicken<br>Breaded Pork Chop<br>German Pot Roast, Day 1<br>Sauerbraten, Day 2 | Barbeque Pork Chop<br>Broiled Chicken<br>Sauerbraten, Day 2<br>Flank Steak<br>Broiled Flounder<br>Turkey Croquettes, Day 2<br>Italian Spaghetti<br>Gravy<br>Barbeque Sauce<br>Mushroom Sauce<br>Grilled Veal Cutlet<br>Cheese Meat Loaf<br>Breaded Pork Chop | Barbeque Pork Chop<br>Broiled Chicken<br>Sauerbraten, Day 2<br>Flank Steak<br>Broiled Flounder<br>Turkey Croquettes, Day 2<br>Italian Spaghetti<br>Breaded Pork Chop<br>Meat Sauce<br>Gravy<br>Barbeque Sauce<br>Mushroom Sauce | Barbeque Pork Chop<br>Broiled Chicken<br>Sauerbraten, Day 2<br>Flank Steak<br>Broiled Flounder<br>Turkey Croquettes, Day 2<br>Italian Spaghetti<br>Breaded Pork Chop<br>Meat Sauce<br>Mushroom Sauce |

Production Plan (spanning header over the four plan columns)

Figure 4.3. A seven-day and three five-day weekly production plans for a hypothetical cook freeze system.

| Day | Production Plan | | | |
|---|---|---|---|---|
| | Seven-day | Five-day Original | Five-day Alternative 1 | Five-day Alternative 2 |
| Monday (continued) | | Meat Sauce<br>Mushroom Sauce<br>Tomato Sauce<br>Roast Pork, Day 1<br>German Pot Roast, Day 1 | | |
| Tuesday | Italian Spaghetti<br>Cheese Meat Loaf<br>Seafood Newburg<br>Meat Sauce<br>Tomato Sauce<br>Swiss Steak<br>Roast Pork, Day 1<br>Broiled Haddock<br>German Pot Roast, Day 2 | Chicken Chop Suey<br>Broiled Haddock<br>Baked Lasagna<br>Roast Pork, Day 2<br>German Pot Roast, Day 2 | Chicken Chop Suey<br>Broiled Haddock<br>Baked Lasagna<br>Grilled Veal Cutlet<br>Cheese Meat Loaf<br>Mushroom Sauce<br>Tomato Sauce<br>Roast Pork, Day 1<br>German Pot Roast, Day 1 | Chicken Chop Suey<br>Broiled Haddock<br>Baked Lasagna<br>Grilled Veal Cutlet<br>Cheese Meat Loaf<br>Mushroom Sauce<br>Tomato Sauce<br>Roast Pork, Day 1<br>German Pot Roast, Day 1<br>Gravy<br>Barbeque Sauce |
| Wednesday | Baked Lasagna<br>Grilled Pork Steak<br>Tomato Sauce<br>Cantonese Steak<br>Beef Stroganoff<br>Roast Pork, Day 2 | Beef Ravioli<br>Tuna Noodle Casserole<br>Cantonese Steak<br>Barbeque Chicken<br>Grilled Pork Steak<br>Beef Stroganoff | Beef Ravioli<br>Tuna Noodle Casserole<br>Cantonese Steak<br>Barbeque Chicken<br>Grilled Pork Steak<br>Beef Stroganoff | Beef Ravioli<br>Tuna Noodle Casserole<br>Cantonese Steak<br>Barbeque Chicken<br>Grilled Pork Steak<br>Beef Stroganoff |

Figure 4.3. (Continued)

| Production Plan | | | | |
|---|---|---|---|---|
| Day | Seven-day | Five-day Original | Five-day Alternative 1 | Five-day Alternative 2 |
| Wednesday (continued) | | Barbeque Sauce<br>Tomato Sauce | Barbeque Sauce<br>Tomato Sauce<br>Roast Pork, Day 2<br>German Pot Roast, Day 2 | Barbeque Sauce<br>Tomato Sauce<br>Roast Pork, Day 2<br>German Pot Roast, Day 2 |
| Thursday | Beef Ravioli<br>Tuna Noodle Casserole<br>BBQ Chicken<br>BBQ Sauce<br>Sauteed Chicken Livers<br>Italian Steak Parmegiana<br>Seafood Newburg | Seafood Newburg<br>Sauteed Chicken Livers<br>Grilled Ham Steak<br>Italian Steak Parmegiana<br>Beef Pot Pie<br>Shrimp Newburg<br>Barbeque Spareribs | Seafood Newburg<br>Sauteed Chicken Livers<br>Grilled Ham Steak<br>Italian Steak Parmegiana<br>Beef Pot Pie<br>Shrimp Newburg<br>Barbeque Spareribs Day 1<br>Swiss Steak<br>Broiled Haddock | Seafood Newburg<br>Sauteed Chicken Livers<br>Grilled Ham Steak<br>Italian Steak Parmegiana<br>Beef Pot Pie<br>Shrimp Newburg<br>Barbeque Spareribs, Day 1<br>Swiss Steak<br>Broiled Haddock<br>Meat Sauce |
| Friday | Grilled Ham Steak<br>Beef Pot Pie<br>Shrimp Newburg<br>Veal Scallopini<br>Chicken and Dumplings<br>BBQ Spareribs, Day 1 | Chicken/Dumplings<br>Beef, Macaroni, Tomato Casserole<br>Chinese Pepper Steak<br>Stuffed Flounder<br>Veal Scallopini<br>Italian Spaghetti | Chicken/Dumplings<br>Beef, Macaroni, Tomato Casserole<br>Chinese Pepper Steak<br>Stuffed Flounder<br>Veal Scallopini<br>Italian Spaghetti | Chicken/Dumplings<br>Beef, Macaroni, Tomato Casserole<br>Chinese Pepper Steak<br>Stuffed Flounder<br>Veal Scallopini<br>Italian Spaghetti |

Figure 4.3. (Continued)

| Production Plan | | | | |
|---|---|---|---|---|
| Day | Seven-day | Five-day Original | Five-day Alternative 1 | Five-day Alternative 2 |
| Friday (continued) | Chinese Pepper Steak | Grilled Veal Cutlet<br>Swiss Steak<br>Barbeque Spareribs, Day 2<br>Meat Sauce<br>Mushroom Sauce<br>Broiled Haddock | Grilled Veal Cutlet<br>Barbeque Spareribs, Day 2<br>Meat Sauce<br>Mushroom Sauce | Grilled Veal Cutlet<br>Barbeque Spareribs, Day 2<br>Mushroom Sauce |
| Saturday | Beef, Macaroni, and Tomato Casserole<br>Stuffed Flounder<br>Swiss Steak<br>Mushroom Sauce<br>Broiled Haddock<br>Oven grilled Veal Cutlet<br>BBQ Spareribs, Day 2 | | | |

Figure 4.3. (Continued)

production items from Monday to Tuesday and from Friday to Thursday (Alternative 1) in an attempt to further even production demands. In Alternative 1 the daily production demand fluctuated by 1,058 entree portions. A second alternative production plan was generated by transferring accompanying sauces from Monday to Tuesday and from Friday to Thursday; the total number of entree portions produced daily did not change.

## Daily Production Sheets

The schedule of the preparation activities for each day of the four different production plans and Alternative 1 with one labor category was generated using the COST-ARREST program. The logic flow diagram for COST-ARREST (Lambert et al., 1979) is given in Appendix C. Output of COST-ARREST consisted of three major pieces of information: a list of the entrees to be produced with specific activity numbers for each entree, a summary chart of the total quantity of a specific resource category allocated for each five-minute period, and the specific resource allocation for each five-minute period.

The list of entrees with identifying activity numbers served as a reference when particular activities needed to be examined. A chart presented the total number of specific resources allocated for each five-minute period. One chart represented a 2.5 hour period, with four charts included in each program. The first line for a specific resource identified the quantity of resource available and the second line showed the total number of resources allocated for each five-minute period. An example of one chart is shown in Figure 4.4.

| CODE | RESOURCES AVAILABLE/ALLOCATED | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CK | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| CK | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 2 | 2 | 1 | 1 |
| AC | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| AC | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| FW | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| MX | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| MX | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| FK | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| FK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| TK | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| TK | 1 | 1 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 2 | 2 | 2 | 2 | 2 |
| SK | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| SK | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OC | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| OC | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 2 | 2 | 3 | 3 |
| OR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| OR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SL | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| SL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| GR | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| GR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| FR | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| FR | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CH | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| CH | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| NUM | WCT | ALLOCATIONS/5 MIN PERIODS. EACH BLOCK = 2 1/2 HOURS | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 661 | AC | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 662 | CK | *** | *** | 1 | 1 | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 663 | TK | *** | *** | 1 | 1 | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 664 | NT | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 665 | CK | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 674 | AC | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 666 | CK | *** | *** | *** | *** | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 667 | TK | *** | *** | *** | *** | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 635 | AC | *** | *** | 1 | 1 | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 636 | AC | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 637 | AC | *** | *** | *** | *** | *** | *** | 1 | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 584 | AC | *** | *** | *** | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 638 | AC | *** | *** | *** | *** | *** | *** | *** | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 639 | OC | *** | *** | *** | *** | *** | *** | *** | *** | *** | 4 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 615 | AC | *** | *** | *** | *** | *** | 1 | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 585 | AC | *** | *** | *** | *** | *** | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 586 | TK | *** | *** | *** | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |
| 668 | TK | *** | *** | *** | *** | *** | *** | *** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | *** | *** | *** | *** |
| 616 | AC | *** | *** | *** | *** | *** | *** | *** | *** | 1 | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** | *** |

Figure 4.4. Specific resource allocation and total resource allocation by time interval for a representative daily production sheet in a hypothetical cook freeze system.

Further breakdown of activities by time interval appeared below the summary chart in Figure 4.4. Activities were listed in order of increasing criterion value with activity number, resource code, and the specific time interval utilized identified. For example, in Figure 4.4, Activity 661, gathering of ingredients, was completed by one assistant cook during the first 10 minutes. Activities 662 and 663 required one cook and one twenty-gallon kettle simultaneously for 20 minutes.

## Results of the COST-ARREST Program

Output from the COST-ARREST program was used to analyze labor requirements and production duration by labor category for each production plan.

### Labor Time Requirements

Required labor time was considered to be time that production personnel devoted to direct work activities. When personnel were not engaged in work activities a forced delay occurred. Forced delays were due to the inavailability of equipment or the lack of work activities in a particular time period.

Seven-day production plan. The seven-day production plan was generated from the master production schedule using the assigned lead times less three days. The required labor minutes by category for the seven-day production plan is shown in Table 4.3. Total daily labor requirements in the seven-day production plan fluctuated

Table 4.3

Required Labor Minutes by Labor Category for a Seven-Day Production Plan

| Labor Category | Day | | | | | | | Range |
|---|---|---|---|---|---|---|---|---|
| | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | |
| Cook | 610 | 220 | 345 | 165 | 320 | 330 | 90 | 90-610 |
| Assistant Cook | 585 | 535 | 405 | 360 | 320 | 335 | 515 | 320-585 |
| Food Serv. Worker | 175 | 135 | 115 | 120 | 115 | 145 | 105 | 105-175 |
| Total | 1370 | 890 | 865 | 645 | 755 | 810 | 710 | 645-1370 |

by 725 minutes, or approximately 12 hours. The average number of cook minutes required daily was 297.

The assistant cook time required ranged from 585 minutes (9.75 hours) on Sunday to 320 minutes (5.3 hours) on Thursday. The variation from day-to-day was less than 60 minutes for four days, although differences of 130 and 180 minutes occurred between Monday and Tuesday, and Friday and Saturday, respectively.

One food service worker was assumed to be available for 360 regular minutes, although the individual was never fully utilized. Labor time varied by 70 minutes from minimum to maximum daily demand.

Five-day production plan—Original. The Original five-day production plan scheduled the necessary entrees to fit within a production period of five days, according to criteria established for MRP. Maximum allowed lead times were used to determine the daily production sheet; no attempt was made to balance production loads. Total daily labor minutes varied as much as 1,445 minutes, 24 labor hours, between minimum and maximum labor demands. The Original five-day production plan labor and equipment time requirements are shown in Table 4.2, page 65.

The total number of cook minutes required ranged from 790 minutes (Monday) to 115 minutes (Tuesday), a difference of 11.25 hours. Cook requirements for each day varied from the adjoining days by at least 60 minutes.

A variation of 9.5 hours occurred in the demand for assistant cook labor time. Large fluctuations in demand from day-to-day occurred between Monday and Tuesday (575 minutes) and between Thursday and Friday (350 minutes).

The demand for food service worker time varied by 3.25 hours. Fluctuations from day-to-day ranged from 55 minutes (Wednesday to Thursday) to 195 minutes (Monday to Tuesday).

Five-day production plan—Alternative 1. In an attempt to improve labor utilization, specific entrees were transferred from Monday to Tuesday and from Friday to Thursday, resulting in a new weekly production schedule, Alternative 1. The required labor minutes by category for Alternative 1 is shown in Table 4.2, page 65. The total labor minutes involved in work activities varied by 9.2 hours.

The demand for cook labor time varied by over 6 hours during the week. The greatest fluctuation between two consecutive days occurred between Monday and Tuesday, 6.3 hours.

The required assistant cook labor minutes fluctuated by 245 minutes, 4.1 hours. The greatest range of time required between two adjoining days, 215 minutes, occurred between Wednesday and Thursday.

A variation of 95 minutes existed in labor time required for the food service worker. The greatest fluctuation, 80 minutes, occurred between Thursday and Friday.

Five-day production plan—Alternative 2. A second rescheduling of entrees was completed to further improve labor utilization. The production plan, Alternative 2, showed a range in total daily labor minutes of 6 hours (see Table 4.2).

The demand for cook time fluctuated by 4.25 hours, during the week. The greatest day-to-day fluctuation, 250 minutes, occurred between Monday and Tuesday.

Required assistant cook time varied by 235 minutes, 3.9 hours. The greatest range between two consecutive days, Wednesday and Thursday, was 230 minutes, 3.8 hours.

The food service worker exhibited a range in demand from 195 minutes on Friday to 130 minutes on Tuesday, a difference of 65 minutes.

Five-day production plan—Alternative 1 with one labor category. The total daily labor time required in the five-day production plan—Alternative 1 using one labor category was identical to that required in Alternative 1. The use of one labor category did not alter the total time required for production-related activities.

Summary of labor time requirements. The greatest variation in total labor demand, 1,445 minutes (24.1 hours), was observed in the five-day production plan—Original. The range was decreased to 360 minutes (6 hours) in the five-day production plan—Alternative 2. The greatest fluctuations in all labor categories occurred in the five-day production plan—Original. The five-day production plan—Alternative 2 exhibited the smallest fluctuation between daily demand for all labor categories. The range in required cook time was decreased by 7 hours in the five-day production plan—Alternative 2 from the five-day production plan—Original. The variation in demand for assistant cook time was decreased by 5.5 hours in the five-day production plan—Alternative 2 from the original five-day production plan. The food service worker was most uniformly utilized in the five-day production plan—Alternative 2. The range in demand was decreased to 65 minutes from the 195 minutes that existed in the original five-day production plan.

## Duration of Production

Duration of production was the time that elapsed between the beginning of production (T0) and completion of the last activity for each labor category. Overtime was time over the 360-minute set production period during which work was required to be completed. The duration of production and overtime for the four production plans and the five-day production plan using one labor category are shown in Tables 4.4 and 4.5.

Seven-day production plan. Large variations in production duration were observed in the seven-day production plan. The cooks required a total of 90 minutes of overtime on one day while on five days 45 to 150 minutes of idle time occurred following completion of production activities. A difference of 3.4 hours was observed between the longest and shortest production periods for the cooks. The assistant cooks needed a total of 65 minutes of overtime on two days, while on five days the allowed production duration was not utilized. Duration of production varied by 3.5 hours for the assistant cooks. A longer duration of production was observed for the food service worker than for the other labor categories, with 110 minutes of

Table 4.4

Actual Production Duration in Minutes and Overtime in Labor Minutes by Labor Category for a Seven-Day Production Plan

| Labor Category | Day | | | | | | | Range |
|---|---|---|---|---|---|---|---|---|
| | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | |
| COOK | | | | | | | | |
| Duration | 360 | 415 | 315 | 220 | 210 | 220 | 260 | 210-415 |
| Overtime | - | 90 | - | - | - | - | - | 0-90 |
| ASSISTANT COOK | | | | | | | | |
| Duration | 415 | 365 | 305 | 230 | 215 | 205 | 275 | 205-415 |
| Overtime | 60 | 5 | - | - | - | - | - | 0-60 |
| FOOD SERVICE WORKER | | | | | | | | |
| Duration | 410 | 420 | 325 | 250 | 250 | 355 | 285 | 250-420 |
| Overtime | 50 | 60 | - | - | - | - | - | 0-60 |

Table 4.5

Actual Production Duration in Minutes and Overtime in Labor Minutes by Labor Category for Various Five-Day Production Plans

| Production Plan | Labor Category | Day Monday | Tuesday | Wednesday | Thursday | Friday | Range |
|---|---|---|---|---|---|---|---|
| ORIGINAL | COOK | | | | | | |
| | Duration | 590 | 130 | 255 | 215 | 425 | 130-590 |
| | Overtime | 460 | - | - | - | 105 | 0-460 |
| | ASSISTANT COOK | | | | | | |
| | Duration | 585 | 250 | 240 | 205 | 435 | 205-585 |
| | Overtime | 450 | - | - | - | 75 | 0-450 |
| | FOOD SERVICE WORKER | | | | | | |
| | Duration | 595 | 265 | 310 | 260 | 440 | 260-595 |
| | Overtime | 235 | - | - | - | 80 | 0-235 |
| ALTERNATIVE 1 | COOK | | | | | | |
| | Duration | 465 | 360 | 260 | 295 | 335 | 260-465 |
| | Overtime | 195 | - | - | - | - | 0-195 |
| | ASSISTANT COOK | | | | | | |
| | Duration | 480 | 310 | 255 | 290 | 345 | 255-480 |
| | Overtime | 240 | - | - | - | - | 0-240 |
| | FOOD SERVICE WORKER | | | | | | |
| | Duration | 490 | 365 | 315 | 330 | 345 | 315-490 |
| | Overtime | 130 | 5 | - | - | - | 0-130 |

Table 4.5 (Continued)

| Production Plan | Labor Category | Day | | | | | Range |
|---|---|---|---|---|---|---|---|
| | | Monday | Tuesday | Wednesday | Thursday | Friday | |
| ALTERNATIVE 2 | COOK | | | | | | |
| | Duration | 465 | 415 | 260 | 290 | 330 | 260-465 |
| | Overtime | 195 | 55 | - | - | - | 0-195 |
| | ASSISTANT COOK | | | | | | |
| | Duration | 480 | 360 | 255 | 295 | 340 | 255-480 |
| | Overtime | 240 | - | - | - | - | 0-240 |
| | FOOD SERVICE WORKER | | | | | | |
| | Duration | 490 | 420 | 315 | 335 | 340 | 315-490 |
| | Overtime | 130 | 60 | - | - | - | 0-130 |
| ALTERNATIVE 1—ONE-LABOR CATEGORY | PRODUCTION COOK (4) | | | | | | |
| | Duration | 485 | 420 | 265 | 265 | 285 | 265-485 |
| | Overtime | 185 | 60 | - | - | - | 0-185 |
| | PRODUCTION COOK (3) | | | | | | |
| | Duration | 560 | 420 | 330 | 335 | 360 | 330-560 |
| | Overtime | 480 | 60 | - | - | - | 0-480 |

overtime required for the week. The job responsibilities of the food service worker, washing equipment and cleaning the production area, were activities completed after production. A range of 2.8 hours in production duration occurred for the food service worker.

Five-day production plan—Original. A total of 23.4 hours of overtime for all labor categories was needed to complete the week's production activities. The actual duration of production was a minimum of 50 minutes less than the allotted time for three of the five days for all labor categories. Cooks accumulated 9.4 hours of overtime on Monday and Friday, while being underutilized on the other three days. The available time for cooks varied from 105 minutes (1.75 hours) on Wednesday to 230 minutes (3.8 hours) on Tuesday. Assistant cooks required 8.75 hours of overtime to complete production activities for the week. A minimum of 1.8 hours was available on three days following the completion of production. The duration of production for the assistant cooks varied by 6.3 hours. A longer duration of activities was observed daily for the food service worker since the worker was required to complete cleaning activities. The duration of production activities varied by 5.6 hours, with 5.25 hours of overtime necessary for the week. A minimum of 50 minutes was expended in idle time following completion of production activities on three days.

Five-day production plan—Alternative 1. The transfer of entrees from Monday to Tuesday and from Friday to Thursday resulted in a decrease of overtime from 23.4 to 9.5 hours. Overtime was eliminated on Friday. Production activities on four of the five days were completed within the allotted period for all labor categories, with a maximum idle time of 105 minutes (1.75 hours) available after completion of all production activities on Wednesday for the assistant cooks. The production duration for the cooks exceeded the 360-minute production period on Monday, requiring 3.25 hours of overtime. The variation in production duration for the cooks was 3.4 hours. Assistant cooks were able to complete necessary activities on all days, except Monday when a total of 4 hours of overtime was required. The duration of production for the assistant cooks varied by 3.75 hours during the week. Idle time following completion of production fluctuated by 1.5 hours within the week. The food service worker required 2.2 hours of overtime on Monday and 5 minutes on Tuesday to complete work activities. The difference between the allotted production time and the actual production duration was 45 minutes or less on Wednesday through Friday. A range of 2.9 hours occurred in the production duration for the food service worker.

Five-day production plan—Alternative 2. The additional transfer of entree components from Monday to Tuesday resulted in a total of 560 minutes (9.3 hours) of overtime. Overtime was required by the cook and food service worker on Monday and Tuesday, with the assistant cook accumulating overtime on Monday. Production activities were completed within the designated period on three days for all labor categories. The range of production duration for the cooks was 3.4 hours. A maximum of 100 minutes was devoted to idle time following the conclusion of production activities. The assistant cooks exhibited a fluctuation of 3.75 hours in the duration of production for the week. Activities were completed prior to the designated production deadline on four days with a range of 20 to 105 minutes spent in idle time. The duration of production for the food service worker exceeded the time required by the cooks and assistant cooks. A range of 2.9 hours occurred in the production duration during the week. Idle time occurring after production activities were completed fluctuated by 25 minutes.

Five-day production plan—Alternative 1 with one labor category. The number of production cooks was varied to observe the effect on production duration. Four production cooks completed production activities in less than the allotted production time on three days with a minimum of 75 minutes of idle time occurring within the week. A total of 4.1 hours of overtime was required on two days. The range in production duration for the four production cooks was 3.7 hours. When three production cooks were employed, overtime increased to 9 hours. The duration of production increased on the other days; however, all activities were completed within the 360-minute production period. The duration of production for three production cooks varied by 3.8 hours within the week.

Summary of production duration. The five-day production plan—Original exhibited the greatest ranges in production duration for all labor categories (Table 4.5, page 81). The seven-day production plan and five-day production plans—Alternatives 1 and 2 illustrated similar variations in production duration. Production variation was decreased by approximately 4 hours for cooks, 3 hours for assistant cooks, and 3 hours for the food service worker for the seven-day and five-day production plans—Alternatives 1 and 2 from the five-day production plan—Original. Although additional entree components were transferred in the five-day production plan—Alternative 2 from Alternative 1 (Figure 4.3, page 68) the duration of production was not changed on Monday. Completion of the remaining menu items was dependent on the availability of oven space. Production duration was increased on Tuesday due to the addition of BBQ Sauce and Gravy. The duration of production on Wednesday through Friday was essentially unchanged from Alternative 1 for all labor categories. Utilization of one labor category did not alter the range of production duration by more than 25 minutes from the cook and assistant cook labor categories in the five-day production plans—Alternatives 1 and 2. The range of production duration for the food service worker in the five-day production plans—Alternative 1 and 2 varied from the range observed when one labor category was employed by a maximum of 55 minutes.

The greatest amount of overtime (23.4 hours) occurred in the five-day production plan—Original, while the five-day production plan—Alternative 1 with one labor category, using four production cooks exhibited the least amount of overtime, 4.1 hours.

Forced Delay Time

Forced delay time was determined for each employee in each labor category by summing all time, between the beginning of the production shift and completion of the last scheduled activity, an employee was not engaged in work activities. All time during this period was attributed to forced delay although personal delay time would be included in the total idle time. Forced delay time by category in minutes and as a percentage of the total of production durations for each employee for the seven-day production plan and five-day production plans are shown in Tables 4.6 and 4.7. Graphs of the resources available and allocated by time period for each labor category were obtained from the GRACOST program and facilitated analysis of forced delay time.

Forced delay time occurred daily in all labor categories in all production plans. The percentage of actual production duration devoted to forced delay varied widely with labor categories.

Seven-day production plan. The average total forced delay for all labor categories was 599 minutes (41%). Cooks exhibited the highest average time devoted to forced delay, 271 minutes (48%) with a range of 490 minutes, 8.2 hours. Forced delay time experienced by assistant cooks varied by 170 minutes (2.8 hours) during the week. The lowest average delay time, 130 minutes (23%) was exhibited by the assistant cooks. The food service worker spent an average of 198 minutes (3.3 hours) daily devoted to forced delay which represented 60% of the total time devoted to production activities. Daily forced

Table 4.6

Forced Delay Time by Labor Category as a Function of Total Employee Production Durations for the Seven-Day Production Plan

| Labor Category | Sunday | | Monday | | Tuesday | | Wednesday | | Thursday | | Friday | | Saturday | | Average | Range | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | min. | % | min. | % | min. | % | min. | % | min. | % | min. | % | min. | % | min. | min. | Average |
| Cook (2) | 110 | 15 | 590 | 71 | 285 | 45 | 275 | 62 | 100 | 24 | 110 | 25 | 430 | 83 | 271 | 100-590 | 48 |
| Assistant Cook (2) | 195 | 23 | 190 | 26 | 205 | 34 | 100 | 22 | 110 | 26 | 75 | 18 | 35 | 6 | 130 | 35-205 | 23 |
| Food Service Worker (1) | 235 | 57 | 285 | 68 | 210 | 65 | 130 | 52 | 135 | 54 | 210 | 59 | 180 | 63 | 198 | 130-285 | 60 |
| TOTAL | 540 | 28 | 1,065 | 54 | 700 | 45 | 505 | 44 | 345 | 31 | 395 | 32 | 645 | 48 | 599 | 345-1,065 | 41 |

( ) Number of personnel in category.

Table 4.7

Forced Delay Time by Labor Category as a Function of Total Employee Production Durations for Various Five-Day Production Plans

| Production Plan | Labor Category | Monday min. | Monday % | Tuesday min. | Tuesday % | Wednesday min. | Wednesday % | Thursday min. | Thursday % | Friday min. | Friday % | Average min. | Range min. | Percent Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORIGINAL | Cook (2) | 390 | 33 | 145 | 56 | 165 | 32 | 155 | 36 | 475 | 56 | 266 | 145-475 | 41 |
| | Assistant Cook (2) | 330 | 28 | 230 | 46 | 155 | 32 | 40 | 10 | 75 | 9 | 166 | 40-330 | 24 |
| | Food Serv. Worker (1) | 350 | 59 | 215 | 81 | 145 | 47 | 150 | 58 | 220 | 50 | 216 | 145-350 | 58 |
| | TOTAL | 1,070 | 36 | 590 | 58 | 465 | 36 | 345 | 31 | 770 | 36 | 648 | 345-1,070 | 38 |
| ALTERNATIVE 1 | Cook (2) | 320 | 34 | 290 | 40 | 75 | 14 | 290 | 49 | 350 | 52 | 265 | 75-350 | 39 |
| | Assistant Cook (2) | 365 | 38 | 125 | 20 | 160 | 31 | 15 | 3 | 165 | 24 | 166 | 15-365 | 25 |
| | Food Serv. Worker (1) | 310 | 64 | 255 | 70 | 145 | 46 | 205 | 62 | 140 | 41 | 211 | 140-310 | 57 |
| | TOTAL | 995 | 42 | 670 | 39 | 380 | 28 | 510 | 34 | 655 | 38 | 642 | 380-995 | 37 |
| ALTERNATIVE 1 | Production Cook (3) | 195 | 12 | 320 | 25 | 30 | 3 | 15 | 2 | 40 | 4 | 120 | 15-320 | 10 |
| | Production Cook (4) | 250 | 15 | 680 | 45 | 100 | 9 | 70 | 7 | 85 | 7 | 237 | 70-680 | 19 |

( ) Number of personnel in category.

delay time for the food service worker varied by 155 minutes (2.6 hours).

Five-day production plan—Original. The average total forced delay for all categories was 648 minutes (10.8 hours). Cooks experienced a higher average time spent in forced delay, 266 minutes (4.4 hours), than the assistant cooks. Time devoted to forced delay by the cooks was greater than 30% of the production duration on all days. Forced delay time varied by 330 minutes (5.5 hours). Assistant cooks exhibited a range of 290 minutes (4.8 hours) in the time spent in forced delay, with an average of 166 minutes. The percentage of time devoted to forced delay was 10% or less on two days. The food service worker experienced the highest percentage of total production time in forced delay, 58%. A minimum of 47% of each daily production duration was attributed to forced delay. The range of time spent idle due to forced delay was 205 minutes (3.4 hours).

Five-day production plan—Alternative 1. An average of 642 minutes (10.7 hours) was expended daily in forced delay for all labor categories, with a range of 615 minutes (10.2 hours). The daily forced delay time experienced by cooks varied by 275 minutes (4.6 hours), with an average of 265 minutes (4.4 hours). Assistant cooks exhibited a range of 350 minutes (5.8 hours) in forced delay. On four days the percentage of production time devoted to forced delay was 20% or greater. The food service worker exhibited a range of 170 minutes (2.8 hours) devoted to forced delays. A minimum of 41% of each day's production duration was attributed to forced delays.

Five-day production plan—Alternative 1 with one labor category. The five-day production plan—Alternative 1 with one labor category revealed a range of 305 minutes (5.1 hours) in the daily forced delay time when three production cooks were employed. The percentage of production duration attributed to forced delay was less than 5% on three days. When four production cooks were utilized, the range of time spent in forced delay was 610 minutes (10.2 hours), and on all five days the percentage of production duration devoted to forced delay exceeded 5%.

Summary of forced delay time. The averages of daily forced delay times for all labor categories were within a range of 50 minutes for the seven-day and the two five-day production plans—Original and Alternative 1. The range of forced delay times experienced by cooks was decreased by 215 minutes (3.6 hours) from the seven-day production plan and by 55 minutes from the five-day production plan—Original to the five-day production plan—Alternative 1. Assistant cooks exhibited a range of 180 minutes (3 hours) less time in forced delay in the seven-day production plan than in the five-day production plan—Alternative 1. The food service worker experienced a range of 155 minutes (2.6 hours) for forced delay time in the seven-day production plan, 15 minutes less than in the five-day production plan—Alternative 1.

The average percentages of forced delay time for the three labor categories were lowest in the five-day production plan—Alternative 1 (Table 4.7, page 89). The use of one labor category with three production cooks resulted in the lowest daily percentage of forced delay time, 10%.

Daily Forced Delay Time

Analysis of the forced idle time on each of the production plans showed two main reasons for delays: a lack of available resources, usually equipment; and a lack of duties requiring action at a specific time interval. A detailed analysis of the day with the most delay time in each production plan was completed using graphs from the GRACOST program (Appendix A.1-A.11).

Seven-Day Production Plan

The greatest amount of forced delay time in the seven-day production plan occurred on Monday. The cook was idle for a total of 590 minutes, due to a lack of work activities which required the cook's skill level. The first activities the cook performed, following a delay of 120 minutes, were the portioning of flounder prior to cooking and the initial preparation of canned chicken for Chicken Chop Suey (Figure A.1). The assistant cook was assigned initial preparation activities for German Pot Roast, Broiled Pork Chops, and Oven-Broiled Veal Cutlets. A second extended period of delay occurred (T240-T360) following the completion of clean up activities associated with Flank Steak, and Mushroom Sauce. The delay was due to waiting for the German Pot Roast to finish cooking so gravy could be made.

The assistant cooks experienced a total of 190 minutes of forced delay (Figure A.2). One assistant cook was delayed for 100 minutes (T170-T270) due to a lack of work activities. During the delay, the second assistant cook was required for 20 minutes to take the

Oven-Broiled Chicken out of the oven and to clean up following the completion of Chicken Chop Suey.

The food service worker was idle for 285 minutes on Monday. Assigned work responsibilities were restricted to cleanup activities which limited work time. The initial activity performed by the food service worker was cleaning the steam kettle used for the sauce for the Broiled Flounder, and occurred 145 minutes after the production shift began (Figure A.3). A second delay of 70 minutes than occurred from T155 to T225. Work activities, such as cleaning equipment from Chicken Chop Suey, Mushroom Sauce, and Breaded Pork Chops required most of the next 125 minutes. The food service worker was then delayed 60 minutes (T350-T410) until the German Pot Roast was completed and cleaning activities could be completed.

Five-Day Production Plan—Original

Forced delay time by labor category for the various five-day production plans are shown in Table 4.7, page 89. In the Original five-day production plan, all categories experienced delays of more than 5 hours on Monday. The cooks were idle for 390 minutes. The longest delay, 150 minutes (T375-T525) occurred because three entree items, Cheese Meat Loaf, German Pot Roast and Italian Spaghetti, were cooking and did not require attention (Figure A.4). During the delay period one cook was utilized for 10 minutes to take BBQ Pork Chops and Cheese Meat Loaf out of the convection ovens. The cooks were needed following the delay to make gravy for the German Pot Roast, bulk portion and wrap the Cheese Meat Loaf and Italian Spaghetti for freezing, and clean up the production area.

The assistant cooks experienced total delay time of 330 minutes with 145 minutes of delay (T375-T520) occurring during one period (Figure A.5). Two activities, cleanup after completion of Meat Sauce and removing Broiled Flounder from the convection oven, required one assistant cook for 10 minutes during the delay period. The assistant cooks were needed following the delay to remove the German Pot Roast from the steam kettle, and clean up after completion of Oven-Broiled Veal Cutlets, Italian Spaghetti, and Oven-Broiled Chicken.

The food service worker was delayed for the initial 25 minutes of the production shift when the employee was needed to prepare fresh vegetables for Sauerbraten (Figure A.6). Delays, ranging in duration from 5 to 70 minutes, occurred during the production shift due to a lack of activities which required the food service worker. The food service worker was scheduled to clean up equipment as soon as each entree was completed, allowing large segments of delay time between activities.

## Five-Day Production Plan—Alternative 1

The five-day production plan—Alternative 1 resulted in a decreased delay time for Monday. The cooks experienced 320 minutes of delay, a decrease of 70 minutes from the Original five-day plan. An extended period of delay, 140 minutes, occurred from T305 to T445 due to a lack of activities requiring the cook's skill (Figure A.7). Three items, Flank Steak, Mushroom Sauce, and Meat Sauce, were just completed and two items, Italian Spaghetti and BBQ Pork Chops, were cooking. The two cooks were required for clean up activities following completion of the Italian Spaghetti and BBQ Pork Chops.

The assistant cooks spent 365 minutes in forced delay. Two periods of extended delays, 75 (T255-T330) and 120 minutes (T345-T465), occurred due to the lack of specified work activities (Figure A.8). The first delay period was encountered immediately after preparation was started for the Mushroom Sauce and the BBQ Pork Chops were placed in the oven. One activity during the delay period required one cook for 5 minutes (T270-T275) to remove the Oven-Broiled Chicken from the oven. Activity resumed for 25 minutes (T330-T355) while the assistant cooks removed the BBQ Pork Chops from the oven and cleaned up the production area. One assistant cook spent an additional 120 minutes (T345-T465) in delay when the Italian Spaghetti and Broiled Flounder were cooking. The second cook expended 70 minutes (T355-T425) in a delay period followed by the activities, removing entree items from the ovens and cleaning up.

The food service worker experienced 310 minutes of forced delay time. The first activity occurring at T5-T25 involved the preparation of fresh vegetables for Sauerbraten (Figure A.9). A delay of 35 minutes (T25-T60) occurred before the food service worker was needed to clean the steam kettle used for the Sauerbraten Sauce. A second delay period, 130 minutes (T80-T210) occurred prior to the next activity requiring the food service worker. From T210 to T230 the worker cleaned the two steam kettles used for preparation of Italian

Spaghetti and Broiled Flounder. The food service worker was idle from T230 until T275 when the employee was needed to clean equipment used for Mushroom Sauce and Flank Steak. A delay period of 65 minutes occurred from T375 to T440 when the food service worker was not needed but was required to wait until the Broiled Flounder and Italian Spaghetti were prepared to complete cleaning activities.

### Five-Day Production Plan—Alternative 1, with One Labor Category

The use of one labor category increased the utilization of personnel. When three production cooks were employed the most delay, 320 minutes, occurred on Tuesday. The longest delay period occurred from T230 to T295 following completion of Tomato Sauce, Oven-Broiled Veal Cutlet, and Chicken Chop Suey (Figure A.10). Three menu items, Baked Lasagna, Roast Pork, and German Pot Roast, were cooking. Following the delay three cooks were used to complete Lasagna, Roast Pork, and Cheese Meat Loaf. Only one cook was needed after T345 to complete preparation activities for German Pot Roast. The use of four production cooks on Tuesday did not increase the percentage of utilization for personnel. The duration of production remained the same as when three production cooks were employed. Total forced delay time increased due to the additional cook being idle. A delay period extended from T175 to T290 following completion of Tomato Sauce, Oven-Broiled Veal Cutlet, and Chicken Chop Suey (Figure A.11). Three entree items, Cheese Meat Loaf, Roast Pork, and German Pot Roast, were cooking with the Cheese Meat Loaf being removed at T215. Only one cook was utilized after T335 to finish the German Pot Roast.

Labor Cost

Weekly labor costs were calculated using the formula described in Chapter 3, under "The Food Production System," for the seven-day production plan, the Original five-day production plan, Alternative 1, and Alternative 1, using one labor category. Sample calculations are shown in Appendix D and summarized in Table D.1. Calculations for weekly labor costs for Alternative 2 were not completed since the overtime was higher than that found in Alternative 1. Overtime was paid for each quarter-hour an employee worked beyond the 360-minute production period, provided the employee worked at least 8 of the 15 minutes.

The weekly labor cost for the seven-day production plan totaled $853.92. The shift from a seven-day plan to the Original five-day production plan resulted in a savings of $124.16 for the week.

Total labor cost for the Original five-day production plan was $729.76, including $137.56 for overtime. The decrease in required overtime resulted in an $81.64 decrease in overtime and total costs for the week using Alternative 1 production plan.

The five-day production plan—Alternative 1 was compared with the five-day production plan—Alternative 1 using one labor category (Table D.2). The hourly wage for production cooks was the same as that paid cooks, $4.18. Both levels of production cooks yielded a savings. The broadening of job description allowed an increased utilization of personnel.

Analysis of Payment Plans

The weekly time requirement for each position was assumed to be the total of the production durations for all days. The total time requirements were evaluated to determine whether a payroll plan based on a 40-hour work week with variable hours daily (40-hour) or an 8-hour per day, 80 hours per 14 days (8/80) resulted in a lower labor cost. In the seven-day production plan, the total time requirements (Table D.3) for each cook, assistant cook, and food service worker were less than the 42 hours allowed weekly for production of entrees. The 40-hour plan would result in no overtime pay. When overtime was paid for the time worked over 6 hours per day, the cook accumulated 1.5 hours of overtime, the assistant cook worked 1 hour of overtime, and the food service worker required 1.75 hours of overtime. The total overtime cost under the 8/80 plan was $24.84.

In the five-day production plans cooks and assistant cooks completed work activities in less than the 30 hours allotted weekly for each employee (Table D.3); no overtime would be paid. The food service worker required 1.25 hours of overtime in the five-day production plan—Original and .75 hours of overtime in the five-day production plan—Alternative 1, when pay was based on a 40-hour work week.

When overtime was paid based on the 8/80 plan, the food service worker received overtime payment for 5.25 hours in the five-day production plan—Original and 2.25 hours in the five-day production plan—Alternative 1. The food service worker received $22.08 more for the week under the 8/80 plan than in the 40-hour per week plan, using the five-day production plan—Original. In the five-day production plan—Alternative 1, the labor cost for the food service worker was $8.28 more for the 8/80 plan than for the 40-hour per week payment plan.

When the five-day production plan—Alternative 1 with one labor category was used, four production cooks completed the required activities within the allotted 30 hours per week per employee. The employment of three production cooks resulted in a total of 9 hours of overtime for the week. The overtime pay was the same for the 40-hour payment plan as for the 8-hour per day/80 hours per 14 days plan.

The 8/80 plan yielded the same or higher labor cost than the 40-hour payment plan in all production plans. If employees were willing to work the uneven hours caused by the production schedule total labor costs would be decreased in all production plans, except the five-day production plan—Alternative 1 with three production cooks when the labor cost would not differ between payment plans.

## Equipment Utilization

The daily demand in minutes for each type of equipment for the seven-day production plan is shown in Table D.4. Two types of equipment, the twenty-gallon kettle and the convection oven, were used every day. The total demand for the twenty-gallon kettles exhibited a range of 5 hours. The greatest demand for the convection ovens was 24% (Monday) of the total utilization while the lowest demand represented 7% (Sunday) of total utilization. Equipment which was used only minimally for the entree menu included the chopper, fryer, rotary oven, and mixer. The assumption was made that equipment would be utilized for other menu items, so the actual total usage could not be determined.

Equipment utilization for the five-day production plans—Original and Alternative 1, are shown in Tables D.5 and D.6, respectively. The current equipment was found to be sufficient to produce the required number of portions in both five-day production plans.

In the five-day production plan—Original, daily utilization was uneven for the twenty-gallon kettles, sixty-gallon kettles and the convection ovens. The convection ovens were utilized for 42% of total demand on Monday and only 3% of total demand on Thursday. Daily demand for the sixty-gallon kettles ranged from 48% (Monday) to 0% (Wednesday and Thursday).

When specific menu items were transferred for Alternative 1 of the five-day production plans, the daily distribution of equipment utilization was improved. The highest demand for convection ovens was 32% (Monday) of the total utilization, while the lowest requirement was 7% (Thursday) of total demand. The variation in demand for the sixty-gallon kettles was decreased from a range of 665 minutes in the Original five-day production plan to 475 minutes in Alternative 1. Utilization of the mixer, five-gallon kettle, and slicer was extended over an additional day in Alternative 1.

# CHAPTER 5

# CONCLUSIONS, RECOMMENDATIONS, AND SUMMARY

Material requirements planning, coupled with the COST-ARREST technique provides foodservice managers with relevant, accurate, and timely data for a feasible and effective method of allocating and scheduling resources. When applied to a hypothetical cook freeze food production system, a master production schedule and daily production sheets were generated which provide data to assist managers in short- and long-term planning decisions.

## Conclusions

The technique of MRP was determined to be a practical and feasible method for developing master production schedules in a cook freeze food service operation. Completion of the planning steps in MRP resulted in the identification of production requirements and resource availability by time period prior to initiation of production. Production priorities were established based on the date the entrees were required to be frozen.

The master production schedule was used to generate four production plans with one plan being used as a basis for a production system employing one labor category. Data from each of the four production plans were used as input for the COST-ARREST program to generate daily production sheets. The total time required, forced delay time, and labor cost were analyzed for each weekly production plan using output of the COST-ARREST and GRACOST programs.

Comparisons of the total production duration time needed to complete work activities revealed that more total time was required to prepare the entree items in the seven-day production schedule than the five-day plans. Fewer entree formulas were produced in the seven-day production plan, allowing more slack time to occur. The total production time required for all personnel to complete work activities varied from day-to-day by as much as 24 hours in the five-day production plan—Original. The range was reduced to 9 hours when entrees were transferred from Monday to Tuesday and from Friday to Thursday, five-day production plan—Alternative 1. Flexibility in the scheduling of entree items within the week allowed a balancing of labor demand. Further revisions in the specific entree items scheduled for daily production, Alternative 2, improved the balance of labor demand, but increased labor cost. An ideal production plan would be difficult to generate since the number of possible combinations of 47 entree component items, taken 8 at a time, exceeded 314,000,000.

Average daily labor requirements in the hypothetical seven-day cook freeze system were similar to demands found by Beach (1974). A greater variation in daily demand for cook and assistant cook time occurred in the hypothetical cook freeze system than in the cook chill system defined by Beach (1974). Daily demand for the food service worker fluctuated less in the cook freeze system than in the cook chill system. Daily menu combinations differed between the two production systems and caused the fluctuations in daily labor demand.

Sequencing of activities influenced the daily duration of production. The production duration required daily was a function of the combination of entree items and the availability of equipment and labor. The combination of menu items designated the type and amount of labor and equipment required, while the availability of labor and equipment determined the daily duration of production. Personnel were not always able to begin a second activity when the first activity was completed due to the inavailability of equipment or lack of activities requiring action at that particular time interval. Duration of production did not increase directly with required production time. When activities were scheduled according to priority daily labor requirements increased in all production plans to reflect forced delay time. Total labor requirements in all production plans increased by approximately 40% due to forced delay time. Fluctuations in daily demand decreased for cooks and assistant cooks when activities were sequenced while daily variations increased for the food service worker.

Labor utilization was limited by job descriptions as supported by analysis of overtime, forced delay, and labor cost. Personnel in the five-day production plan—Alternative 1, using one labor category with four production cooks needed the least amount of overtime to accomplish the necessary production activities; the most overtime was accumulated by personnel in the five-day production plan—Original. Forced delays caused fluctuations in utilization to occur daily within each labor category. In the seven- and five-day production plans, activities were available for scheduling; however, a specific skill level was required which was limited. The use of one labor category with three production cooks exhibited the least amount of forced delay.

Total labor cost reflected the differences in the number of days of production and the amount of overtime. Labor cost for the week was highest in the seven-day production plan and lowest in the five-day production plan—Alternative 1 using one labor category with three production cooks. The lower labor cost was caused by the decrease in forced delay and overtime from the other production plans. Employment of production cooks increased the flexibility of allocating labor resources which improved the percentage of labor utilization and decreased the number of employees required from five to three. Rigid and restrictive job descriptions were detrimental to the effectiveness of scheduling. The efficient utilization of labor is enhanced when job descriptions provide for flexibility in assigned tasks. The feasibility of using one labor category in an actual facility would depend on the skill of employees and the amount of training necessary.

Implementation of a flexitime plan could decrease the amount of overtime and idle time if employees could adjust work schedules to handle fluctuating work loads. Debit or credit hours could be accumulated based on weekly work loads. Employees attain increased responsibility in flexitime plans which theoretically improve job performance, attitudes, and satisfaction.

## Recommendations

The techniques of material requirements planning and COST-ARREST were used to generate daily production sheets which illustrated resource requirements by time intervals for an established menu. Additional study is needed to investigate the use of resource requirements as a tool for menu planning to determine if daily resource demands could be equalized. The coordination of the simplex method of linear programming and COST-ARREST should be studied to determine if production of the menu items on a weekly production plan could be distributed over a five-day production schedule and equalize labor and equipment demands.

Material requirements planning and COST-ARREST provided a systematic method of generating reliable data for allocating and scheduling resources; however, additional applications exist in purchasing, inventory, production control, personnel development, cost control, and budgeting. Material requirements planning demands accurate record keeping in and control of purchasing, inventory, and production. The technique could be presented in an undergraduate course in production management. The use of MRP as a management decision-making tool for system cost control, budgeting, and long-range planning, and the COST-ARREST program could be presented at the graduate level to provide students with an opportunity to practice decision-making techniques.

Data obtained from the executive approach to CPM should be compared with work measurement data to determine the reliability of the executive approach. The feasibility of the executive approach would be enhanced if production demands for specific entrees have a limited variance, eliminating the need for numerous time estimations for an activity.

The technique of material requirements planning for a food production system was developed using a hypothetical cook freeze food production system; however, it could be applied directly to a ready foods or conventional operation. The use of MRP in a conventional food service system could be investigated to determine the effects on total food cost, personnel cost, and raw material inventory cost. A comparison of inventory costs using MRP and other traditional methods, such as economic order quantity and economic order period, could be completed.

The percentages of labor activity expended in direct work, indirect work, and delay functions within a continuous food production system need to be determined. If studies were conducted on each position, changes in job responsibilities could be identified and job descriptions altered appropriately. Production tasks should be analyzed to determine the minimal skill level required in order to increase scheduling flexibility. The feasibility of using flexitime in cook freeze production systems should be studied to determine the effects on production scheduling, labor cost, and employee morale.

The COST-ARREST program should be investigated to determine options which would facilitate the application. The format of the data input could be changed to allow two resources to be allocated for the same activity. The quantity of input for the program would be decreased and management of data would be facilitated.

Two additional options for the COST-ARREST program are recommended. The current study utilized a hypothetical cook freeze system which required entrees to be produced as soon as resources were available, while a conventional system produces menu items based on a production deadline or service time. The development of an option within the COST-ARREST program to schedule activities based on a set production deadline, rather than on an initial starting time is recommended to increase the applications of the program. Current output of the COST-ARREST program did not provide a separate time schedule of activities for each labor category. The value of the program would be greatly enhanced if daily production sheets could be generated for each labor category. Personnel would have a daily guide to assist in personal scheduling of work activities; long delays could be identified so additional work activities could be accomplished.

Material requirements planning and the COST-ARREST program can be beneficial as management tools. The techniques should be tested in an actual operation and refined as necessary to improve coordination and convenience of data management.

## Summary

Costs of food service system resources are steadily increasing, with labor being cited as the most costly resource. A management tool is needed which would schedule production personnel and equipment to minimize forced delay time and decrease total labor costs.

The purpose of this study was to develop and test a model for the determination of daily production sheets in a hypothetical cook freeze food production system and to analyze labor utilization, forced delay time, and labor cost for various production plans. Material requirements planning was adapted to generate production data for two nine-day menu cycles. Data for the total production plan; master food product schedule; and bill of materials, consisting of a standardized formula, list of production activities, and an AON flow diagram of the preparation process for each entree, were obtained from a hypothetical food production system serving 1,000 meals for noon and supper defined by Beach (1974). Three categories of labor: cook, assistant cook, and food service worker, and eight major kinds of equipment were utilized to produce the 42 different entrees. Ten hours were available for scheduling necessary production activities. Food product requirements plans for each entree were used to develop daily labor and equipment requirements plans and a master production schedule for the eighteen-day period. A seven-day and three five-day production plans, an original and two alternatives, were developed. Alternative 1 was used as the basis for a production system employing one labor category. The COST-ARREST program was used to generate daily production sheets for each of the four production plans.

Required labor time varied between days for all labor categories in all production plans. The five-day production plan—Alternative 2 minimized the total day-to-day fluctuation in required labor time. Duration of production varied from day-to-day in all production plans, with the allotted production period being exceeded on a maximum of two days in any of the production plans. Overtime was minimized when one labor category was utilized with four production cooks. Total forced delay time was less in the five-day production plans than in the seven-day production plan. Labor cost for the week was highest in the seven-day production plan and lowest in the five-day production plan—Alternative 1 using one labor category with three production cooks.

Material requirements planning and the COST-ARREST program were determined to be practical and feasible techniques to provide food service managers with accurate and timely data for allocating and scheduling resources. Comparison of total production time needed to complete work activities revealed that more time was required to prepare entree items in the seven-day production plan than the five-day plans. Total daily labor demand varied by as much as 24 hours in the five-day production plan—Original. Flexibility in the scheduling of entrees within the week allowed a balancing of labor demand.

Labor utilization was limited by job descriptions as supported by analysis of overtime, forced delay, and labor cost. Personnel in the five-day production plan—Alternative 1, using one labor category with four production cooks needed the least amount of overtime; the most overtime was accumulated by personnel in the five-day production plan—Original. Implementation of a flexitime plan could decrease the amount of overtime if employees could adjust work schedules to handle fluctuating work loads. When activities were scheduled according to priority daily labor requirements increased in all production plans by approximately 40% to reflect forced delay time. The use of one labor category with three production cooks exhibited the least amount of forced delay.

Additional study to investigate the use of resource requirements as a tool for menu planning was recommended to determine if daily labor and equipment demands could be equalized. Coordination of the simplex method of linear programming and COST-ARREST should be studied to determine if production of the menu items on a weekly production plan could be distributed over a five-day production schedule and equalize labor and equipment demands. The techniques of MRP and COST-ARREST could be presented as management decision-making tools in food systems management courses. The COST-ARREST program should be studied to identify options which would enhance the application to all types of food production systems. The percentages of labor activity expended in direct work, indirect work, and delay functions within a continuous food production need to be determined. Job descriptions could be altered to allow increased scheduling flexibility. The feasibility of using flexitime in cook freeze production systems should be studied to determine the effects on production scheduling, labor cost, and employee morale. Implementation of MRP and COST-ARREST in an actual food production system was recommended to determine additional refinements which would improve the techniques as management decision-making tools.

# LIST OF REFERENCES

## LIST OF REFERENCES


Aley, P. N. 1976. Priority scheduling reduces inventory. Ind. Eng. 8(1): 4.

American Hospital Association. 1976. "Shared Food Services in Health Care Institutions," Amer. Hosp. Assoc., Chicago, Ill.

American Hospital Association. 1977. Hospital indicators. Hospitals. 51 (10-24) May through Dec.

American Hospital Association. 1978. Hospital indicators. Hospitals. 52 (1-6) January through March.

Anonymous. 1974. Fair Labor Standards Act of 1938, as Amended by the Fair Labor Standards Amendments of 1974 and Related Provisions of Law. U. S. Government Printing Office, Washington, D. C.

Anonymous. 1975. Flexitime—a social phenomenon. Pers. J. 54(5): 318.

Beach, B. L. 1974. A conceptual framework and decision model for application of value analysis of entrees in a food production system. Unpublished Doctoral dissertation, University of Wisconsin, Madison.

Beach, B. L. and Matthews, M. E. 1972. Computerized Inventory Management Systems. A Computer Simulation Model (unpublished). Department of Food Science, Nutrition, and Food Systems Administration. University of Tennessee, Knoxville.

Berry, W. L. and Whybark, D. C. 1975. Research perspectives for material requirements planning systems. Prod. and Inv. Mgt. 16(2): 19.

Beyer, C. E. 1971. A hospital converts to ready foods. Cornell HRAQ 12(1): 39.

Biegel, J. E. 1971. "Production Control, A Quantitative Approach," Prentice-Hall. Englewood Cliffs, New Jersey.

Bobeng, B. J. and David, B. D. 1977. HACCP models for quality control of entree production in foodservice systems. J. Food Protection. 40(9): 632.

Bobeng, B. J.,and David, B. D. 1978. HACCP models for quality control of entree production in hospital foodservice systems. J. Amer. Dietet. Assoc. 73: 524.

Boyer, C. H. 1977. Production control: MRP ends guessing at Southwire. Ind. Eng. 9(3): 26.

Brisley, C. L. 1971. Work Sampling, IN "Industrial Engineering Handbook," ed. H. B. Maynard. McGraw-Hill Book Co. New York.

Brown, R. M. 1969. Estimating dietary labor by use of work modules. Hospitals. 43(20): 103.

Buchan, J. R. and Davis, J. G. 1976. Project control through network analysis and synthesis. Unpublished textbook manuscript, University of Tennessee, Knoxville.

Chase, R. B. and Aquilano, N. J. 1977. "Production and Operations Management. A Life Cycle Approach," Richard D. Irwin, Inc., Homewood, Ill.

Conway, R. W., Maxwell, W. L. and Miller, L. W. 1967. "The Theory Scheduling," Addison-Wesley Publishing Co., Reading, Mass.

David, B. D. 1973. Systems approach is key to success. Hospitals. 47(12): 80.

David, B. D. 1978. Work measurement in foodservice operations. School Foodserv. Res. Rev. 2(1): 5.

Davis, J. G. and Buchan, J. R. 1969. Project scheduling: use the REST approach. J. Systems Mgt. 20(8): 7.

Doyon, P. R. 1970. Automated food delivery systems. Hospitals. 44(3): 109.

Ellis, C. 1976. Old, new meld in ready foods system. Mod. Healthcare. 6(7): 41.

Faulkner, M. T. 1977. A computer program for the most efficient allocation of resources in a critical path network. Term paper for I.E. 5900, University of Tennessee Industrial Engineering Department.

Fleuter, D. L. 1975. "The Workweek Revolution," Addison-Wesley Publishing Co., Reading, Mass.

Fuchs, J. H. 1978. "Computer Inventory Control Systems," Prentice-Hall, In. Englewood Cliffs, New Jersey.

Goldberg, C. M. and Kohlligian, M. 1974. Conventional, convenience, or ready food service? Hospitals. 48(8): 80.

Goodwin, W. L. 1976. RAPS: a resource allocation production scheduling algorithm for hot food production systems. Unpublished Masters thesis. University of Tennessee, Knoxville, Tennessee.

Greene, J. H. 1974. "Production and Inventory Control—Systems and Decisions," Rev. Ed. R. D. Irwin, Inc., Homewood, Ill.

Heinemeyer, J. M. and Ostenso, G. L. 1968. Food production materials handling. J. Amer. Dietet. Assoc. 52: 490.

Hill, M. A. and Glew, G. 1974. Recipe development. Hospitals. 48(12): 124.

Hillier, F. S. and Lieberman, G. J. 1974. "Operations Research," Holden-Day, Inc., San Francisco, California.

Hopeman, R. J. 1976. "Production. Concepts, Analysis, Control," Charles E. Merrill Publishing Co., Columbus, Ohio.

Institution Management Personnel. 1967. "Methodology Manual for Work Sampling," Department of Foods and Nutrition. University of Wisconsin, Madison.

Ivanicky, M. C., Mason, H. A. and Vierow, S. C. 1969. Food preparation: labor time versus production quantity. Hospitals. 43(20): 99.

Kent, J. W. and Ostenso, G. L. 1965. Productivity relationships of hospital dietary departments. J. Amer. Dietet. Assoc. 47: 104.

Kossovitsas, C., Navab, M., Chang, C. M. and Livingston, G. E. 1973. A comparison of chilled-holding versus frozen storage on quality and wholesomeness of some prepared foods. J. Food Sci. 38: 901.

Kuhne, R. J. and Blair, C. O. 1978. Changing the workweek. Bus. Hor. 21(2): 39.

Lambert, C. U., Lambert, J. M. and Beach, B. L. 1979. Computerized Scheduling Technique—using Algorithms RAPS and REST (COST-ARREST) (unpublished) Department of Food Science, Nutrition and Food Systems Administration. University of Tennessee, Knoxville.

Matthews, M. E. 1975. Productivity studies reviewed, trends analyzed. Hospitals. 49(24): 81.

Matthews, M. E., Waldvogel, C. F., Mahaffey, M. J. and Zemel, P. C. 1978a. Master standard data quantity food production code: macro elements for synthesizing labor time. J. Amer. Dietet. Assoc. 72: 612.

Matthews, M. E., Waldvogel, C. F., Mahaffey, M. J. and Zemel, P. C. 1978b. Food production relationships between entree combinations and forecasted demand. J. Amer. Dietet. Assoc. 72: 618.

Milwaukee Chapter, Inc., APICS. 1977. MRP symposium. Prod. and Inv. Mgt. 18(2): 29.

Miller, J. G. and Sprague, L. G. 1975. Behind the growth in material requirements planning. Harv. Bus. Rev. 53(5): 83.

Millross, J. and Glew, G. 1974. Staff, equipment, and wastage. Hospitals 48(16): 72.

Millross, J., Hill, M. A. and Glew, G. 1974. Consequences of a switch to c-ok freeze. Hospitals 48(17): 118.

Moder, J. J. and Phillips, C. R. 1970. "Project Management with CPM and PERT," Van Nostrand Reinhold Co. New York.

Montag, G. M., McKinley, M. M. and Klinschmidt, A. C. 1964. Predetermined motion times—a tool in food production management. J. Amer. Dietet. Assoc. 45: 206.

New, C. 1973. "Requirements Planning," John Wiley and Sons, New York.

Niland, P. 1970. "Production Planning, Scheduling, and Inventory Control," The Macmillan Co. London.

Nollen, S. D. and Martin, V. H. 1978. "Alternative Work Schedules. Part 1: Flexitime," AMACOM. New York.

O'Brien, J. J. 1971. "CPM in Construction Management. Project Management with CPM." 2nd Ed. McGraw-Hill Book Co. New York.

Ostenso, G. L. and Donaldson, B. 1966. Effective use of hospital dietary labor resources. Hospitals. 40(14): 127.

Owen, J. D. 1977. Flexitime: some problems and solutions. Ind. and Lab. Rel. Rev. 30(2): 152.

Quam, M. E., Fitzsimmons, C. and Godfrey, R. L. 1967. Ready-prepared versus conventionally prepared foods. J. Amer. Dietet. Assoc. 50: 196.

Rinke, W. J. 1976. Three major systems reviewed and evaluated. Hospitals. 50(4): 73.

Ruf, K. and Matthews, M. E. 1973. Production time standards. Hospitals. 47(9): 82.

Schell, M. L. and Korstad, P. J. 1964. Work sampling study shows division of labor time. Hospitals. 38(2): 99.

Stoneham, J. M. 1970. Efficient convenience in food service. Cornell HRAQ 10(4): 92.

Swart, J. C. 1978. "A Flexible Approach to Working Hours," AMACOM. New York.

Thompson, J. A. 1978. A linear programming model for labor planning. Proc. 1978 AIIE Spring Annual Conference, p. 289.

Thurston, P. H. 1972. Requirements planning for inventory control. Harv. Bus. Rev. 59(4): 67.

Waldvogel, C. F. and Ostenso, G. L. 1977a. Quantity food production labor time. J. Amer. Dietet. Assoc. 70: 172.

Waldvogel, C. F. and Ostenso, G. L. 1977b. Labor time per portion and volume in foodservice. J. Amer. Dietet. Assoc. 70: 178.

Welsh, J. N. 1975. Four-day workweek implemented. Hospitals. 49(8): 89.

Wiest, J. D. and Levy, F. K. 1977. "A Management Guide to PERT/CPM." 2nd Ed. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Wight, O. W. 1974. "Production and Inventory Management in the Computer Age." Cahners Books International, Inc., Boston, Mass.

Williams, J. E. and Donaldson, B. 1969. SCORE: a management evaluation program for dietary departments. J. Amer. Dietet. Assoc. 54: 283.

Wise, B. I. and Donaldson, B. 1961. Work sampling in the dietary department. J. Amer. Dietet. Assoc. 39: 327.

Zallen, E. M., Hitchcock, M. J. and Goertz, G. E. 1975. Chilled food systems: effects of chilled holding on quality of beef loaves. J. Amer. Dietet. Assoc. 67: 552.

Zolber, K. K. and Donaldson, B. 1970. Distribution of work functions in hospital food systems. J. Amer. Dietet. Assoc. 56: 39.

# APPENDICES

# APPENDIX A

# SELECTED GRACOST FIGURES

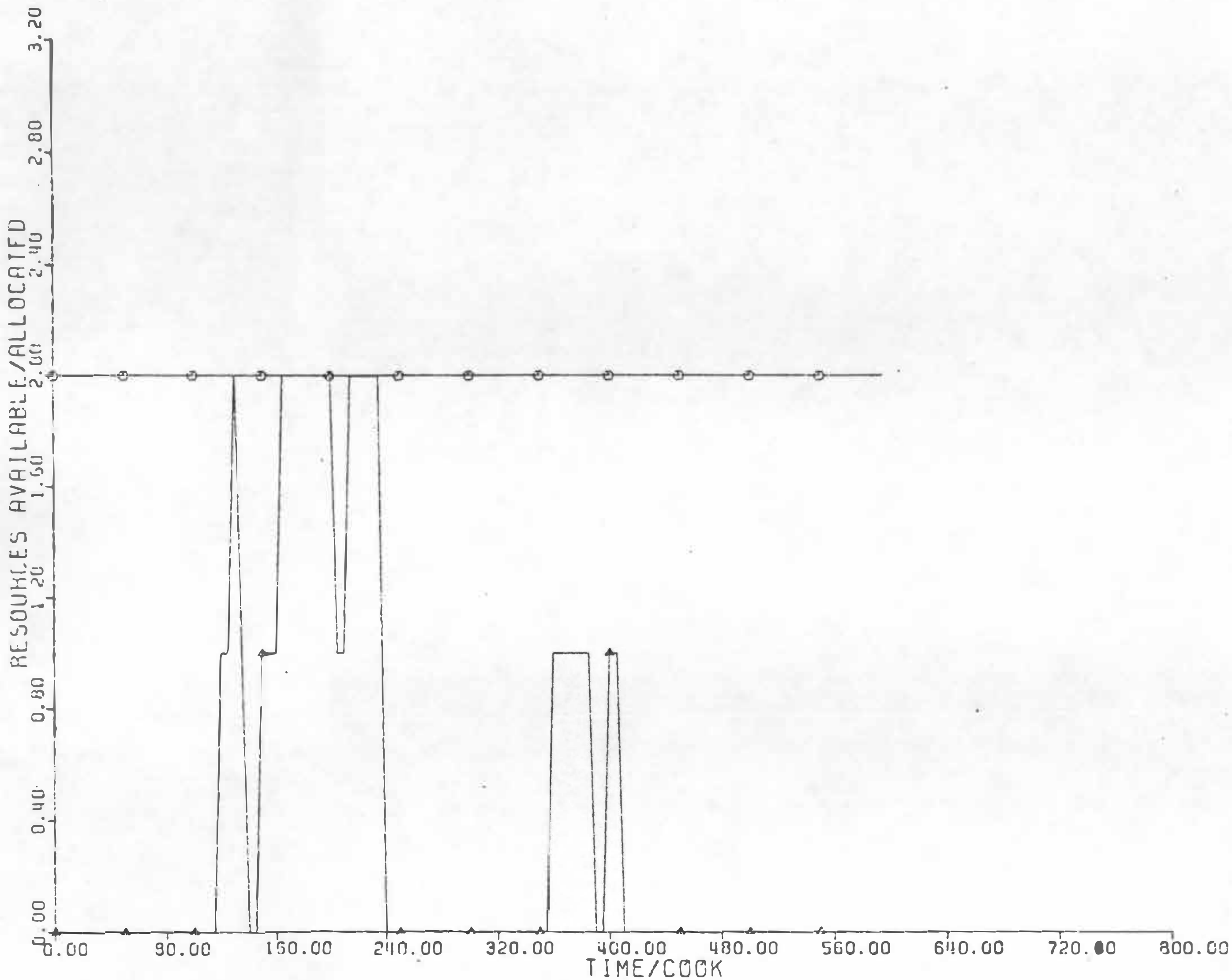



Figure A.1. Profile of cook utilization by five-minute intervals for Monday in the seven-day production plan.

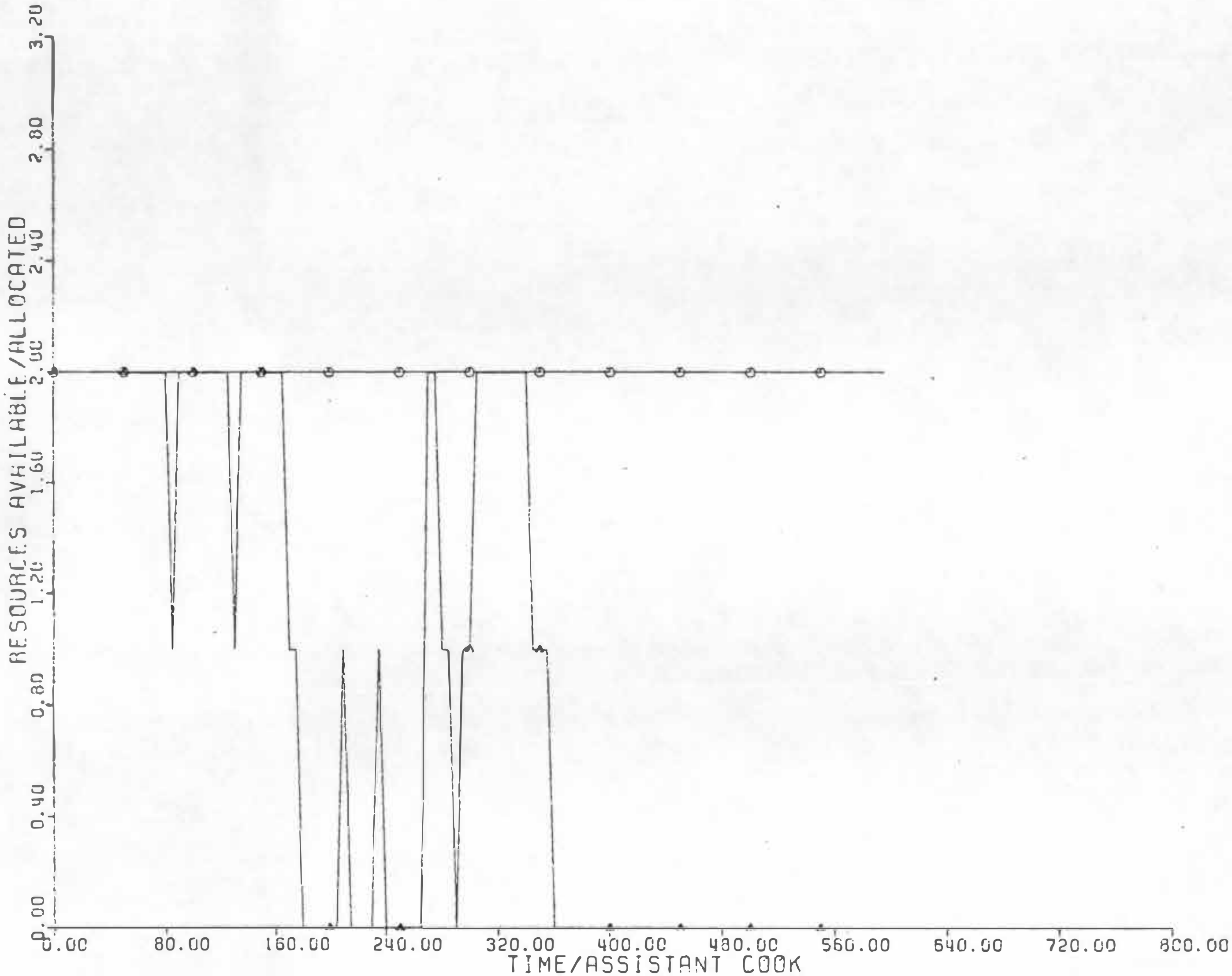



Figure A.2. Profile of assistant cook utilization by five-minute intervals for Monday in the seven-day production plan.

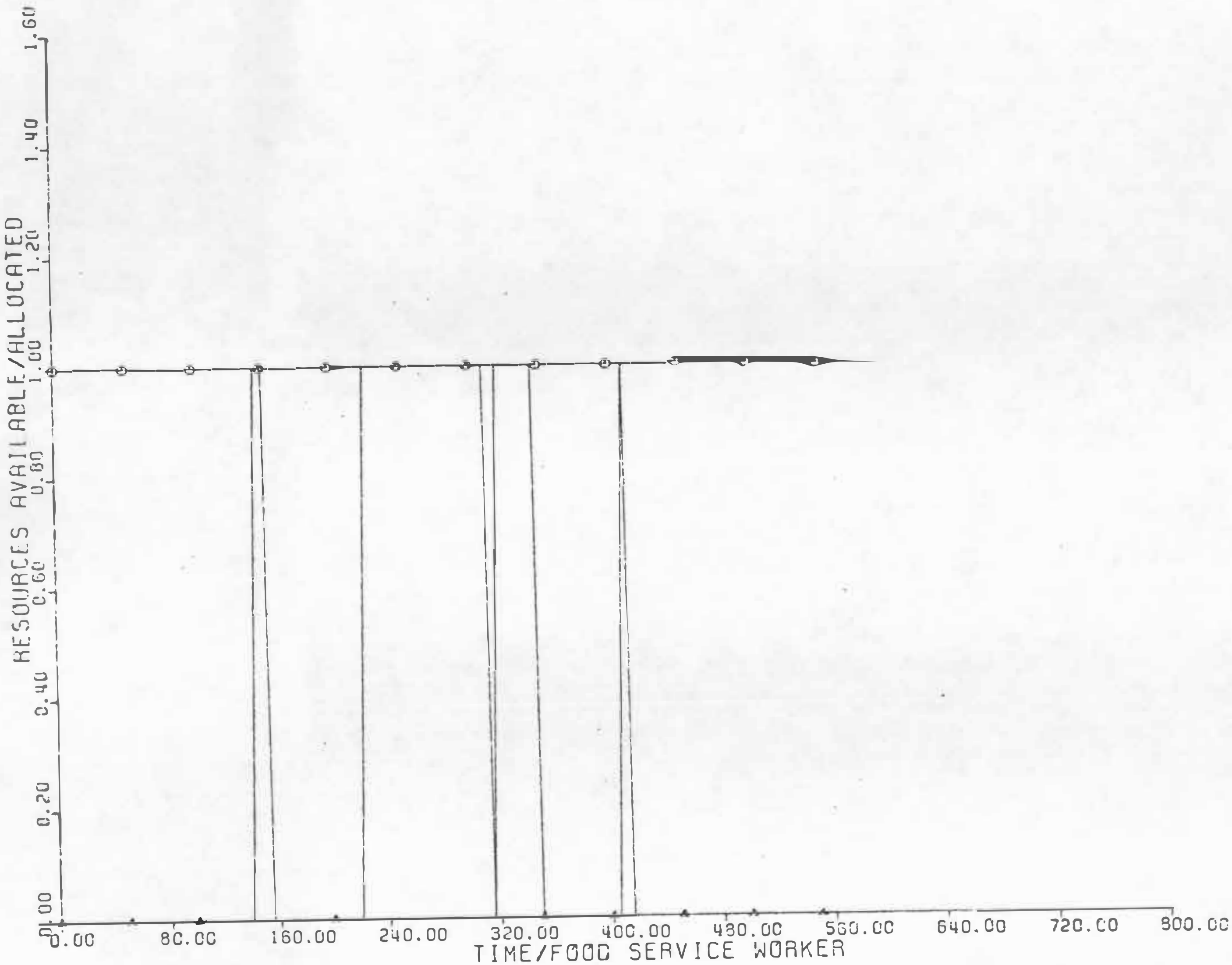



Figure A.3. Profile of food service worker utilization by five-minute intervals for Monday in the seven-day production plan.

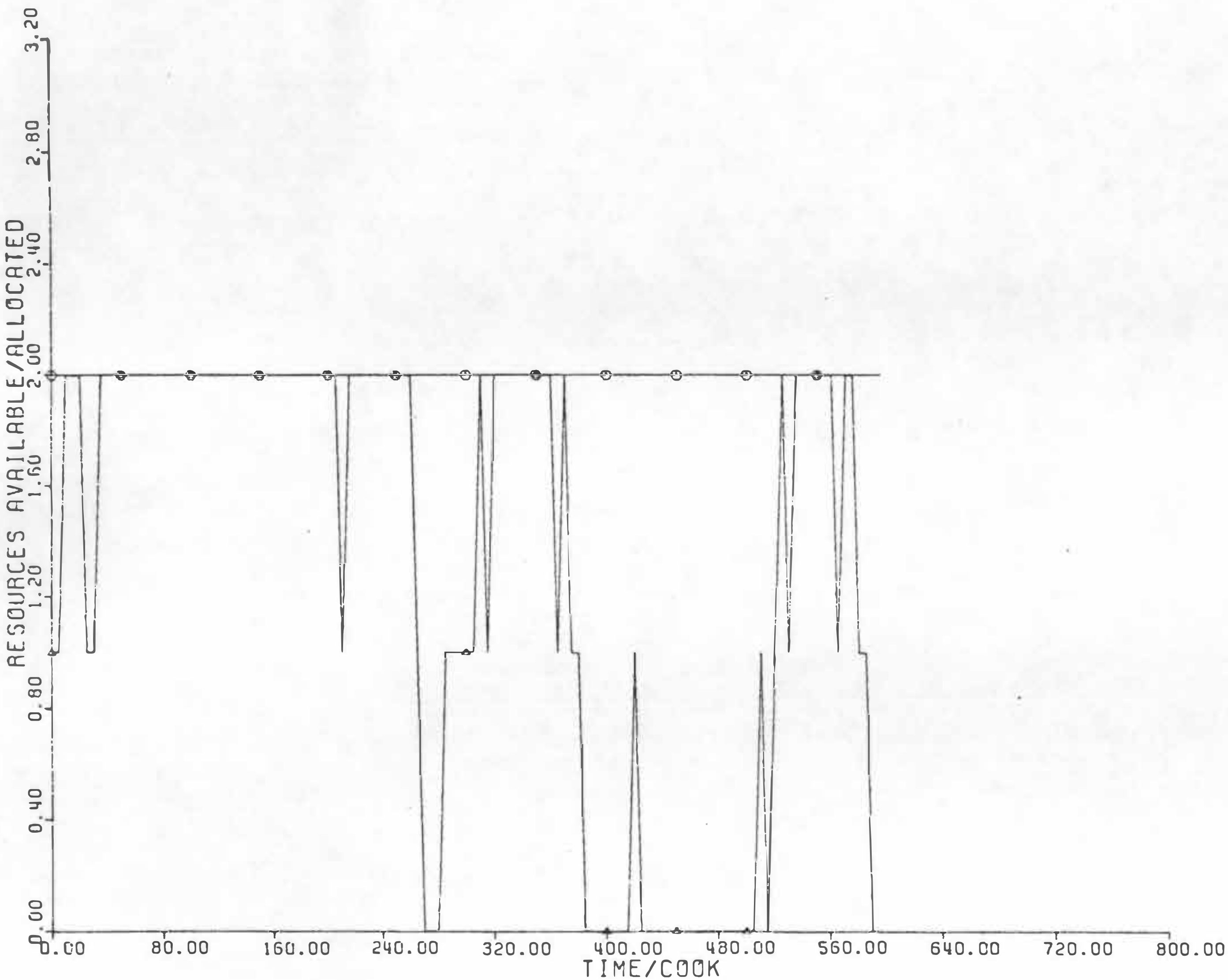



Figure A.4. Profile of cook utilization by five-minute intervals for Monday in the five-day production plan—Original.

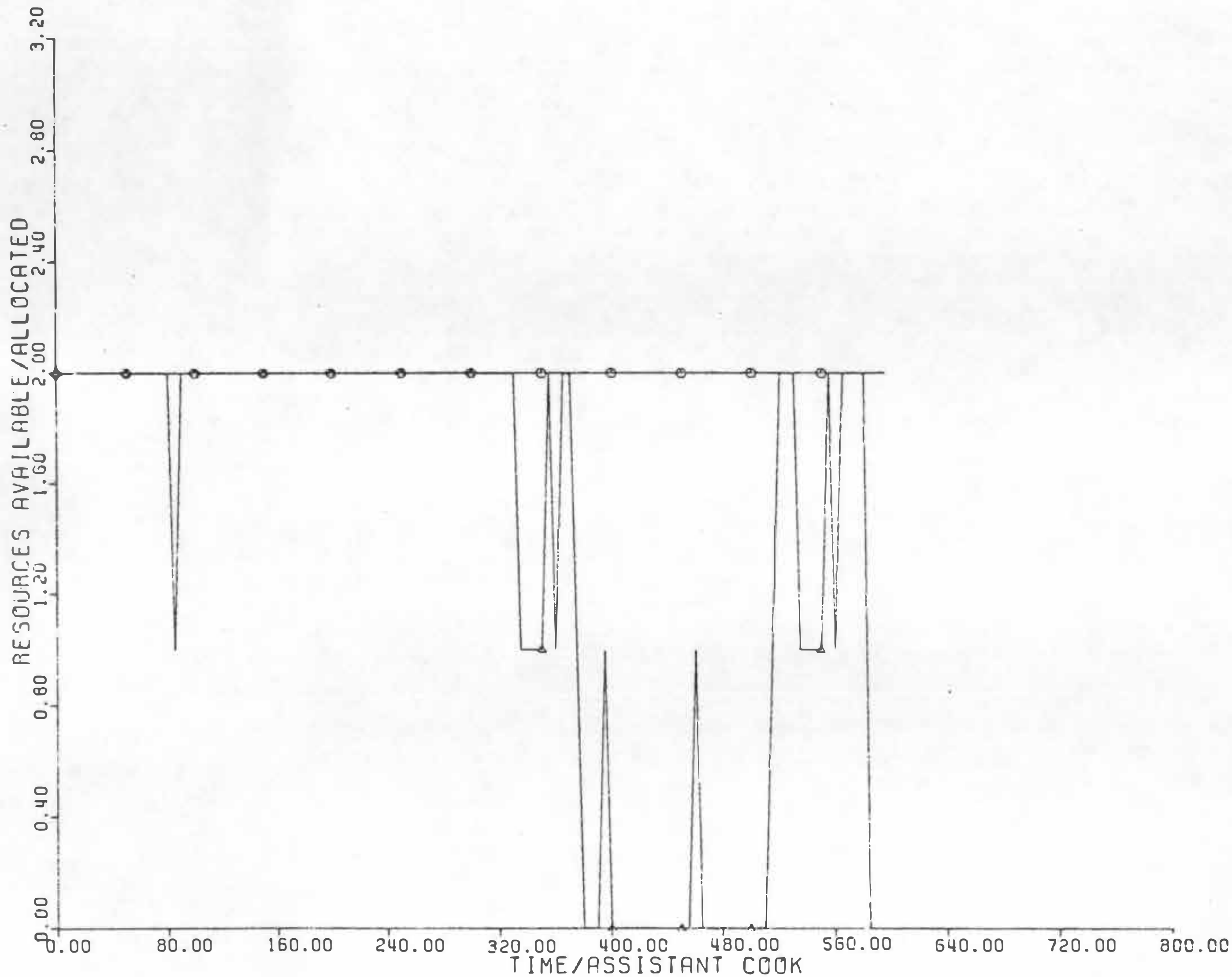



Figure A.5. Profile of assistant cook utilization by five-minute intervals for Monday in the five-day production plan—Original.

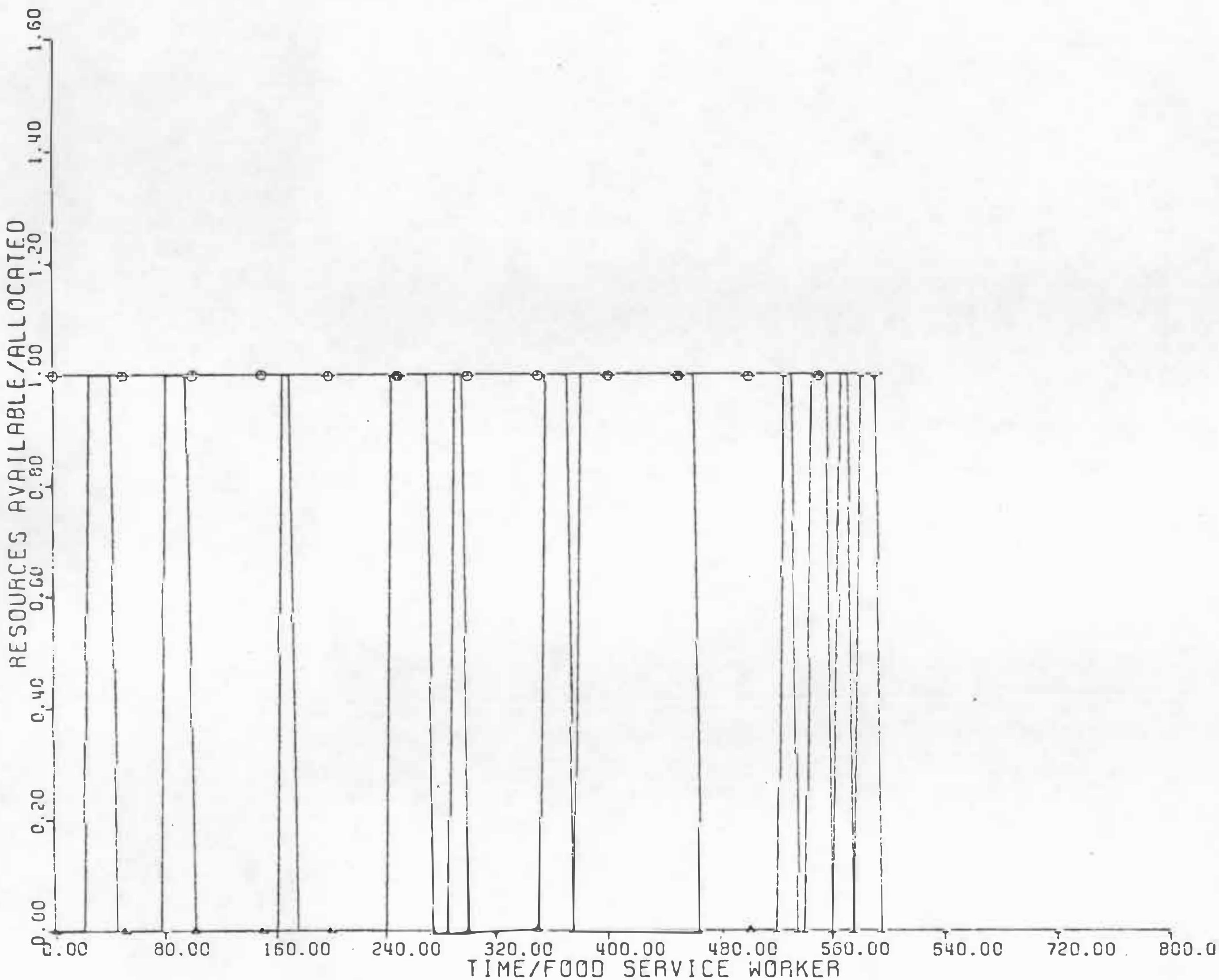



Figure A.6. Profile of food service worker utilization by five-minute intervals for Monday in the five-day production plan—Original.

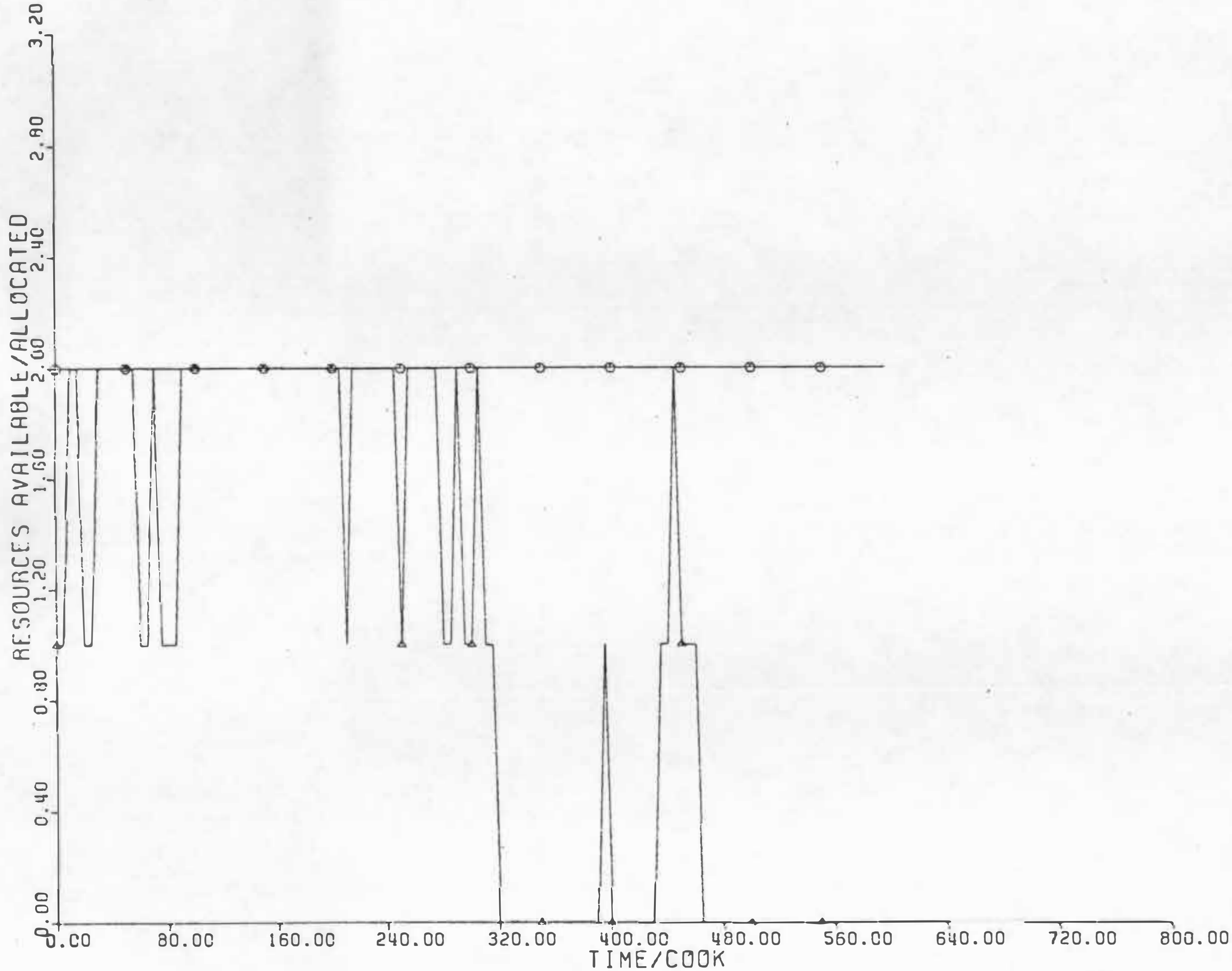



Figure A.7. Profile of cook utilization by five-minute intervals for Monday in the five-day production plan—Alternative 1.

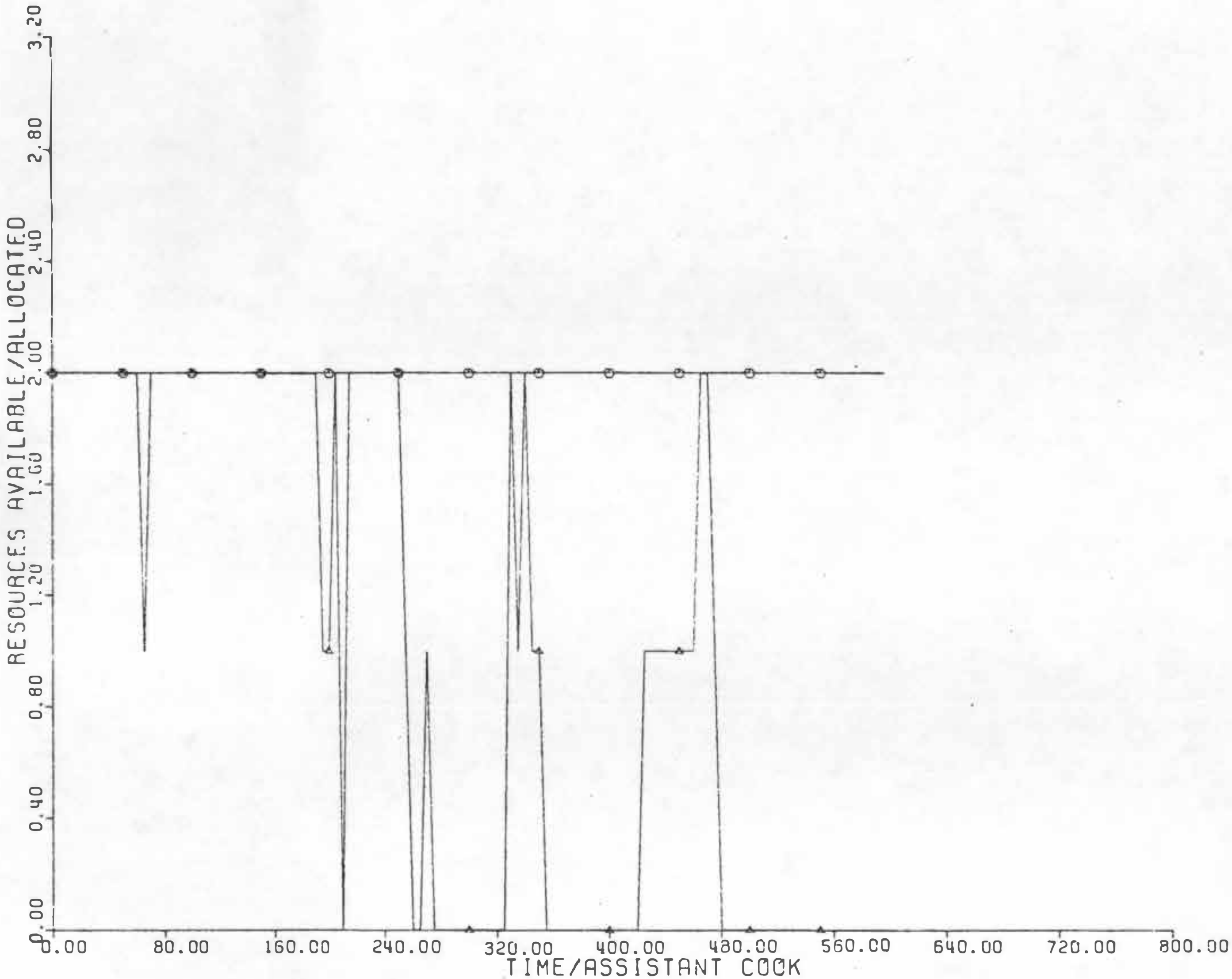



Figure A.8. Profile of assistant cook utilization by five-minute intervals for Monday in the five-day production plan—Alternative 1.

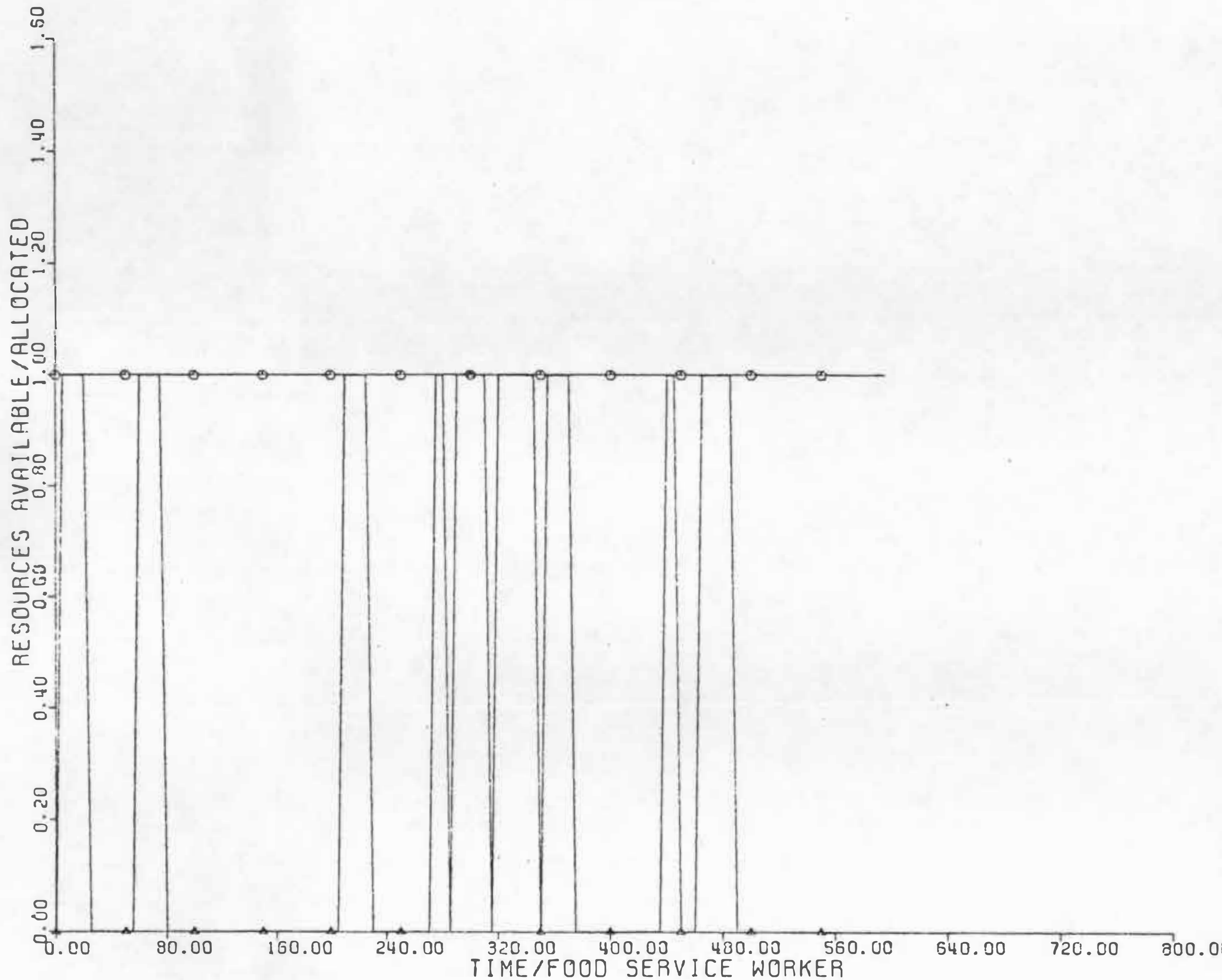



Figure A.9. Profile of food service worker utilization by five-minute intervals for Monday in the five-day production plan—Alternative 1.

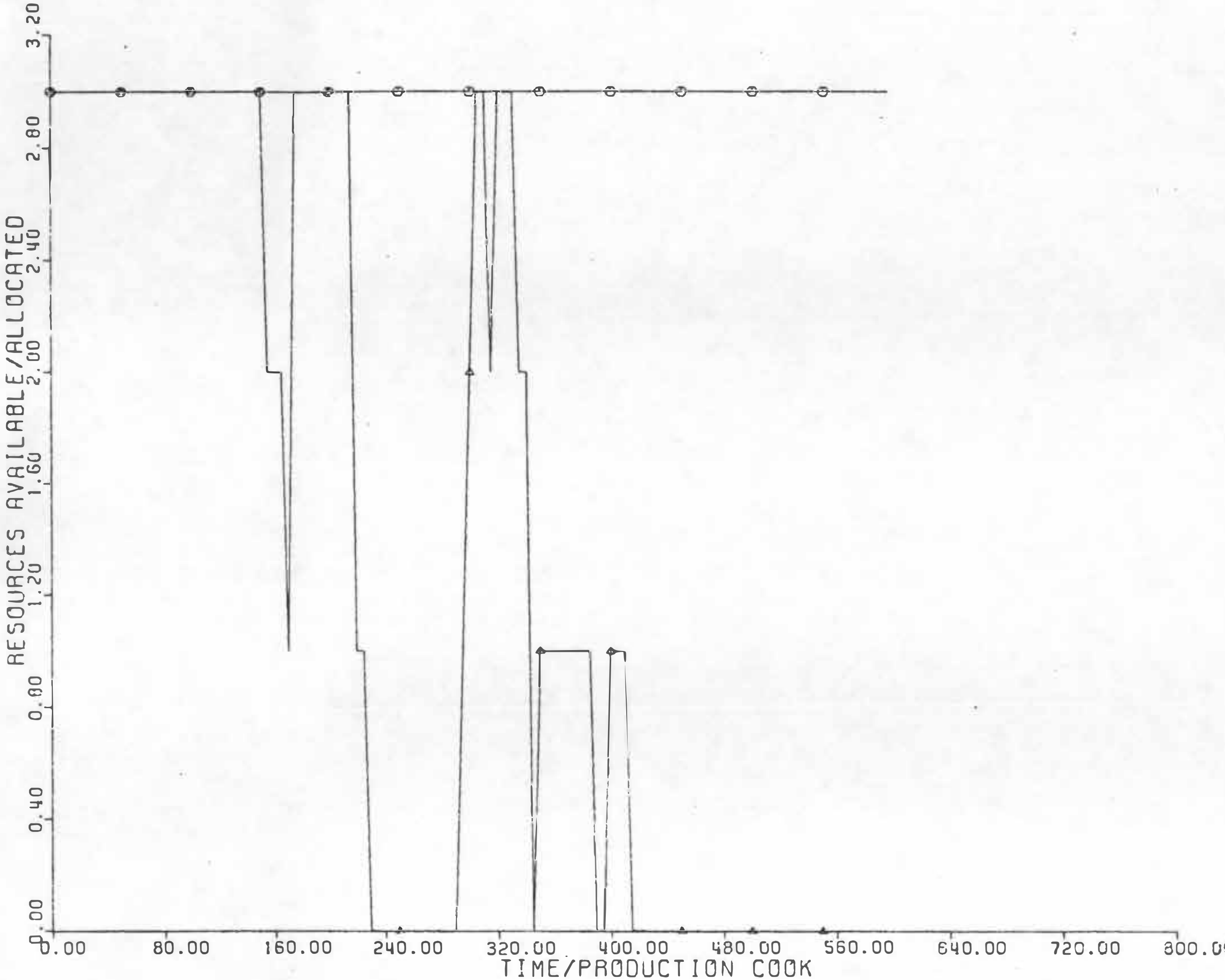



Figure A.10. Profile of production cook (3) utilization by five-minute intervals for Tuesday in the five-day production plan—Alternative 1, using one labor category.

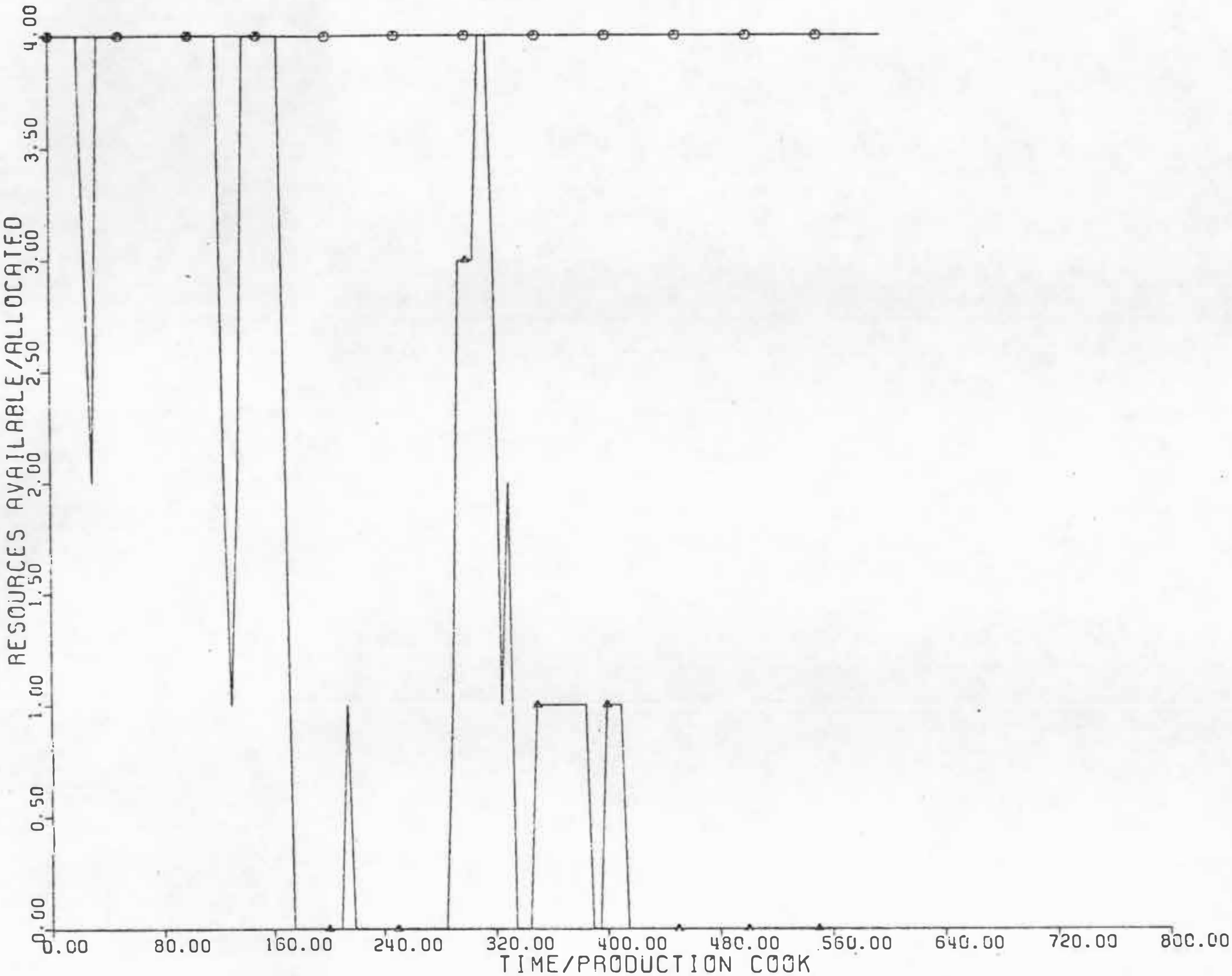



Figure A.11. Profile of production cook (4) utilization by five-minute intervals for Tuesday in the five-day production plan—Alternative 1, using one labor category.

APPENDIX B

BILL OF MATERIALS

FC0822- COMPLETE RECIPE LIST

RECIPE 1225 SPAGHETTI W/MEAT SAUCE 6/16/77

SERVING PAN 20X12X6 PORTIONS PER PAN 88 PORTION SIZE 4.5 OZ

UTENSIL 3 OZ LADLE TEMPERATURE HOT

| STK. | LN. | INGREDIENT | 65 | 130 | 520 | 780 |
|---|---|---|---|---|---|---|
| 17975 | | YIELD | 2.25 GAL | | | |
| 79440 | 1 | ONIONS,DEHYD.CHOP,2.5LBS.XSTD.6/10 | 2.00 OZ | .25 LB | 1.00 LB | 1.50 LB |
| 17950 | 2 | WATER, COLD | 1.00 CUP | 2.00 CUP | 2.00 QT | 3.00 QT |
| 51025 | 3 | GRD BF BULK REG.20PCNT.A.FAT #136 | 7.50 LB | 15.00 LB | 60.00 LB | 90.00 LB |
| 73180 | 4 | DAVIS,SPICE MIX 14OZ BAG | .25 BAG | .50 BAG | 2.00 BAG | 3.00 BAG |
| 79130 | 5 | TOMATOES,PASTE,HVY, 33PCNT.SLD.A10 | 2.00 CUP | 1.00 QT | 1.00 GAL | 1.00 GAL |
| | | | | | | 2.00 QT |
| 79235 | 6 | TOMATOES,DICED,HVY,PUREE,FCY,6/10 | 2.00 CAN | 4.00 CAN | 16.00 CAN | 24.00 CAN |
| 17950 | 7 | WATER, COLD | 1.00 QT | 2.00 QT | 2.00 GAL | 3.00 GAL |
| 72950 | 9 | SPAGHETTI,LONG THIN,20LB. | 6.50 LB | 13.00 LB | 52.00 LB | 78.00 LB |
| 17955 | 10 | WATER, HOT 160 DEG. | 3.50 GAL | 7.00 GAL | 28.00 GAL | 42.00 GAL |
| 76701 | 11 | SALT,100LB.BAG. | 2.50 OZ | .25 LB | 1.25 LB | 1.75 LB |
| | | | | 1.00 OZ | | 2.00 OZ |

PREPARATION PROCEDURE

1. REHYDRATE ONIONS IN FIRST AMOUNT OF WATER.
2. SAUTE REHYDRATED ONIONS AND GROUND BEEF IN STEAM KETTLE. COOK UNTIL MEAT IS WELL BROWNED STIRRING OCCASIONALLY TO PREVENT LUMPING. SKIM OFF EXCESS FAT.
3. ADD SPICE MIX, TOMATO PASTE, ITALIAN SAUCE, AND WATER TO BROWNED MEAT AND SIMMER FOR 2 HOURS STIRRING OCCASIONALLY TO PREVENT STICKING.
4. PLACE 3 GAL MEAT SAUCE IN COUNTER PANS 20X12X6.
5. BREAK SPAGHETTI TWICE AND COOK IN BOILING SALTED WATER UNTIL TENDER, APPROX. 20 MIN. RINSE AND DRAIN. PLACE IN COUNTER PANS.
6. SERVE 3 OZ LADLE OF MEAT SAUCE WEIGHT 4.5 OVER 5.5 OZ OF SPAGHETTI SERVE SPAGHETTI WITH TONGS.

COOKING TIME: SEE ABOVE.
COOKING TEMP: SEE ABOVE.,
EQUIPMENT: STEAM KETTLES
NOTE: YIELD IS FOR GALLONS OF MEAT SAUCE.

Figure B.1. Bill of materials: standardized recipe for Italian Spaghetti/Meat Sauce.

FORMULA: Italian Spaghetti/Meat Sauce

AVERAGE NUMBER OF SERVINGS: 520

| Activity Number | Activity | Labor Level and Type | Major Equipment | Immediate Task Predecessor | Time in Minutes |
|---|---|---|---|---|---|
| 1 | Get ingredients from refrig. and | A. Cook | | - | 10 |
| | dry stores, take to work area | | | | |
| 2 | Reconstitute onions | - | | 1 | 11 |
| 3 | Saute onions and ground beef | Ck | SJK | 2 | 30 |
| 4 | Add spices, tomato paste, puree | Ck | SJK | 3 | 10 |
| | and water | | | | |
| 5 | Simmer 2 hours | - | SJK | 4 | 120 |
| 6 | Place in pans | Ck | SJK | 5 | 15 |
| 7 | Take to freezer | A. Cook | - | 6 | 5 |
| 8 | Clean steam jacketed kettle | FSW | SJK | 6 | 15 |
| 9 | Clean area | A. Cook | - | 7 | 5 |
| | | | | | |
| | SJK = steam kettle | | | | |
| | A. Cook = Assistant Cook | | | | |
| | FSW = Food Service Worker | | | | |
| | | | | | |
| | | | | | |

BEACH 1974

Figure B.2. Bill of materials: List of production activities for Italian Spaghetti/Meat Sauce.

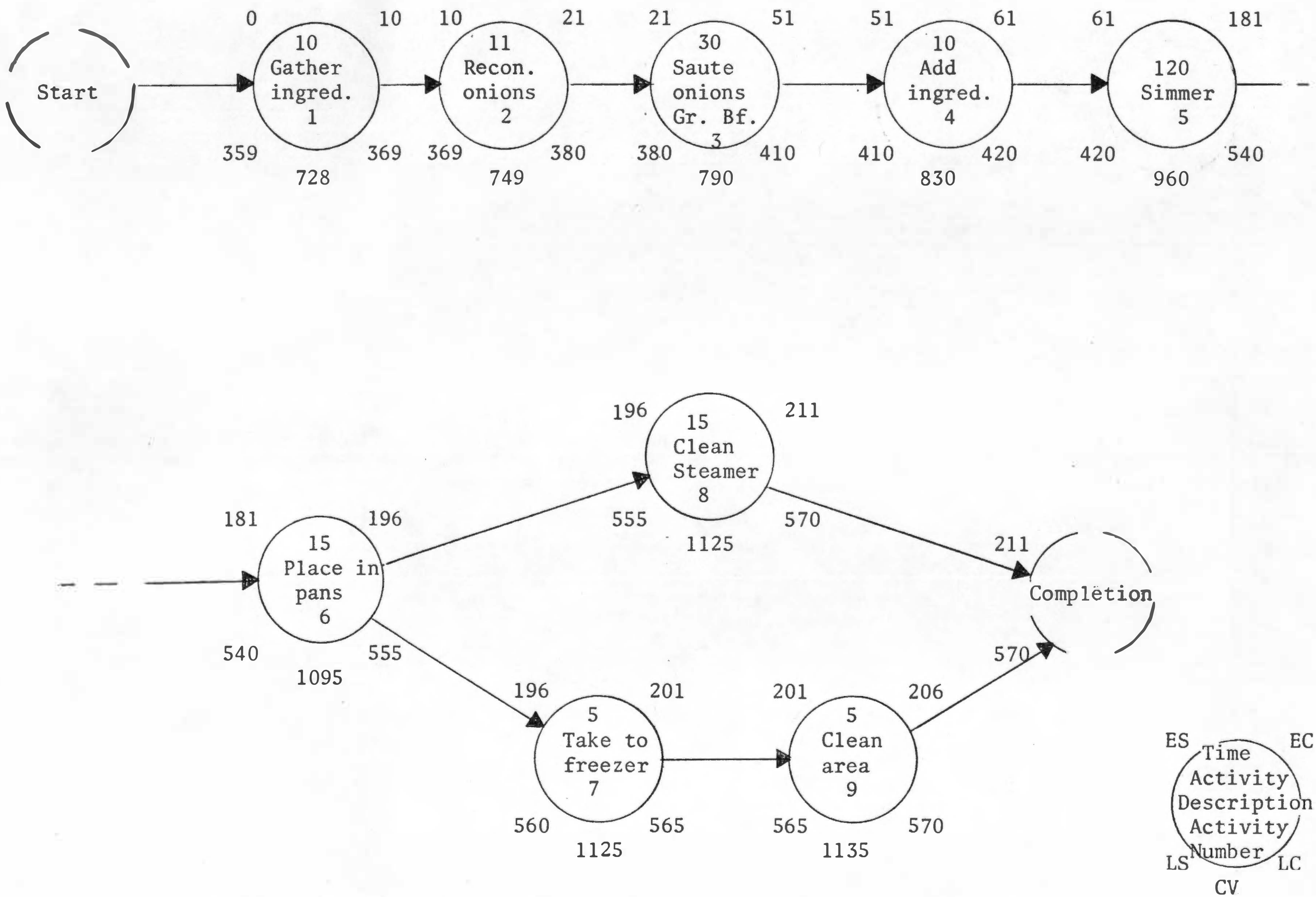



Figure B.3. Bill of materials: AON subproject network for Meat Sauce.

# APPENDIX C

## LOGIC FLOW DIAGRAM FOR COST-ARREST

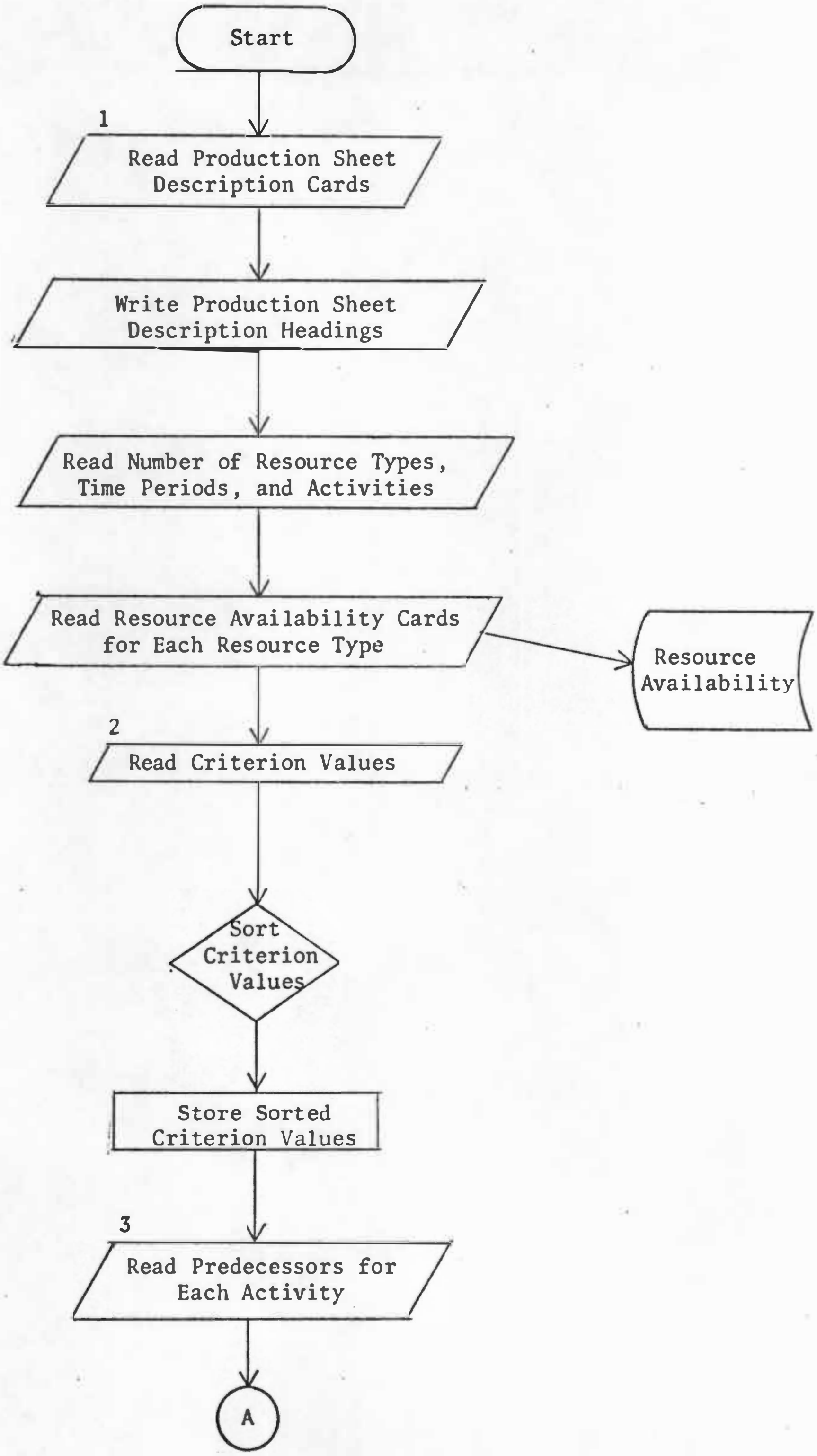



Figure C.1. Logic flow diagram for COST-ARREST program.

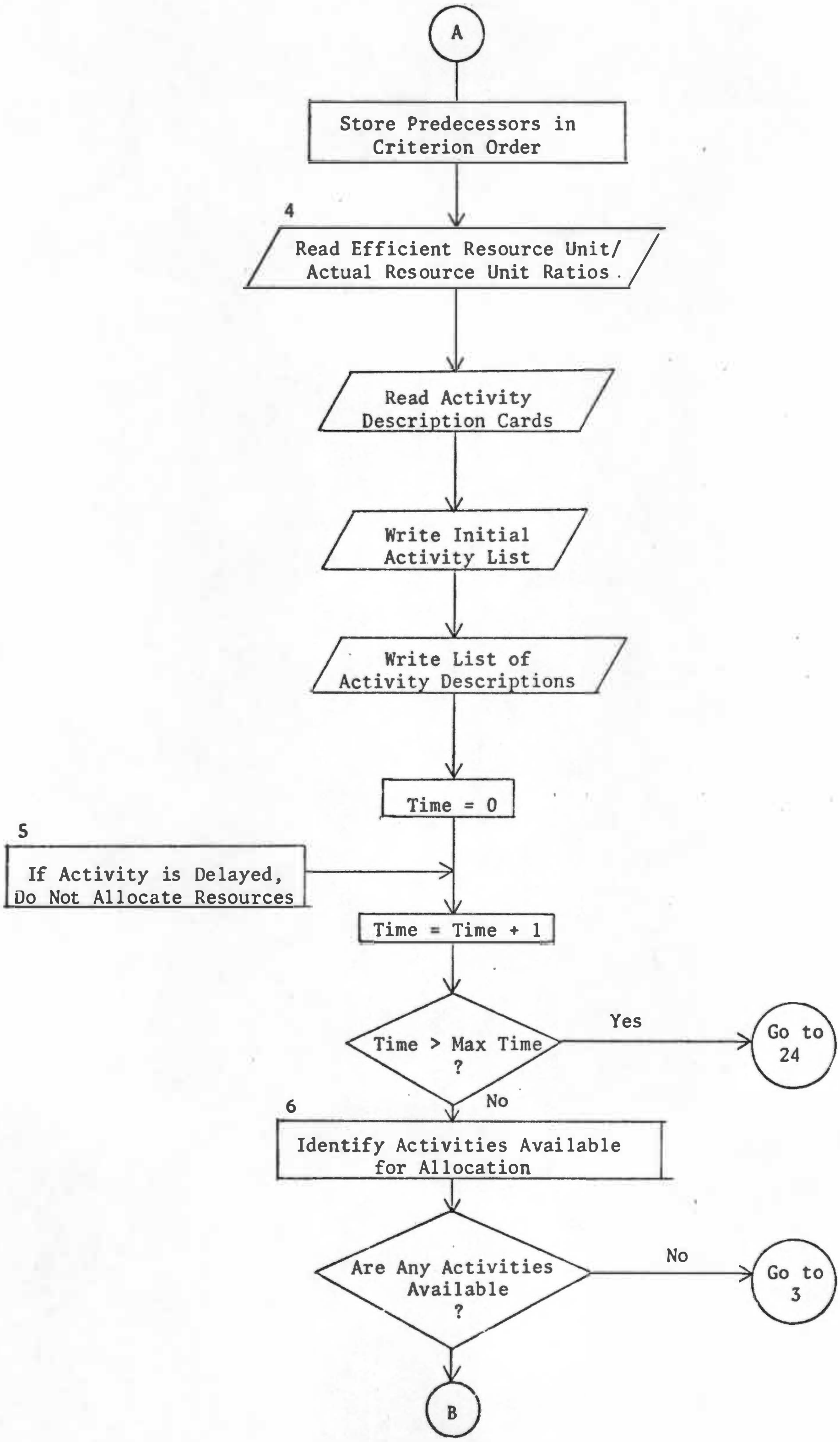



Figure C.1 (Continued)

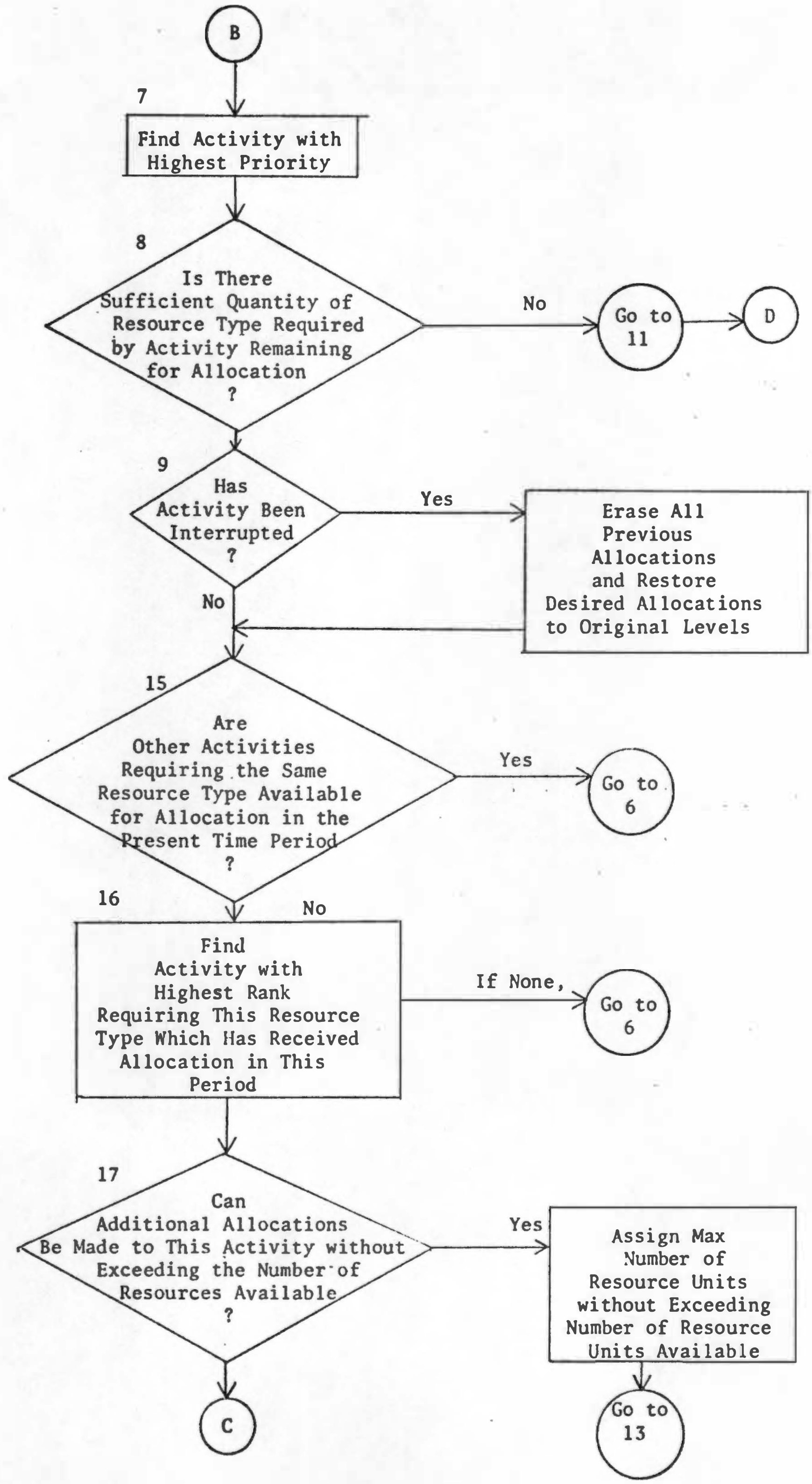



Figure C.1 (Continued)

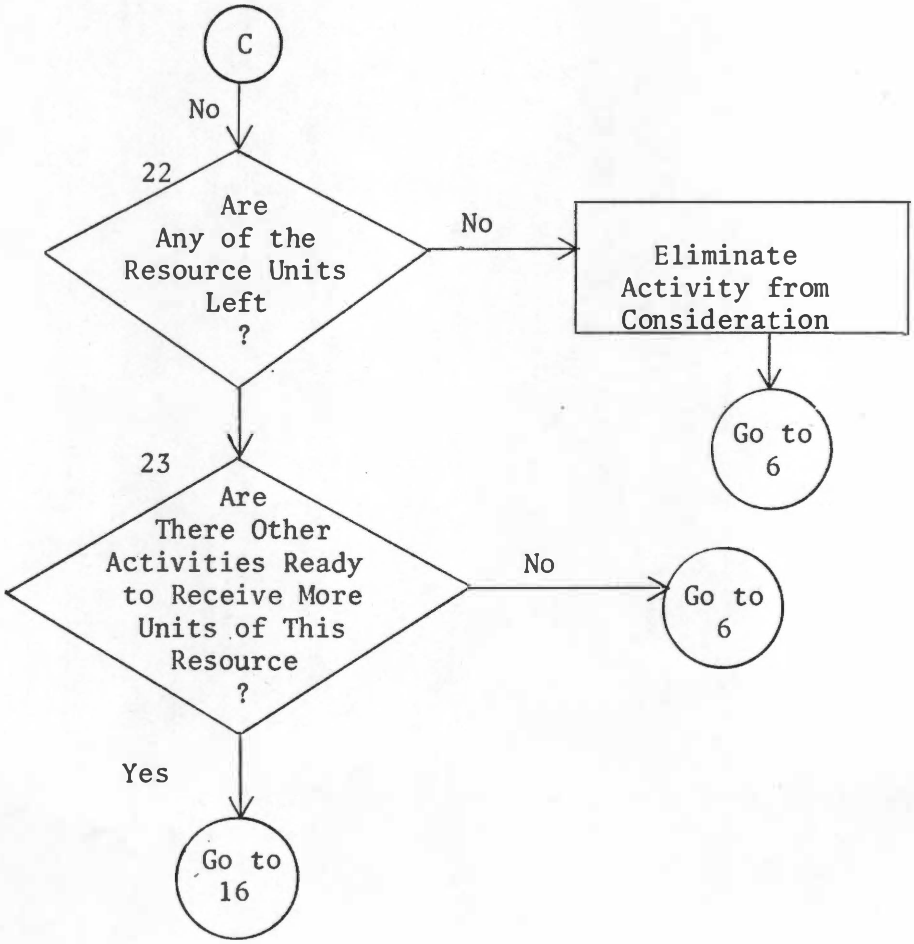



Figure C.1 (Continued)

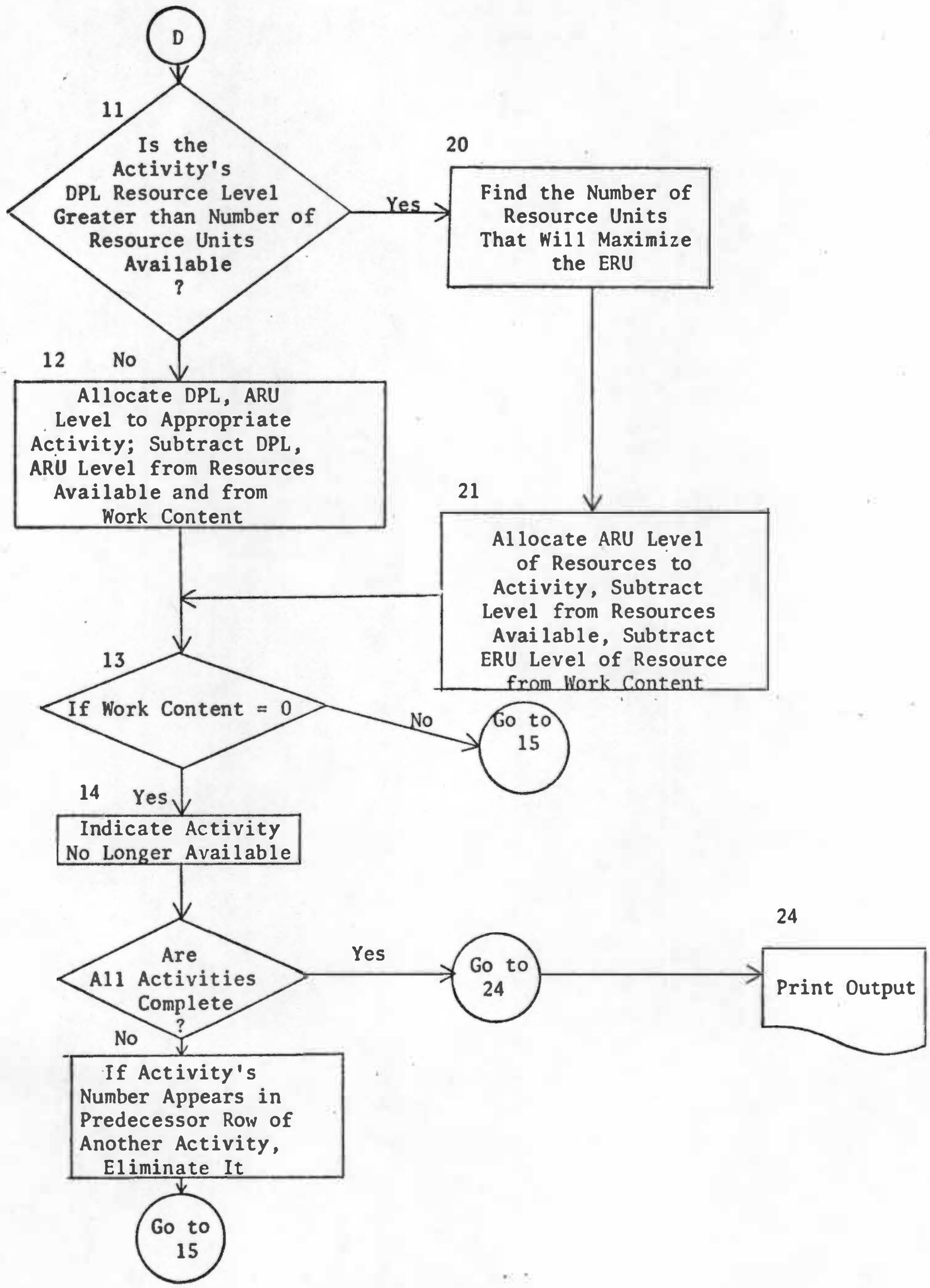



Figure C.1 (Continued)

# APPENDIX D

# RESOURCE ANALYSIS DATA

## Sample Calculations for Determination of Labor Cost for Cooks for Five-day Production Plan-Original

The total weekly labor cost was calculated for each labor category using the formula described in Chapter 3, under "Analysis of Results."

Daily Labor Cost (DLC) = $(P_o - P_r)\,[Thr - (Hr)(W_i)]^+ + Pr[Thr - (Hr)(W_i)]^- + Pr(Thr)$

where:

$P_o = \$6.27$     Thr = total hours worked/shift

$P_r = \$4.18$     Hr = 6

$W_i = 2$

Monday:

$LC = (6.27 - 4.18)[19.5 - (6)(2)]^+ + 4.18[19.5 - (6)(2)]^- + 4.18(19.5)$

$= \$97.19$

Tuesday:

$LC = (6.27 - 4.18)[12 - (6)(2)]^+ + 4.18[12 - (6)(2)]^- + 4.18(12)$

$= \$50.16$

Wednesday and Thursday: Same as Tuesday

Friday:

$LC = (6.27 - 4.18)[13.75 - (6)(2)]^+ + 4.18[13.75 - (6)(2)]^- + 4.18(13.75)$

$= \$61.13$

Total Weekly Labor Cost = $308.80

Table D.1

Regular, Overtime, and Total Weekly Labor Costs Using the 8/80 Payment Plan
for Various Production Plans

| Category | Plan | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Seven-day | | | Five-day Original | | | Five-day Alternative 1 | | |
| | Regular | OT | Total | Regular | OT | Total | Regular | OT | Total |
| Cook (2) | $351.12 | $ 9.40 | $360.52 | $250.80 | $ 58.00 | $308.80 | $250.80 | $20.38 | $271.18 |
| Assistant Cook (2) | 323.40 | $ 5.78 | 329.18 | 231.00 | 50.58 | 281.58 | 231.00 | 23.12 | 254.12 |
| Food Service Worker (1) | 154.56 | 9.66 | 164.22 | 110.40 | 28.98 | 139.38 | 110.40 | 12.42 | 122.82 |
| Total | $829.08 | $24.84 | $853.92 | $592.20 | $137.56 | $729.76 | $592.20 | $55.92 | $648.12 |

Table D.2

Regular, Overtime, and Total Labor Costs Using the 8/80 Payment Plan for Five-Day Production Plan—Alternative 1 Using One Labor Category

| Number of Production Cooks | Regular Pay | Overtime Pay | Total Pay | Savings over Alternative 1 |
|---|---|---|---|---|
| Three | $376.20 | $56.43 | $432.63 | $215.49 |
| Four | $501.60 | $25.08 | $526.68 | $121.44 |

Table D.3

Maximum Total Weekly Labor Hours Required per Employee Based on Production Duration for Various Production Plans

| Labor Category | Seven-Day | Five-Day Original | Five-Day Alternative 1 | Five-Day Alternative 2 | One Labor Category |
|---|---|---|---|---|---|
| Cook | 33.33 | 26.92 | 28.58 | 29.33 | - |
| Assistant Cook | 33.50 | 28.58 | 28.00 | 28.83 | - |
| Food Service Worker | 38.25 | 31.17 | 30.75 | 31.67 | - |
| Production Cook (3) | - | - | - | - | 33.42 |
| Production Cook (4) | - | - | - | - | 28.67 |

Table D.4

Equipment Demand in Minutes for Seven-Day Production Plan in a Hypothetical Cook Freeze System

| Equipment | Day | | | | | | | Total Demand | Range |
|---|---|---|---|---|---|---|---|---|---|
| | Sunday | Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | | |
| Mixer | 30 | - | 30 | - | - | - | - | 60 | 0-30 |
| Five-Gallon Kettle | - | 30 | 100 | 60 | 65 | 30 | - | 285 | 0-100 |
| Twenty-Gallon Kettle | 390 | 90 | 105 | 305 | 325 | 125 | 155 | 1,495 | 90-390 |
| Sixty-Gallon Kettle | 310 | 470 | 250 | - | - | 230 | 90 | 1,350 | 0-470 |
| Convection Oven | 210 | 730 | 505 | 450 | 595 | 305 | 265 | 3,060 | 210-730 |
| Rotary Oven | - | - | 290 | - | - | - | 105 | 395 | 0-290 |
| Slicer | 45 | 35 | 70 | 30 | - | 45 | - | 225 | 0-70 |
| Grill | 215 | - | 90 | 190 | 70 | 180 | 90 | 835 | 0-215 |
| Fryer | 240 | - | - | - | - | - | - | 240 | 0-240 |
| Chopper | - | 15 | - | - | - | 10 | - | 25 | 0-15 |

Table D.5

Equipment Demand in Minutes for Five-Day Production Plan—Original in a Hypothetical Cook Freeze System

| Equipment | Day | | | | | Total Demand | Range |
|---|---|---|---|---|---|---|---|
| | Monday | Tuesday | Wednesday | Thursday | Friday | | |
| Mixer | 60 | - | - | - | - | 60 | 0-60 |
| Five-Gallon Kettle | 100 | - | 95 | 60 | - | 255 | 0-100 |
| Twenty-Gallon Kettle | 240 | 55 | 465 | 175 | 215 | 1,150 | 55-465 |
| Sixty-Gallon Kettle | 665 | 65 | - | 185 | 475 | 1,390 | 0-665 |
| Convection Oven | 1,265 | 420 | 605 | 100 | 645 | 3,035 | 100-1,265 |
| Rotary Oven | 290 | - | - | - | 105 | 395 | 0-290 |
| Slicer | 90 | 70 | - | 15 | 30 | 205 | 0-90 |
| Grill | 120 | - | 190 | 270 | 90 | 670 | 0-270 |
| Fryer | 250 | - | - | - | - | 250 | 0-250 |
| Chopper | - | 15 | - | 10 | - | 25 | 0-15 |

Table D.6

Equipment Demand in Minutes for Five-Day Production Plan—Alternative 1 in a Hypothetical Cook Freeze System

| Equipment | Day | | | | | Total Demand | Range |
|---|---|---|---|---|---|---|---|
| | Monday | Tuesday | Wednesday | Thursday | Friday | | |
| Mixer | 30 | 30 | - | - | - | 60 | 0-30 |
| Five-Gallon Kettle | 30 | 70 | 95 | 60 | - | 255 | 0-95 |
| Twenty-Gallon Kettle | 195 | 100 | 465 | 230 | 160 | 1,150 | 100-465 |
| Sixty-Gallon Kettle | 260 | 470 | - | 185 | 475 | 1,390 | 0-475 |
| Convection Oven | 980 | 705 | 605 | 210 | 535 | 3,035 | 210-980 |
| Rotary Oven | - | 290 | - | - | 105 | 395 | 0-290 |
| Slicer | 60 | 30 | 70 | 15 | 30 | 205 | 15-70 |
| Grill | 120 | - | 190 | 360 | - | 670 | 0-360 |
| Fryer | 250 | - | - | - | - | 250 | 0-250 |
| Chopper | - | 15 | - | 10 | - | 25 | 0-15 |

# APPENDIX E

# FORMS FOR DATA COLLECTION

MASTER FOOD PRODUCT SCHEDULE/FOOD PRODUCT REQUIREMENTS PLAN

ENTREE ____________________

DAYS

| | Menu Cycle I | | | | | | | | | Menu Cycle II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Master Food Product Schedule | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | | | | | | | | | | | | | | |

| Food Product Requirements Plan | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Projected Requirements | | | | | | | | | | | | | | | | | | |
| Actual Requirements | | | | | | | | | | | | | | | | | | |
| Scheduled Product Receipts | | | | | | | | | | | | | | | | | | |
| On Hand | | | | | | | | | | | | | | | | | | |
| Planned Production Order | | | | | | | | | | | | | | | | | | |

Lead Time:

Order Quantity:

Figure E.1. Form for Master Food Product Schedule/Food Product Requirements Plan.

LABOR AND EQUIPMENT REQUIREMENTS PLAN

| ENTREE | Cook | Asst. Cook | Food Service Worker | Mixer | 5-gal Kettle | 20-gal Kettle | 60-gal Kettle | Convect. Oven. | Rotary Oven | Slicer | Grill | Fryer | Food Chopper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| TOTAL | | | | | | | | | | | | | |

Figure E.2. Form for Labor and Equipment Requirements Plan.

MASTER PRODUCTION SCHEDULE

DAYS

| LEAD TIME (DAYS) | ENTREE | Menu Cycle I | | | | | | | | | Menu Cycle II | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |

Figure E.3. Form for master production schedule.

# VITA

Carolyn Sue Unklesbay Lambert was born on November 21, 1947, in Columbia, Missouri. She received an Associate of Arts degree from Stephens College, Columbia, Missouri, in 1967, and a Bachelor of Science degree in Home Economics from the University of Missouri in 1969. Ms. Lambert completed a dietetic internship at the University of Wisconsin Hospitals in June 1970 and received a Master of Science degree in Food Science in August 1971.

Ms. Lambert has worked mainly in academic institutions. She taught one year at the University of Washington, Seattle, and five years in the Pennsylvania State University system where she was Director of the Dietetic Technician Program.

Ms. Lambert is a member of the American Dietetic Association and its state and local affiliates, and the Institute of Food Technologists. She is a member of Omicron Nu and Phi Upsilon Omicron Honor Societies.

She is married to Joseph Michael Lambert, Jr., and has one son, Brian William.