8-1977

A Computer Simulation Model of the Service Component of a Fast Food Operation: Development, Validation, and Use

Sarah Ritchey Jordan
University of Tennessee, Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Sarah Ritchey Jordan entitled "A Computer Simulation Model of the Service Component of a Fast Food Operation: Development, Validation, and Use." 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, D. H. Pike, John M. Larsen,Jr.

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 Sarah Ritchey Jordan entitled "A Computer Simulation Model of the Service Component of a Fast Food Operation: Development, Validation, and Use." 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, Major Professor

We have read this dissertation and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

A COMPUTER SIMULATION MODEL OF THE SERVICE COMPONENT OF A FAST FOOD OPERATION: DEVELOPMENT, VALIDATION, AND USE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee, Knoxville

Sarah Ritchey Jordan

August 1977

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 throughout the development of this study and to David H. Pike, Ph.D., Associate Professor of Industrial Engineering, for his guidance and consultation in the development of the simulation model. Appreciation is expressed, also, to Mary Jo Hitchcock, Ph.D., Professor of Food Systems Administration, and to John M. Larsen, Jr., Ph.D., Professor of Industrial Management, for their suggestions in the development of the study.

Special appreciation is extended to William L. Sanders, Ph.D., Statistician, Agricultural Experiment Station, for his consultation in the statistical analysis, and to D. H. Hutchinson, Ph.D., Associate Professor of Industrial Engineering, for his guidance in the construction and validation of the simulation model.

This research was supported by an Allied Health Traineeship in Administrative Dietetics; 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; and the College of Home Economics, University of Tennessee, Knoxville. Special appreciation is extended to Grayce E. Goertz, Ph.D., Associate Dean, for the flexibility afforded the investigator in scheduling time for the collection, analysis, and interpretation of data.

Appreciation is, also, expressed to the University of Tennessee, Knoxville, Computing Center, especially to Mr. John Boling and to Mr. Don Broach, who provided technical guidance.

The author wishes to thank her parents, Mr. and Mrs. J. M. Ritchey, for their encouragement throughout her educational achievements. Special appreciation is extended to her husband Jim, whose encouragement, understanding, and support made possible the accomplishment of this study.

ABSTRACT

A management tool is needed in the food service industry, especially in the area of fast food service, to generate data on which to base the decision to add menu items which could better meet the nutritional needs of the clientele while maintaining an acceptable margin of profit and meeting service needs of the clientele. A computer simulation model of the service component of a fast food service operation was developed and validated to analyze the influence of an additional menu item on speed of service to the customer and margin of profit realized by management. Data were collected for eight consecutive days in a fast food service operation during peak serving periods. Stopwatch measurements were made of arrival and service times. The composition of the order, number of people in an arrival, and whether the order was to be taken out or eaten in the facility, also, were recorded. The data were analyzed to determine the parameters to be utilized in the simulation model.

General Purpose Simulation System/360 (GPSS) was used to model the system. The composition of the order was simulated according to the independent cumulative distributions of the observed frequency of items in each of four established food categories. The number of people in the arrival and whether the order was to be taken out or eaten in were simulated according to the cumulative distributions of the frequencies observed. The mean interarrival time for each day was used in the model along with the distribution of the interarrival times, all of which were exponential.

The service times were divided into three elements. The observed distribution of element one service times, the time required for placing and paying for an order, was used in the simulation model. Element two, the waiting time of the customer after placement of an order and before receipt of food, occurred only when more than one order was taken by the service personnel before the first order was filled. Element three service times included the time required for the employee to fill the order and give to the customer. Element three service times and the corresponding frequency of items ordered within each food category were used to determine through regression analysis the partial regression coefficients by day of each category of food. The regression equation was used in the model to obtain the simulated element three values.

The distributions and/or the mean values of the simulated data compared favorably with those of the observed data. Simulations of the system with an expanded menu were done on Friday and Monday to determine the effect of an additional menu item on speed of service to the customer and margin of profit realized by the management. Friday evening, with larger orders and longer service and waiting times of the customer, was more sensitive to the addition of a menu item. The addition of fruit to the menu in the simulation model did not negatively alter the various aspects of the queue on Monday. The conclusion was made that the addition of fruit to the menu during the week should be considered by management. Further study of the system on week end days, especially Friday evenings, was recommended to better assess the addition of fruit during that time. Further research was recommended, also, to

identify and quantify other components of the fast food service operation that affect waiting time of the customer and margin of profit realized by management through the collection of refined data over a longer period of time.

TABLE OF CONTENTS

LIST OF TABLES

TABLE | PAGE

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The practice of eating away from home has increased in the past decade in the United States from one meal in four in 1965 to one meal in three in 1976. Vaughn (1976) has predicted that by 1980 approximately one-half of all meals will be eaten away from home.

Several reasons have been given for the increase in away-from-home eating (Call, 1972; Vaughn, 1976; McLamore, 1976). The population has increased in the past decade, resulting in more people to be fed. Family size has decreased, and a smaller family is reported to eat out more often and to spend more money eating out than a larger family. The teenagers of the 1950's and 1960's have maintained their fast food preferences after attaining adulthood. Affluence and changing life styles have favorably influenced eating away from home. Disposable household income is reported to be increasing and an increased number of women in the work force has resulted in families eating out more frequently. The increase in the number, mobility, and supplemental income of persons over 65 has afforded this group greater opportunity for eating out. Increased educational level, increased leisure time and travel, shortened work week, and the trend toward vacations all have provided greater opportunity for eating away from home. Continued urbanization has increased the pool of potential customers, causing the price and quality of the food to be more attractive. Technological developments, especially among chains, have improved efficiency and productivity,

resulting in relatively lower prices for good food away from home.

Concomitant with the increase in away-from-home eating has been the growth in fast food restaurant chains (Vaughn, 1976). McLamore (1976), Chairman of the board of Burger King, stated that much of the credit for promoting the dining out concept to the public should go to the franchise fast food chains. The franchised fast food service establishments featuring a limited menu have shown the greatest growth rate since 1950 (Sherck, 1971).

1.1 IDENTIFICATION OF THE PROBLEM

As fast food chains are moving from the highways into the urban locations, Weiss (1974) has predicted that community participation will become a primary concern of the fast food establishment. The menu itself, Weiss (1974) warned, will be hard hit by community activists interested in nutritional needs being met by the fast food industry.

Questions concerning the effect of ready-prepared foods on total health and nutritional status are being asked by consumers. These questions deal with the safety of the food supply, nutritional quality of the food supply, and the quality of the American diet (Call, 1972). Weiss (1974) reported results of a study by Hoffman-LaRoche which indicated nutrition ranked second to price as a food buying concern. With greater use of ready-prepared foods in fast food service, the consumer is asking for more nutrition information in order to better judge the nutritional quality of what the family eats at home, in the full service restaurant, and in the fast food establishment (Call, 1972; Sherck, 1971; Weiss, 1974).

Nutritional analyses of fast food meals, defined as a specialty item (Big Mac, Whopper or Super Chef), french fries, and vanilla milkshake, showed low amounts of fiber and relatively high amounts of calories and fat content (Goldberg, 1975; Anonymous, 1975; Appledorf, 1974). The researchers differed on their findings for vitamins A and C.

If the objective of a food service operation is consumer satisfaction and optimum margin of profit, with increased consumer cognizance of nutritional excesses and deficits of the food items offered, additional menu items will be needed. Before items can be added to the menu, managers of these units need information concerning costs generated by adding these items and an indication of the patron's continued satisfaction with the quality of food, speed of service and purchase price. Currently, decisions are made based on field studies in a particular location. A new item is introduced and its marketable success is judged by actual sales, the effect of the new items on speed of service, and reaction by the patron to this new item (Detzel, 1976).

Present information from the literature and discussions with an executive of a fast food chain (Detzel, 1976) have indicated that managers of fast food operations do not have a method for generating objective data on which to base the decision of composition of the menu. A management tool is needed to generate data on which to base the decision to add menu items which could better meet the nutritional needs of the clientele while maintaining an acceptable margin of profit and meeting service needs of the clientele.

1.2 PURPOSE OF THE STUDY

The need exists in the food service industry, especially in the area of fast food service, for a management tool that could assist management in making decisions regarding menu composition. The purpose of this study was to:

1. Develop a computer simulation model of the service component of a fast food service operation,

2. Validate the model by comparing simulated data with observed data, and

3. Analyze the influence of an additional menu item on speed of service to the customer and margin of profit realized by management.

CHAPTER 2

REVIEW OF LITERATURE

The technique of simulation and modeling has been used by many researchers in various disciplines. Evidence of simulation of service in a fast food operation, however, was not found in the literature. The service component of a fast food service was recognized as a queueing problem, the type problem with which industrial engineers often deal, using the operations research tool of simulation.

2.1 QUEUEING

A queue is defined as a waiting line (Hillier and Lieberman, 1974; Parish, 1975; Rosenshine, 1975). Queueing problems occur in processes and systems in which customers or transactions arrive at a service facility and must wait in line until served (Meier et al., 1969; Smith, 1968). Researchers have reported that the most common assumption of the statistical pattern by which customers are generated over time is according to a poisson process (Parish, 1975; Hillier and Lieberman, 1974; Meier et al., 1969). Events or arrivals occur randomly but at a particular average rate over a period of time and are equally likely to occur in any one interval of time. The occurrence of one event is independent of the occurrence of another event. A second assumption reported is that the probability distribution of the interarrival times is exponential (Parish, 1975; Hillier and Lieberman, 1974). Interarrival times are defined as the times between

consecutive arrivals. After being generated, the customer enters the queueing system and joins a queue. Periodically, a customer is chosen for service by the established rule for order of service. Some of the orders in which customers are selected for service are first-come-first-served, random, or according to a priority procedure. The service facilities, each of which contains one or more servers, performs the required service for each queue and the customer leaves the queueing system.

Various aspects of a queueing problem might be of interest to the manager and/or researcher. Several of these aspects are the number of servers, service time distribution, arrival distribution, and service discipline on the distribution of queue length, distribution of time in the queue, total time of the customer or transaction in the facility, and utilization of the facility (Meier et al., 1969).

2.2 SIMULATION

Morgenthaler (1961) defined simulation as duplicating the essence of the system or activity without actually attaining reality itself. The dynamic behavior of complex interactive systems can be observed through simulation. As a result, hypotheses, decision rules, and alternate systems of operation can be tested under a number of assumed conditions (Meier et al., 1969). Thus, simulation is the use of a model to represent over time essential characteristics of a system or process under study. Manipulation of the model can be done in ways that are impossible or impractical to perform in the real system. Inferences can then be drawn from the behavior observed in the model to

the actual system. Meier et al. (1969) reported that time is a universal characteristic of simulation models. Simulation models are distinguished from other mathematical models by the fact that in simulation, behavior of the system is described over time and one has the ability to observe this behavior. Simulation has wide applicability in business such as production control systems, inventory control systems, service facilities, and customer behaviors. Simulation techniques and mathematical models have been used to study in the food service industry the movement of customers through a cafeteria (Beach and Ostenso, 1969; Knickrehm et al., 1963; Ostenso et al., 1965); food procurement (Matthews and David, 1971); and inventory management (Blondeau and David, 1971; Montag and Hullander, 1971).

The following four steps can be identified in the process of applying simulation (Rupli, 1973; Smith, 1968): (1) defining clearly the objectives to be attained, including the isolation, definition, and quantification of important features of the system to be simulated; (2) constructing a mathematical model simple enough to permit easy experimentation and yet thorough enough to include the relevant aspects of the business situation being simulated and programming this model for the computer; (3) validating the model to insure correct functioning; and (4) running the model to simulate the effects of various proposed system configurations and, thus, assessing relative costs and benefits.

Computer simulation is fast, accurate, and increases the amount of detail that can be handled (Collier, 1973). Many types of mathematical formulas exist for the various simulation techniques (Meier et al., 1969). Because most require considerable record keeping, a

computer can replace tedious hand computation. The objective of computer simulation is to provide data which enable management to make decisions on a rational basis (Bucatinsky, 1973).

Classification of Simulation Models

Simulation models have been classified in a number of ways, although no single classification has been complete (Bucatinsky, 1973; Emshoff and Sisson, 1970; Lucas, 1976; Shannon, 1975). Lucas (1976) reviewed and categorized the various kinds of models into three dichotomous groups: empirical vs rational models; deterministic vs stochastic; and dynamic vs steady state. These categories were not described as mutually exclusive.

Empirical and rational models were differentiated by the explanation that empirical models are descriptive mathematical forms whose distributions fit observed data; rational models are causal mathematical forms obtained by reasoning from facts and insights about the structure and behavior of the system. With the rational models, underlying forces and mechanisms are taken into account where feasible, affording definite interpretation of the parameters.

Lucas (1976) stated that outputs of a model could be explainable or unexplainable. Only the explainable aspects are noted in a deterministic model; whereas, both explainable and unexplainable aspects are handled in a stochastic model. The degree of explainable variability is related to the degree of logic and how completely exploited is the knowledge about the system. In a deterministic model outputs are expressed as functions only of particular identified variables and associated parameters. By specifying probability distributions from which parameters

and variables of a deterministic form are regarded as samples of the population, stochastization can be obtained.

The interaction of inputs and side conditions with system state has been noted to influence outputs and changes of system state. Dynamic models are described as those that take into account changing system state, as well as inputs and outputs. A system that approaches equilibration is said to be steady-state. In such a system a certain state with certain output rates is approached or a periodic pattern of variation in state and outputs occurs. As a result, output rates and state can be expressed as functions of input rates and side conditions and of parameters which reflect constant system properties.

2.3 SIMULATION LANGUAGES

Simulation languages, termed special-purpose languages, are designed to solve a certain type problem, as compared to general-purpose languages, such as FORTRAN and COBOL, designed to solve a broad class of problems (Shannon, 1975). The development of simulation languages has evolved since the late 1950's. The advantages and disadvantages of general-purpose and special-purpose languages were outlined by Shannon (1975). General-purpose languages have the advantage of having a minimal number of restrictions imposed on format of output and are languages in which people are frequently already knowledgeable. General-purpose languages, however, require longer programming time and do not have a feature by which simulation language terms are debugged. In contrast, special-purpose languages require less programming time; provide more comprehensive error checking techniques; provide a brief, direct vehicle for expressing the concepts of the simulation; are able to construct and

furnish user subroutines essential to any simulation routine; automatically generate data necessary for simulation runs; facilitate collection and display of data generated; and control management and allocation of computer storage during the simulation run. Disadvantages given for special-purpose languages were the necessity of adhering to output format requirements of the language, reduced flexibility in models, and increased computer running time.

Two distinct types of special-purpose digital simulation languages developed separately: simulation of discrete-change and continuous-change processes. Various categories of languages, each containing several languages, were developed under each type. Meier et al. (1969) stated that the best known and most frequently used simulation languages are Dynamo, Simscript, and General Purpose Simulation System (GPSS). Dynamo is an example of a language that simulates a continuous-change process. Dynamo was characterized by Shannon (1975) as a language helpful in modeling variables continuous in value but discrete in time. Dynamo uses an equation structure with an orientation around aggregate rates of flow and levels rather than around transactions as in GPSS. Meier et al. (1969) described Dynamo as less flexible than GPSS, for it lacked the ability to go outside the standard block operations and existing equation forms.

Simscript and GPSS are examples of languages that simulate a discrete-change process. The former represents the statement-oriented school of thought and the latter, the flow-chart symbols. Simscript language is reported to require knowledge of computer programming, unlike GPSS and Dynamo. The system to be simulated in Simscript is defined in

terms of entities, attributes of the entities, attributes of the system, and sets. Simscript is termed an event-oriented language (Shannon, 1975).

The developers referred to GPSS as a program rather than a language, because the user of GPSS does not write computer programs in the traditional sense. GPSS has the capability of simulating a great variety of systems in which the flow of transactions through a series of processing functions is the principle feature (Meier et al., 1969; Emshoff and Sisson, 1970).

GPSS is represented in terms of specialized blocks through which transactions move in time through a system and whereby actions are executed (Shannon, 1975; International Business Machines Corporation, 1971; Meier et al., 1969). The essential components of the system in GPSS are facilities, storages, and queues. Certain statistics regarding facility utilization, storage utilization, queue contents, and number of transactions flowing through the blocks of the system are automatically compiled and printed. Additional information can be collected and printed in table form and "savevalues" according to the needs of the user (Meier et al., 1969). The blocks are used in the flow chart and contain the message to be programmed in the model. All times in the GPSS model are expressed as integers (International Business Machines Corporation, 1971; Meier et al., 1969).

Shannon (1975) reported that while easier to learn, flow-chart languages (GPSS) were less flexible than statement-oriented languages (Simscript). On the other hand, Meier et al. (1969) pointed out the flexibility of GPSS through the use of multiple transactions, facilities

storages, and queues in model construction. In a survey conducted by Kleine (1971), users rated ten simulation languages. GPSS was ranked first in ease of the use of the language, second as the preferred language, and fourth in the category of capability of the language. The structure of GPSS has been noted to be quite applicable to queueing problems (Meier et al., 1969).

2.4 METHODS TO GENERATE DATA

Two methods were found for the generation of time data in a fast food service operation. Predetermined motion times and stop-watch time study have been used in various aspects of industry including food service.

Predetermined Motion Times

Methods Time Measurement (MTM). MTM was developed by Maynard et al. (1948) through analysis of motion pictures of industrial operations. In the study, 16 mm film was used with sixteen frames per second. The equivalent of 1/16 second expressed in a decimal hour is approximately 0.00001, the value of one Time Measurement Unit (TMU). This value is 1/100,000 of an hour. The relationship of 1 TMU to a minute and a second are 0.0006 and 0.036, respectively. In 1 hour, 1 minute, and 1 second there are 100,000; 1,670; and 28 TMU, respectively. MTM consists of the classification of all manual motions into seven categories, each of which is subdivided into several additional categories. Each subcategory is assigned a time expressed in time measurement units. A major advantage of MTM is its precision which contributes to its

success as a tool for measuring short-cycle, highly repetitive work. The feasibility of using such predetermined motion-time techniques was evaluated by Beach and Ostenso (1969) to accurately determine performance times for elements of entree serving cycles. The mean element times determined by MTM were found to be equivalent to those determined by stopwatch time study. Disadvantages of MTM were noted as very time consuming, difficult, and expensive when applied to long-cycle activities. A simpler time standard was created.

Master Standard Data (MSD). An outgrowth of Methods Time Measurement, MSD was developed by Crossan and Nance (1972). MSD was based on the same measurement unit, TMU, but consisted of only seven basic elements and no subcategories. The principle feature was an alpha-mnemonic coding scheme to simplify memory of the elements comprising the time units. Although less precise, MSD was found to be accurate, consistent, and economical to use. Several studies have dealt specifically with the establishment and/or use of time standard codes in food production (Montag et al., 1964; Ruf and Matthews, 1973; Waldvogel and Ostenso, 1977a and 1977b). MSD was utilized in all three studies.

Stopwatch Time Study

Antis (1971) defined time study as a procedure used to measure the time required by a qualified operator working at the normal performance level to perform a given task in accordance with a specified method. A tool of work measurement, stopwatch time study has been used in the food service industry to determine the time required to do work

(Coffey et al., 1964; Heinemeyer and Ostenso, 1968; Beach and Ostenso, 1969; Knickrehm et al., 1963; Ostenso et al., 1965).

Initially, the operation to be observed should be subdivided into smaller elements that can be studied and timed separately. An element has been defined by Antis (1971) as a subdivision of an operation that is distinct, measurable, and contains a logical portion of the work.

Various tools are required for time study. Three types of time study watches are used primarily: the decimal minute watch, the decimal hour watch, and the split-second watch (Antis, 1971). A time study or observation form is needed. Such a form should be developed so that its arrangement facilitates the recording of times and provides space for marginal notes. Such a form would then allow the observer to tell the complete story of events being observed. A thin board, light in weight, is needed to hold the time study form(s) and watch(es).

Two principal methods of reading the watch when conducting a time study are the snapback method and the continuous method (Antis, 1971). When the continuous method is utilized, every event that occurred during the study can be recorded sequentially and, thus, provide information on each instant of the study. The recording of elements performed out of the normal sequence is facilitated by using the snapback method. Objection to the snapback method has been voiced in lost time when the watch was snapped back to zero. Multiple watches, however, have been used to overcome this objection.

CHAPTER 3

PROCEDURE

The initial purposes of this research were to build and validate a computer simulation model for the service component of a fast food operation. The model was then used to analyze the influence of an additional menu item on speed of service to the customer and margin of profit realized by management.

Stopwatch time study was used to generate data primarily because of the greater ease of its use in a commercial operation. The continuous method was used to time the arrival of customers to provide a sequential recording of arrival times so that interrival times could be determined. The snapback method was used to time the service elements which were often performed out of the normal sequence. The General Purpose Simulation System was selected as the special-purpose language to be used in this study to simulate the service component of the fast food operation observed. The applicability of GPSS to queueing problems was the major consideration in the selection.

3.1 DESCRIPTION OF THE SYSTEM

The manager of a group of local units of a national franchise was approached to obtain permission to

1. Draw the layout of the service area of a local unit, and
2. Use the local unit to record arrival time of customers and to measure service time.

The drawing of the layout assisted in describing the system. The time data were required to study the distribution of the real data and to provide the framework for development and validation of the computer simulation model.

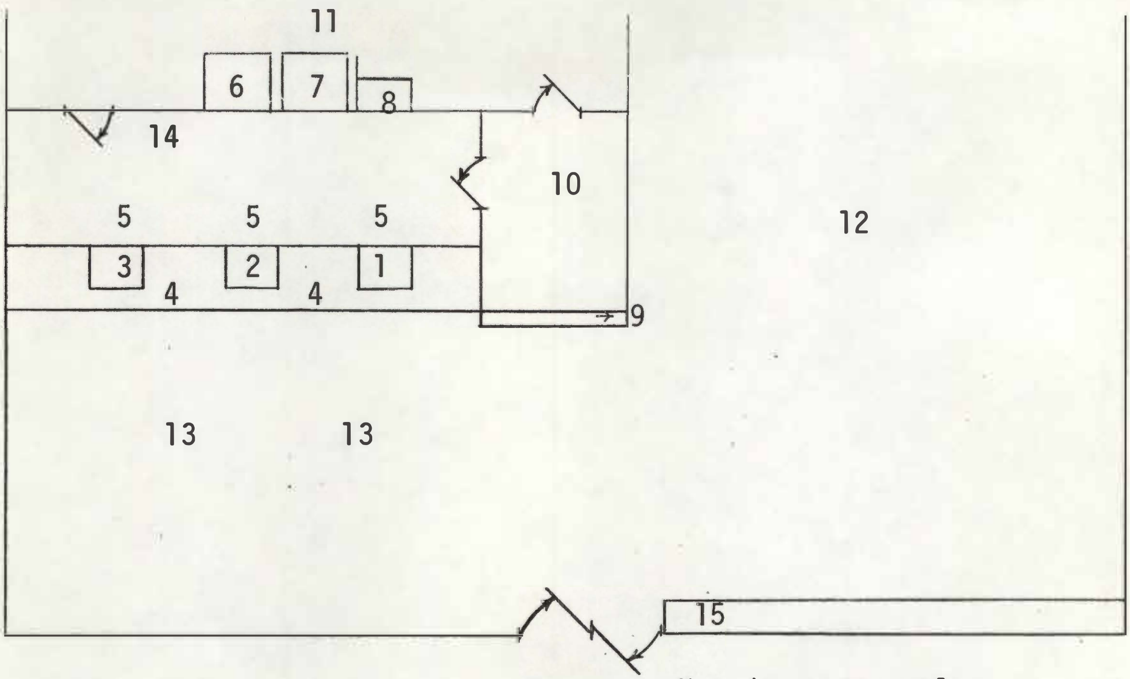
The system contained three cash registers, designated 1, 2, 3 in Figure 3.1, from which three service queues formed. Food was prepared by production personnel in area 11 and placed according to category on a pickup counter. For example, all kinds of burgers were placed under infrared lights on the pickup counter, area 7, and all kinds of beverages on the pickup counter designated as area 6.

The service personnel, stationed in area 5, called out each item of a customer's order. This signaled production personnel to begin preparation of the item and/or to place it on the pickup counter. Condiments were kept under the service counter (area 4) and were placed on the tray or in the sack if the customer ordered salt, pepper, or catsup. Napkins and straws were kept between the service area and the dining area in area 9 and were obtained by the customer while waiting for or after receiving the order.

3.2 METHODOLOGY

Audit Trail Data

In the establishment observed, considerable information was computerized and available on the cash register tape. The registers were computer programmed to provide profile information on customers served, such as, the number of orders placed, the number and type of food items per order, whether the order was "take out" or "eat in,"



Not drawn to scale.

KEY:

1 - Cash Register No. 1
2 - Cash Register No. 2
3 - Cash Register No. 3
4 - Service Counter
5 - Area in which service personnel were stationed
6 - Beverage area of pickup counter
7 - Sandwich (Burger) area of pickup counter
8 - French Fry and Onion Ring area of pickup counter
9 - Area where napkins and straws were kept
10 - Manager's Office
11 - Preparation Area
12 - Dining Area
13 - Area of queue formation for service
14 - Area where Investigator 1 stood and observed
15 - Area where Investigator 2 sat and observed

Figure 3.1. Service Area of a Fast Food Operation.

and the clock time at which each order was placed. The tapes on all three cash registers were marked at the beginning and end of each observation period. After each observation period was completed, the tapes were removed and the data recorded on a form developed for this purpose (Form D.1).

Preliminary Study

Over a two-week period a preliminary study of the system was undertaken to identify and define the elements to be measured and to refine the forms developed for recording the data. Sample data were collected during one-to two-hour observation periods on five different days to determine the logistics of the study and the number of observers required. The elements of service were defined initially to encompass only one or two actions; however, the time of some of the actions was short and difficult to time. For this reason and because the sequence of the actions was consistent, several actions were combined, resulting in three elements of service.

The stopwatches to be used in collecting the time data of arrival and service were selected. A Meylan continuous decimal minute stopwatch was selected to time the arrival of customers. To record the service times a Heuer-Leonidas snap-back decimal minute stopwatch was chosen. Both were calibrated to 1/100 of a minute.

Arrival Times

Actual arrival times were recorded on Form D.2 within the two-hour observation period. Using a continuous stopwatch with a maximum range of 30 minutes, the observer timed arrivals for

four consecutive 30 minute periods, starting each time at 0.00 minutes and ending at 30.00 minutes. Interarrival times were calculated by taking the difference between each arrival time recorded and the arrival time preceding it. With each recording of an arrival time, a tally was made of the number of people in the arrival. While observer one was measuring service times, observer two was concurrently recording arrival times.

Service Times

The definitions for three elements of service evolved as a result of the preliminary observation. All three elements were recorded throughout each two-hour period of observation using Form D.3 for elements one and two and Form D-4 for element three.

Element one. This element began when the employee said, "May I help you?" The employee then rang up each item on the cash register as it was ordered, tallied the order, called out the items over the microphone to the production personnel, reached for the customer's money, made change and gave it to the customer, and closed the cash register drawer. The sequence of performance usually occurred in this order. Occasionally, the last two were reversed. Element one ended with either making change and giving it to the customer or closing the cash register drawer.

Element two. This element was the waiting time of the customer in a second queue. When the system was full, a management policy instructed the employee to take up to three orders before filling the

order for the first customer. This policy resulted in the formation of a second queue after one to three orders were placed and before the food was received by the customers. Occasionally, during peak periods, these queues increased to four or five people. However, when the system was not full, element two was usually zero. If no one were waiting, the service personnel, after giving change to a customer and/or closing the cash register drawer, picked up a tray or sack and went to the pickup counter to get the food for that customer, signaling the beginning of element three. Element two for a particular customer began after the closing of the cash register and/or the giving of change to that customer and ended when the service personnel picked up a tray or sack and went to the pickup counter to get the order for that customer.

Element three. Element three began after the employee closed the cash register drawer and/or gave change to the customer. Timing of the element started when the employee reached for a sack or tray and/or walked to the pickup counter. The employee then placed the items ordered in a sack(s) or on a tray(s), sometimes waiting at the pickup counter for various items. The employee then returned to the counter, gave the order to the customer, asked if they'd like condiments (salt, pepper, catsup), and then said, "Thank you." Element three was thought to be a function of the number and composition of items ordered. Correlating the audit trail information with specific stop-watch time readings in the preliminary observation was not feasible. Therefore, food items were tallied by category while timing the third element of service. Six categories were established: burgers, beverages,

french fries, onion rings, dessert a and dessert b. These categories coincided with the arrangement of food items on the pickup counter. For example, all burgers were in one section and all beverages in another (Figure 3.1).

A schematic diagram (Figure 3.2) depicts the sequencing of the three elements of service for three customers, all of whom placed their orders before the first customer received his/her food. The waiting time, element two, of the first customer included the time required for the next two customers to place their orders (element one). The waiting time of the second customer included the time required for the third customer to place his/her order (element one) and the time required for the first customer to receive his/her food (element three).

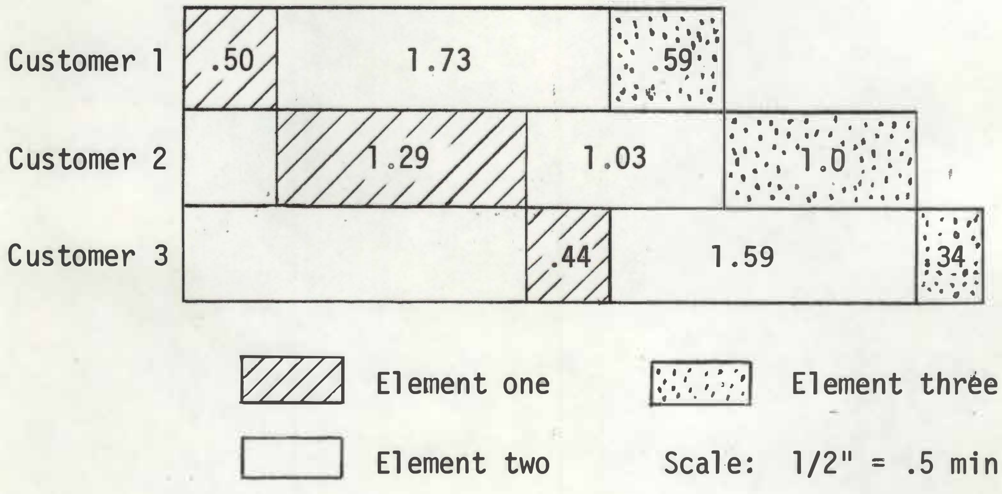


Figure 3.2. Schematic Diagram Depicting Sequencing of the Three Elements of Service for Three Customers in Minutes.

The waiting time (element two) of the third customer included the time required for the first two customers to receive their food (element three). These elements were timed consecutively during 120 minute observation periods. A set of three snap-back stopwatches were used. The watches were arranged on a board and synchronized through mechanical linkage to result in continuous timing of short elements.

<u>Observation Period</u>

Observations were made on week ends and weekdays during peak periods as designated by the manager of the unit and confirmed by preliminary study. The periods of observation were:

Monday through Thursday - 11:00 a.m. - 1:00 p.m.
Friday - 5:30 p.m. - 7:30 p.m.
Saturday - 12:00 noon - 2:00 p.m.

Eight consecutive days of observation were made beginning and ending on Friday evening. Eight days were chosen to provide data for four days each of week end and weekday observation.

Two observers collected the data. One stood in area 14 (Figure 3.1) to record service times and to tally the categories of items selected. The other observer sat at a counter at the entrance to area 15 (Figure 3.1) to record arrival times and to tally the number in each arrival.

3.3 STATISTICAL ANALYSIS

<u>Audit Trail Data</u>

Audit trail data were analyzed in two ways: (1) The frequency of the number of items in each food category was obtained by day from

the cash register audit trail data, and (2) all the combinations of food items ordered each day were listed with frequencies noted for each combination. Independent cumulative distributions of the frequency of items in each category were deemed appropriate for the simulation for two reasons:

1. The number of combinations of food items ordered during the two-hour observation period was quite high. Approximately one-half of the observed orders on weekdays and two-thirds of those on week ends were of combinations ordered only once. The number of frequencies for many of the order compositions was deemed too low to provide a feasible approach to simulation, although joint distributions of food items were recognized by the investigator as probably real.
2. Management of any fast food service is not confined to particular combinations of an order, but rather must take the order as given by the customer and fill it in as short a time as possible. Merchandising would have an influence on items selected by the customer, but merchandising was not an aspect of this study.

To determine independence across day, the frequency of items was evaluated by chi square contingency tables. If significant, the overall chi square value was partitioned in an attempt to identify the source of differences. The distributions for those days that were not significantly different were combined, cumulated, and used in the simulation model.

Information concerning whether the order was to be taken out or eaten in was obtained from the audit trail data. Percentages of these orders were determined for use in the simulation model. The composition of food items in orders to be eaten in was compared with that in orders to be taken out.

Arrival Times

Interarrival times were computed from the arrival times. The range of interarrival times was determined for each period of observation and divided into ten equal intervals. The frequency of interarrival times during each interval was plotted, using the upper limit point of the interval. The Kolmogorov-Smirnov test was used to test the goodness of fit of each day's distribution of interarrival times with that of an assumed theoretical distribution, using the following complement of the cumulative probability (Hillier and Lieberman, 1974):

$$P \{ T > t \} = e^{-\lambda t}$$

where:

P = Probability

T = Interarrival time

t = Interval of time

e = Natural logarithm base which is approximately 2.7183

λ = Mean arrival rate.

Mean interarrival times for each day were calculated to be used in the simulation model.

The frequency of the number of people in each arrival was derived for each day observed. To determine independence across day, the frequency of the number in an arrival was evaluated by chi square

contingency tables. If significant, the overall chi square was partitioned in an attempt to identify the source of differences. The distributions for those days that were not significantly different were combined, cumulated, and used in the simulation model.

Service Times

Element one. Since no *a priori* evidence of specific statistical distributions was available, the range of times observed each day was divided into ten equal intervals. The probability of occurrence within each interval was estimated empirically and was used in the simulation model. The frequency of element one time values falling within each interval was plotted, using the upper limit point of the interval. Mean values for element one service times were calculated for each day.

Element two. The simulation model, given the interarrival time, distribution of interarrival times, and the service times obtained from the system observed, had the capability of indicating the time in the second queue or element two. Thus, element two values were not used in developing the simulation model. However, the mean and standard deviation of the observed values were calculated for comparison with the values obtained in the simulation.

Element three. The frequency of element three service times was plotted for each day. The range of times observed was divided into ten equal intervals and the frequency of element three falling within each interval was plotted, using the upper limit point of the intervals.

The Kolmogorov-Smirnov test was used to test the goodness of fit of the observed values with an assumed theoretical distribution.

The total service time of an order was analyzed by multiple regression to enable the prediction of service times from the combinations of items ordered. After the initial multiple regression analysis, the categories of pie and ice burger were omitted. The sample sizes of these two categories in this study were deemed to be insufficient to provide definitive evaluation of the effect of pie and ice burger on service time. The relationships between service time and composition of order was estimated separately through multiple regression analysis for each day. On examination of the residual variance by Bartlett's test, heterogeneity was observed. In addition, the magnitude of the partial regression coefficients was observed to be different among days. Therefore, after consideration of both findings, day by day analysis was deemed the appropriate approach.

CHAPTER 4

RESULTS AND DISCUSSION

The procedure presented in Chapter 3 was used to generate and to analyze data required to build a computer simulation model of the service component of a fast food operation. From this analysis, estimates of the parameters necessary for the model were determined and were subsequently compared with the simulated data to validate the model.

4.1 AUDIT TRAIL DATA

The frequency by category of food ordered for each day was estimated from data obtained from the audit trail tapes. In Table 4.1 chi square statistics resulting from contingency table analyses of the frequency of food items by category obtained from audit trail data for the observation periods are shown. Except for the distribution of frequency of onion rings ordered on the four week end days, the frequencies of all other categories ordered on weekdays and week end days were significantly different.

The variation in frequency of beverages ordered on the week end was relatively more significant than the variation in burgers and french fries ordered on those four days. The greater significance in variation of number of beverages ordered might be explained, in part, by the differences in percent of zero ("0") beverage orders or percent of orders containing no beverages (Table 4.2). Friday I and Friday II had greater percentages of "0" beverage orders than did Saturday and

TABLE 4.1

CHI SQUARE STATISTICS RESULTING FROM CONTIGENCY TABLE ANALYSES OF THE FREQUENCY OF FOOD ITEMS BY CATEGORY OBTAINED FROM AUDIT TRAIL DATA FOR THE OBSERVATION PERIODS IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

	Four Weekdays	Four Week end Days	Two Friday Nights
Categories	X^2	X^2	X^2
Burgers	25.99*	26.40$^+$	2.53
Beverages	21.27*	47.01**	1.61
French Fries	21.83*	19.65$^+$	1.14
Onion Rings	8.94*	4.57	2.75

*Significant at $P \leq .05$.

**Significant at $P \leq .001$.

$^+$Significant at $P \leq .10$.

TABLE 4.2

COMPARISON OF SELECTED AUDIT TRAIL DATA FOR THE OBSERVATION PERIODS IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

Days	Total Orders Number	"O" Beverage Orders Percent	"Take Out" Orders Percent	"O" Beverage "Take Out" Orders Percent
Week End Days				
Friday I	179	33.5	84.9	33.5
Saturday	198	17.7	57.6	17.2*
Sunday	144	25.7	57.6	25.7
Friday II	214	37.4	78.0	37.4
Weekday Days				
Monday	176	31.8	73.3	30.7*
Tuesday	159	18.2	58.5	17.6**
Wednesday	177	14.7	63.8	14.7
Thursday	222	26.6	68.0	25.7**

*The "Eat In" orders with "O" beverages contained french fries, onion rings, and/or dessert items.

**The "Eat In" orders with "O" beverages contained burger(s), french fries, and onion rings.

Sunday. Friday I and Friday II, also, had a greater percentage of "take out" orders than did the other two days of the week end. All of the "0" beverage orders on Friday I and II were "take out" orders. In comparing the week end days and the weekdays, the percentages of "0" beverage orders of the four week end days were more divergent than were the percentages of the four weekdays. In addition, a slightly greater number of "0" beverage orders were eaten in the food service on the four weekdays.

The categories of food ordered (Table 4.1) on the two Friday nights were not significantly different, indicating an influence of day, in some respect, on the combinations of orders placed. The number in the group and the activities of the evening culminating a work or school week may have influenced the composition of orders.

4.2 ARRIVAL TIMES

The statistics of the observed interarrival times of customers by day are shown in Table 4.3. The distribution of the frequency of interarrival times for each day was not significantly different from the assumed theoretical exponential distribution for that day. The goodness of fit of the distribution of the frequency of observed interarrival times on Friday II and Monday with the assumed theoretical exponential distribution is shown in Figures A.1 and A.2, respectively, as two representative days. The plots of the other six days are on file in the Department of Food Science, Nutrition and Food Systems Administration at the University of Tennessee, Knoxville. The

TABLE 4.3

STATISTICS OF THE OBSERVED INTERARRIVAL TIMES OF CUSTOMERS BY DAY IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

Days	Observations Number	Range Minutes	Mean Minutes	Standard Deviation Minutes
Friday I	166	0.02-04.56	0.712	0.736
Saturday	176	0.02-03.37	0.682	0.679
Sunday	137	0.02-03.74	0.874	0.756
Monday	121	0.01-06.49	0.989	1.093
Tuesday	135	0.01-10.42	0.889	1.329
Wednesday	140	0.02-08.27	0.856	0.997
Thursday	144	0.02-11.69	0.833	1.171
Friday II	172	0.02-03.73	0.697	0.629

arrivals met the criteria for constituting a poisson process (Hillier and Lieberman, 1974).

Chi square statistics resulting from contingency table analyses of the number of people observed in an arrival are shown in Table 4.4. The difference in distribution of frequencies was significantly different when all eight days were compared. However, when the four weekdays were compared as a group and the four week end days were compared as a second group, the distributions of the frequencies within both groups were not significantly different. The differences in weekday and week end patterns of the number in an arrival were observed. Families and larger groups were eating out on the week ends; whereas, singles and groups of two stopped at a fast food service during the week. Arrivals with one and two people accounted for 87% to 93% of

TABLE 4.4

CHI SQUARE STATISTICS RESULTING FROM CONTINGENCY TABLE ANALYSES OF THE NUMBER OF PEOPLE OBSERVED IN AN ARRIVAL IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

Comparisons	Chi Square Values
All days of observation	37.21*
Four weekdays	6.85
Four week end days	10.38

*Significant at $P \leq .05$.

the arrivals on weekdays, compared with 76% to 82% of the arrivals on week ends. Arrivals with more than three people accounted for only 3% to 6% of the arrivals on weekdays, but 5% to 12% of the arrivals on week ends.

4.3 SERVICE TIMES

Element One

The statistics of the observed element one service times by day are shown in Table 4.5. The four highest mean values were observed on week end days. Data indicated that larger orders were placed on the week end and the investigator observed that more children gave the order on week ends and appeared somewhat slower in giving the order of their family or group than an adult might have been. Friday I and Friday II had the largest means with Sunday being third and Saturday being fourth. The means for the four weekdays ranged from 0.594 to 0.677. The standard deviations for all eight days varied from 0.222 for Monday to 0.412 for Sunday. Except for Saturday, the standard deviations were larger for the four week end days than for the four weekdays. Various factors were observed which influenced the element one service times. Special orders would take longer at times for the employee to obtain the information from the customer and note it on the cash register tape. Sometimes the customer would take somewhat longer in paying for the order, especially if giving exact change and paying only with change. In turn, the employee would organize the change for placement in the drawer. Another cause for a longer time for element one was the employee's need to get change for a large bill from the assistant

TABLE 4.5

STATISTICS OF THE OBSERVED ELEMENT ONE SERVICE TIMES BY DAY IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

Days	Observations Number	Range Minutes	Mean Minutes	Standard Deviation Minutes
Friday I	37	0.24-1.75	0.823	0.357
Saturday	65	0.28-1.32	0.686	0.260
Sunday	59	0.17-2.60	0.735	0.412
Monday	70	0.21-1.48	0.594	0.222
Tuesday	59	0.29-1.67	0.677	0.292
Wednesday	68	0.20-1.24	0.606	0.238
Thursday	66	0.22-2.10	0.637	0.289
Friday II	60	0.19-1.62	0.740	0.306

manager. On occasion, the customer might change his/her mind on an item and reorder, causing element one to be lengthened.

A comparison of the cumulative distribution of frequencies of observed element one service times on Friday II and Monday with the cumulative normal distribution is shown in Figures A.3 and A.4, respectively. Examination of the plots of these two representative days indicated that a multimodal distribution existed. Such multimodality existed for all eight days and might be explained by the occurrence of a normal distribution for slower service times and a separate normal distribution for faster times. An effect was believed to be influencing the distribution of element one time values. Such an effect was attributed to day in this research; however, the determination of the specific aspects of day causing such an effect was not within the scope of this investigation. The plots of the other six days are on file in the Department of Food Science, Nutrition and Food Systems Administration at the University of Tennessee, Knoxville.

Element Two

The statistics of the observed element two values by day are given in Table 4.6. The mean values ranged from 0.703 on Wednesday to 1.267 on Friday II. Except for Friday I, the means and standard deviations were larger for the four week end days than for the four weekdays. The smaller mean on Friday I might be explained, in part, by the small sample of times obtained for that day.

Element Three

The statistics of the observed element three service times by day are shown in Table 4.7. The goodness of fit of the distribution

TABLE 4.6

STATISTICS OF THE OBSERVED ELEMENT TWO VALUES
BY DAY IN THE SERVICE COMPONENT
OF A FAST FOOD OPERATION

Days	Observations Number	Range Minutes	Mean Minutes	Standard Deviation Minutes
Friday I	37	0.00-3.10	0.764	0.948
Saturday	65	0.00-3.98	1.215	1.023
Sunday	59	0.00-4.38	0.896	1.095
Monday	70	0.00-3.42	0.865	0.884
Tuesday	59	0.00-2.64	0.766	0.738
Wednesday	68	0.00-3.62	0.703	0.770
Thursday	66	0.00-3.15	0.834	0.788
Friday II	60	0.00-5.32	1.267	1.091

TABLE 4.7

STATISTICS[a] OF THE OBSERVED ELEMENT THREE SERVICE TIMES BY DAY IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

Days	Observations Number	Range Minutes	Mean Minutes	Standard Deviation Minutes
Friday I	25	0.27-2.75	1.255	0.461
Saturday	73	0.10-2.38	0.666	0.516
Sunday	57	0.09-3.96	0.938	0.438
Monday	70	0.10-4.17	0.521	0.252
Tuesday	61	0.11-2.38	0.575	0.350
Wednesday	64	0.15-2.55	0.677	0.443
Thursday	64	0.12-1.55	0.574	0.248
Friday II	61	0.09-4.65	1.070	0.637

[a]Statistics of element three service times that did not obtain dessert a and/or dessert b.

of the frequency of observed element three service times on Friday II and Monday with the assumed theoretical exponential distribution is shown in Figures A.5 and A.6, respectively.

The distributions of frequencies for each day, except Tuesday and Thursday, were not significantly different from the assumed theoretical exponential distributions (Figures A.7 and A.8). On both Tuesday and Thursday the number of frequencies in the first interval was less than the number in the second interval, causing the difference of the cumulative percentage of frequencies in the first interval from one to be greater than on most of the other days; thus the percentage notation for the first interval approximated or slightly exceeded the limits of the theoretical distribution. The percentage noted for all other intervals fell within the limits. On Thursday a busload of 95 people arrived during the two hours of observation. Although the service times of the orders of the busload were not timed, the presence of the 95 people in the system congested the queueing area and influenced the time required to fill orders for others in the system. Some of the element three times of service appeared to be lengthened somewhat, falling into the second interval rather than the first. The presence of a busload of 95 people could have conceivably caused the slight increase which, in turn, altered the distribution slightly. Apparently, a similar phenomenon occurred on Tuesday, although it was not obvious to the observer. The change may have been due to the make-up or configuration of production personnel. The arrival of customers may have affected service, if the arrivals were more sporadic than constant. Tuesday and Thursday had the greatest range of interarrival times, 0.01 to 10.42 and 0.02 to 11.69, respectively, indicating a somewhat sporadic

arrival of customers (Table 4.3, page 31). The total number of arrivals for these two days was similar to that of the other two weekdays. Such sporadic arrivals could result in periods when the system was full and, in turn, caused the time of element three to be lengthened slightly and fall in the second interval, rather than the first. The plots of the other days are on file in the Department of Food Science, Nutrition and Food Systems Administration at the University of Tennessee, Knoxville.

A second possible explanation for a slightly longer element three value might be performance of the employee in response to the demands of the system. When the system was full, the employees may have been motivated to be more productive; when customers arrived sporadically, the employees may have relaxed somewhat and lowered the level of productivity.

Another possible explanation of a slightly longer element three could be the fact that with sporadic arrivals and a resulting unfilled system the employee probably waited at the pickup counter for the items ordered, rather than taking the order of a second customer. Thus, time allocated to element two when the system was full was allocated to element three when the system had fewer customers.

Simulated element three service times were predicted from a regression model whose partial regression coefficients had been determined from the observed element three service times and corresponding frequency of items in each food category. The partial regression coefficients were determined from the following model:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + E$$

Where:

Y = Observed element three service time for each order

a = Intercept

b_1 = Partial regression of Y on number of burgers

X_1 = Number of burgers ordered

b_2 = Partial regression of Y on number of beverages

X_2 = Number of beverages ordered

b_3 = Partial regression of Y on number of french fries

X_3 = Number of french fries ordered

b_4 = Partial regression of Y on number of onion rings

X_4 = Number of onion rings ordered

$E = Y - \hat{Y}$, where $\hat{Y}$ = Estimated value of element three.

The estimated values of the partial regression coefficients by food category in the regression model for the eight days observed are presented in Table 4.8. Coefficients of determination are given for each day to reflect the variation in time which has been explained by the regression model. Thus, for the two samples obtained on Friday I and Friday II about 56% of the variation in time was explained by the regression equation. Saturday and Tuesday only had about 22% and 33%, respectively, of the variation in service time explained by the regression equations for the respective days.

Behavior was observed that appeared to have influenced the time of element three. Special orders, such as mustard and pickle only, increased service time if the service employee had to wait on production. During very hectic times of service with many customers in queues awaiting service, special orders were called out over the microphone to production personnel immediately after the customer said the item,

TABLE 4.8

ESTIMATED VALUES OF THE PARTIAL REGRESSION COEFFICIENTS BY FOOD CATEGORY IN THE REGRESSION MODEL FOR THE EIGHT DAYS OBSERVED FOR DETERMINATION OF THE SIMULATED ELEMENT THREE SERVICE TIMES IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

	Partial Regression Coefficients					Coefficient of Determination
Days	a (Intercept)	b_1 (Burgers)	b_2 (Beverages)	b_3 (French Fries)	b_4 (Onion Rings)	(R^2)
Friday I	0.169	0.314	0.104	0.029	-----*	0.5639
Saturday	0.311	-0.001	0.116	0.169	-0.256	0.2238
Sunday	0.203	0.213	0.017	0.070	0.466	0.5795
Monday	0.276	-0.040	0.093	0.131	0.273	0.7730
Tuesday	0.189	0.232	-0.037	0.011	0.264	0.3346
Wednesday	0.162	0.150	0.125	-0.019	1.095	0.5127
Thursday	0.086	0.162	0.112	0.067	0.290	0.5168
Friday II	-0.005	0.206	0.243	0.103	0.620	0.5604

*No onion rings were in the orders that were observed and timed for element three values.

rather than after the entire order was placed. This was an effort by service personnel to eliminate excessive service times. The management policy of taking a maximum of three orders before filling the first order sometimes resulted in the service employee's waiting at the pickup counter for one or more items. In hectic times the production personnel might not hear a special order, necessitating repeating the order and increasing the total time of element three. If all the customers had had their orders taken, the service employee might wait at the pickup counter for an order, thus, increasing the time attributed to element three, rather than having that time applied to the waiting time in the second queue, element two.

Onion rings were not continuously prepared as were french fries but were dropped into the fryer when the service personnel called out the item as the customer placed his/her order. The production of onion rings occurred in the same area as french fries and had to be rotated into the fryer. Once fried, the onion rings were usually placed with tongs in the bag one or two at a time, rather than being scooped up with a specially designed tool as were french fries.

Other factors were recognized as possible influences on element three service times, such as daily management decisions concerning the configuration of production and/or service personnel. For example, a change to less experienced personnel preparing burgers, beverages, or onion rings could increase production and assembly time of that category and, in turn, cause a delay in service. Skill level variation as to length of time on the job and degree of training could influence service

times. Management decisions could cause changes to occur in all aspects of production and service such that the composition of employees scheduled was altered in all stages of production and service.

CHAPTER 5

SIMULATION OF THE SYSTEM

Using the GPSS/360, a model was developed to simulate the service component of the fast food operation described in Chapter 3. Estimates of the parameters of the model were determined as a result of stopwatch time data collected. To determine the validity of the generalized model developed, estimates of the parameters from observed data were compared with those of the simulated data. Simulations of the system with an expanded menu were done for two days to determine the effect on speed of service to the customer and margin of profit realized by management.

5.1 LOGIC OF THE SIMULATION

The time unit of the simulation was 1/1000 of a minute to allow for rounding off of time units to the nearest hundredth of a minute, the unit of time used in the collection of data for establishing the parameters. The logic used in building the computer simulation model is depicted in Figure B.1, and is illustrated using the parameters of Friday II.

"Gate NU" blocks were used to test if each of the three facilities (cash registers) were not in use. Two queues were designated for each facility to simulate the formation of the second queue at each facility when more than one order was taken before the first customer was served. To simulate the management policy of taking up to three orders

when the queues were long before the first order was filled, a series of "test" blocks, "logic switches" and a "gate LR" block were used. The first series follows the "release 1" block of queue 1 and precedes the "queue 2" block. If all three facilities were being used, a series of "test" blocks were used to determine the shortest queue for the entering transaction to join. The series of "test" blocks were named BEE, BOP, BBB, SAS, HOW, and SOC.

Ten parameters were utilized by the model. The first two parameters contained the values for the number of people in the arrival and whether the order was taken out or eaten in. In the next four parameters were the number of burgers, beverages, french fries, and onion rings ordered, respectively. Parameters 7, 8, and 9 contained the element one, two, and three service times, respectively. The value of "fvariable 3" was stored in parameter 10.

A 6% margin of profit after taxes was assumed. Average prices were determined for each category of food. These were $.90, $.30, $.30, and $.40 for the four categories of burgers, beverages, french fries, and onion rings, respectively. The corresponding assumed 6% margin of profit was $.054, $.018, $.018, and $.024 for each category, respectively. These profit values were referenced in variable 2. The margin of profit of each order was cumulated in "savevalue 10" and the total for the period of observation was printed. Alterations in this value and the corresponding changes in speed of service were evaluated when variations were made in the system.

Audit Trail Data

Cumulative distributions of the burgers, beverages, french fries, and onion rings obtained from the audit trail data were recorded in functions 4, 5, 6, and 7, respectively. In turn, the numbers in these functions were assigned by "assign" blocks to parameters 3, 4, 5, and 6, respectively, of each transaction generated. These values were summarized in Tables 4, 5, 6, and 7, respectively, in the simulation model. The "tabulate" block and the corresponding table definition cards referenced the entities of each table. The cumulative distributions of "take out" and "eat in" orders were recorded as 0 and 1, respectively, in function 3 and were subsequently assigned to parameter 2. To simulate the logic of "0" beverage orders being "take out" orders, a "test" block preceded the assignment of a 0 or 1 to parameter 2. The order was designated "take out" if the order contained no beverages. If the order contained one or more beverages, parameter 2 was assigned a 0 or 1 according to the percentage of "eat in" and "take out" orders observed in the remaining orders. These values were summarized in Table 3 of the simulation model. The "tabulate 3" block and "table 3" definition card referenced the entities of the table.

Arrival Times

The arrivals were generated with a "generate" block according to the mean calculated from the sample data obtained for the day being simulated and the cumulative distribution of an exponential distribution of a population. The interarrival times were recorded in Table 1 according to the distribution of the observed data. The "tabulate 1" block and the "table 1" definition card referenced the table entities.

Cumulative distributions of the number of people in each arrival were recorded in function 2 and subsequently assigned with an "assign" block to parameter 1. These values were summarized in Table 2 of the simulation model. The "tabulate 2" and "table 2" definition card referenced the table entities.

Service Times

Element one. The cumulative distributions of the observed values of element one were recorded in function 20, which, in turn, was used in the "advance" blocks of queues 1, 3, and 5. The "advance" block was preceded by a "mark" block and followed by a "tabulate" block to summarize element one service times in Table 8 of the simulation model. The "tabulate 8" and "table 8" definition card referenced the entities of the table.

Element two. The distributions of the observed values of element two, the waiting time of the customer in an imaginary second queue after placement of an order and before receipt of the food, were not used as one of the parameters of the model. The time in these queues, as well as the waiting time of the customer before placement of an order, was calculated by the simulation model, given the interarrival times and distribution and the element one and element three service times. The "queue" blocks for queues 2, 4, and 6 were preceded by a "mark" block and the "depart" block of each queue was followed by a "tabulate" block to summarize element two values in Table 10 of the simulation model. The "tabulate 10" and "table 10" definition card referenced the

entities of the table. Values generated from this component of the model were compared with those observed.

Element three. The regression formula derived from the observed data was referenced in variable 1. The observed element three values were normally distributed about the regression line. To obtain the variance of each simulated value comparable to the observed data, the standard deviation of the observed data was multiplied times a random number obtained from a normal distribution (Snorm function) with a mean of 0. Variable 1 was added to the variance in "fvariable 3"; "fvariable 3" was referenced in parameter 10 which was used in the "advance" blocks of queues 2, 4, and 6. The "advance" block was preceded by a "mark" block and followed by a "tabulate" block to summarize element three service times in Table 9 of the simulation model. The "tabulate 9" and "table 9" definition card referenced the entities for the table.

Theoretically, the values of parameters 3, 4, 5, and 6 could all be 0, since a probability for 0 of each food category existed. With a negative intercept, the value of this variable would then be a negative number. A negative or zero time in a queue was not logical for a transaction entering the queue. In reality, a person could enter a queue and not give an order for food if someone else in the party gave the order for one or more people. It was decided that such individuals would take one to three seconds of time to walk by the cash register. Thus, a "test" block was used before the "advance" block of queues 2, 4, and 6 to test if variable 1 were greater than

0. If not, these transactions were advanced 2 ± 1 seconds (.033 ± .017). These "test" blocks were named LIK, LOK, and ADD.

5.2 COMPARISON OF SIMULATED AND OBSERVED DATA

Chi square statistics resulting from contingency table analyses of the frequencies of simulated data with the frequencies of observed data are shown in Table 5.1. The simulated data were not significantly different from the observed data for the following categories: the number of burgers, beverages, french fries, and onion rings ordered, the number of people in an arrival, whether the order was "take out" or "eat in," the interarrival times, and the element one service times. The means and standard deviations for the interarrival times and the element one service times were similar for observed and simulated data for each day (Tables 5.2 and 5.3).

The distributions of the observed and simulated element two values were statistically different for all days except one (Table 5.1). The mean values of simulated data for element two were less than that for the observed data for all days, although the simulated data approximated more closely the observed data on the two Fridays (Table 5.4). The major differences appeared to be caused primarily by delays observed in production. Some of the delays were due to the placement of special orders requiring production after ordering; others were delays in production due to variations in productivity. The orders on Friday evening were observed to be more varied in the frequency and number of food items than on any of the other days. The production personnel

TABLE 5.1

CHI SQUARE STATISTICS RESULTING FROM CONTINGENCY TABLE ANALYSES OF THE FREQUENCIES OF SIMULATED DATA WITH THE FREQUENCIES OF OBSERVED DATA FOR THE OBSERVATION PERIODS IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

	Categories of Data Distribution									
	Number Burgers Ordered	Number Beverages Ordered	Number French Fries Ordered	Number Onion Rings Ordered	Number People In Each Arrival	Number "Take Out" and "Eat In" Orders	Inter-arrival Times	Element One Service Times	Element Two Service Times	Element Three Service Times
Day	x^2	x^2	x^2	x^2	x^2	x^2	x^2	x^2	x^2	x^2
Friday I	0.58	3.34	1.97	0.34	1.65	0.01	4.14	0.51	1.13	2.78
Saturday	1.79	2.59	1.57	1.10	1.71	0.01	3.69	4.05	53.10*	15.72*
Sunday	3.22	3.06	2.37	0.22	2.13	1.20	1.23	2.86	27.17*	5.14
Monday	0.60	1.34	0.41	0.65	0.84	0.61	2.67	1.69	64.30*	12.23*
Tuesday	0.29	2.76	0.54	0.00	0.65	0.74	7.35	2.55	89.85*	6.27
Wednesday	0.18	1.45	0.52	1.41	1.02	0.19	1.93	4.11	69.34*	12.90*
Thursday	0.22	2.67	0.34	1.35	1.80	0.04	0.46	1.43	74.48*	4.76
Friday II	0.60	2.41	2.38	2.19	1.71	0.00	3.52	1.31	78.73*	17.15*

*Significant at $P \leq .05$.

TABLE 5.2

COMPARISON BY DAY OF SIMULATED AND OBSERVED INTERARRIVAL TIMES IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

	Observed		Simulated		Differences Observed to Simulated
	Mean	Standard Deviation	Mean	Standard Deviation	
Day	minutes	minutes	minutes	minutes	per cent
Friday I	0.712	0.736	0.783	0.702	+10.0
Saturday	0.682	0.679	0.641	0.595	- 6.0
Sunday	0.874	0.756	0.894	0.706	+ 2.3
Monday	0.989	1.093	0.983	0.946	- 0.6
Tuesday	0.889	1.329	1.002	0.863	+12.7
Wednesday	0.856	0.997	0.903	0.820	+ 5.5
Thursday	0.833	1.171	0.843	0.787	+ 1.2
Friday II	0.697	0.629	0.720	0.690	+ 3.3

TABLE 5.3

COMPARISON BY DAY OF SIMULATED AND OBSERVED ELEMENT ONE SERVICE TIMES IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

	Observed		Simulated		Differences Observed to Simulated
	Mean	Standard Deviation	Mean	Standard Deviation	
Day	minutes	minutes	minutes	minutes	per cent
Friday I	0.823	0.357	0.807	0.334	- 1.9
Saturday	0.686	0.260	0.715	0.257	+ 4.2
Sunday	0.735	0.412	0.804	0.374	+ 9.4
Monday	0.594	0.222	0.594	0.241	0.0
Tuesday	0.677	0.292	0.732	0.303	+ 8.1
Wednesday	0.606	0.238	0.648	0.231	+ 6.9
Thursday	0.637	0.289	0.667	0.248	+ 4.7
Friday II	0.740	0.306	0.745	0.290	+ 0.7

TABLE 5.4

COMPARISON BY DAY OF SIMULATED AND OBSERVED ELEMENT TWO TIME VALUES IN THE SERVICE COMPONENT OF FAST FOOD OPERATION

	Observed		Simulated		Differences Observed to Simulated
	Mean	Standard Deviation	Mean	Standard Deviation	
Day	minutes	minutes	minutes	minutes	per cent
Friday I	0.764	0.948	0.762	1.328	- 0.3
Saturday	1.215	1.023	0.547	1.080	-55.0
Sunday	0.896	1.095	0.300	0.706	-66.5
Monday	0.865	0.884	0.120	0.408	-86.1
Tuesday	0.766	0.738	0.087	0.443	-88.6
Wednesday	0.703	0.770	0.112	0.425	-84.1
Thursday	0.834	0.788	0.134	0.456	-83.9
Friday II	1.267	1.091	1.189	1.730	- 6.2

appeared to anticipate a busier serving period on Friday evenings. Perhaps management was better able to forecast demand on Friday evening and/or the employees were motivated to be more productive on these evenings. These factors would need to be studied in future research but were not part of the scope of this study.

The distributions of the observed and simulated element three service times were statistically different for four of the eight days (Table 5.1). However, the mean and standard deviation of the simulated element three service times were very similar to the mean and standard deviation for the corresponding observed data for all eight days (Table 5.5). Element three values were simulated with the regression formula derived from the observed time values and the corresponding composition of that order (category of food items and frequency of each category). The failure of the distributions of the observed element three service times to approximate the simulated data for all days can be explained, in large part, by the decision to model the composition of the simulated order on the observed independent cumulative distributions of each of the four categories of food items, rather than on the cumulative distributions of the orders. Thus, the composition of simulated orders when analyzed as an order rather than as separate items could have differed from the observed orders in frequency of items within a category and combinations of categories, although the independent percentages and frequency distribution of each food item was not significantly different from the observed data. Thus, the distribution of simulated element three time values could differ from the observed element three values, since these values were derived from the

TABLE 5.5

COMPARISON BY DAY OF SIMULATED AND OBSERVED ELEMENT THREE SERVICE TIMES IN THE SERVICE COMPONENT OF A FAST FOOD OPERATION

	Observed		Simulated		Differences Observed to Simulated
	Mean	Standard Deviation	Mean	Standard Deviation	
Day	minutes	minutes	minutes	minutes	per cent
Friday I	1.255	0.461	1.225	0.640	- 2.4
Saturday	0.666	0.516	0.860	0.518	+29.1
Sunday	0.938	0.438	0.988	0.572	+ 5.3
Monday	0.521	0.252	0.625	0.396	+20.0
Tuesday	0.575	0.350	0.589	0.361	+ 2.4
Wednesday	0.677	0.443	0.816	0.612	+20.5
Thursday	0.574	0.248	0.525	0.269	- 8.5
Friday II	1.070	0.637	1.340	0.733	+25.2

regression formula, whereby the partial regression coefficients for each category of food was multiplied times the number of items ordered in each category.

5.3 SIMULATION OF THE SYSTEM WITH AN EXPANDED MENU

The next objective was to simulate the system to reflect an expanded menu. Given the linear model which was estimated from multiple regression of the observed data as a basis for the simulation, this model was expanded by adding one other variable to reflect an additional menu item. To facilitate this objective certain assumptions were necessary. These assumptions were as follows:

1. The variable to be added, fruit, was independent of the other four variables, burgers, beverages, french fries, and onion rings.
2. In each simulation the magnitude of the coefficient was sequentially set to be equal to that for burgers, beverages, french fries, and onion rings, respectively.
3. In each simulation the distribution of the frequency of the number of fruit ordered was sequentially set to be equal to that for burgers, beverages, french fries, and onion rings, respectively.

Simulations were done on two days, a week end day and a day during the week. Friday II was chosen for several reasons. Data were collected on two consecutive Fridays, and the distribution of each category ordered on the two Fridays was not significantly different. The coefficient of determination (R^2 value) for Friday II was 0.56,

and the number of observations on Friday II was greater than on Friday I. Monday was chosen as a representative weekday because of its high coefficient of determination, 0.77.

Fresh fruit was the item chosen to be added to the menu. The price of the fruit was set at $.20. With an assumed 6% margin of profit after taxes, a profit of $.012 was realized for each piece of fruit selected by a customer. The constant, .012, was placed in variable 2 and multiplied times the number of fruit ordered. The total value of variable 2 for each transaction was cumulated in "savevalue 10" to provide the total margin of profit realized for the period of simulation.

The cumulative distribution assumed for the number of fruit was recorded in function 10. The random number generated by function 10 was assigned to parameter 12. These values were summarized in Table 11. The "tabulate 11" block and "table 11" definition card referenced the entities of the table. Element one which consisted of the customer's giving the order to the employee, the employee's calling out the order to the service personnel, taking the money, and making change, was assumed to be only marginally affected. Thus, element one was not altered in the simulation of the system with an expanded menu.

Simulation of Friday II

The average percent utilization of the three service facilities (cash registers) was increased for all simulations; most reached maximum capacity (Table C.1). The average percent utilization of the service facilities in two of the simulations was similar to the average percent utilization of the service facilities

before the menu was expanded; these similarities occurred when the coefficient of fruit was equal to the partial regression coefficient of french fries and the distribution of the number of fruit ordered was equal to that for beverages and for onion rings. The average time per transaction in each of the three service facilities, the average for all element one and element three values, was not greatly altered by any of the simulations (Table C.2). The greatest variation was an increase in two-thirds of a minute at service facility one. A better insight into changes occurring in the system with each simulation can be obtained by comparing element three service times and the waiting time of the customer.

The change in the mean time required for service (element three) and the corresponding percent change in margin of profit were the largest when the coefficient of fruit was equal to the partial regression coefficient for onion rings, except when the distribution of the number of fruit ordered was, also, equal to that for onion rings (Tables C.3 and C.4). The partial regression coefficient for onion rings was the largest of the four categories. As a result of the large proportion of time allocated to fruit when its coefficient was equal to that of onion rings, the average time per transaction (customer) in all six queues and the maximum number of customers that did accumulate were unrealistically long and, thus, unfeasible (Tables C.5 and C.6).

The service times that were most similar to the simulated system with the original menu occurred primarily in two ways: (1) when the distribution of the number of fruit ordered was equal to that for onion

rings, i.e. when only 15% of the orders contained fruit; and (2) when the coefficient of fruit was equal to the partial regression coefficient of french fries, i.e. when the unit service time of fruit was low (Table C.3). The margin of profit for these simulations approximated in two cases and increased in the others the margin of profit realized by the system before the fruit was added (Table C.4). When the distribution of the number of fruit ordered equalled that of burgers and the coefficient of fruit equalled the partial regression coefficient of french fries, the margin of profit increased approximately 26% (Table C.4), while the average time for service increased only 0.114 minutes or 8.5% (Table C.3). The average time per transaction (customer) awaiting service (queues 1, 3, and 5) increased five times (Table C.5). The number in queues 1, 3, and 5 increased, also (Table C.6). In addition, the time spent by the customer and the number of customers waiting to receive the food (queues 2, 4, and 6) increased (Tables C.5 and C.6).

The configuration that caused the smallest increase in service time and in waiting time for the customer and provided an approximate 11% increase in margin of profit occurred when the distribution of fruit equalled that of beverages and the coefficient of fruit equalled the partial regression coefficient of french fries (Tables C.3, C.4, and C.5). The service time increased 0.080 minutes. The waiting time increased 0.799 minutes for queue 1, and remained approximately the same for queues 3 and 5. The maximum queue length was not altered (Table C.6). Zero or two beverages were ordered most frequently. Orders with one beverage were third in frequency. The partial regression coefficient of french fries was low. Thus, if the

distribution of fruit ordered were equal or similar to that of beverages and the contribution to service time were minimal, fruit could be a profitable addition to a fast food service operation, while not altering appreciably the waiting time of the customer and the time required for service and at the same time, providing an initial step to satisfy an increasing consumer wish for a more varied menu.

Simulations of Monday

The average percent utilization of the three service facilities was only negligibly altered by any of the simulations (Table C.7). None of the facilities was fully utilized in the simulation of the system as observed; the average percent utilization of facilities 1, 2, and 3 were 0.575, 0.324, and 0.189, respectively. The average time per transaction (customer) in each of the three service facilities or the average element one and element three service times of each customer, was not greatly altered in any of the simulations (Table C.8). The largest variation was approximately one-fifth of a minute.

The simulations of the system on Monday with the expansion of the menu to include fruit resulted in minimal effects on the speed of service to and the waiting time of the customer while resulting in a 1.6% to 12.4% increase in margin of profit realized for the two-hour period simulated (Tables C.9, C.10, and C.11). The greatest increase in the mean time required for service was the simulation in which the distribution of the number of fruit ordered equalled that of burgers and the coefficient of fruit equalled the partial regression coefficient of onion rings (Table C.9). The increase, however, was only approximately one-third of a minute. The total service time, when the negative

partial regression coefficient of burgers was used as the coefficient of fruit, remained approximately the same. In addition, the total service time was not measurably changed when the distribution of fruit equalled that of onion rings, i.e. when only 7% of the orders contained fruit.

The percent change in the margin of profit was greatest when the distribution of fruit was equal to that for burgers or for french fries (Table C.10). These two distributions had a smaller percentage of orders with zero fruit ordered; thus, more orders contained fruit and the amount of profit was increased slightly.

On an average, the waiting time of the customer in the queue was not altered to any degree (Table C.11). As discussed in section 5.2 of this chapter, the waiting time in queues 2, 4, and 6 was considerably less in the simulation of the system with the original menu than when times were obtained by stopwatch measurements. The reason for this discrepancy on all days except Friday was thought to be due primarily to delays in production especially when special orders were placed. The maximum number in the queues in the simulation of the system with an expanded menu approximated the maximum number when the system as observed was simulated (Table C.12). Thus, according to the data obtained, the addition of fruit to the menu on Monday would not measurably increase the time of service nor the waiting time of the customer and would provide some increase in profit.

CHAPTER 6

CONCLUSIONS, RECOMMENDATIONS, AND SUMMARY

Quite applicable to analysis of queue formation, General Purpose Simulation System/360 (GPSS) was shown to be an effective tool for modeling the service component of a fast food operation. The data collected before construction of the model provided basic information for managers of and researchers in food systems administration. These data allowed the estimation of the parameters in the model.

6.1 CONCLUSIONS

Basic data were obtained regarding various aspects of the service component of a fast food operation. The frequencies by category of food ordered were specific to the day of the week. The distributions of the frequencies by category of food ordered on the two Friday nights were not significantly different. The ordering of a beverage(s) appeared to be a function of whether the order was to be taken out or eaten in the establishment. The arrivals met the criteria for a poisson process; the distribution of the frequency of interarrival times was exponential. Differences were noted in weekday and week end patterns of the number in an arrival; larger groups were noted on the week end days observed.

The mean element one service times were larger on the week end days. Occurrences which were observed to have influenced the element one service times were noted. The distributions of the frequencies of

element one service times appeared to be multimodal; slower service times appeared to have a normal distribution and faster times, a different normal distribution. The effect causing the multimodality was not determined in the scope of this study.

The waiting time of the customer after the placement of an order and before receipt of the food was greater, for the most part, on week ends than during the week. Except for two days, the distributions of the overall frequency of element three time values were exponential. Sporadic arrivals of customers on those two days were believed to have affected the distributions, causing fluctuation in demands on production and productivity of production and service personnel.

Partial regression coefficients were determined by day for each category of food items. The percent of variation in time explained by the regression equations varied for each day. Behavior was noted that appeared to have influenced the variation in element three values.

Simulations of the system with an expanded menu were done on the parameters of Friday evening and Monday noon to determine the effects of an additional item (specified as fruit) to the menu. Friday evening with larger orders and longer service and waiting times of the customer was more sensitive to the addition of an item. Analysis of the variations indicated that, given the system on the week end day observed, the configurations of the addition of fruit could be profitable to management if the unit service time of fruit were low and the frequency of the number ordered were similar to that for beverages, i.e., approximately

36% contained zero fruit; 19% of the orders had one fruit; 25%, two fruits; 14%, three fruits; and 6% had more than three fruits.

The addition of fruit to service from 11:00 a.m. to 1:00 p.m. on Monday, given the configuration of the system on that day, did not measurably increase the time of service nor the waiting time of the customer in any of the simulations. In addition, an increase in margin of profit was noted.

Thus, when the service component of a fast food operation was studied, the addition of fruit to the menu through simulation indicated that the various aspects of the queue were not negatively altered on Monday, while the margin of profit increased. The impact of the addition of fruit on a Friday evening, however, had more of a negative effect on waiting time of the customer.

Although simulations were done only on Monday, the service times and distributions of the number of people arriving on the four days during the week were comparable. Thus, the addition of fruit to the menu should be seriously considered by management for the four week days, because such an addition appears to be profitable, to maintain current speed of service, and to provide a less calorically dense item with more fiber. Evidence appears, also, to exist from the simulations of the system with an expanded menu that the addition of fruit on Friday evening may be profitable to management and desirable to the customer. Such advantages, also, may be obtained from the addition of fruit on the other days of the week end, since the service times and the distributions of the number of people arriving on these days were comparable.

6.2 RECOMMENDATIONS

The simulation model developed can be utilized in future research as the basic component to which more refined data are applied to achieve a more dynamic model. The model, also, can be used at the graduate level to demonstrate and to provide experience with the management tool of simulation.

The simulated data compared favorably with the observed data with two exceptions: the element two values, the waiting time of the customer after placement of an order and before receipt of food, and the element three time values, the time required to fill an order. The lack of comparison of element two values and their distributions was attributed primarily to delays in production; such delays were observed to be caused by placement of a special order that required production after ordering and by variations in productivity. The aspects of production and productivity were not within the scope of this study. In addition, the effects of the configuration of employees and management decisions were not considered in this study. All these factors are recognized by the researcher as essential components that ultimately affect service. The data collected indicated that variation in elements within a day and variation of times from day to day did occur. Observations were noted as to possible causes for some of these variations. Additional research is needed to identify and to quantify these other aspects of the various components of a fast food service operation that affect the waiting time of the customer and margin of profit realized by management.

The distribution of the frequencies of the simulated element three values varied from those of the observed values, although the mean service times were comparable. This variation was attributed to the necessity for using the independent cumulative distributions. The number of combinations of food items ordered during the two-hour observation period was high; approximately one-half of the sample orders on weekdays and two-thirds of those on week ends were observed to be ordered only once. The number of frequencies for many of the order compositions was deemed too low to provide a feasible approach to simulation, although joint distributions of food items were recognized by the investigator as probably real. Observation in a fast food operation over a longer period of time could provide a sufficient data base to simulate the composition of an order according to the cumulative distribution of the combinations of food items.

The addition of fruit to the menu was concluded to be apparently profitable and desirable during the week and possibly advantageous on Fridays and the other days of the week end. Additional study in which refined data collected over a longer period of time and obtained on additional aspects of the system are needed.

6.3 SUMMARY

Away-from-home eating has increased in the past decade as has the growth in fast food restaurant chains with a limited menu. Consumers concerned about nutritional quality, also, may want fast service. A management tool is needed in the food service industry, especially in the area of fast food service, to generate data on which to base the

decision to add menu items which could better meet the nutritional needs of the clientele while maintaining an acceptable margin of profit and meeting service needs of the clientele.

The purpose of this study was to develop and validate a computer simulation model of the service component of a fast food service operation and to analyze the influence of an additional item on speed of service to the customer and margin of profit realized by management. Data were collected for eight consecutive days in a fast food service operation during peak serving periods, as defined by the manager and confirmed by preliminary study. The data were analyzed to determine the parameters to be utilized in the simulation model.

General Purpose Simulation System/360 (GPSS) was used to model the system. The composition of the order was simulated according to the independent cumulative distributions of the frequency of items in each category. Whether the order was to be taken out or eaten in was simulated according to the cumulative distributions of the frequencies observed. The mean interarrival time for each day was used in the model along with the distribution of the interarrival times, all of which were exponential.

The service times were divided into three elements. Element one consisted of the customer's placing an order and the employee's calling out the order to production personnel, taking the money and making change. The observed distribution of element one service times was used in the simulation model. Element two comprised the waiting time of the customer after placement of an order and before receipt of food; this element occurred only when more than one order was taken by the

service personnel before the first order was filled. These observed values were not used in the simulation model, because in GPSS, given the mean interarrival time and distribution and service times, the number of transactions (customers) and the time in a queue builds up over time according to the occurrences within the system. Element three consisted of the employee's picking up a sack or tray, walking to the pickup counter, filling the order, returning to the counter, and giving the order with the requested condiments to the customer. Element three service times and the category and corresponding frequency of items ordered within each category were used to determine through regression analysis the partial regression coefficients by day of each category of food. The regression equation was used in the model to obtain the simulated element three values.

The distribution of the frequencies of the simulated data was not significantly different from that of the observed data for all categories across all eight days, except for elements two and three. The variations in element two distributions were believed to be due primarily to various aspects of production which were not within the scope of this study. Although the distribution of the frequency of simulated element three values of four days differed significantly from those of the observed values, the means for both sets of data were comparable. The variations in the distributions were attributed to the decision to model the composition of the simulated order on the observed independent cumulative distribution of each of the four categories of food items, rather than on the cumulative distributions of the orders.

Simulations of the system with an expanded menu were done on two of the days to determine the effect of an additional menu item on speed of service to the customer and margin of profit realized by the management. Friday and Monday were the days on which these simulations were made. Friday evening with larger orders and longer service and longer waiting times of the customer was more sensitive to the addition of a menu item. The addition of fruit to the menu in the simulation model did not negatively alter the various aspects of the queue on Monday. The conclusion was made that the addition of fruit to the menu during the week should be considered by management. Further study of the system on week end days, especially Friday evenings, was recommended to better assess the addition of fruit during that time. Further research was recommended, also, to identify and quantify other components of the fast food service operation that affect waiting time of the customer and margin of profit realized by management through the collection of refined data over a longer period of time.

LIST OF REFERENCES

LIST OF REFERENCES

Anonymous. 1975. How nutritious are fast-food meals? Cons. Rep. 40(5):278.

Antis, W. 1971. Stopwatch time study. In Maynard, H. B., ed. "Industrial Engineering Handbook," 3rd ed., p. 3-12. McGraw-Hill Book Co., New York.

Appledorf, H. 1974. Nutritional analysis of foods from fast-food chains. Food Technol. 28(4):50.

Beach, B. L. and Ostenso, G. L. 1969. Entree serving times. Relationship of serving time to system capacity. J. Amer. Dietet. Assoc. 54:290.

Blondeau, L. and David, B. D. 1971. Choosing from alternatives in expanding storage space for frozen food. J. Amer. Dietet. Assoc. 59:362.

Bucatinsky, J. 1973. Ask your computer 'what if. . . .' Finan. Exec. 41(7):56.

Call, D. L. 1972. The changing food market--nutrition in a revolution. J. Amer. Dietet. Assoc. 60:384.

Coffey, C. A., Spragg, D., McCune, E. and Gordon, R. 1964. Continuous time study shows how scheduled time is spent. Hospitals, J.A.H.A. 38(4):96.

Collier, R. J. 1973. Simulation of computer systems. An introduction. Mgt. Accting. 54(11):45.

Crossan, R. M. and Nance, H. W. 1972. "Master Standard Data," 2nd ed. McGraw-Hill Book Co., Inc., New York.

Detzel, D. 1976. Personal communication. Chicago, Ill.

Emshoff, J. R. and Sisson, R. L. 1970. "Design and Use of Computer Simulation Models," The MacMillan Co., New York.

Goldberg, J. 1975. The fast food phenomenon. Fam. Health. 7(4):38.

Heinemeyer, J. M. and Ostenso, G. L. 1968. Food production materials handling. Labor needed by centralized and conventional methods. J. Amer. Dietet. Assoc. 52:490.

Hillier, F. S. and Lieberman, G. J. 1974. "Operations Research," 2nd ed. Holden-Day, Inc., San Francisco.

International Business Machines Corporation. 1971. "General Purpose Simulation System/360 User's Manual," International Business Machines Corporation, White Plains, N.Y.

Kleine, H. 1971. A second survey of users' views of discrete simulation languages. Simulation. 17(2):89.

Knickrehm, M. E., Hoffman, T. R. and Donaldson, B. 1963. Digital computer simulations of a cafeteria service line. J. Amer. Dietet. Assoc. 43:203.

Lucas, H. L., Jr. 1976. Formulation and role of input-output models in animal production. Presented at the 1st International Symposium on Feed Computerization of Diets, July 11-16, at Logan, Ut.

Matthews, M. E. and David, B. D. 1971. Effect of varying the number of entree selections in the hospital menu. Evaluation of four hypothetical purchasing methods. J. Amer. Dietet. Assoc. 59:575.

Maynard, H. B., Stegemerten, G. J., and Schwab, J. L. 1948. "Methods-Time Measurement," McGraw-Hill Book Co., Inc., New York.

McLamore, J. W. 1976. The future of the restaurant industry. Cornell HRAQ 17(1):2.

Meier, R. C., Newell, W. T., and Pazer, H. L. 1969. "Simulation in Business and Economics," Prentice-Hall, Inc., Englewood Cliffs, N.J.

Montag, G. M. and Hullander, E. L. 1971. Quantitative inventory management. J. Amer. Dietet. Assoc. 59:356.

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.

Morgenthaler, G. W. 1961. The theory and application of simulation in operations research. In Ackoff, R. L., ed. "Progress in Operations Research," Vol. 1, p. 363. John Wiley and Sons, Inc., New York.

Ostenso, G. L., Moy, W. A., and Donaldson, B. 1965. Developing a generalized cafeteria simulator. Application to interactions of food systems. J. Amer. Dietet. Assoc. 46:379.

Parish, C. C. M. 1975. On the application of queueing theory to analysing on-line computing systems. Computer J. 18(2):117.

Rosenshine, M. 1975. Queueing theory: the state-of-the-art. AIIE Transactions. 7(3):257.

Ruf, K. and Matthews, M. E. 1973. Production time standards. Application of Master Standard Data is best way to determine food service production time standards. Hospitals, J.A.H.A. 47(9):82.

Rupli, R. G. 1973. How to improve profits through simulation. Mgt. Accting. 55(5):16.

Shannon, R. E. 1975. "Systems Simulation. The Art and Science," Prentice-Hall, Inc., Englewood Cliffs, N.J.

Sherck, C. K. 1971. Changes in food consumption patterns and their relation to R & D, retail sales, food service, and nutrition. Food Technol. 25:914.

Smith, J. 1968. "Computer simulation models," Hafner Publ. Co., New York.

Vaughn, C. L. 1976. Growth and future of the fast food industry. Cornell HRAQ 17(3):31.

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

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

Weiss, E. B. 1974. Fast service and the urban location challenge. Instit. Vol. Fdg. 74(4):17.

APPENDICES

APPENDIX A

DISTRIBUTION OF THE FREQUENCIES OF TIMES OBSERVED

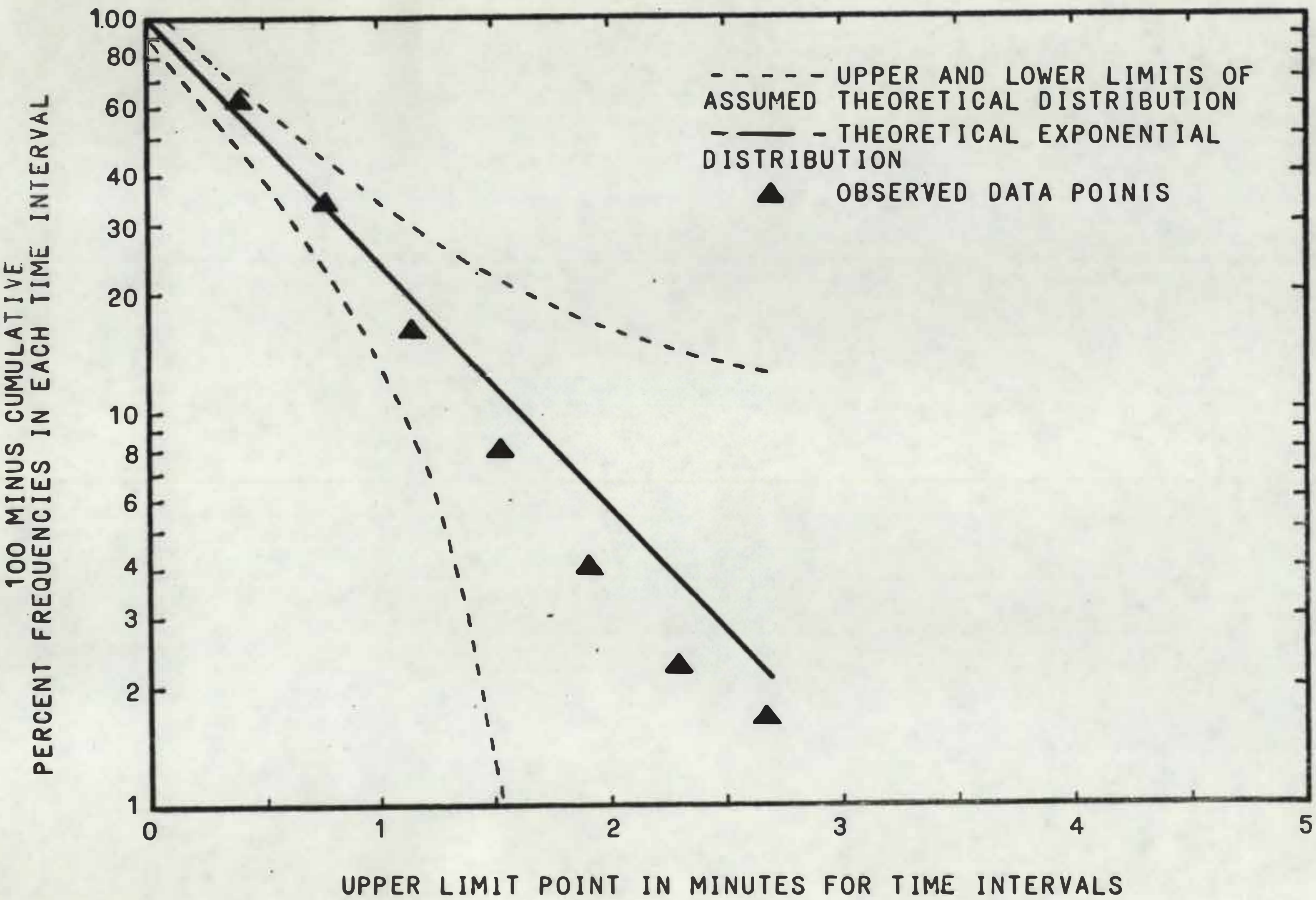


Figure A.1. Goodness of Fit of the Distribution of the Frequency of Observed Interarrival Times on Friday II with the Assumed Theoretical Exponential Distribution.

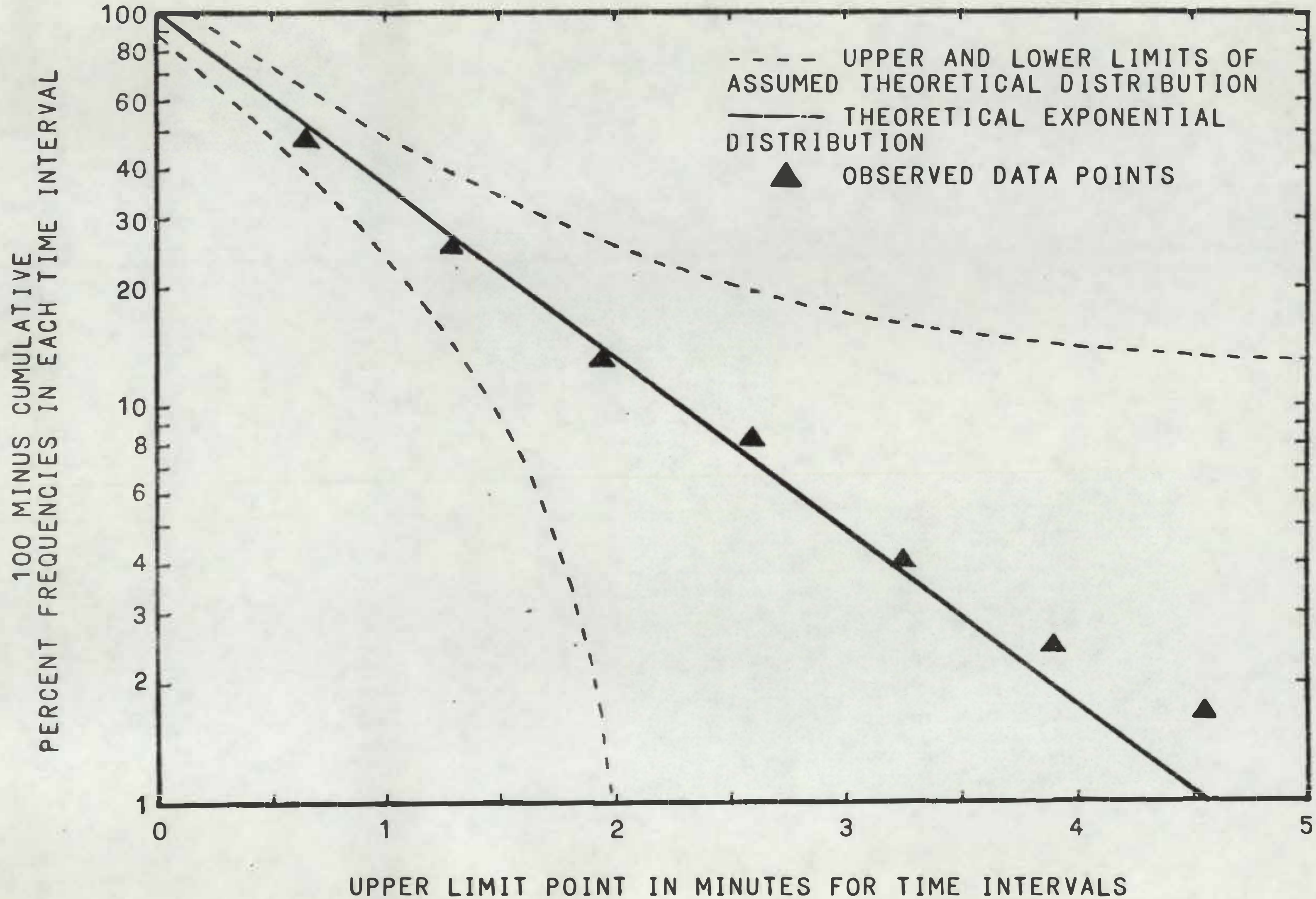


Figure A.2. Goodness of Fit of the Distribution of the Frequency of Observed Interarrival Times on Monday with the Assumed Theoretical Exponential Distribution.

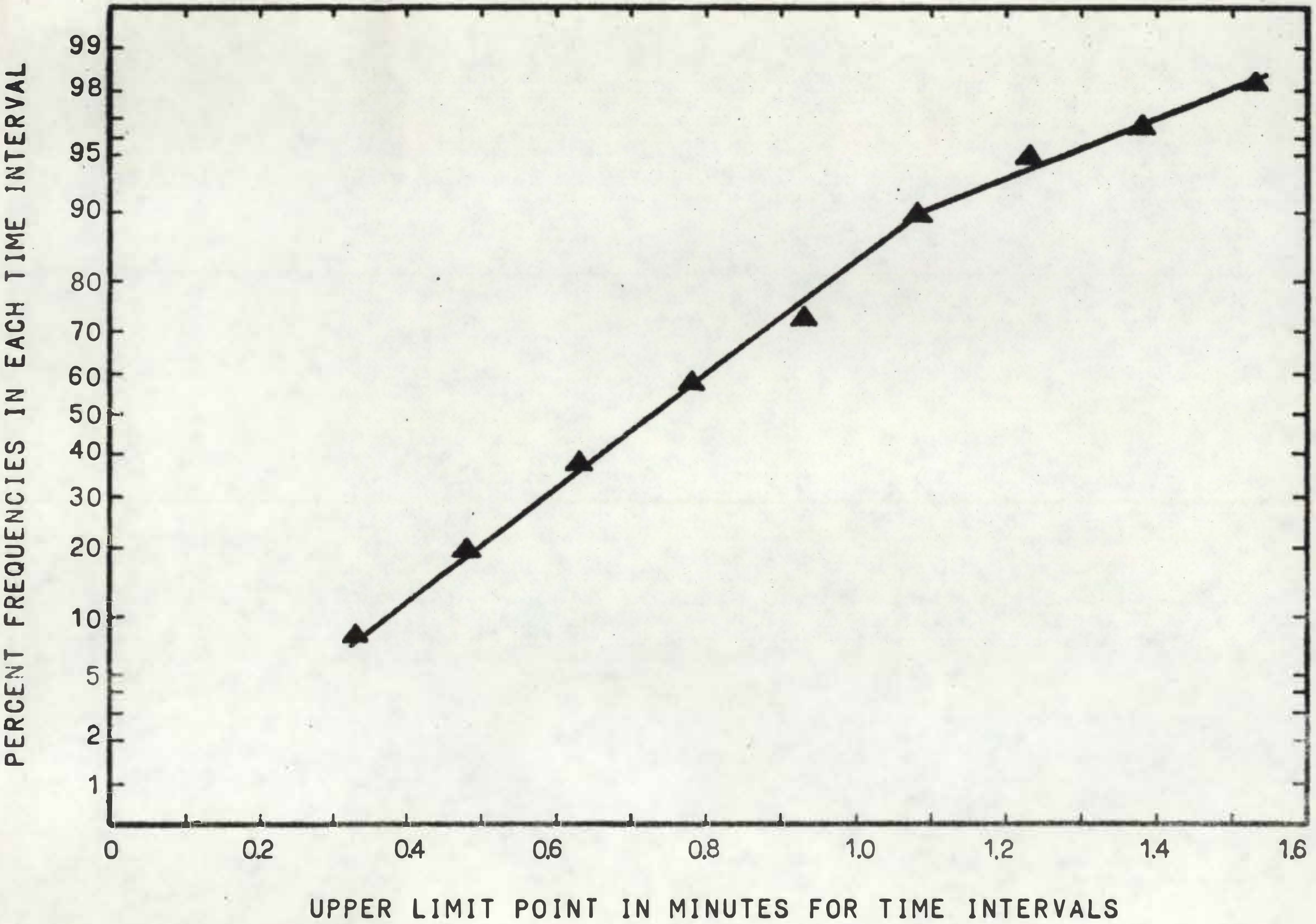


Figure A.3. Comparison of the Cumulative Distribution of Frequencies of Observed Element One Service Times on Friday II with the Cumulative Normal Distribution.

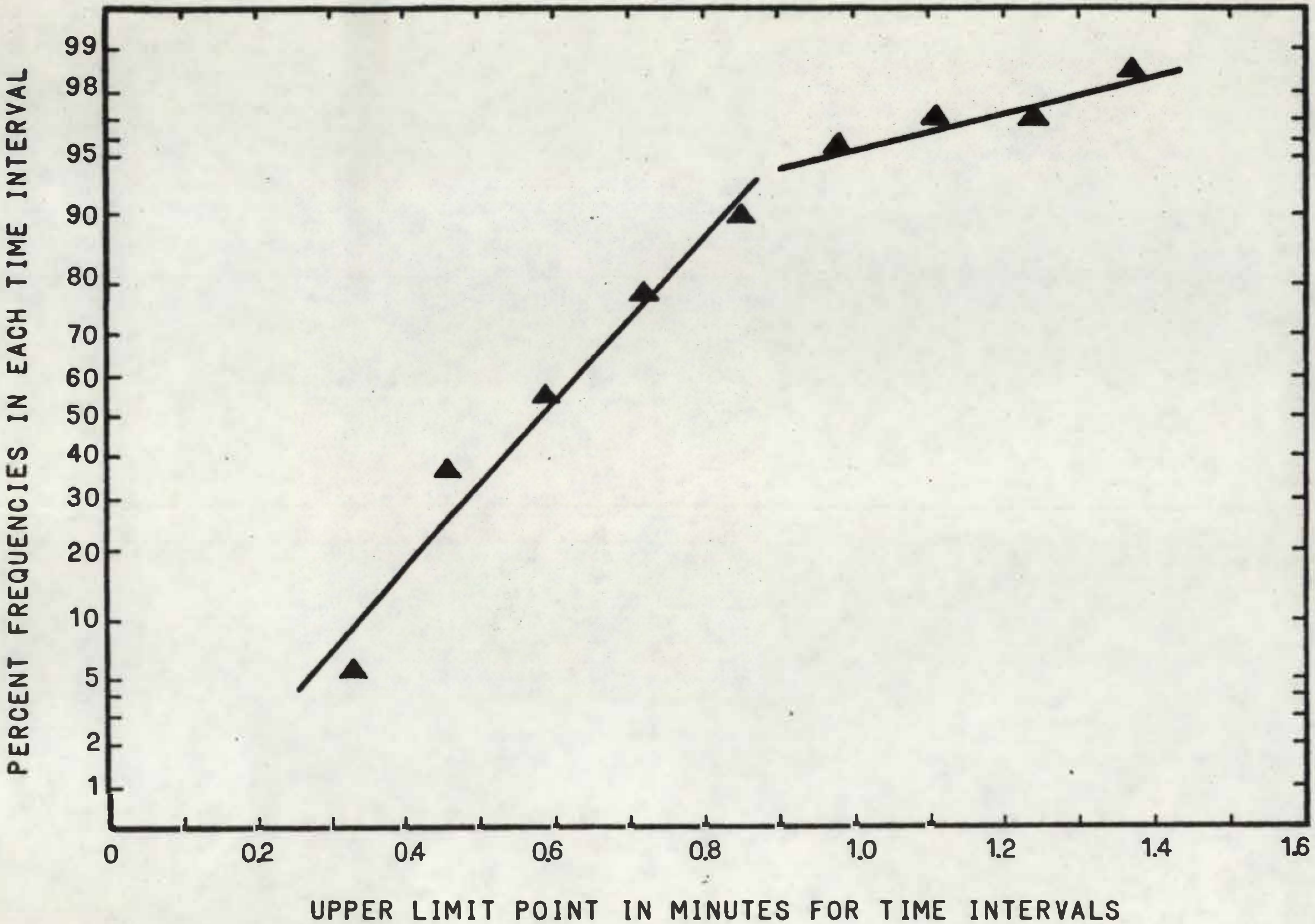


Figure A.4. Comparison of the Cumulative Distribution of Frequencies of Observed Element One Service Times on Monday with the Cumulative Normal Distribution.

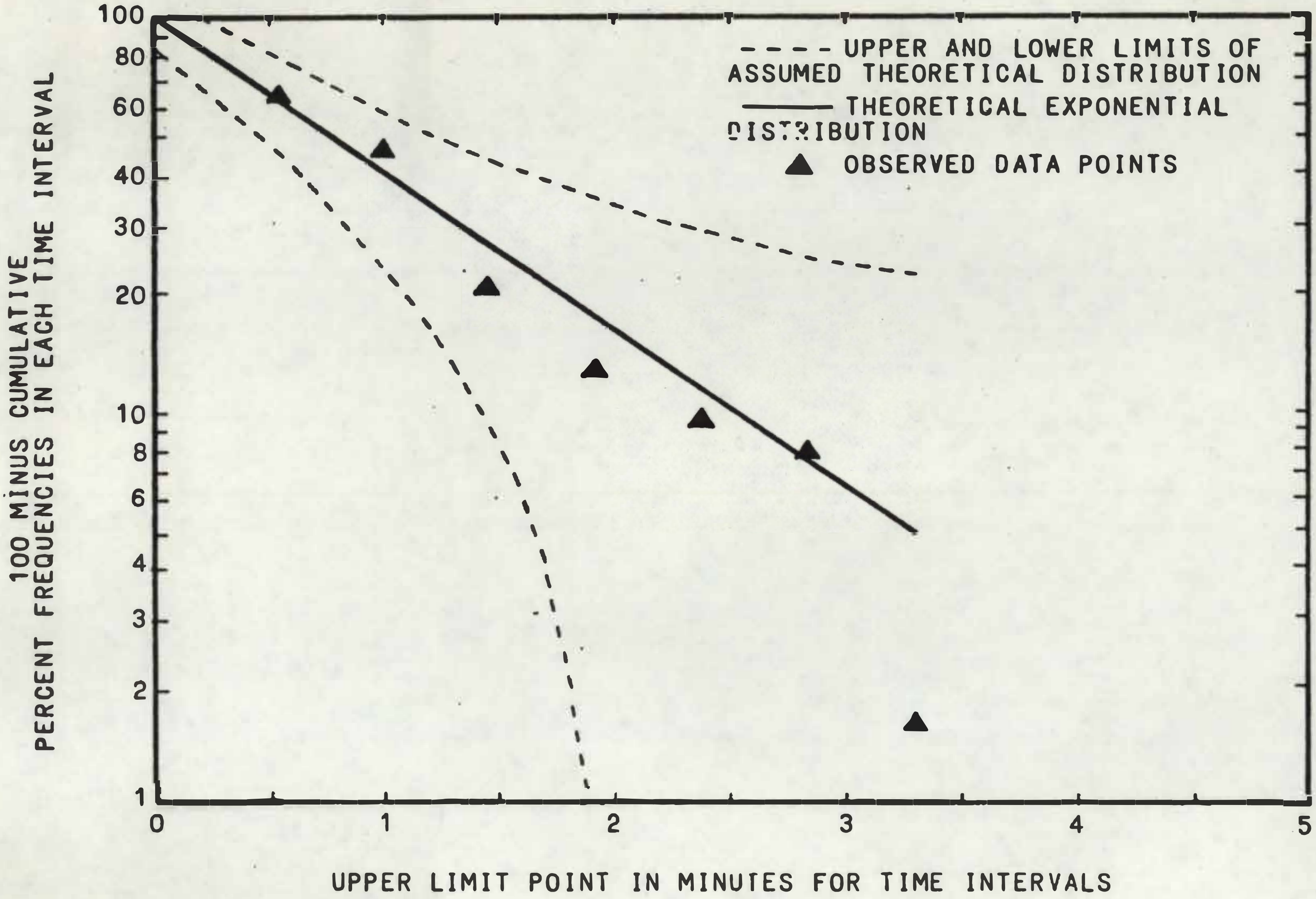


Figure A.5. Goodness of Fit of the Distribution of the Frequency of Observed Element Three Service Times on Friday II with the Assumed Theoretical Exponential Distribution.

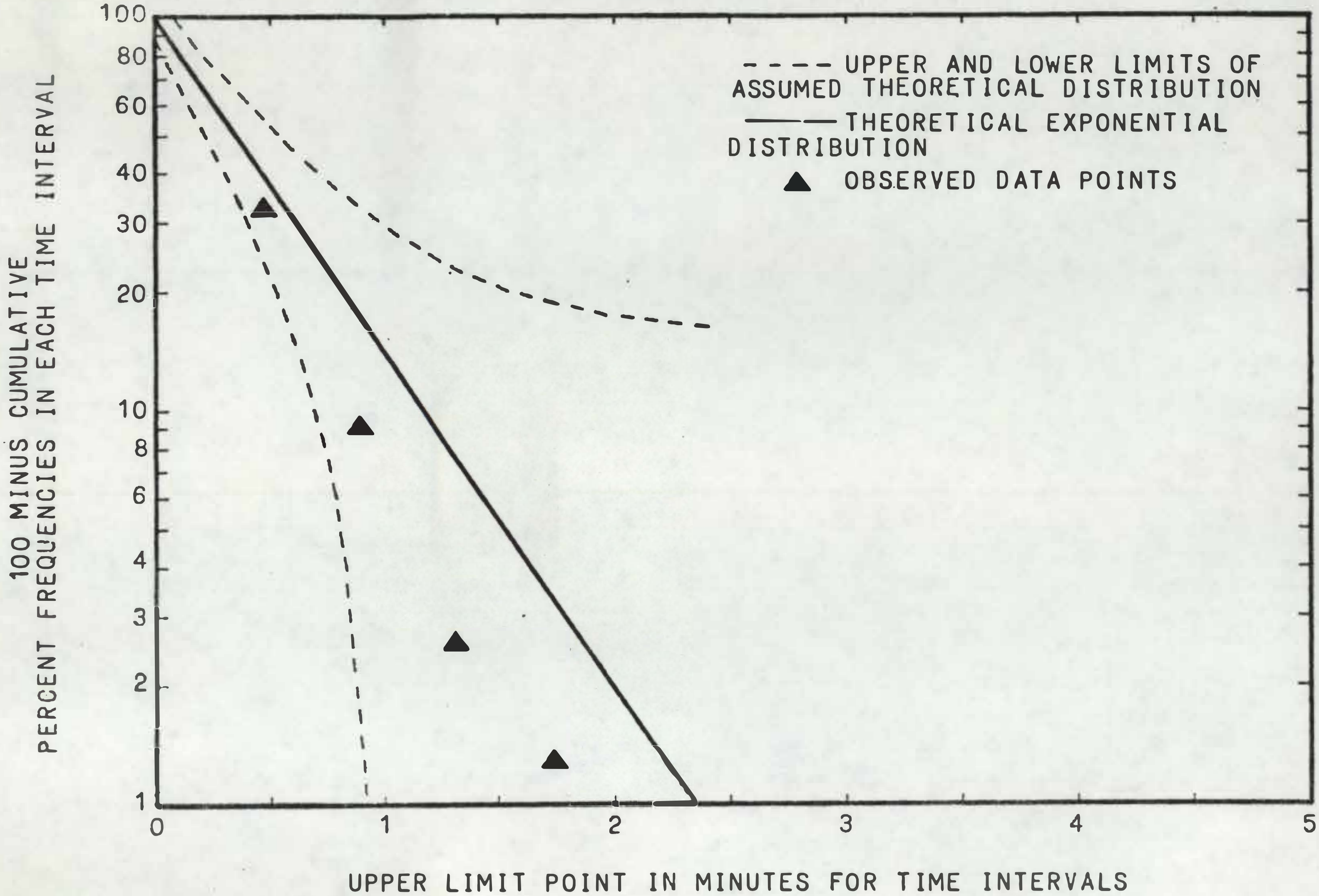


Figure A.6. Goodness of Fit of the Distribution of the Frequency of Observed Element Three Service Times on Monday with the Assumed Theoretical Exponential Distribution.

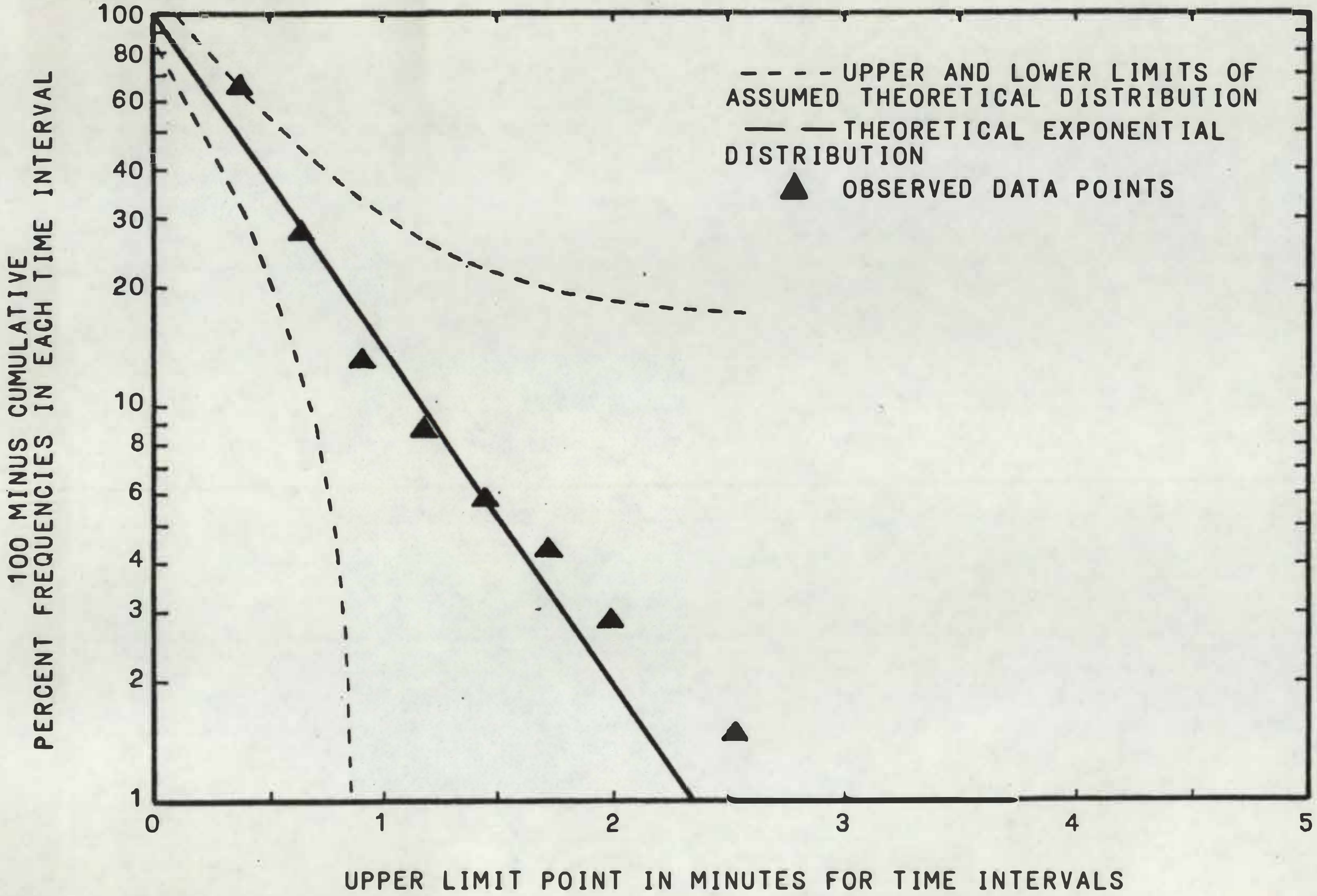


Figure A.7. Goodness of Fit of the Distribution of the Frequency of Observed Element Three Service Times on Tuesday with the Assumed Theoretical Exponential Distribution.

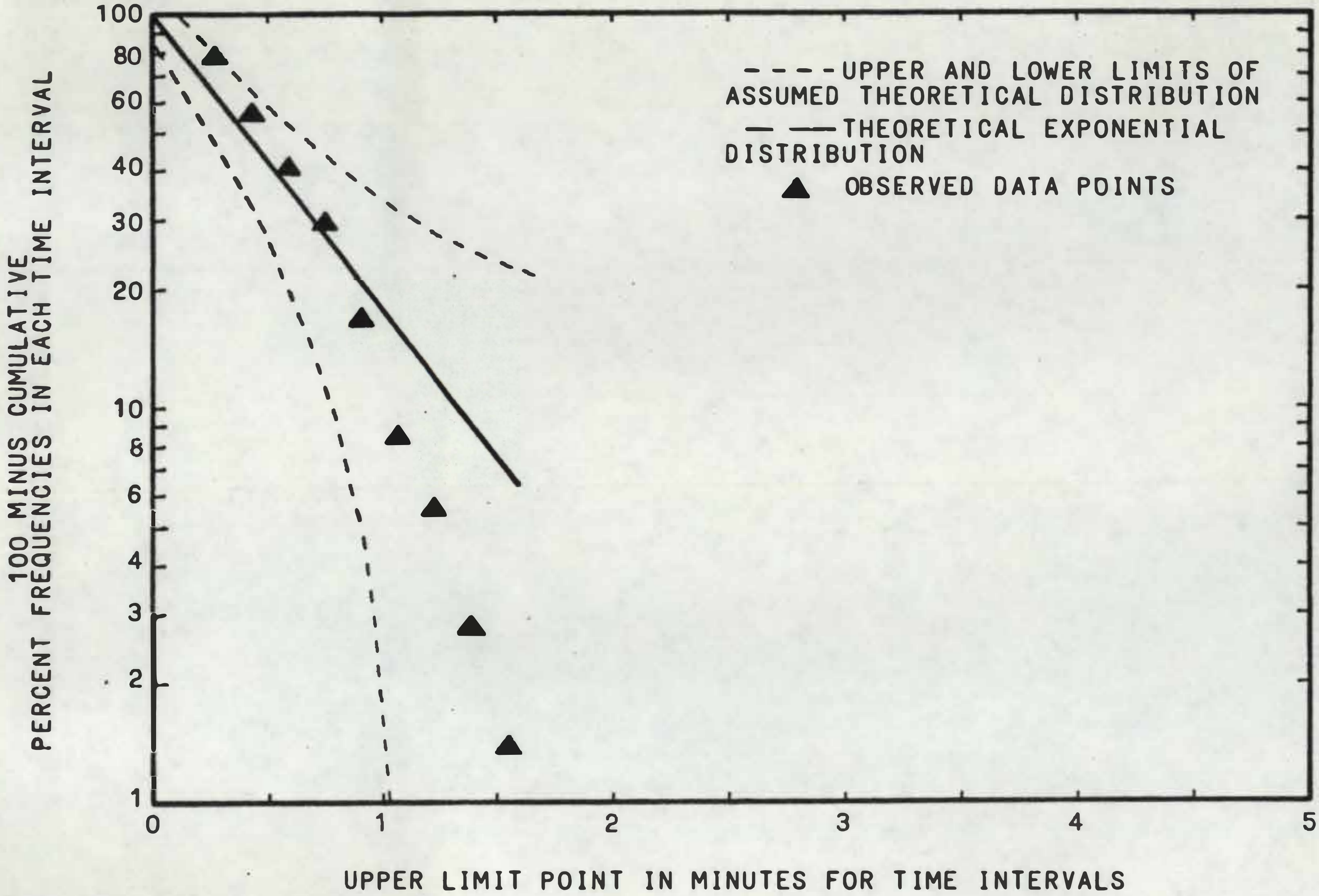


Figure A.8. Goodness of Fit of the Distribution of the Frequency of Observed Element Three Service Times on Thursday with the Assumed Theoretical Exponential Distribution.

APPENDIX B

FLOWCHART OF THE SIMULATION MODEL

The parameters of Friday II were used as examples in the flowchart. The data for the function definition cards, function follower cards, table definition cards, and the variable definition cards for Friday II are as follows:

```
 1      FUNCTION   RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509
.5,.69/.6,.915/.7,1.2/.75,1.38/.8,1.6
.84,1.83/.88,2.12/.9,2.3/.92,2.52
.94,2.81/.95,2.99/.96,3.2/.97,3.5
.98,3.9/.99,4.6/.995,5.3/.998,6.2
.999,7/.9997,8

 2      FUNCTION   RN2,D7
.542,1/.799,2/.909,3/.978,4/.991,5
.997,6/1.0,7

 3      FUNCTION   RN2,D2
.78,0/1.0,1

 4      FUNCTION   RN2,D9
.092,0/.288,1/.623,2/.830,3
.934,4/.977,5/.992,6/.997,7/1.0,9

 5      FUNCTION   RN2,D6
.356,0/.550,1/.802,2/.944,3/.992,4
1.0,5

 6      FUNCTION   RN3,D7
.254,0/.560,1/.819,2/.924,3/.987,4
.997,6/1.0,7

 7      FUNCTION   RN3,D6
.847,0/.962,1/.990,2/.992,3
.997,4/1.0,5

 20     FUNCTION   RN4,C10
.083,330/.200,480/.383,630/.583,78
.733,930/.900,1080/.950,1230/.967,138
.983,1530/1.0,1620

 SNORM  FUNCTION   RN3,C25
0,-5/.00003,-4/.00135,-3/.00621,-2.5
.02275,-2/.06681,-1.5/.11507,-1.2
.15866,-1/.21186,-.8/.27425,-.6
.34458,-.4/.42074,-.2/.5,0
```

Figure B.1. Flowchart of the Simulation Model.

```
.57926,.2/.65542,.4/.72575,.6
.78814,.8/.84134,1/.88493,1.2
.93319,1.5/.97725,2/.99379,2.5
.99865,3/.99997,4/1,5

    1 TABLE      IA,390,380,15
    2 TABLE      P1,1,1,8
    3 TABLE      P2,0,1,3
    4 TABLE      P3,0,1,11
    5 TABLE      P4,0,1,7
    6 TABLE      P5,0,1,9
    7 TABLE      P6,0,1,7
    8 TABLE      MP7,330,150,11
    9 TABLE      MP8,540,460,11
   10 TABLE      MP9,530,540,11

    1 VARIABLE   206*P3+243*P4+103*P5+620*P6-5
    2 VARIABLE   54*P3+18*P4+18*P5+24*P6
    3 FVARIABLE  .637*FN$SNORM+V1
```

Figure B.1. (Continued)

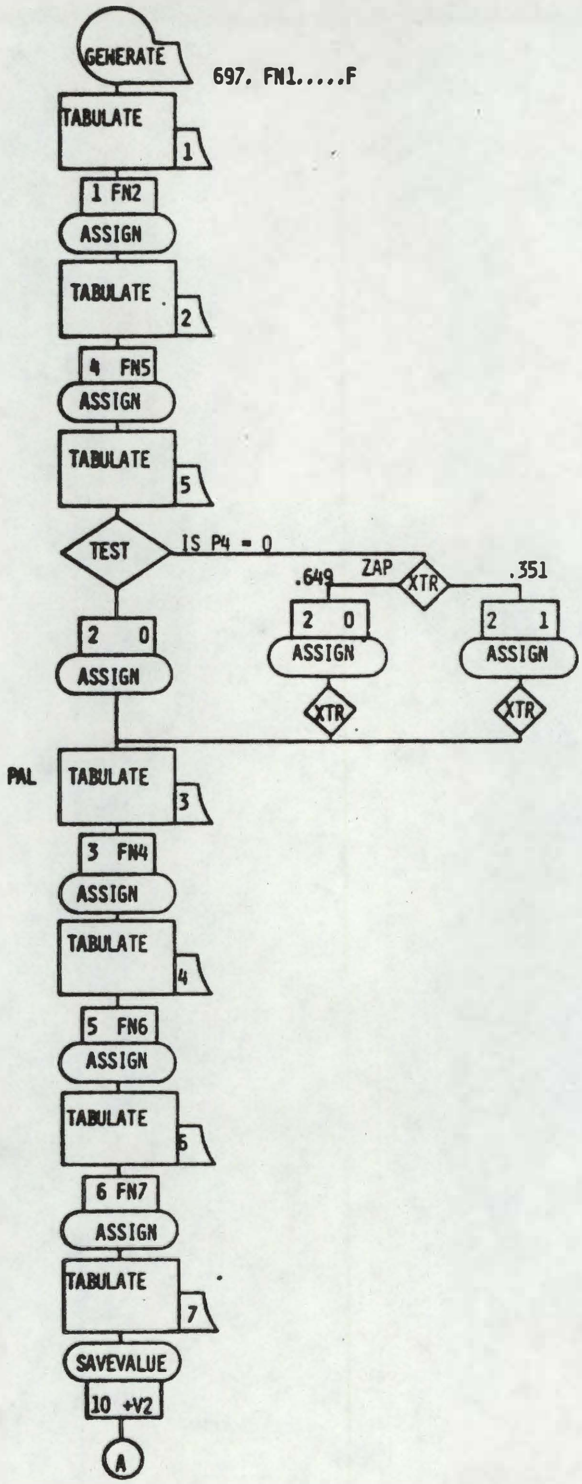


Figure B.1 (continued)

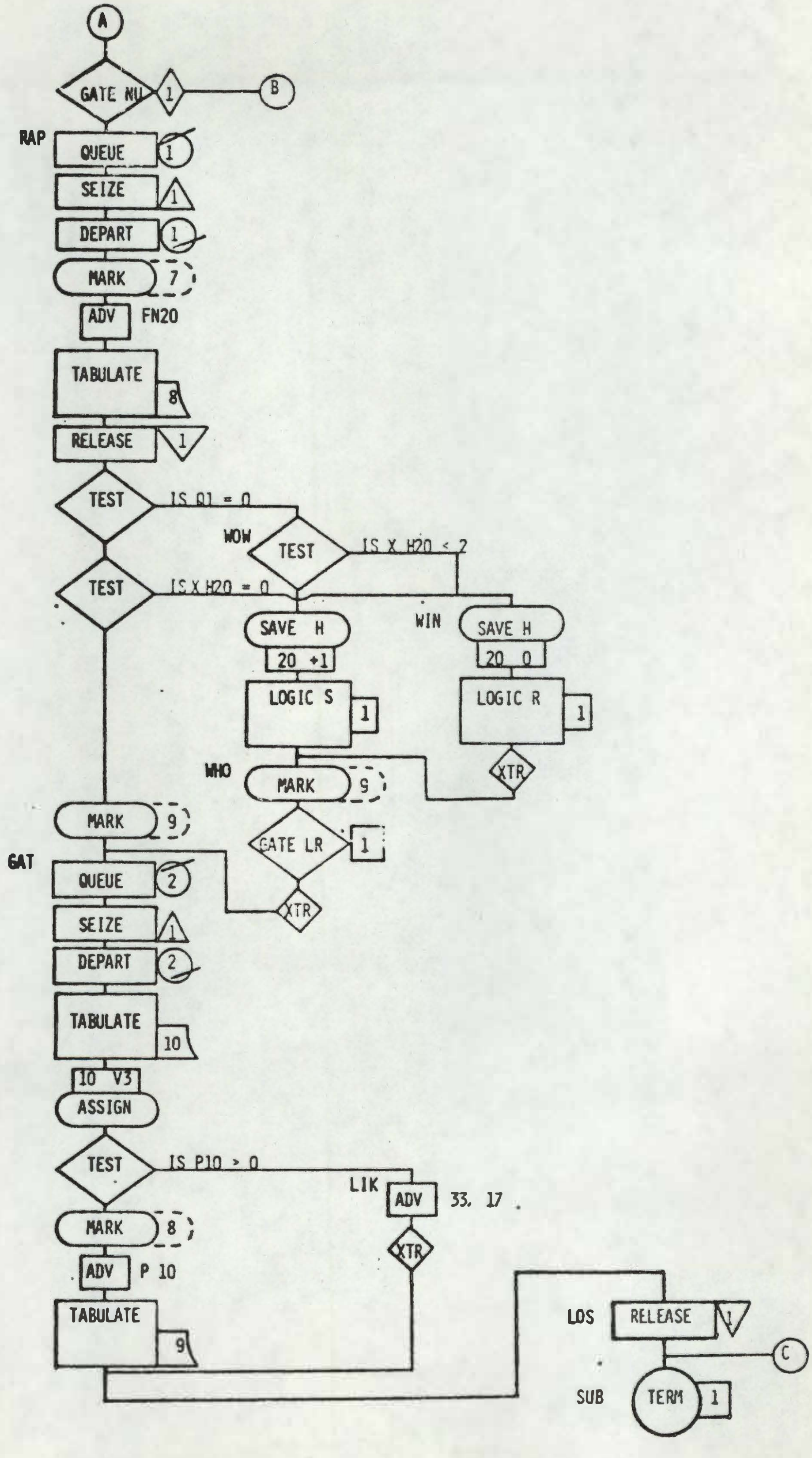


Figure B.1 (continued)

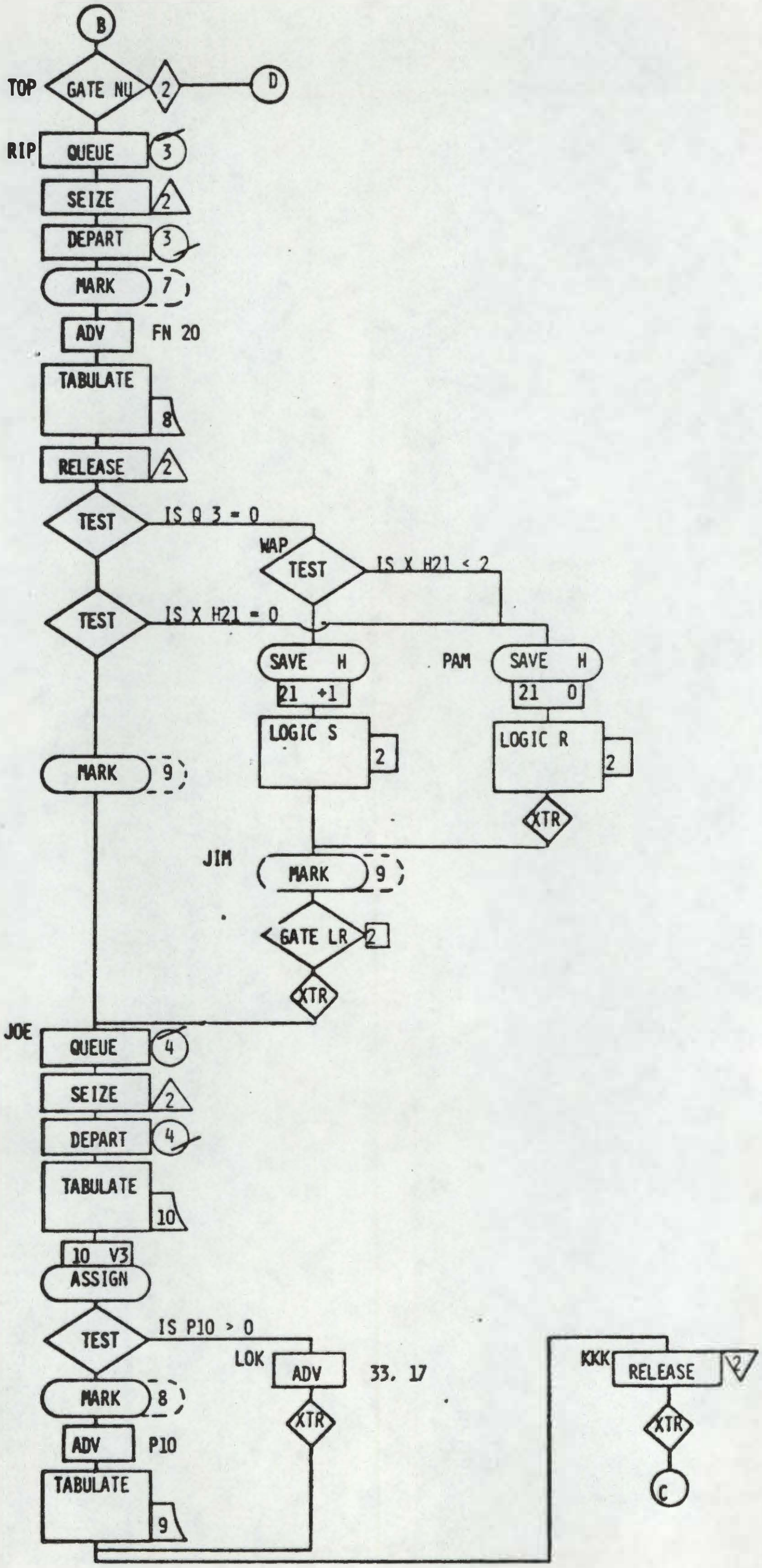


Figure B.1 (continued)

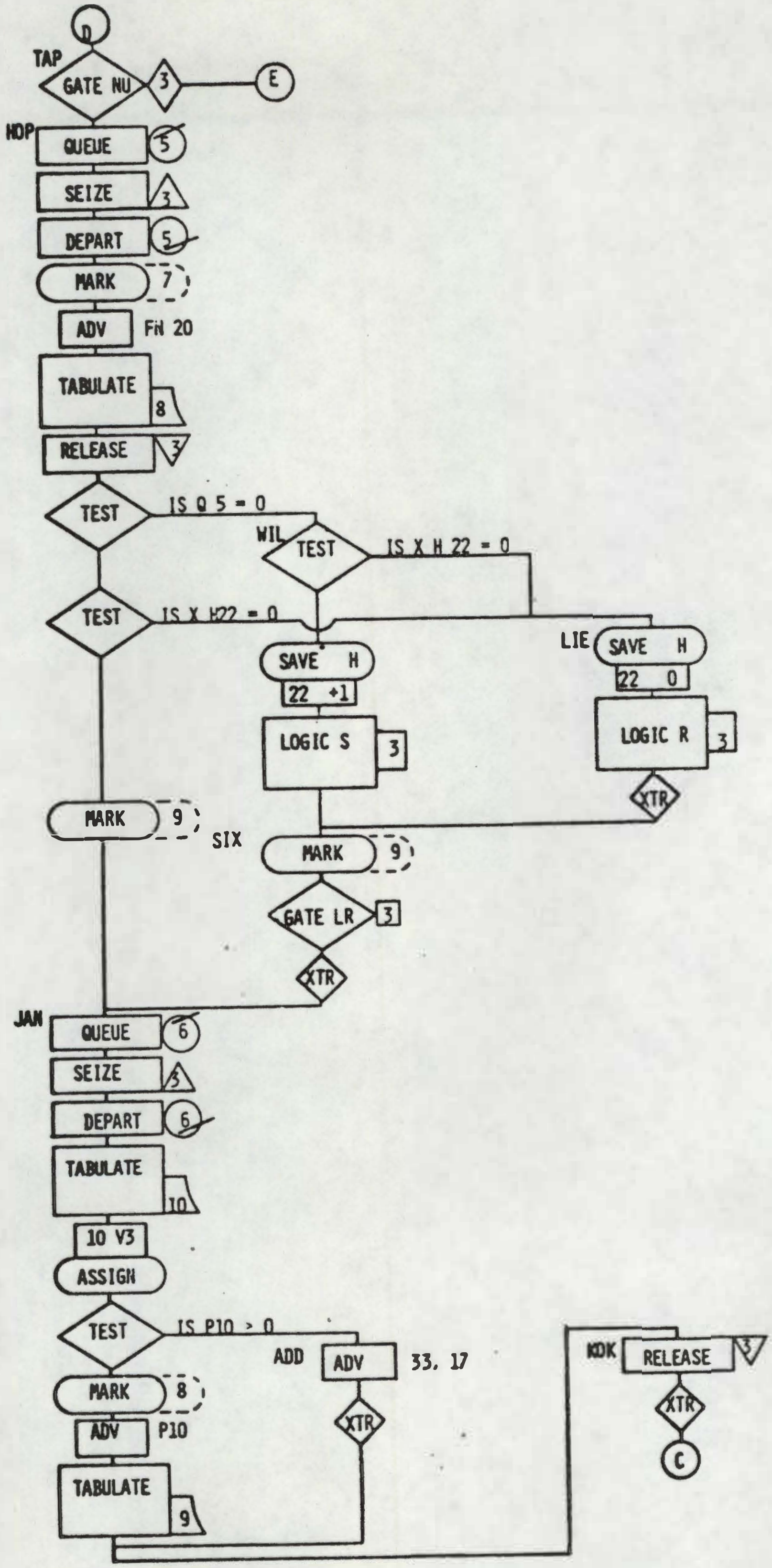


Figure B.1 (continued)

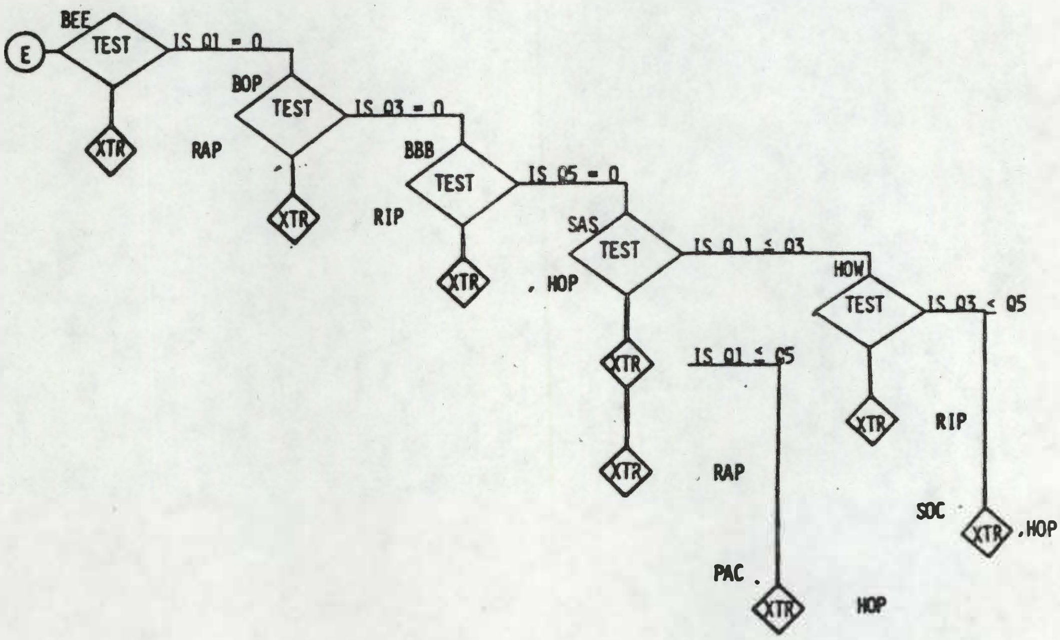


Figure B.1 (continued)

APPENDIX C

DATA OF INFLUENCE OF ADDITIONAL MENU ITEM ON VARIOUS ASPECTS OF THE SYSTEM

TABLE C.1

AVERAGE PERCENT UTILIZATION[a] OF THE THREE SERVICE FACILITIES ON FRIDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Service Facility Number	Coefficient of Fruit: Equal to That of Burgers Percent	Equal to That of Beverages Percent	Equal to That of French Fries Percent	Equal to That of Onion Rings Percent
Equal to That of Burgers	1	.999	.999	.998	.999
	2	.989	.990	.988	.992
	3	.988	.989	.963	.991
Equal to That of Beverages	1	.999	.999	.967	.999
	2	.989	.988	.924	.988
	3	.970	.981	.856	.976
Equal to That of French Fries	1	.999	.999	.999	.999
	2	.988	.989	.975	.991
	3	.987	.988	.978	.990
Equal to That of Onion Rings	1	.999	.983	.963	.996
	2	.984	.951	.906	.959
	3	.983	.924	.885	.924

[a]In the simulation of the system before expansion of the menu, the average utilization of facilities 1, 2, and 3 was 0.944, 0.891, and 0.833 percent, respectively.

TABLE C.2

AVERAGE TIME PER TRANSACTION[a] (CUSTOMER) IN EACH OF THE THREE SERVICE FACILITIES ON FRIDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Service Facility Number	Coefficient of Fruit: Equal to That of Burgers	Equal to That of Beverages	Equal to That of French Fries	Equal to That of Onion Rings
		Minutes	Minutes	Minutes	Minutes
Equal to That of Burgers	1	1.134	1.243	1.009	1.548
	2	1.180	1.200	1.067	1.501
	3	1.179	1.199	1.096	1.512
Equal to That of Beverages	1	1.137	1.093	1.145	1.215
	2	1.105	1.268	1.037	1.339
	3	1.085	1.031	0.945	1.299
Equal to That of French Fries	1	1.036	1.122	0.999	1.285
	2	1.136	1.159	1.072	1.360
	3	1.048	1.073	1.029	1.325
Equal to That of Onion Rings	1	1.055	0.943	0.960	1.070
	2	0.951	0.994	0.942	1.048
	3	0.959	0.983	1.015	1.113

[a]In the simulation of the system before expansion of the menu, the average time per transaction was 0.896, 1.157, and 0.922 minutes for facilities 1, 2, and 3, respectively.

TABLE C.3

CHANGE IN THE MEAN TIME REQUIRED FOR SERVICE[a] (ELEMENT THREE) ON FRIDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Coefficient of Fruit			
	Equal to That of Burgers	Equal to That of Beverages	Equal to That of French Fries	Equal to That of Onion Rings
	Minutes	Minutes	Minutes	Minutes
Equal to That of Burgers	+0.346	+0.424	+0.114	+1.156
Equal to That of Beverages	+0.225	+0.261	+0.080	+0.606
Equal to That of French Fries	+0.124	+0.218	+0.029	+0.694
Equal to That of Onion Rings	-0.016	+0.001	-0.033	+0.151

[a]In the simulation of the system before expansion of the menu, the average element three value was 1.340 minutes.

TABLE C.4

PERCENT CHANGE IN THE MARGIN OF PROFIT ON FRIDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM AS COMPARED TO THE SIMULATION OF THE SYSTEM AS OBSERVED

Distribution of Number of Fruit Ordered	Coefficient of Fruit: Equal to That of Burgers Percent	Equal to That of Beverages Percent	Equal to That of French Fries Percent	Equal to That of Onion Rings Percent
Equal to That of Burgers	+28.3	+35.3	+25.8	+85.7
Equal to That of Beverages	+21.4	+23.1	+10.6	+29.7
Equal to That of French Fries	+20.8	+29.6	+ 9.5	+46.4
Equal to That of Onion Rings	+ 3.2	+ 0.1	+ 0.7	+ 3.1

TABLE C.5

AVERAGE TIME PER TRANSACTION[a] (CUSTOMER) IN QUEUES ON FRIDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers Minutes	Equal to That of Beverages Minutes	Equal to That of French Fries Minutes	Equal to That of Onion Rings Minutes
Equal to That of Burgers	1	5.984	9.170	5.722	28.413
	3	5.862	8.320	5.561	27.773
	5	5.122	7.632	5.053	27.151
	2	2.441	4.126	2.992	16.785
	4	2.308	3.925	2.486	16.815
	6	2.071	3.580	2.318	16.702
Equal to That of Beverages	1	4.466	6.437	2.404	8.037
	3	4.101	6.891	1.272	8.331
	5	3.249	5.010	0.895	7.415
	2	1.909	3.158	1.324	4.136
	4	1.788	3.300	0.726	3.876
	6	1.465	2.229	0.447	3.469
Equal to That of French Fries	1	7.453	9.594	3.916	16.684
	3	7.661	9.685	3.579	16.856
	5	6.266	8.495	2.900	16.050
	2	3.476	5.038	1.630	9.448
	4	3.537	5.732	1.602	9.931
	6	3.099	4.716	1.297	9.311

TABLE C.5 (CONTINUED)

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers	Equal to That of Beverages	Equal to That of French Fries	Equal to That of Onion Rings
		Minutes	Minutes	Minutes	Minutes
Equal to That of Onion Rings	1	4.307	2.546	2.148	2.196
	3	3.313	2.326	1.490	1.850
	5	2.817	1.876	1.388	1.351
	2	1.827	1.146	0.998	1.085
	4	1.407	1.097	0.674	1.016
	6	1.203	0.996	0.648	0.878

[a]In the simulation of the system before expansion of the menu, the average time per transaction in queues 1, 3, and 5 was 1.605, 1.348, and 0.687, respectively; the average time per transaction in queues 2, 4, and 6 was 0.850, 0.858, and 0.453, respectively.

TABLE C.6

MAXIMUM NUMBER OF CUSTOMERS[a] IN EACH QUEUE WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers — Number	Coefficient of Fruit: Equal to That of Beverages — Number	Coefficient of Fruit: Equal to That of French Fries — Number	Coefficient of Fruit: Equal to That of Onion Rings — Number
Equal to That of Burgers	1	6	9	5	26
	3	5	9	5	26
	5	5	8	5	26
	2	4	5	4	14
	4	3	5	4	13
	6	3	4	3	12
Equal to That of Beverages	1	6	7	3	10
	3	6	7	2	10
	5	6	6	2	9
	2	4	4	2	6
	4	3	4	2	4
	6	2	4	2	4
Equal to That of French Fries	1	6	9	5	14
	3	6	8	5	14
	5	6	8	5	14
	2	4	5	4	8
	4	4	5	3	8
	6	3	5	3	8

TABLE C.6 (CONTINUED)

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit Equal to That of Burgers Number	Equal to That of Beverages Number	Equal to That of French Fries Number	Equal to That of Onion Rings Number
Equal to That of Onion Rings	1	5	3	4	3
	3	4	3	3	3
	5	4	3	3	2
	2	4	2	2	2
	4	3	2	2	2
	6	2	2	3	2

[a]In the simulation of the system before expansion of the menu, the maximum number of customers was 3 for queue 1 and 2 for queues 2-6.

TABLE C.7

AVERAGE PERCENT UTILIZATION[a] OF THE THREE SERVICE FACILITIES ON MONDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Service Facility Number	Coefficient of Fruit: Equal to That of Burgers Percent	Equal to That of Beverages Percent	Equal to That of French Fries Percent	Equal to That of Onion Rings Percent
Equal to That of Burgers	1	.605	.544	.574	.624
	2	.362	.372	.387	.466
	3	.179	.164	.178	.219
Equal to That of Beverages	1	.613	.532	.563	.590
	2	.368	.359	.370	.415
	3	.181	.158	.163	.211
Equal to That of French Fries	1	.588	.637	.622	.639
	2	.340	.376	.417	.411
	3	.163	.161	.175	.219
Equal to That of Onion Rings	1	.622	.639	.641	.640
	2	.346	.404	.405	.408
	3	.152	.158	.158	.167

[a]In the simulation of the system before expansion of the menu, the average utilization of facilities 1, 2, and 3 was 0.575, 0.324, and 0.189 percent, respectively.

TABLE C.8

AVERAGE TIME PER TRANSACTION[a] (CUSTOMER) IN EACH OF THE THREE SERVICE FACILITIES ON MONDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Service Facility Number	Coefficient of Fruit: Equal to That of Burgers Minutes	Equal to That of Beverages Minutes	Equal to That of French Fries Minutes	Equal to That of Onion Rings Minutes
Equal to That of Burgers	1	.519	.621	.659	.729
	2	.509	.586	.618	.725
	3	.538	.571	.556	.682
Equal to That of Beverages	1	.526	.597	.633	.689
	2	.517	.579	.589	.662
	3	.543	.552	.534	.628
Equal to That of French Fries	1	.533	.584	.579	.642
	2	.447	.557	.617	.679
	3	.566	.549	.562	.611
Equal to That of Onion Rings	1	.546	.547	.549	.557
	2	.467	.491	.492	.496
	3	.564	.518	.518	.516

[a]In the simulation of the system before expansion of the menu, the average time per transaction in facilities 1, 2, and 3 was 0.541, 0.533, and 0.561 minutes, respectively.

TABLE C.9

CHANGE IN THE MEAN TIME REQUIRED FOR SERVICE[a] (ELEMENT THREE) ON MONDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Coefficient of Fruit: Equal to That of Burgers Minutes	Equal to That of Beverages Minutes	Equal to That of French Fries Minutes	Equal to That of Onion Rings Minutes
Equal to That of Burgers	-.055	+.095	+.137	+.324
Equal to That of Beverages	-.039	+.059	+.086	+.222
Equal to That of French Fries	-.070	+.037	+.075	+.192
Equal to That of Onion Rings	-.040	-.034	-.031	-.020

[a]In the simulation of the system before expansion of the menu, the mean element three value was 0.527 minutes.

TABLE C.10

PERCENT CHANGE IN THE MARGIN OF PROFIT ON MONDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM AS COMPARED TO THE SIMULATION OF THE SYSTEM AS OBSERVED

Distribution of Number of Fruit Ordered	Coefficient of Fruit			
	Equal to That of Burgers Percent	Equal to That of Beverages Percent	Equal to That of French Fries Percent	Equal to That of Onion Rings Percent
Equal to That of Burgers	+12.4	+11.5	+11.2	+11.4
Equal to That of Beverages	+ 8.4	+ 7.5	+ 7.2	+ 7.2
Equal to That of French Fries	+10.8	+13.0	+13.0	+13.3
Equal to That of Onion Rings	+ 1.6	+ 3.3	+ 3.3	+ 3.3

TABLE C.11

AVERAGE TIME PER TRANSACTION[a] (CUSTOMER) IN QUEUES ON MONDAY WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers Minutes	Equal to That of Beverages Minutes	Equal to That of French Fries Minutes	Equal to That of Onion Rings Minutes
Equal to That of Burgers	1	0.025	0.068	0.078	0.203
	3	0.000	0.074	0.083	0.087
	5	0.000	0.000	0.074	0.048
	2	0.026	0.029	0.013	0.027
	4	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.048	0.000
Equal to That of Beverages	1	0.026	0.060	0.065	0.121
	3	0.000	0.074	0.079	0.083
	5	0.000	0.000	0.064	0.078
	2	0.027	0.025	0.011	0.014
	4	0.000	0.000	0.000	0.000
	6	0.000	0.000	0.051	0.097
Equal to That of French Fries	1	0.040	0.028	0.032	0.072
	3	0.013	0.000	0.000	0.028
	5	0.037	0.000	0.000	0.015
	2	0.047	0.071	0.083	0.105
	4	0.010	0.000	0.000	0.000
	6	0.000	0.000	0.000	0.036

TABLE C.11 (CONTINUED)

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers Minutes	Equal to That of Beverages Minutes	Equal to That of French Fries Minutes	Equal to That of Onion Rings Minutes
Equal to That of Onion Rings	1	0.053	0.081	0.081	0.082
	3	0.016	0.038	0.038	0.038
	5	0.042	0.029	0.029	0.028
	2	0.057	0.098	0.098	0.100
	4	0.011	0.047	0.047	0.047
	6	0.000	0.034	0.034	0.032

[a] In the simulation of the system before expansion of the menu, the average time per transaction in queues 1, 3, and 5 was 0.107, 0.029, and 0.027 minutes, respectively; the average time per transaction in queues 2, 4, and 6 was 0.037, 0.024, and 0.049 minutes, respectively.

TABLE C.12

MAXIMUM NUMBER OF CUSTOMERS[a] IN EACH QUEUE WITH THE EXPANSION OF THE MENU TO INCLUDE FRUIT IN THE SIMULATION OF THE SYSTEM

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers	Equal to That of Beverages	Equal to That of French Fries	Equal to That of Onion Rings
		Number	Number	Number	Number
Equal to That of Burgers	1	1	1	1	2
	3	1	1	1	1
	5	1	1	1	1
	2	2	1	1	1
	4	1	1	1	1
	6	1	1	1	1
Equal to That of Beverages	1	1	1	1	1
	3	1	1	1	1
	5	1	1	1	1
	2	2	1	1	1
	4	1	1	1	1
	6	1	1	1	2
Equal to That of French Fries	1	1	1	1	1
	3	1	1	1	1
	5	1	1	1	1
	2	2	2	2	2
	4	1	1	1	1
	6	1	1	1	1

TABLE C.12 (CONTINUED)

Distribution of Number of Fruit Ordered	Queue Number	Coefficient of Fruit: Equal to That of Burgers Number	Coefficient of Fruit: Equal to That of Beverages Number	Coefficient of Fruit: Equal to That of French Fries Number	Coefficient of Fruit: Equal to That of Onion Rings Number
Equal to That of Onion Rings	1	1	2	2	2
	3	1	1	1	1
	5	1	1	1	1
	2	2	2	2	2
	4	1	2	2	2
	6	1	1	1	1

[a]In the simulation of the system before expansion of the menu, the maximum number of customers was 1 for queues 1, 3, 5, 4, and 6, and was 2 for queue 2.

APPENDIX D

FORMS FOR DATA COLLECTION

FORM D.1

FORM FOR COLLECTION OF AUDIT TRAIL DATA

Date__________Day___________Beginning Time___________Ending Time______

		CATEGORIES OF FOOD				
TIME	TRA	BURGER	BEVERAGES	FF	OR	DESSERTS a/b

FORM D.2

FORM FOR COLLECTION OF ARRIVAL TIMES

Date________Day________Ending time________Beginning time________

ARRIVAL TIMES	NUMBER	ARRIVAL TIMES	NUMBER	ARRIVAL TIMES	NUMBER

FORM D.3

FORM FOR COLLECTION OF ELEMENT ONE AND ELEMENT TWO TIME VALUES

Place________________ Date________________ Day________________

Ending time________ Weather________ Beginning time________________

Employee________________________

COMMENTS	ELEMENT ONE Take order, ring it up, call out order, make change	ELEMENT TWO Waiting time

FORM D.4

FORM FOR COLLECTION OF ELEMENT THREE SERVICE TIMES
AND CATEGORIES OF FOOD ORDERED

Place__________Date__________Day__________Ending time____________

Weather_____________Beginning time____________Employee____________

Element Three	No. of Food Items Chosen in Each Category				
Fill order and give to customer	Burger	Beverage	FF	OR	Desserts a b

VITA

Sarah Sue Ritchey Jordan was born in Memphis, Tennessee, on July 31, 1946. She grew up and was educated in the public schools of Clarksdale, Mississippi. Ms. Jordan attended Mississippi University for Women and received the Bachelor of Science degree in Home Economics Education from the University of Mississippi in 1968. She attended graduate school at the University of Alabama and received the Master of Science degree in Nutrition in 1971. Ms. Jordan completed her dietetic internship at Indiana University Medical Center in Indianapolis.

Ms. Jordan has worked in school food service and public health. She was an Area Supervisor for School Food Service in Mississippi, traveling 22 counties. In Public Health Ms. Jordan has held the position of Director, Bureau of Nutrition, Jefferson County Health Department, Birmingham, Alabama, and has, also, had experience as a Nutritionist, Knox County Health Department, Knoxville, Tennessee.

Ms. Jordan holds membership in the American Dietetic Association, its state and local affiliates. She has held the position of Public Relations Chairman and has served as a site evaluator for the national association. Ms. Jordan is a member of Omicron Nu, Phi Upsilon Omicron, and Phi Kappa Phi Honor Societies.

She is married to James Howard Jordan of Dunn, North Carolina.