USING MARKOV CHAINS MODEL IN FOODSERVICE SYSTEM

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1976

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 1978

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IN FOODSERVICE SYSTEM

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ACKNOWLEDGMENTS

Deepest appreciation is expressed to Dr. Esther A. Winterfeldt and Dr. Anna M. Gorman for their help and guidance throughout the course of my graduate study and research and also the other committee member, Mrs. Allene Brown, for the assistance in the writing of the thesis.

Thanks are also extended to Mr. David Schwake, Manager of the Student Union Cafeteria, for allowing this study to be performed and to Miss. Hao Truong for assistance in typing, arranging and doing final tasks for the completing of this degree.

To my parents, Huen-Yu Huang, I wish to express my greatest appreciation. Without their financial and moral support this goal could not have been achieved.

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CHAPTER I

INTRODUCTION

Eating is one of life's most pleasurable and satisfying activities. Eating "out", among the amazing variety of restaurant and other types of food service available today, adds greatly to this enjoyment of life. Testifying to the popularity of eating out is the sheer dollar volume of food service revenues in the United States. Economic, technology, and social trends in the United States are likely to bring about a continuation of the growth of this industry. On the other hand, the continuing problem of inflation, which cuts across all industries and in particular food service, has caused owners to face a hard dilemma-- how to maintain high standards of quality while sustaining increased costs for facilities, equipment, supplies, and labor. Therefore, the management skills to utilize in food service that yield the greatest profit are among the most important decisions to be made.

The objectives of a food service system are to serve food to the customers and be able to satisfy the customers, and at the same time to make as much profit as possible. So food service operators are always faced with the problem of cost analysis and forecasting menu demand (1). Once the price or prices of one or more items is increased, it is hard to know if the customers would still choose the same item or switch to other items. So the condition of over-and under-production always exists in food service system (1).

The customer food preference is very important data to the food service operator. Pilgrim (2) stated that food consumption is predictable, and it has been shown that one of the important predictors was food preference. Eindhoven and Peryam (3, p.379) substantiated this viewpoint by stating: "one of the best ways of predicting whether people will eat a food, or how much of it they will eat is to ask them how well they like it."

Purpose of the Study

The purpose of this research was to find the mathematical relationship between food preference, net profit, and menu items consumption by using the technique of Markov Chains to analyze a limited amount of data to determine the best policy in making a profit for food service operators.

Objectives of the Study

The overall objective of this research was to (1) study the reliability of Markov Chains for predicting customers actual entree choice from a selective menu; (2) study consumer's preferences for entree items; (3) make the best policy recommendation--optimize the food preference and net profit.

Assumptions

The assumptions basic to this study had two parts. One was for Markovian Decision Model. The other was for measuring customer food preferences. There were three basic assumptions of the Markovian Decision Model. All of which were satisfied by food service operations.

1. The returns from different activities can be measured in common units (4, p.2).
2. The return from any activity is independent of the allocation to the other activities (4, p.2).
3. The total return can be obtained as the sum of the individual return (4, p.2).
4. Customers knew and would state their food preferences.
5. Both male and female were randomly selected from customers.
6. The population of student union customers was homogeneous.
7. Each entree item was prepared under standard recipes and procedures.

Definitions

The following terms were defined for use in this research.

Mathematical Model - one of the most fundamental concepts of mathematic referring to the representation of a real system in terms of mathematical. (5, p.76).

Stochastic Process - a broad term referring to a sequence of experiments where the outcome of each particular experiment may depend on some chance element (5, p.218).

Different Activities - refers to menu items or groups of menu items.

Common Unit - can be expressed as the gross or net profit of each menu item or groups of menu items (4, p.2).

Total Return - means that the total profit of a food service unit is made up of the profits of each of the items sold in the unit (4, p.2).

Markovian Chain - a Markovian Chain is a stochastic process where at each step, the transition probability matrix determines the conditional probability of the outcome of the experiment, provided the outcome of the previous experiment is given (5, p. 241).

CHAPTER II

REVIEW OF LITERATURE

The concept of using mathematical models in the food service system to help managers make decisions has been developed for several years. The problem of finding a nutritionally adequate diet at least cost was a classic example of the application of mathematical model, linear programming methods. The idea was to develop a model for obtaining a nutritionally adequate diet at least cost based on the Recommended Dietary Allowance and also for evaluating the food acceptability, food preference, menu structure, and menu item combination's acceptability.

Recently a mathematical model has been formulated and tested to determine quantitatively how to measure food preferences. This is the new method of measuring food preferences, particularly the principle of constrained optimization. Balintfy (6) suggested that the best area in which to test this model was in college food service management, where the skilled personnel and computer capacity needed for implementation were readily available.

The following literature presented the results of investigation by many authors of measuring food preferences, mathematical models in menu planning, application of Markov Chain, and various research procedures and methods.

Measuring Food Preferences

The rating scale method had widespread use in food research to measure food preference. The hedonic rating scale is described as the method of successive intervals expressed as "like extremely" through "neither like nor dislike". It is flexible enough to be used for laboratory consumer preference evaluations and ot measure general attitudes toward foods.

The hedonic scale method was first used at the Food and Container Institute as a method of predicting soldiers' food choices. Peryam and Pilgrim (7) forecasted the hedonic scale mthod as the technique for the achievement of reliablility in consumer preference evaluation.

Peryam and Pilgrim (7) summarized some of the advantages of the hedonic scale method. The simplicity was an important element of the hedonic scale, i.e., the hedonic scale and the instructions were designed for use with inexperienced subjects. Wood and Peryam (8) analyzed a nationwide Army Food Preference survey which involved the use of the hedonic scale. They used a nine-point scale. Preliminary tests showed that respondent fatigue or boredom affected results when more than 60 food items were rated as part of a single questionnaire.

Jone, Peryam, and Thurstone (9) had made several reports on trying to determine the optimum width, position and number of intervals. Unfortunally, they were not able to determine the exact specification for a superior scale, but they (9) did develop some conclusions of the essential features of measuring food preferences. They were as follows:

1. Descriptive phrases may differ greatly in ambiguity.
2. They differ also in the level of preference implied, and this can not always be predicted on prior basis.
3. Increasing the length of a scale, up to nine intervals is related to only a negligible increase in the time required for completion.

4. Test-retest reliability, within the range of five to nine intervals is relatively invariant.

5. Longer scales, up to nine intervals, tend to more sensitive to difference among foods.

6. Elimination of the "neutral" category seems to be beneficial.

7. Balance, i.e., an equal number of positive and negative intervals, is not an essential feature of a rating scale.

For what did the scores stand? Peryam and Girardot (10) found the following meanings:

1. Mean ratings below 5.0 generally represented poor quality or strange foods basing on nine-point scale.

2. Mean ratings over 7.5 represent good quality samples of highly popular foods basing on nine-point scale.

If sampling of observers was appropriate and tests were properly run, the hedonic scale method might serve a fourfold purpose: (1) to detect small differences in the direct response to foods; (3) to reveal differences in group preference attitudes; and (4) to make general predictions about the acceptance level of any food (10).

Schutz (11) had obtained food preference ratings on two occasions from 91 men at a military installation. A nine-point rating scale for 94 foods was used. "The subjects were on an ad libitum eating schedule for one month during which the amount of each food taken and eaten by each subject was recorded" (11, p.412). When correlations were computed between the mean preference ratings and two measures of food behavior, the correlations obtained were all significant (.51 to .77). The data indicated that up to 59 per cent of the variance in food behaviors could be accounted for by preference ratings. "Acceptance at the serving line" and "actual consumption" were the two measures of food behavior correlated with the mean preference ratings (11). So collecting the food preference data was the first step for the food service operator to forecast the menu items consumption.

Mathematical Model in Menu Planning

Effective planning of menus required a satisfactory simultaneous interrelationship of several variables: Customer preference an frequency of acceptance for menu items; type of customers; cost; variety in texture; flavor, color; preparation time; labor and equipment to prepare and serve food; and nutritional adequacy. A system for determinating the interrelationships of these food service variables was needed so effective planning and execution of plans could be optimized in food service facilities.

It is a complex process to develop a computer program to plan institutional menu. A model is used to specify the relationship among key factors; it guides program development. Mathematical Models, which are a series of equations, are the most common type. Three types of equations are common in models for decision-making (12). Definitional equations define relationships among variable. Technological equations express results of physical processes. Behavioral equations simulate or predict behavior of customers. Mathematical model will not predict correct results unless it considers the actual operation and realism. The mathematical model is only a complicated and impressive way of making an unverified guess. It is dangerous for both the model builder and management to confuse the real world with model which simulates the situation.

Poor menus and poor decisions regarding use of the menus might result.

The history of using mathematical models in menu planning has about 30 years. The first formulation of the diet problem was made in 1941 and was original by solved using a calculator (13). Linear programming solutions to the diet problem have been used to great advantage in formulating various feed blends for animals. Smith and Stigler (14) developed a model for obtaining a nutritionally adequate subsistance diet at least cost in 1945 based on the 1943 Recommended Dietary Allowance and selected premises regarding nutritional requirements and the nutrient contributions of a small variety of foods. After several years of research in developing solutions to the diet problem, Smith concluded that the principal problem to be solved in putting programming into operational use in institutional feeding is controlling the palatability of the diet.

Stochastic programming techniques and random selection methods are also used by several researchers in planning a menu (15, 16, 17, 18). They take into account customer's satisfaction, food/labor cost ratio, nutritional constraints and develop responsive menu planning systems that more nearly meet the needs of consumers, workers, and management.

Some Applications of Markov Chains to a Variety of Fields

Krenz (19) used Markov Chains to predict the number of farms of various sizes in the future. The transition probabilities were estimated by using census data; they did not use a mathematical way to determine the transition matrix.

Henry, McGinnis, and Tegtmeyer (20) had been using Markov Chains model for studying human mobility. They attempted to model short run moves among industrial categories, intergenerational occupational mobility, and human migration. In studying human migration, sociologists used various geographical locations as the states and estimated the transition probabilities using past data.

Bruce (21) proposed a simple four-state Markov model to describe the dynamics of a lending library. He stated that the work load on the library might be regarded as transitions between the states occupied by the library user, and performance might be regarded as the proportion of the various transitions between these states. These states included the borrower requesting the item for the first time, the borrower requesting an item for the second or later time, the borrower in possession of the book, and the borrower who left the system and would not attempt to borrow that book again. Markov model was to interrelate the demand factors and service factor and suggested the best loan period policy to the library.

Trommelen, Grace, and Hanson (22) used a Markov Chain to predict student enrollment in grades one to 12 for the school years of 1971 to 1985. This was a long term model for primary and secondary education. The transition probabilities were estimated by using the data from the <u>Education Annual Report of the Province of Alberta</u> which gave the failure rates and dropout rates.

Policy Improvement Technique for Finding Optimal Procedures

Markov Chain models derived their name from the fact that the equations of the model involved a transition matrix whose elements might be interpreted as the probabilities that a customer would change his or her mind to pick up another menu item. Borsenik (4) had applied this model in fast food service operation. The foodservice operator always faced the problem of deciding what to offer the customer to maximize the profit from the unit. The Policy Improvement Technique was introduced to solve this problem. It would indicate the best or optimum pricing policy for a foodservice unit. It could be summarized as follows (23):

Step 1:

For an arbitrarily chosen policy R, used $P_{ij}\left[d_i(R)\right]$ and $q_i\left[d_i(R)\right]$ to solve the set of equations.

$V_i(R) = q_i\left[d_i(R)\right] + \sum_{j=1}^{M} P_{ij}\left[d_i(R)\right] \; V_i(R)$, for i=1,2,...,M for all present values $V_i(R)$.

where

$$q_i\left[d_i(R)\right] = \sum_{j=1}^{M} P_{ij}\left[d_i(R)\right] \; r_{ij}\left[d_i(R)\right]$$

$P_{ij}\left[d_i(R)\right]$ was the transition probability of going from state i to state j when decision $d_i(R)$ was made while operating under policy R. $r_{ij}\left[d_i(R)\right]$ was the reward associated with the transition from state i to state j when decision $d_i(R)$ was made while operating under policy R. $V_i(R)$ was defined as the present value of the total expected reward for a system starting in state i under a given policy R.

Step 2:

Found the alternative policy R', for each state i, $d_i(R)$ was the decision made

$$q_i\left[d_i(R')\right] + \sum_{j=1}^{M} P_{ij}\left[d_i(R')\right] \; V_j(R)$$

a maximum, using the present values $V_j(R)$ just computed from the previous policy. Then R' became the new policy and $d_i(R')$ became the new decision in the i th state, $q_i\left[d_i(R')\right]$ became $q_i\left[d_i(R)\right]$, and $P_{ij}\left[d_i(R')\right]$ became $P_{ij}\left[d_i(R)\right]$, and Step 1 was repeated with this policy R'. The iterition cycle would be able to make policy improvements until the policies on the successive iterition were identical. At this point the optimal policy had been found, and the procedure was completed.

If there was no prior basis for selecting an initial policy in Step 1, it was often convenient to start the process with Step 2 in the policy improvement technique with all $V_i(R)$ set equal to zero. The initial policy selected would then be the one that maximized the reward.

In order to determine the average expected reward per unit time criterion with optimum policy rather than total expected reward criterion, one must have a simple modification in Step 1. This modification replaced the equation that must be solved in Step 1 by the equations.

$$G(R) + V_i(R) = q_i\left[d_i(R)\right] + \sum_{j=1}^{M} P_{ij}\left[d_i(R)\right] V_j(R) \quad \text{for } i=1,2,\ldots,M.$$

The value for G(R) indicated that the average expected reward per unit time for the policy R.

These equations were solved for all $V_i(R)$ and G(R) by setting $V_M(R)$ equal to zero. The final value of G(R) was the average expected reward per unit time for the optimal procedure (23).

CHAPTER III

METHOD AND PROCEDURE

The customers eating in the Student Union cafeteria at Oklahoma State University were surveyed to determine their reactions to a list of foods. Student Union cafeteria offered both a la carte and contract service. The contract type of food service was available to students living in Murray Hall. An a la carte food service was available to those university faculty, employee, visiting people, and students. This a la carte type of service was selected as the site of the study. It served three meals per day, seven days per week and had one serving line. A full regular breakfast was served between 7:00 A.M. The regular luncheon menu was served from 11:00 A.M. to 1:30 P.M. and dinner from 5:00 P.M. to 6:30 P.M. The average number of customers served at breakfast was 90 and at luncheon was 150 and at dinner was 90.

The Check List

A survey was designed to collect data about food preferences. The use of a check list seemed to be a most economical, logical way of obtaining the needed information for this study. The check list was composed of 37 luncheon and dinner entree items from the a la carte cafeteria menu (see Appendix A). The author had reviewed the past two months of menu served in a la carte cafeteria. To delimit the study, only entree items were included because they traditionally comprised the most costly part of the menu; also, it was hypothesized that the entree was a major factor in patron menu acceptance. In order to establish the transition probabilities, the entree items were grouped in four categories. They were chicken, pork, beef, and fish. Instructions printed at the top of the page seemed to sufficiently explain how to complete the check list. The hedonic scale was used to rate foods along a seven-point from "like very much" to "never tasted". It was under the assumption that the population was homogeneous, that the mean ratings could represent the customer preference for the entree items.

The check lists were distributed when customers came through the cafeteria serving line in the mealtime. Data collection was from November 28, 1977 to December 9, 1977. In order to draw random samples, checklists were passed out to customers on Tuesday and Thursday in the first week then Monday, Wednesday, and Friday in the second week. During the second week, the customers were asked whether they have filled out the checklist or not to avoid the repetition on the sampling. The valid sample size was 132 checklists. The sample size was determined by using the Table for Determining Sample Size from a Given Population (24). Whenever the customers finished their food preferences check lists, they turned it in with their receipts to the cashier.

Analysis of Data

The Policy Improvement Technique for Finding Optimal Procedure was introduced to analyze the collected data. The transition probability data were obtained from food preference rating scales. Using the data from the returned check lists for calculation, the mean rating scale for each entree item was determined (see Appendix D). Then, the mean rating scales were converted to percentages. In order to establish the transition probability, it would be assumed that if the customer did not select beef, he or she then would select pork or chicken or fish, if the establishment served the beef, chicken, pork and fish in one meal. Therefore, input of these data into the Markov Chains model was used to predict the percentage of customers who would consume each entree served in one meal. After knowing the net profit for each entree, this could be determined by the food service operator, the Policy Improvement Technique for Finding Optimal Procedure could be used to maximize the profit and also consider customers' food preferences.

CHAPTER IV

RESULTS AND DISCUSSION

The objectives of this research were to use the Markovian Chain technique to determining relationships between customers food preferences and net profit and menu item consumption. The results of this research were divided into two parts. One was a survey of food preferences and the other was Markov model for policy improvement technique.

Survey of Food Preferences

The customers included in this survey were randomly drawn from the customers in the Student Union cafeteria, so they would represent the characteristic of the population. Similar entrees were grouped into four categories, poultry, pork, beef, and fish on a check list handed to customer as they came through the serving line. The preparation methods of the entrees were considered as a factor to influence the food preference transition probabilities. Table I was a compilation of the mean preference scores for the 37 entrees by categories included on the instrument. A higher preference scores indicated greater degree of "like" for an entree. The mean rating scores below 3.85 generally represented entrees not selected. The mean rating scores over 5.39 represented selection entrees of highly popular foods (9).

Table XI and Table XII summarized the number and percentage responses for the preference data (see Appendix B and Appendix C). The

Maryland chicken had a high percentage of "Never tasted" responses. The ambiguous name for this entree might have been responsible for the high degree of unfamiliarity. Roast beef had the highest (6.10) mean rating score among the 37 entree items. Cheeseburger loaf had the lowest mean rating score among the 37 entree items. However, the data from each entree item were analyzed through "like very much" to "Never tasted". It showed charcoal steak also had a very high response as indicated by their checking "like very much" (6.01 mean score). Sixty-six persons in this survey checked they liked charcoal steak very much. Cheeseburger loaf had the highest responses to the check "Never tasted" (mean score of 4.03). Thirty-three persons in this survey indicated they had never tasted the cheeseburger loaf. But the tuna potato chip casserole had the highest number of persons (17) that indicated they "disliked it very much". Table IV shows the rank order of the 134 raters ot the 37 food items listed.

Markov Model for Policy Improvement Technique

Under this research, the best menu item combination was to be tested by using the Policy Improvement Technique. The foodservice manager in the Student Union cafeteria plans the menu. There were several chicken, ham, and fish items offered on the menu. Each item would be offered at different prices as determined by food and labor cost. Table V indicated the possible combination for these items with pricing and net profits. But, it had been found that it was too costly for all food items to be prepared in one meal and therefore the food service operator could not offer all these items. So the next step was to decide the best combination of foods to prepare for customers. The price was obtained from

TABLE I

MEAN PREFERENCE SCORES FOR 37 ENTREE ITEMS ON THE CHECK LIST

Food Entree Items	Mean of Food Preferences
1. Fried Chicken	5.90
2. Baked Chicken	5.72
3. Maryland Chicken	4.95
4. Bar-B-Que Chicken	5.33
5. Turkey Supreme	4.22
6. Sliced Turkey/Dressing	5.68
7. Chicken A La King	4.55
8. Chicken Pot Pie/Biscuit	4.90
9. Ham Steak	5.43
10. Grilled Ham Slice	5.31
11. Baked Ham	5.93
12. Roast Pork/Dressing	5.06
13. Grilled Pork Cutlet	5.07
14. Ham and Beans/Cornbread	5.12
15. Ham Loaf/Mustard Glaze	4.14
16. Bar-B-Que Spareribs	5.50
17. Roast Beef	6.10
18. Grilled Beef Steak	5.67
19. Salisbury Steak	5.44
20. Baked Steak	5.28
21. Smothered Steak	5.55
22. Charcoal Steak	6.01
23. Swiss Steak	5.63
24. Chicken Fried Steak	5.68
25. Beef Pot Pie/Crust	4.75
26. Creamed Chipped Beef	4.41
27. Meat Loaf	5.16
28. Cheeseburger Loaf	4.03
29. Beef Stew	5.34
30. Beef Chop Suey	4.66
31. Lasagna	5.34
32. French Fried Cod	4.78
33. French Fried Catfish	4.96
34. Tuna Potato Chip (Casserole)	4.25
35. Tuna Noodle Casserole	4.66
36. Baked Halibut	4.66
37. French Fried Perch Fillets	4.64

TABLE II

RANK ORDER OF FOOD PREFERENCES
AS SELECTED BY 134 RATERS

FOOD	Mean	Rank Order
Roast Beef	6.10	1
Charcoal Steak	6.01	2
Baked Ham	5.93	3
Fried Chicken	5.90	3
Baked Chicken	5.72	4
Sliced Turkey/Dressing	5.68	5
Chicken Fried Steak	5.68	6
Grilled Beef Steak	5.67	7
Swiss Steak	5.63	8
Smothered Steak	5.55	9
Bar-B-Que Spareribs	5.50	10
Salisbury Steak	5.44	11
Ham Steak	5.43	12
Beef Stew	5.34	13
Lasagna	5.34	14
Bar-B-Que Chicken	5.33	15
Grilled Ham Slice	5.31	16
Baked Steak	5.28	17
Meat Loaf	5.16	18
Ham and Bean/Cornbread	5.12	19
Grilled Pork Cutlet	5.07	20
Roast Pork/Dressing	5.06	21
French Fried Catfish	4.96	22
Maryland Chicken	4.95	23
Chicken Pot Pie/Biscuit	4.90	24
French Fried Cod	4.78	25
Beef Pot Pie/Crust	4.75	26
Beef Chop Suey	4.66	27
Baked Halibut	4.66	28
Tuna Noodel Casserole	4.66	29
French Fried Perch Fillets	4.64	30
Chicken A La King	4.55	31
Creamed Chipped Beef	4.41	32
Tuna Potato Chip	4.25	33
Turkey Supreme	4.22	35
Ham Loaf/Mustard Glaze	4.14	36
Cheeseburger Loaf	4.03	37

TABLE III

SELECTED COMBINATION OF ENTREE ITEMS ACCORDING TO PRICING, AND NET PROFITS

Item	Price	Net Profits*
Poultry Item:		
Fried Chicken	1.00	.45
Baked Chicken	1.00	.45
Maryland Chicken	1.10	.43
Bar-B-Que Chicken	1.00	.41
Sliced Tufkey/Dressing	1.25	.56
Turkey Supreme	.85	.37
Chicken A La King	.85	.38
Pork Item:		
Ham Steak	1.25	.56
Grilled Ham Slice	1.25	.54
Baked Ham	1.25	.56
Roast Pork/Dressing	1.25	.56
Ham and Beans/Cornbread	.85	.38
Ham Loaf/Mustard Glaze	.85	.36
Fish Item:		
French Fried Cod	1.00	.40
French Fried Catfish	1.00	.40
French Fried Perch Fillets	1.00	.40
Tuna Potato Chip	.85	.40
Tuna Noodle Casserole	.85	.38
Baked Halibut	1.00	.40

* Does not include cost of production

the menu and the net profits was from purchasing and/or purchasing and production records. The profits shown in Table III were net profits figures, only considering the cost of the food not the production charges.

To maximize the net profit and customer food preferences, the researcher selected thae best combination of three foods for entrees that is Fried Chicken, Ham Steak, and French Cod. Utilizing the mean preference scores obtained from the preference checklist, the next set of data that was required in order to use the Markovian technique was the transition probabilities. In order ot obtain the transition probabilities, baked chicken, Maryland chicken were grouped in one category called fried chicken, Grilled ham slice, and baked ham were placed in the category of ham steak, and French Fried catfish, French Fried perch fillets were classified as French Fried cod (see Table IV).

TABLE IV

MENU ENTREES FOR THE MARKOV ANALYSIS

Fried Chicken
Baked Chicken
Maryland Chicken
Ham Steak
Grilled Ham Slice
Baked Ham
French Fried Cod
French Fried Catfish
French Fried Perch Fillets

The purpose of this procedure was to weigh the mean preference scores, assuming that if the customer did not select the chicken, he or she would select ham or one of the other fish. It was assumed that this procedure should precisely indicate the customers food preferences. The principle of this grouping procedure was to determine whether a customer would select a food because it was prepared to his or her liking or if another food would be selected because he or she likes that food no matter how it was prepared.

TABLE V

MEAN PREFERENCE SCORES AND PERCENTAGE
OF MEAN PREFERENCE SCORES FOR
EACH ENTREE ITEM SHOWN
IN TABLE VI

Item	Mean Preference Score	Percentage mean Score(%)
Fried Chicken	5.90	12.4
Baked Chicken	5.72	12.0
Maryland Chicken	4.95	10.4
Ham Steak	5.43	11.4
Grilled Ham Slice	5.31	11.2
Baked Ham	5.93	12.5
French Fried Cod	4.78	10.0
French Fried Catfish	4.96	10.4
French Fried Perch Fillets	4.64	9.7

Table V shows the mean preference scores and percentage mean preference scores for the indicated menu items. The researcher then calculated the percent that would select chicken as in a poultry group, or ham as in a pork group, or fish as a group based on the breakdown of percentage mean preference scores. The next step was to determine the actual transition data from these data. For example, (0.124 + 0.120 + 0.104) 34.8 percent would select chicken and 35.1 percent would select ham, and 30.1 percent would select the fish. So 47.2 percent of the non-fried chicken orders $\left(\frac{0.351}{0.652} \times 0.876\right)$ would select ham group and 40.4 percent of the non-fried chicken orders $\left(\frac{0.301}{0.652} \times 0.876\right)$ would select the fish group. The 0.652 term is 0.351 + 0.301. A similar analysis for the baked chicken orders indicated the following: 47.4 percent $\left(\frac{0.351}{0.652} \times 0.880\right)$ would select ham group and 40.6 percent $\left(\frac{0.301}{0.652} \times 0.880\right)$ would select fish group. Table VIII indicated all the transition probabilities for each entree item. Another way to view the Table VIII was to add all the transition probabilities column by column and get the subtotal, (subtotal(chicken), subtotal (ham), subtotal(fish), then add these subtotals up to overall total (overall total = subtotal(chicken) + subtotal (ham) + subtotal(fish)). Each subtotal was divided by overall total. The figure was indicated how many percentage of the population would select that menu item. This forecast basing on Markov technique was to predict the customers food selection. The function of this prediction was to reduce the over- and under-production in foodservice system. In this research, the author predicted 34.6 percent would select the chicken group and 34.8 percent would select the ham group and 30.6 percent on fish group.

Subtotal (chicken) = 3.112

Subtotal (ham) = 3.134

Subtotal (fish) = 2.754

Overall total = 3.112 + 3.134 + 2.754 = 9.000

Percentage of Chicken = $\frac{3.112}{9.000}$ x 100 = 34.6%

Percentage of ham = $\frac{3.134}{9.000}$ x 100 = 34.8%

Percentage of fish = $\frac{2.754}{9.000}$ = 30.6%

The final step was to determine the profit levels that correspond to the transition probabilities. A weighted average profit was determined and the results were shown in Table VII. Combining Tables V and VI results, transition probabilities and expected profits, as was shown in Table VIII.

Based on policy improvement technique, the initial policy selected would then be the one that maximized the reward ($q_i[d_i(R)]$). The rewards (profit and customer preference) could be computed using the formula from Step 1, policy improvement technique. For example, for fried chicken, the reward should have the following results:

Reward (F.Chix) = 0.124 x 0.45 + 0.472 x 0.51 + 0.404 x 0.43 = 0.47024

Reward (B.Chix) = 0.120 x 0.45 + 0.474 x 0.51 + 0.404 x 0.43 = 0.47032

Table XI indicated the results of the reward computation.

The (*) indicated the initial policy to follow, which was

Policy(R1) = (Baked Chicken, Ham Steak, French Fried Cod).

After getting the initial policy, we should go back to step 1 to solve the set of equations and get the total expected reward for a system starting in state i under a initial policy R.

G(R) + V1(R) = 0.47023 + 0.124 V1(R) + 0.472 V2(R) + 0.404 V3(R)

G(R) + V2(R) = 0.50337 + 0.475 V1(R) + 0.114 V2(R) + 0.411 V3(R)

G(R) + V3(R) = 0.44960 + 0.448 V1(R) + 0.452 V2(R) + 0.100 V3(R)

TABLE VI

TRANSITION PROBABILITIES FOR A TIME PERIOD OF CUSTOMER ORDERS

Item	Transition j=Chicken	Probability j=ham	j=fish
Fried Chicken	0.124	0.472	0.404
Baked Chicken	0.120	0.474	0.406
Maryland Chicken	0.104	0.482	0.414
Ham Steak	0.475	0.114	0.411
Grilled Ham Slice	0.476	0.112	0.412
Baked Ham	0.469	0.125	0.406
French Fried Cod	0.448	0.452	0.100
French Fried Catfish	0.446	0.450	0.104
French Fried Perch Fillets	0.450	0.453	0.097

TABLE VII

EXPECTED PROFITS FOR THE MENU THAT CORRESPOND TO THE SELECTION OF VARIOUS MENU ITEMS

Menu Item	Expected Gross Food Profit		
	i=chicken	i=ham	i=fish
Fried Chicken	0.45	0.51	0.43
Baked Chicken	0.45	0.51	0.43
Maryland Chicken	0.43	0.50	0.42
Ham Steak	0.51	0.56	0.48
Grilled Ham Slice	0.51	0.54	0.47
Baked Ham	0.50	0.56	0.48
French Fried Cod	0.43	0.48	0.40
French Fried Catfish	0.43	0.47	0.40
French Fried Perch Fillets	0.42	0.48	0.40

TABLE VIII

TRANSITION PROBABILITIES AND EXPECTED PROFITS
FOR THE CAFETERIA MENU ITEMS

Menu Items	Transition Probability			Expected Gross Food Profit		
	i=chicken	i=ham	i=fish	i=chicken	i=ham	i=fish
Fried Chicken	0.124	0.472	0.404	0.45	0.51	0.43
Baked Chicken	0.120	0.474	0.406	0.45	0.51	0.43
Maryland Chicken	0.104	0.482	0.414	0.43	0.50	0.42
Ham Steak	0.475	0.114	0.411	0.51	0.56	0.48
Grilled Ham Slice	0.476	0.112	0.412	0.51	0.54	0.47
Baked Ham	0.469	0.125	0.406	0.50	0.48	0.48
French Fried Cod	0.448	0.452	0.100	0.43	0.48	0.40
French Fried Catfish	0.446	0.450	0.104	0.43	0.47	0.40
French Fried Perch Fillets	0.450	0.453	0.097	0.43	0.48	0.40

TABLE IX

REWARDS FOR THE CAFETERIA
ENTREE ITEMS

Item	Rewards	
Fried Chicken	0.47024	
Baked Chicken	0.47032	*
Maryland Chicken	0.45960	
Ham Steak	0.50337	*
Grilled Ham Slice	0.49688	
Baked Ham	0.49938	
French Fried Cod	0.44960	*
French Fried Catfish	0.44488	
French Fried Perch Fillets	0.44524	

These equations were solved for all $V_1(R)$, $V_2(R)$, $V_3(R)$, and $G(R)$ By setting $V_3(R) = 0$ and the results were

$V_1(R) = 0.0163$

$V_2(R) = 0.0405$

$V_3(R) = 0$

$G(R) = 0.4752$

Now, the author defined the expected reward as the following:

$$ER_i = q_i\left[d_i(R')\right] + \sum_{j=1}^{M} P_{ij}\left[d_i(R')\right] \; V_j(R)$$

For example, the expected reward for fried chicken was shown below:

ER = 0.47024 + 0.124 x 0.0163 + 0.0405 x 0 x 0.404 = 0.49138

The expected reward for baked chicken was:

ER = 0.47032 + 0.0163 x 0.120 + 0.0405 x 0.474 + 0 x 0.406 =0.49147

Table X showed the results of all the computations.

TABLE X

EXPECTED REWARDS FOR EACH MENU ITEM

Item	Expected Reward	
Fried Chicken	0.49138	
Baked Chicken	0.49147	*
Maryland Chicken	0.48082	
Grilled Ham Slice	0.50917	
Ham Steak	0.51573	*
Baked Ham	0.51209	
French Fried Cod	0.47512	*
French Fried Catfish	0.47037	
French Fried Perch Fillets	0.47092	

This policy was the same as the previous policy, hence there was no change in policy so the procedure was completed. This policy indicated the foodservice operator, because of the rewards, should select baked chicken, ham steak, and french fried cod to the food entrees. Little emphasis should be placed on Maryland chicken, Grilled ham slice, and french fried catfish. It should be noted that the policy did not increase the number of customers, it only made better use of customer food preferences.

CHAPTER V

SUMMARY AND CONCLUSIONS

The need for accurate forecasting techniques has become more important in foodservice management because of rising food costs. Production forecasting consists of two basic interrelated elements: The population estimate and the food selection prediction. Accurate forecasting relies on the reliability of the collected data and the forecasting technique used. The purpose of this research was to find the mathematical relationship between food preference, net profit, and menu item consumption to determine the best policy in making a profit for food service operators.

The study focused on recommending the best menu item combination to the food service operator, based on the present customers preferences. The survey instrument consisted of a listing of 37 entree items derived by review of the past two months of menus served in a la carte cafeteria. The hedonic scale was employeed to measure the customers food preferences. The Student Union cafeteria was selected as the site of the study. Research instruments were delivered to each customer in the sample; 89 percent was returned (N=134). The check lists were distributed when customers came through the cafeteria serving line in the meal time.

Preference findings indicated that roast beef had the highest mean rating score among the 37 entree items. Cheeseburger loaf had the lowest mean rating score among the 37 entree items. Items liked by at least 66 percent of the respondents were fried chicken, baked chicken, roast beef, grilled beef steak, charcoal steak, ans swiss steak. Items disliked by 33 percent or more of the respondents included turkey supreme, chicken a la king, ham loaf, creamed chipped beef, cheeseburger loaf, beef chop suey, tuna potato chip, tuna noodle casserole, baked halibut, and french fried perch fillets. Many of the same foods were included in both the disliked and never tasted categories.

The Markovian Technique is used to indicate the best menu item combination for a foodservice operator. The Technique is based on customer food preference. The transition probabilities were established by using the customer mean rating scales. The net profit for each entree item was determined by the manager. The Markov Model for Policy Improvement Technique was introduced to analyze these data. In this research, the Technique implied that baked chicken, ham steak, and french fried cod were the best entree combination to the customers and food service operators, if they should offer chicken, ham, and fish to the customers.

Recommendation

These data provided valuable background information and a basis for further study. When the Markovian Technique is correctly applied, it can control over- and under-production and is also a good method to control inventory and cost to increase the net profits for the food service industry.

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APPENDIXES

APPENDIX A

FOOD PREFERENCE CHECK LIST

Food Preference Checklist

The food preference questionnaire on this page is one of several containing representative foods of entrees. No one list is complete, so do not be concerned if there are other menu items about which you would like to comment. When making your choice, think of the entrees as served to you here, if they have not been served, then think of them in the form in which you have eaten them elsewhere. This is a part of Master Thesis study in the Department of Food, Nutrition and Institution Administration.

Your cooperation in completing this questionnaire is appreciated.

HWA-YUAN HUANG

FNIA Graduate Student

DIRECTION: As you read the folling list of foods, place a check (√) in the column which best indicates your preference.

	Food Entree Item	Like Very Much	Like Moder- ately	Like Sligh- tly	Dislike Sligh- tly	Dislike Moder- ately	Dislike Very Much	Never Tasted
1.	Fried Chicken							
2.	Baked Chicken							
3.	Maryland Chicken							
4.	Bar-B-Que Chicken							
5.	Sliced Turkey/Dressing							
6.	Turkey Supreme							
7.	Chicken A La King							
8.	Chicken Pot Pie/Biscuit							
9.	Ham Steak							
10.	Grilled Ham Slice							
11.	Baked Ham							
12.	Roast Pork/Dressing							
13.	Grilled Pork Cutlet							
14.	Ham and Beans/Cornbread							
15.	Ham Loaf/Mustard Glaze							
16.	Bar-B-Que Spareribs							
17.	Roast Beef							
18.	Grilled Beef Steak							
19.	Salisbury Steak							
20.	Baked Steak							
21.	Smothered Steak							
22.	Charcoal Steak							
23.	Swiss Steak							
24.	Chicken Fried Steak							

Food Entree Item	Like Very Much	Like Moder-ately	Like Sligh-tly	Dislike Sligh-tly	Dislike Moder-ately	Dislike Very Much	Never Tasted
25. Beef Pot Pie/Crust							
26. Creamed Chipped Beef							
27. Meat Loaf							
28. Cheeseburger Loaf							
29. Beef Stew							
30. Beef Chop Suey							
31. Lasagna							
32. French Fried Cod							
33. French Fried Catfish							
34. Tuna Potato Chip(casserole)							
35. Tuna Noodle Casserole							
36. Baked Halibut							
37. French Fried Perch Fillets							

APPENDIX B

THE NUMBER OF CUSTOMERS RESPONSE TO THE

37 FOOD ENTREE ITEMS

TABLE XI

THE NUMBER OF CUSTOMERS RESPONSE TO THE
37 FOOD ENTREE ITEMS

	Food Entree Items	Like Very Much	Like Moder- ately	Like Sligh- tly	Dislike Sligh- tly	Dislike Modera- tely	Dislike Very Much	Never Tasted
1.	Fried Chicken	59	41	18	5	2	7	2
2.	Baked Chicken	45	48	26	4	1	5	5
3.	Maryland Chicken	17	49	33	10	6	8	11
4.	Bar-B-Que Chicken	34	42	30	9	7	5	7
5.	Turkey Supreme	8	33	39	16	5	4	29
6.	Sliced Turkey/Dressing	42	44	30	9	2	4	3
7.	Chicken A La King	12	36	40	15	5	9	17
8.	Chicken Pot Pie/Biscuit	21	34	42	9	14	4	10
9.	Ham Steak	39	48	24	5	2	5	11
10.	Grilled Ham Slice	34	46	29	4	5	5	11
11.	Baked Ham	57	48	15	3	2	5	4
12.	Roast Porking/Dressing	28	44	25	13	6	5	13
13.	Grilled Pork Cutlet	26	43	28	13	9	6	9
14.	Ham and Beans/Cornbread	43	29	25	8	7	11	11
15.	Ham Loaf/Mustard Glaze	16	22	31	19	10	14	22
16.	Bar-B-Que Sparerib	49	31	30	9	2	3	10
17.	Roast Beef	66	40	14	8	3	1	2
18.	Grilled Beef Steak	43	47	24	11	1	2	6
19.	Salisbury Steak	31	49	33	8	2	4	7
20.	Baked Steak	28	44	37	10	2	3	10
21.	Smother Steak	35	51	25	12	3	3	5
22.	Charcoal Steak	72	34	14	4	0	1	9
23.	Swiss Steak	40	50	23	8	6	2	5
24.	Chicken Fried Steak	50	35	27	10	5	4	3

TABLE XI (Continue)

	Food Entree Items	Like Very Much	Like Moder-ately	Like Sligh-tly	Dislike Sligh-tly	Dislike Modera-tely	Dislike Very Much	Never Tasted
25.	Beef Pot Pie/Crust	13	38	38	20	5	4	3
26.	Creamed Beef	14	33	38	15	14	15	13
27.	Meat Loaf	31	34	34	11	13	6	5
28.	Cheeseburger Loaf	18	24	31	7	12	9	33
29.	Beef Stew	32	35	47	6	2	5	7
30.	Beef Chop Suey	18	36	34	15	7	7	17
31.	Lasagna	42	41	18	8	7	14	4
32.	French Fried Cod	27	35	31	6	6	15	14
33.	French Fried Catfish	29	40	24	11	8	11	11
34.	Tuan Potato Chip(casserole)	18	30	26	13	9	17	21
35.	Tuan Noodle Casserole	29	26	32	10	8	13	16
36.	Baked Halibut	32	30	23	10	5	6	18
37.	French Fried Perch Fillets	27	36	26	5	6	15	19

APPENDIX C

THE PERCENTAGE OF CUSTOMERS RESPONSE TO

THE 37 FOOD ENTREE ITEMS

TABLE XII

THE PERCENTAGE OF CUSTOMERS RESPONSE TO
THE 37 FOOD ENTREE ITEMS

	Food Entree Items	Like Very Much	Like Moderately	Like Slightly	Dislike Slightly	Dislike Moderately	Dislike Very Much	Never Tasted
1.	Fried Chicken	44	31	13	4	1	5	1
2.	Baked Chicken	34	36	19	3	1	4	4
3.	Maryland Chicken	13	37	25	7	4	6	8
4.	Bar-B-Que Chicken	25	31	22	7	5	4	5
5.	Turkey Supreme	6	25	29	12	4	3	22
6.	Sliced Turkey/Dressing	31	33	22	7	1	3	2
7.	Chicken A La King	9	27	30	11	4	7	13
8.	Chicken Pot Pie/Biscuit	16	25	31	7	10	3	7
9.	Ham Steak	29	36	18	4	1	4	8
10.	Grilled Ham Slice	25	34	22	3	4	4	8
11.	Baked Ham	43	36	11	2	1	4	3
12.	Roast Beef	21	33	19	10	4	4	10
13.	Grilled Pork Cutlet	19	32	21	10	7	4	7
14.	Ham and Beans/Cornbread	32	22	19	6	5	8	8
15.	Ham Loaf/Mustard Glaze	12	16	23	14	7	10	16
16.	Bar-B-Que Spareribs	37	23	22	7	1	2	7
17.	Roast Beef	49	30	10	6	2	1	1
18.	Grilled Beef Steak	32	35	18	8	1	1	4
19.	Salisbury Steak	23	37	25	6	1	3	5
20.	Baked Steak	21	33	28	7	1	2	7
21.	Smothered Steak	26	38	19	9	2	2	4
22.	Charcoal Steak	54	25	10	3	0	1	7
23.	Swiss Steak	30	37	17	6	4	1	4
24.	Chicken Fried Steak	37	26	20	7	4	3	2

TABLE XII (continued)

	Food Entree Items	Like Very Much	Like Moder- ately	Like Sligh- tly	Dislike Sligh- tly	Dislike Moder- ately	Dislike Very muvh	Never Tasted
25.	Beef Pot Pie/Crust	10	10	28	28	15	8	1
26.	Creamed Chipped Beef	10	25	22	11	10	11	10
27.	Meat Loaf	23	25	25	7	11	4	4
28.	Cheeseburger Loaf	13	18	23	5	9	7	25
29.	Beef Stew	24	26	35	4	1	4	5
30.	Beef Chop Suey	13	27	25	11	5	5	13
31.	Lasagna	31	31	13	6	5	10	3
32.	French Fried Cod	20	26	23	4	4	11	10
33.	French Fried Catfish	22	30	18	8	6	8	8
34.	Tuna Potato Chip(casserole)	13	22	19	10	7	13	16
35.	Tuna Noodle Casserole	22	19	24	7	6	10	12
36.	Baked Halibut	25	21	17	7	4	12	13
37.	French Fried Perch Fillets	20	27	19	4	4	11	14

APPENDIX D

PROGRAM LISTING

```
      DIMENSION AVEPRE(37),A1(37),A2(37),A3(37),A4(37),A5(37),
     1A6(37),A7(37),B1(37),B2(37),B3(37),B4(37),B5(37),B6(37),B7(37)
      INTEGER FOOD(37), SUM(37)
      DATA IN/5/,LP/6/
      M=0
      DO 3 I=1,37
      SUM(I)=0
      A1(I)=0.
      A2(I)=0.
      A3(I)=0.
      A4(I)=0.
      A5(I)=0.
      A6(I)=0.
      A7(I)=0.
      B1(I)=0.
      B2(I)=0.
      B3(I)=0.
      B4(I)=0.
      B5(I)=0.
      B6(I)=0.
      B7(I)=0.
    3 CONTINUE
   40 READ (IN,1) (FOOD(I), I=1,37)
    1 FORMAT(37I2)
      IF(FOOD(1) .EQ. -1) GO TO 10
      DO 2 I=1,37
      SUM(I)=FOOD(I)+SUM(I)
      IF(FOOD(I).EQ.1)A1(I)=A1(I)+1.
      IF(FOOD(I).EQ.2)A2(I)=A2(I)+1.
      IF(FOOD(I).EQ.3)A3(I)=A3(I)+1.
      IF(FOOD(I).EQ.4)A4(I)=A4(I)+1.
      IF(FOOD(I).EQ.5)A5(I)=A5(I)+1.
      IF(FOOD(I).EQ.6)A6(I)=A6(I)+1.
      IF(FOOD(I).EQ.7)A7(I)=A7(I)+1.
    2 CONTINUE
      M=M+1
      GO TO 40
   10 DO 50 I=1,37
      AVEPRE(I)=FLOAT(SUM(I))/FLOAT(M)
   50 CONTINUE
      DO 18 I=1,37
      B1(I)=A1(I)/FLOAT(M)
      B2(I)=A2(I)/FLOAT(M)
      B3(I)=A3(I)/FLOAT(M)
      B4(I)=A4(I)/FLOAT(M)
      B5(I)=A5(I)/FLOAT(M)
      B6(I)=A6(I)/FLOAT(M)
```

```
      B7(I)=A7(I)/FLOAT(M)
   18 CONTINUE
      WRITE(LP,13)M
   13 FORMAT(1X,' THE NUMBER OF SURVEYS ARE ',I3)
      WRITE (LP,11)
   11 FORMAT(10X,' FOOD ENTREE ITEMS',10X,' MEAN OF FOOD PREFERENCES')
      WRITE(LP,12) (AVEPRE(I), I=1,37)
   12 FORMAT(10X,'1. FRIED CHICKEN',17X,F5.2,/,10X,'2. BAKED CHICKEN',
     117X,F5.2,/,10X,'3. MARYLAND CHICKEN',14X,F5.2,/,10X,'4. BAR-B-QUE
     2CHICKEN',13X,F5.2,/,10X,'5. SLICED TURKEY/DRESSING',
     38X,F5.2,/,10X,'6. TURKEY SUPREM',16X,F5.2,/,10X,'7. CHICKEN A LA K
     4ING',13X,F5.2,/,10X,'8. CHICKEN POT PIE/BISCUIT',8X,
     5F5.2,/,10X,'9. HAM STEAK',21X,F5.2,/,10X,'10. GRILLED HAM SLICE',
     612X,F5.2,/,10X,'11. BAKED HAM',20X,F5.2,/,10X,'12. ROAST PORK/DRES
     7SING',10X,F5.2,/,10X,'13. GRILLED PORK CUTLET',10X,
     8F5.2,/,10X,'14. HAMAND BEANS/CORNBREAD',6X,F5.2,/,10X,'15. HAM LOA
     9F/MUSTARD GLAZE',7X,F5.2,/,10X,'16. BAR-B-QUE SPARERIBS',
     110X,F5.2,/,10X,'17. ROAST BEEF',19X,F5.2,/,10X,'18. GRILLED BEEF
     2STEAK',9X,F5.2,/,10X,'19. SALISBURY STEAK',12X,F5.2,/,10X,'20. BAK
     3ED STEAK',18X,F5.2,/,10X,'21. SMOTHERED STEAK',12X,F5.2,
     4/,10X,'22. CHARCOAL STEAK',13X,F5.2,/,10X,'23. SWISS STEAK',18X,
     5F5.2,/,10X,'24. CHICKEN FRIED STEAK',9X,F5.2,/,10X,'25. BEEF POT P
     6IE/CRUST',10X,F5.2,/,10X,'26. CREAMED CHIPPED BEEF',8X,F5.2,/,
     710X,'27. MEAT LOAF',20X,F5.2,/,10X,'28. CHEESEBURGER LOAF',11X,
     8F5.2,/,10X,'29. BEEF STEW',20X,F5.2,/,10X,'30. BEEF CHOP SUEY',
     914X,F5.2,/,10X,'31. LASAGNA',22X,F5.2,/,10X,'32. FRENCH FRIED COD'
     1,12X,F5.2,/,10X,'33. FRENCH FRIED CATFISH',8X,F5.2,/,10X,
     2'34. TUAN POTATO CHIP',12X,F5.2,/,10X,'35. TUNA NOODLE CASSEROLE',
     37X,F5.2,/,10X,'36. BAKED HALIBUT',15X,F5.2,/,10X,'37. FRENCH FRIED
     4PERCH FILLETS',3X,F5.2)
      WRITE(LP,23)
   23 FORMAT(10X,' FOOD ENTREE ITEMS',5X,'CUSTOMERS PREFERENCES FOR ENTR
     1EES',/)
      DO 22 I=1,37
      WRITE(LP,15)I,A1(I),A2(I),A3(I),A4(I),A5(I),A6(I),A7(I)
   15 FORMAT(19X,I2,15X,7F5.1)
   22 CONTINUE
      DO 21 I=1,37
      WRITE(LP,16) I,B1(I),B2(I),B3(I),B4(I),B5(I),B6(I),B7(I)
   16 FORMAT(19X,I2,15X,7F5.2)
   21 CONTINUE
      STOP
      END
```

VITA

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