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**THE DEVELOPMENT OF ALTERNATIVE
FOOD COST INDEXES**

by

Philip Brandler

November 1974

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**UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760**



**Operations Research and Systems
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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A number of different methods have been developed and evaluated for creating a Food Cost Index (FCI). Pending passage of a Uniform Ration Law (URL), it is recommended that a food subgroup type FCI be formulated consistent with the provisions of the existing Navy Ration Law (NRL) and with actual military food utilization patterns. After the adoption of a new URL, an improved FCI should be formulated using a least squares technique applied to the latest military food utilization data. A reference menu approach for | | |

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SUMMARY

A number of different methods have been developed and evaluated for creating a Food Cost Index (FCI). The FCI is used to determine the monetary value of the basic daily food allowance (BDFA) for feeding enlisted personnel under the subsistence-in-kind program. Pending passage of a Uniform Ration Law (URL), it is recommended that a food subgroup type FCI be formulated consistent with the provisions of the existing Navy Ration Law (NRL) and with actual military food utilization patterns. After the adoption of a new URL, an improved FCI should be formulated using a least squares technique applied to the latest military food utilization data. A reference menu approach for determining the BDFA should also be further developed and evaluated. This approach would use DoD food preference data (rather than food utilization data) to develop a high preference cyclic menu subject to cost constraints and nutritional requirements. The recapitulation of this menu would then be costed (average daily costs) periodically to determine new values of the BDFA as food component prices varied over time. This approach should offer the unique advantages of using math programming and computer capabilities to provide both a reference menu and the associated BDFA that derive from optimization of preference, cost and nutritional considerations.

PREFACE

During fiscal year 1974, the Operations Research/Systems Analysis Office (OR/SA) conducted a systems analysis study to develop a new Uniform Ration Cost System under Task 01 of Project No. IT762713AJ45, Identification of Existing Feeding Systems, System Components and Alternatives, of the DoD Food Research, Development, Testing, and Engineering Program. The objectives of this total effort were to develop a new uniform ration cost system which would be directly related to known consumer preferences and nutritional requirements, and more responsive to innovations and new technology in food and food service systems. As a result of this effort a "Cost/Date Standard" ration cost system has been recommended. The details of this new system can be found in U.S. Army Natick Laboratories TR 75-69-OR/SA "Uniform Ration Cost System-Summary Report." An important element of the new ration cost system is the method for developing a food cost index (FCI) which can be used to compute the basic daily food allowance. The derivation and evaluation of methods for this purpose is the subject of this report.

Very few projects of this scope can be successfully completed without the cooperation and assistance of many individuals. Specifically, the guidance, support, and many helpful suggestions provided by Mr. Richard P. Richardson, Manager of the Uniform Ration Cost System Program, are gratefully acknowledged. In addition, the efforts of Mr. Ronald Deacon in carrying out the necessary mathematical calculations in the interim before computer programs were developed, as well as in completing all mathematical calculations for Navy Ration Law based Food Cost Indexes, deserves very special credit. The programming efforts of Mr. Peter Walsh and Mr. Joseph Fitzpatrick of the Boston Regional Office of General Services Administration are also gratefully acknowledged. Finally, an expression of appreciation is extended to Miss Mary Dwyer of the Navy Food Service Systems Office; her guidance on the interpretation of the Navy Ration Law as related to the Food Cost Index brought many issues into clearer focus.

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SECTION I.

INTRODUCTION

The existing DoD Food Cost Index is a list of 48 food items and the quantities of each required to feed 100 persons daily. In order to calculate the monetary value of the Basic Daily Food Allowance (BDFA), these food quantities are multiplied by the unit price of each item as determined from the current Defense Personnel Supply Center (DPSC) price list and summed. To this is added an allowance for condiments which are not specifically listed and the result divided by 100 to provide the value of the BDFA, which applies for one person for one day. To compensate for unusual conditions that might make food procurement more costly (e.g., small dining facilities), the system allows this value to be increased by a supplemental amount in the form of a percentage increase. In addition, a special allowance is granted for such special operational conditions as submarine or field (combat, maneuvers) feeding. At the beginning of each service's accounting period, a new BDFA is calculated as described above using the latest DPSC price list for all items except cereal, bread, and milk for which local prices are used. This permits the system to adjust to changing food prices with a minimum of effort in what is essentially an unconstrained manner.

Prior to 1967, each service utilized its own individual "Food Cost Index" (FCI) for calculating the monetary value of the daily ration. The Army and the Air Force used the 39 component garrison ration listed in Executive Order 5952 of 23 November 1932 as a ceiling on their ration allotment. The Navy used a weighted 250 food item list for calculating its daily food allowance. The U.S. Marine Corps utilized a 47 food item list. Both the Navy and Marine Corps FCI's were directly related to and constrained by the Navy Ration Law (NRL) of 1933 (Section 6082, Title 10, U.S. Code). The Hoover Commission report of 1955 as well as a later Logistics Management Institute report of 1966 both emphasized that the result of this proliferation of applicable regulations was an unjustifiable difference in the rations authorized for different segments of the Armed Forces.

In order to insure that all enlisted personnel regardless of branch of service received a uniform BDFA, a standard FCI was established in 1967. This FCI, which most closely resembled the Marine Corps food item list, was consistent with the food types and quantities specified in the Navy Ration Law, and was implemented for all services by DoD Directive 1338.9, "Uniform Food Allowance for Enlisted Members of the Military Departments." This was rescinded in January 1972 and superseded by a new DoD Directive 1338.10, which contained a slightly revised FCI. The purpose of these directives was to create a uniform ration for all services as well as a management scheme to enable the Office of The Secretary of Defense to exercise management control over the food served each person entitled to rations, while still providing the service manager with sufficient flexibility to exercise reasonable choice in the food he serves. It has been the accepted view that the FCI does more than set a recommended dollar expenditure; it is a tool through which the quantity, quality, and nutritional standards of food served can be influenced.

The philosophy behind this FCI, and a number of proposed changes to it, is that any index used by regulation to set a BDFA must adhere to the NRL articles both with respect to food components and to quantities. As long as the FCI adheres to the statute, the food that is actually served in dining halls is permitted to vary from the NRL under the provision that "any article may be issued in excess of the authorized quantity if there is an under issue of the same value in other articles."

The FCI, however, is much more specific in detailing specific food items and reflects somewhat more modern means of food preparation than the NRL. Basically then, the FCI adheres to the guidelines of the ration law, but attempts to be more cognizant of modern food technology and more recent food preferences.

However, examination of the NRL and its associated FCI has revealed a number of problem areas. The generic listing of components in the NRL has not kept pace with advances in food products and changing military food preferences and usage. For example, the listing does not include certain high usage items such as carbonated beverages, margarine, and ice cream, or certain high usage food forms such as frozen foods. Therefore, strict compliance with the NRL could preclude the serving of many items in military dining halls which are already served in large quantities. Large variances may also be noted between the quantities specified in the NRL and the FCI and the actual utilization experience of the military. While certain substitutions are permitted by the NRL, it is concluded that legislation and an associated index which reflects, and could be periodically updated to continue to reflect, actual practice would represent an improvement over the current system. Also, within the existing listing of foods in the NRL, the generic nature of some components (e.g., 20 oz. of fresh meat, poultry, or fish) does not provide a firm degree of control over the level of feeding (monetary value of the BDFA) since there is no legally prescribed method for deriving the FCI from the NRL. For example, it is possible to create FCI's which yield BDFA's ranging from \$1.20 to \$5.37 (using June 1974 DPSC prices) by selecting the lower or higher cost specific food items within the generic NRL nomenclatures for inclusion in a FCI. Theoretically then, considerable latitude is available to the DoD to change the military level of feeding (BDFA) while strictly complying with the existing NRL. It should be noted that these few comments merely highlight some of the deficiencies of the NRL; a complete discussion is available in another URCS report (1).

Despite the drawbacks of the existing NRL-based system, the managers and operators of DoD food service systems have established a reasonable level of feeding in comparison with comparable civilian organizations, (2) and the system operates at reasonable levels of expenditure and does address local needs and requirements. This has been more the result of the capability and

(1) Richardson, R.P., "Uniform Ration Cost System-Summary Report" USA Natick Laboratories TR 75-69-OR/SA.

(2) Brandler, P. et al, "The Basic Level of Feeding-A Comparison of Military and Comparable Civilian Food Utilization" USA Natick Laboratories TR 75-43-OR/SA.

good judgment of military food service personnel, coupled with the flexibility of the NRL permitted by the aforementioned exception or substitution rule, than the full explicit form of the NRL. What now exists under the present ration cost system is a management and cost control which has progressively moved in the direction of the exception in the law becoming the rule with the basic controlling factor being the dollar constraint (BDFA).

Because of the problems mentioned above and other associated considerations, the URCS program has recommended a new ration control system which recognizes the dollar constraint (BDFA) as the predominant constraint as does current practice, but which would include this limitation in a statute. This statute would be written so as to allow this dollar limitation to fluctuate over time as food prices rise or fall through the mechanism of a new improved DoD FCI.

This report examines the alternate methods for generating improved FCI's, both in support of the recommended new ration control system and the current NRL.

SECTION II.

OBJECTIVES

The basic objective of this study effort is to investigate alternatives and recommend one or more methods for formulating a new Food Cost Index that will support the overall URCS program recommendations and will:

1. Meet military nutritional standards.
2. Address food preferences in a rational manner based on accurate quantitative data.
3. Be consistent with reasonable economic considerations.
4. Reflect current food technology and consumption patterns and trends.
5. Be suitable for usage by all military services.
6. Be easy to understand and use.
7. Provide a BDFA capable of meeting consumer preferences and requirements as well as nutritional standards under changing food price conditions.
8. Be flexible enough to endure over a reasonable period of time.

The general approach utilized in this report is:

1. To explore a number of different alternative approaches (computational methods) for FCI generation.
2. To select the best alternatives and to develop FCI's by each of these methods.
3. To evaluate these FCI's and the alternative methods by which they were generated, and to recommend one or more alternatives for future implementation.

SECTION III.

ALTERNATIVE BASES FOR FOOD COST INDEX GENERATION

A number of alternative methods may be used in the development of a FCI. Part of the reason for this proliferation of methods is due to the existence of a number of different data bases from which a FCI can be developed. Secondly, given an appropriate data base more than one method of manipulating it can be developed. This report will initially present a discussion of all possible data bases before proceeding with a presentation of mathematical methodologies for deriving FCI's from those data bases deemed suitable. The data base options scrutinized in the course of this project included:

- A. The NRL and the Present FCI.
- B. The February 1972 Recommendations of the Joint Service Task Group of the DoD Food Planning Board.
- C. The 1955 Bureau of Labor Statistics Recommendations.
- D. Civilian Food Utilization Patterns.
- E. Foreign Military Ration Systems.
- F. Other Federal Agencies' Ration Systems.
- G. Actual Food Utilization Patterns for the DoD.
- H. Food Preference Surveys.
- I. "Reference" Menus.

An evaluation of each of these as a basis for FCI development follows below:

A. The NRL and the Present FCI - The current NRL has proved satisfactory to the Navy and the Marines since 1933. The present ration control system has generally served the four services in a satisfactory manner since 1967; however, as noted in the introduction, this has been more the result of the capability and good sense of military food service personnel than to specific application of the NRL. Recently, questions have been raised with regard to the effectiveness and suitability of the NRL and its related FCI as well as other facets of the current ration control system in the face of developments in food processing and food service systems, changes in military consumption patterns, as well as inequities and problems that were pointed out in the introduction. Nevertheless, it is appropriate in this analysis of FCI's to include the current FCI as well as to consider other alternatives based on adherence to the NRL. In effect, the current FCI represents a baseline against which proposed alternatives are evaluated.

The history of the development of the current FCI suggests that the dominant consideration in its creation was to comply with the component requirements of the NRL rather than to design to a specific cost level, or to specific nutrition guidelines, or to any other criteria. This is not to suggest that other factors are ignored because cost factors, for example, are always examined critically, but only to indicate the relative importance of conformance to the NRL. Considerations of nutrition in particular are considered secondarily since the NRL allowances are supposedly formulated to provide sound nutrition. As expected, a nutritional analysis of the current FCI reveals that it meets or exceeds all Daily Dietary Allowances specified by The Surgeon General.

While considerations of nutrition are indirectly factored into the current FCI by designing to the NRL, up until November of 1973 no clearly expressed cost constraints had been placed on the design of the FCI. In November 1973, an Interservice Task Group was requested to restructure the FCI such that the incorporation of open market rather than Department of Agriculture donated butter would increase the value of the BDFA no more than \$.04. The reason given for this cost constraint was that the subsistence budget was already strained from rising food prices. There was perhaps also the tacit assumption in such a request that the cost (BDFA value) of the original FCI represented a slightly high level of feeding. Regardless of the validity of this particular assumption, the incorporation into the design of a FCI of a cost guideline pertaining to an objectively determined level of feeding seems eminently desirable. The particular level that seems to be most worthy of consideration is the level of feeding in civilian operations deemed comparable to the military.

While decisions related to cost, nutrition, and prescribed food quantities for the current FCI could all be made with reference to readily available quantitative data or to the NRL, item choice with respect to food preference was handled in a more intuitive fashion. Basically, the approach in this area was to select food items for the index that were most representative (in terms of type and quantity) of those being used by the services in each of the components required by the NRL. Thus, an attempt has been made to make the FCI an indicator of current food utilization patterns insofar as concomitant adherence to NRL constraints would permit. In effect, this approach attests that consistency with feeding patterns represents the best available approach to a high-preference food listing in the FCI. Without arguing the relative merits of this approach, it is recognized that it did represent a rational one. During the Uniform Ration Cost System (URCS) program, comprehensive data on DoD food utilization patterns have been gathered to allow decisions to be made as to appropriate FCI revisions reflecting current food utilization.

One may interject that the general question of factoring in food preferences can be handled in another fashion. A large body of survey information on expressed food preferences has been gathered in recent years, and the means of incorporating these data into a FCI will be discussed later.

In summary, it may be stated that the current FCI is formulated primarily to one constraint, the law, rather than to any set of relevant constraints. Having met this one constraint, checks for nutritional or cost adequacy are then performed. The approach of designing to one major constraint and then iteratively adjusting the results in an empirical fashion to satisfy other secondary constraints is a perfectly sound approach provided one is not seeking to determine an absolute maximum or minimum, in which case a mathematical programming approach is much more effective.

One may note at this point that while this sequential approach to FCI design may be adequate, the particular sequence of first designing to a law which specifies quantities within specific categories necessarily depends on the existence of such a law. Even given the desirability of such a law, the sequence of a law yielding a FCI could justifiably be reversed by first designing a FCI to meet desired constraints of cost, nutrition, preference, etc., and then designing legislation to encompass it.

Later a number of specific methods of developing FCI's based on the NRL will be presented, as will other techniques for developing FCI's that are unconstrained by any legislation.

B. The February 1972 Recommendations of the Joint Service Task Group of the DoD Food Planning Board - In Fiscal Year 1972, it was realized that the FCI then in operation (the current FCI), was in need of revision. In October and December 1971, the Office of The Assistant Secretary of Defense for Installations and Logistics requested that the DoD Food Planning Board choose a task group to be chaired by the Navy member to revise the FCI. The new Index was to be compatible with the NRL, but it was expected that realistic interpretations would be applied to the law to comply with guidance that the index reflect as much as possible the food utilization patterns of the services. This group drafted a revised Index based upon its review of Individual service recommendations and the Navy Ration Law. Discussions in 1974 with service dieticians have indicated that the revisions suggested by that task group, which were not adopted at that time, should be given strong consideration in the URCS study. In view of the recommendations of these experienced professionals, this recommended FCI has been included as a proposed alternative for evaluation.

C. 1955 Bureau of Labor Statistics (BLS) Recommendations - In 1955 work on a Uniform Ration Law resulted in a proposed ration entitlement to combine into a common ration those features which "experience" with existing rations had shown to be essential in meeting reasonable food preferences and nutritive allowances for all services. A condensed list of approximately 200 food items had been developed which was taken as "representative" of the food requirements of the military services. In order to determine military ration allowances, the BLS was contacted for assistance in the development of a statistically derived FCI. The BLS utilized this list of 200 items to develop its proposed FCI. They did state, however, that the cost index they developed was to be considered an interim estimate of the total cost of all food items purchased since it could not be used indefinitely. The quantity weights in their index are not the amounts of these items to be included in the daily ration, but

rather represent other related items as well. The weights assigned, therefore, have no significance except for statistical calculations. The weights are obtained by computing cost per 100 men of a group of items represented by a sample (index) item and dividing this total by the price of the sample item. The BLS suggested two alternative lists of 45 and 40 sample items. These sample items represent 84% and 77% of the value of the daily ration based on 200 items. Two criteria were used by the BLS in the selection of items and the allocation of related items:

1. The importance of the items in a daily ration as measured by the 200 items; and,

2. The similarity of price change over the three-year period for which DoD supplied price data to the BLS.

In making their choice as to sample items, the BLS minimizes the allocation to the index of items which are locally procured due to the variation from place-to-place in the price of locally procured items. Nowhere in the correspondence related to this undertaking is any mention made of adjusting this index to the NRL. This is due to the fact that the development of this index was part of a larger program to develop a new Uniform Ration Law to replace the NRL. The BLS tested the alternative lists for the one-year period, April 1954 through March 1955, a period for which complete cost information had been supplied for the 200-item list. For that particular period, the maximum difference in the cost of the daily ration as determined by the 200-item list and the 40-item list is 0.9% and the maximum using the 45-item sample is 0.6%.

While the explicit formulation of the index proposed by the BLS is clearly out-of-date by now, the methods used definitely have merit. The DoD food usage data, discussed below, in fact will be subjected to similar analyses as the aforementioned 200-item list in order to develop an alternative FCI that is essentially analogous to the BLS list but much more current.

D. Civilian Food Utilization Patterns - in the course of this project, and reported under a separate report,⁽¹⁾ food usage data for certain civilian organizations, which represented situations generally comparable to the military in terms such as physical activity, age distribution, and sex distribution, have been compared with military food usage in order to determine an appropriate level of feeding. It might be conjectured that this same data base could be used for the development of a FCI. However, this idea must be rejected for a number of reasons. First, although each individual organization has some specific points of identification with the military situation, none represents a completely comparable situation. In addition, the data base represents too small a sample size, both from the point of view of the number of meals included in the sample and in terms of encompassing less than a full year's data. The alternative of combining all of the civilian data rather than attempting to develop a FCI from any one

(1) Brandier, P. et al, "The Basic Level of Feeding-A Comparison of Military and Comparable Civilian Food Utilization" USA Natick Laboratories TR 75-43-OR/SA.

organization's data has its drawbacks as well. Even though each organization would contribute its own particular similarities to this data pool, each would additionally add its unique dissimilarities, so that the final data base would represent a heterogeneous mixture.

The US Department of Agriculture has also gathered civilian consumption data which one might consider utilizing. However, a number of problems exist with these data as well. The USDA presents its data on two bases: first, by individuals, identified by age, sex and family income; and, second, by household, identified by income, part of US, rural or urban, etc. While the individual data would allow us to choose a group of appropriate age and sex, the food quantities referenced are "as consumed" rather than "as purchased" and hence would require some careful adjustment to put it on an "as purchased" basis needed for FCI development. This adjustment factor should include allowable wastage factors (as opposed to existing wastage as in the DoD data) and cooking shrinkage factors. The USDA family household data is on an "as purchased" basis; however, it represents the consumption of an average family of 3.4 members, including both sexes and all ages, a group which is not comparable to the military. The last complete survey of United States consumption took place in 1965 when entirely different considerations of food price economics held true. The nine-year time span between that survey and the present probably represents a considerable gulf with respect to current food consumption patterns. In addition, utilization by individual item, which is the kind of data necessary for FCI development, is not readily accessible but is available from the USDA only at the expense of a great deal of effort. In sum then, while the individual data might perhaps be utilizable for the generation of a FCI, the time span since the survey and the difficulties in accessing the data preclude its usage.

E. Foreign Military Ration Systems - Data have also been gathered on the ration systems of 9 different foreign military organizations (Canada, Australia, United Kingdom, West Germany, Italy, Spain, Portugal, The Netherlands and France), and a complete discussion of these systems is available in "Analysis of Foreign Military and U.S. Institutional Ration Cost Systems," US Army Natick Laboratories, TR 75-66-OR/SA. In terms of factors such as age distribution, activity level, and occupation, these organizations represent suitable subjects for consideration as bases for FCI development. The one major drawback is that in most of these cases the cultural eating patterns are considerably different from American eating patterns. A few situations, however, do not represent significant departures, for example, Canada or the United Kingdom. Even in these situations where the cultural eating patterns are comparable, the systems utilized in providing and accounting for rations differ with the American system in certain respects such that their ration scales could not be adopted in an unchanged fashion. For example, these systems generally rely upon a roster count rather than a headcount system; therefore, there is a strong reliance in these systems on absentee rates to provide flexibility in the system with respect to food item choice, portion size, etc. As a result, the food allowances tend to be low as compared to those used in a headcount system. In addition, many of

these are food plan systems where issues are controlled by food group rather than controlling simply on a cash basis. Therefore, the makeup of these ration scales is quite detailed and extensive in terms of alternatives in order to provide a measure of flexibility in food item choice. Finally, there is no real reason to believe any of these ration scales necessarily represents the results of more careful scientific analysis than the current US FCI or one which might be developed from current research.

F. Other Federal Agencies; Ration Systems - As in the case of the military, at least two other Federal Agencies, the Veterans Administration and the Federal Bureau of Prisons, are faced with the responsibility of administering large scale feeding systems as part of their mission. A complete discussion of these systems is also presented in "Analysis of Foreign Military and U. S. Institutional Ration Cost Systems, "TR 75-66-OR/SA. Neither one of these situations, however, represents a situation that is similar to the military. First, the Veterans Administration involves a sedentary population of different age distribution subject to special diet considerations. Hospital feeding, in general, would seem to be a very poor basis for developing a daily food allowance for the active military man. The Federal Bureau of Prisons also seems to be a rather poor choice as a basis for military feeding if only for the punitive connotation involved. The Federal Prison System represents a non-voluntary food service operation subject to tight budgetary constraints and with no desire to increase patronage. As such, it represents a poor basis for a military FCI especially in the context of today's modern volunteer forces.

G. Actual Food Utilization Patterns for the DoD - The DoD Food Utilization Survey, discussed in another report, ⁽²⁾ provides a firm quantitative basis for the generation of a FCI. It is doubtful that as thoroughgoing a survey in terms of data collection was carried out in 1955 to determine the consumption patterns which were used by the Bureau of Labor Statistics.

Question may be raised as to whether a FCI generated from DoD food utilization data would be a carbon copy of the present FCI since this FCI was a major constraint on the system. It must be remembered, however, that the utilization of a FCI still allows the food service manager wide flexibility to exercise a wide choice in his food selection provided he stays within the daily dollar allowance (BDFA). This is, in fact, the case when the data from our study is compared to the FCI ⁽²⁾. It seems reasonable, therefore, to assume that the food service manager utilizes this flexibility to the maximum extent possible to meet what he considers to be the preferences of his customers based on his personal experience. The incentive toward this course of action is clear. A radical misjudgment as to the likes and dislikes of his customers could leave the food service manager with large amounts of unused cooked food on his hands with no headcount (credits) to cover its cost,

⁽²⁾ Brandler, P., Deacon, R. "Patterns of Food Utilization in the DoD," USA Natick Laboratories, TR-75-65-OR/SA.

resulting in his exceeding his BDFA in violation of regulations. It must be admitted that the food service manager adjusts his menu to reflect considerations other than customer preference. Questions of commissary supply, economic considerations, difficulty of preparation, labor availability, and his personal food preference also affect his choices as well. Nevertheless, food consumption data must be considered at least to some degree as an indirect indication of food preference.

The DoD food usage data collected in our recent study was gathered with a view towards its utilization as a basis for the development of a FCI. As such, it reflects the "real" situation by measuring item usage on an "as purchased" basis, linking these purchases to the resultant number of meals or rations served. These data, therefore, contain factor allowances for such things as preparation and plate waste. This particular feature can be considered either as a deficit or an advantage. The advantage is that it reflects actual experience. A FCI based on these data, which resulted from a survey of a reasonably broad cross section of DoD, allows the average food service manager suitable leeway for error due to such wastage without overly harsh penalty, while still providing incentive for the more capable manager to improve his menu by trimming his wastage.

Finally, the data base is suitably broad and the system for its analysis sufficiently sophisticated so that a number of different FCI's can be developed using different techniques and desired criteria or assumptions.

H. Food Preference Surveys - While DoD food utilization data have, as explained previously, been thought to represent or at least reflect to a reasonable extent consumer preferences within the armed services, it was felt that a such more scientific body of knowledge developed by professional psychologists on the basis of statistically analyzed surveys utilizing carefully constructed questionnaires was necessary. This approach is a "grass roots" approach wherein the individual customer states his likes and dislikes, thus providing direct information on food preferences rather than depending on the dining facility manager's decisions as is the case when using actual food utilization data. In view of this fact, the Operations Research/Systems Analysis Office tasked the Behavioral Sciences Division of Food Sciences Laboratory of the US Army Natick Laboratories with a program to gather and analyze these data. At this time, therefore, a large body of sound scientific data exists which expresses the preference of U.S. service personnel for a large list of menu items, both with respect to hedonic ratings (desirability on a scale from 1 to 9) and desired frequency of serving. The data base, therefore, exists for the development of FCI's which should represent the maximum in food preferences. Since the preference survey considers menu items (such as beef stew) rather than individual food components (such as diced-beef, carrots, peas, etc.), the development of FCI's from these data can only be accomplished by using the data to develop a reference menu and then by using the reference menu as discussed below. It is impossible to get

valid preference data on component items since consciously or unconsciously judgments of food are normally made with reference to the prepared state.

1. "Reference" Menus - All of the previously mentioned alternatives have a view toward creating a relatively short FCI which could be costed easily by manual methods. With increasing availability of computer processing capability, the necessity for a very short list is diminished. This rapid data processing capability makes it feasible to cost-out an entire menu rather than just a representative sample of times. That is, all of the recipes in the menu would be recapitulated as to the total amounts of each food component included. Then this total quantity by item data would be merged with a file of DPSC unit price information to yield a resulting total raw food cost. The concept, therefore, of designing a reference menu which serves both as a FCI as well as a standard for meal planning becomes attractive. The design of such a menu can be greatly enhanced by utilizing the preference hedonic ratings developed by the aforementioned preference surveys in the choice of food items.

A number of approaches can be taken which permit the incorporation of preference data into a reference menu in a systematic manner: (1) maximize the overall preference rating of a menu subject to cost and nutrition constraints; or (2) minimize the cost of the menu subject to preference and nutrition constraints. The first approach could be used in designing a menu to a desired level of feeding measured in monetary and nutritive terms. The second approach would be taken in a situation where minimum preference and nutritive levels had been decided upon, and the most cost-effective means of achieving this goal was desired. In both cases an indicator could be incorporated which would flag situations where either the maximum preference was below desirable levels in the first case, or the minimum cost was in excess of "reasonable" costs in the second case. At this point, a decision would be made whether to relax the constraints to permit a change in the solution or adopt the solution as is.

One possible sequence in the application of these two approaches would be to first apply the cost minimization model subject to preference constraints to generate a DoD reference menu. This menu would then be costed to establish a DoD BDFA. Next, a "local" reference menu could be generated using the preference maximization model with the DoD BDFA as the cost constraint and applying organizational (i.e., one service, one region, or possibly one installation) preference data. That is, all DoD would be subject to the same BDFA, but the "local" reference menu would derive from "local" preference data.

It must be admitted that the current state-of-the-art does not permit the mathematical optimization processes that have been suggested if selective menus are desired. Nevertheless, a preliminary investigation by the study team indicates that the use of standard menu planning techniques by qualified professionals but making use of food preference data permits the preparation of reference menus with improved hedonic ratings.

In addition, research efforts are underway to develop the desired mathematical optimization techniques, and good progress has already been made in designing non-selective (single choice) menus.

One attractive facet of such a FCI is that a food service manager who adheres closely to the reference menu prepared under the preceding approach (using appropriate preference data) has high assurance of providing an appealing, nutritious menu to the troops within acceptable costs, and all this without burden of complex local menu planning or costing. This is not meant to imply that adoption of the reference menu approach should require that the menu developed be served everywhere. What is offered is a guide which if followed will produce the most consumer-oriented menu based on available data. Thus, the objective is much like that of current Master Menus, but the effort should benefit from more extensive use of recently obtained DoD-wide and military service food preference data. Capable menu planners would still enjoy the normal freedom of making changes reflecting local preferences and other requirements, such as food availability considerations. Naturally, menus so developed would be periodically revised to meet changing food preferences as indicated by regular enlisted personnel surveys.

The major advantages, however, of the computer optimized preference menu are that it: (a) allows menu design to parameter values which are confined to a desired range (e.g., nutrient values equal to the Daily Dietary Allowance, plus or minus a stated percentage) rather than just working in a very broad range of values (e.g., energy of no less than 3400 calories); (b) allows the simultaneous consideration of more than one parameter constraint (e.g., cost and nutrition); (c) provides mathematically optimized computation of the "objective" parameter (e.g. preference) subject to the constraints; and, (d) does everything rapidly, saving much time over manual approaches even if partial computer assistance is available. As has been pointed out above, the approach can allow override by the menu preparer or dietician if desired. For the above reasons, it is considered that a menu-based FCI represents an interesting alternative.

The use of a reference menu should not be discarded even if the concept of complete menu costing for setting the BDFA is rejected in favor of a short index. The same techniques which will be suggested later for developing FCI's from DoD food utilization data can be applied to reduce the number of listed foods in a menu recap, with almost the same benefits as cited for the complete costing approach.

Despite the strong arguments that favor the use of a reference menu as a basis for a FCI, a number of salient points are recognized:

1. The use of food utilization data is well understood and accepted, and more proof may be necessary to demonstrate that some other approach offers better results.

2. Current Master Menus have a preference orientation, and it must be established that a preference survey derived menu is better overall from the perspective of the consumer.

3. A judgment must be made as to whether a selective or non-selective preference menu should be used as a basis for a FCI.

4. If a selective preference menu is used, a decision must be made as to how to evaluate its preference rating. (An improved method of evaluating the preference of non-selective cyclic menus has been developed in the URCS effort).

5. If a selective preference menu is used, an important issue to be resolved is what issue factors (percentage of consumers taking each item, such as one entree as opposed to another) to use in recaping the menu.

6. First results in designing a preference menu indicate that larger quantities of a smaller number of raw foods are used than with a typical Master Menu. While this has certain potential logistics advantages as well as the expected preference gains, the overall practicability of the menu remains to be validated.

SECTION IV.

TECHNIQUES FOR FOOD COST INDEX FORMULATION

The net result of the prior discussion has been to identify three alternative bases for the generation of FCI's: (1) the Navy Ration Law, (2) DoD Food Utilization Patterns, and (3) reference menus incorporating preference survey data. Even given what may be deemed an appropriate base upon which to construct a FCI, more than one reasonable alternative can be formulated depending upon the desired constraints and assumptions.

A. FCI's Based on the NRL - Before proceeding to any new calculations, three NRL based FCI's exist which should be discussed. Presented in Table 1 is the current FCI. As has been noted before, it is composed of 48 items falling into the food groups detailed in the Navy Ration Law. Recent research into DoD food utilization reveals that this FCI operates mainly as a cost constraint, and considerable independence is exercised by local food service managers with respect to their choice of food items actually served. This is particularly true with respect to the issue factors of the items in this FCI. For example, research indicates, as reported in "Patterns of Food Utilization in the DoD," USA Natick Laboratories TR 75-65-OR/SA, that vegetables are served in considerably lower quantities than specified in the FCI. Table 2 presents a summary comparison of actual DoD utilization in each of 13 categories with FCI indicated allotments in each category. Differences will be noted in almost all categories and many of these differences are significant, indicating that actual usage is not in line with the FCI.

In February 1972, the FCI Joint Service Task Group of the DoD Food Planning Board proposed a series of revisions to the FCI which are compatible with the NRL ration allowances and the increased milk allowance authorized under the current DoD Appropriation Act. The total NRL quantitative allowance for each component is represented in that proposed FCI revision, the philosophy of its construction with respect to the NRL adhering to that of the current FCI. Food utilization patterns within the services are reflected to the extent possible in that proposed FCI, but the Task Group felt that food service system differences and operational conditions preclude uniform service-wide consumption patterns. Frozen fruits, vegetables, fruit juices, and cake mixes are added and the quantity of purchased bread increased in this FCI. Comment was made that some increase in the allowance for eggs is desirable, as well as the addition of a greater variety of formulated and convenience foods, but that these changes to the FCI are not feasible under the current NRL prescribed ration entitlements. Provision for the use of the new fabricated beef items is also made. Table 3 presents this proposed FCI.

Finally, as noted previously, the first specifically cost-constrained FCI was proposed by OASD (i&L) in connection with the use of the market price of butter. Table 4 presents this April 1974 proposal. Although the concept is novel, the actual changes represented by this FCI as compared with

TABLE 1

THE CURRENT FOOD COST INDEX (FCI)

| Component | | Unit | Quantity Per 100 | Unit Price | Value of Component |
|--------------------------------|--------------------|-------|---------------------|---------------|-----------------------|
| Bacon, Slab, Sliced | 8905-403-9592 | Pound | 7.00 | | |
| Beef, Boneless, Grill Steak | 8905-151-6586 | " | 10.17 | | |
| Beef, Boneless, Pot Roasts | 8905-151-6585 | " | 12.02 | | |
| Beef, Boneless, Ground, Frozen | 8905-285-2075 | " | 12.025 | | |
| Beef, Boneless, Patties | 8905-935-3268 | " | 12.025 | | |
| Ham, Smoked, Boneless | 8905-682-6643 | " | 6.30 | | |
| Pork Roast, Boned | 8905-753-6568) 50% | | | | |
| Pork Slices, Boned | 8905-753-6569) 50% | " | 8.74 | | |
| Chicken, Rtc, Cut-up | 8905-965-2128 | " | 11.54 | | |
| Fish Fillet, Flounder | 8905-164-0490 | " | 4.00 | | |
| Butter, Fresh, Patties | 8910-782-3195 | " | 10.00 | | |
| Cheese, Cheddar, Natural | 3910-125-8440 | " | 3.125 | | |
| Eggs, Fresh, in Shell | 8910-043-3198 | Dozen | 10.00 | | |
| Apples, Fresh, Eating | 8915-126-8812 | Pound | 17.00 | | |
| Bananas, Fresh | 8915-126-8748 | " | 5.00 | | |
| Oranges, Fresh | 8915-616-0212 | " | 18.00 | | |
| Cabbage, Fresh | 8915-616-0194 | " | 14.75 | | |
| Carrots, Fresh | 8915-127-8019 | " | 13.00 | | |
| Celery, Fresh | 8915-252-3783 | " | 12.00 | | |
| Lettuce, Fresh, Head | 8915-117-3358 | " | 13.00 | | |
| Onions, Dry | 8915-615-0200 | " | 15.00 | | |
| Potatoes, White, Fresh | 8915-616-0220 | " | 98.00 | | |
| Tomatoes, Fresh | 8915-582-4059 | " | 13.00 | | |
| Lard, Svc, or Shortening GP | 8945-516-0091 | " | 10.00 | | |
| Apples, Canned | 8915-126-4060 | " | 5.25 | | |
| Asparagus, Canned | 8915-286-8696 | " | 3.00 | | |
| Beans, Green, Canned | 8915-616-4820 | " | 8.25 | | |
| Cherries, Rsp, Canned | 8915-286-5486 | " | 4.00 | | |
| Corn, Whole Grain, Canned | 8915-257-3947 | " | 7.50 | | |
| Juice, Orange, Canned | 8915-241-2800 | " | 1.875 | | |
| Juice, Pineapple, Canned | 8915-634-2439 | " | 1.875 | | |
| Juice, Tomato, Canned | 8915-255-0523 | " | 3.75 | | |
| Peaches, Sliced, Canned | 8915-577-4203 | " | 3.25 | | |
| Pears, Halved, Canned | 8915-616-3223 | " | 2.25 | | |
| Peas, Green, Canned | 8915-127-9282 | " | 6.125 | | |
| Pineapple, Sliced, Canned | 8915-170-5148 | " | 4.00 | | |
| Tomatoes, Canned | 8915-582-4060 | " | 14.50 | | |
| Flour, Wheat, Hard | 8920-125-9423 | " | 37.50 | | |

TABLE 1 (Cont'd)

THE CURRENT FOOD COST INDEX (FCI)

| Component | | Unit | Quantity Per 100 | Unit Price | Value of Component |
|--|---------------|------|---------------------|---------------|-----------------------|
| Noodles, Egg | 8920-126-3388 | " | 2.00 | | |
| Rice, Parboiled | 8920-530-2185 | " | 3.00 | | |
| Spaghetti | 8920-125-9441 | " | 3.00 | | |
| Sugar, Granulated | 8925-127-3074 | " | 31.25 | | |
| Jam, Strawberry | 8930-197-1917 | " | 1.875 | | |
| Jelly, Grape | 8930-127-3079 | " | 1.875 | | |
| Oil, Salad | 8945-616-0081 | " | 2.8875 | | |
| Catsup | 8950-127-9789 | " | 4.76 | | |
| | 8950-221-0297 | | | | |
| Vinegar | 8950-616-0213 | " | 3.1725 | | |
| Cocoa, Natural | 8955-223-5806 | " | 3.125 | | |
| Coffee, Regular and Ground | 8955-286-5372 | " | 9.375 | | |
| Cereal, Cornflakes | 8920-125-8447 | " | 2.00 | | |
| Bread, White, Plain | | " | 37.50 | | |
| Milk, Whole, Fresh | | Pint | 200.00 | | |
| Subtotal | | = | _____ | | |
| Condiments and Accessory Foods - Add 2% of Subtotal | | = | _____ | | |
| Grand Total (Value of Basic Daily Food Allowance for 100 Persons) | | = | _____ | | |
| Divide By 100 (Value of Basic Daily Food Allowance for One Man) | | = | _____ | | |

TABLE 2

A COMPARISON OF FOOD UTILIZATION PER RATION

(All Units in Lbs.)

| Food Group | Food Cost Index | U.S. Army | U.S. Marines | U.S. Navy | U.S. Air Force | DOD |
|-------------------------------|-----------------|-----------|--------------|-----------|----------------|-------|
| Meat, Poultry, Fish | .838 | .969 | .862 | 1.010 | 1.009 | .980 |
| Eggs | .120 | .224 | .243 | .217 | .205 | .220 |
| Milk and Milk Products | 2.281 | 2.242 | 2.709 | 1.719 | 2.287 | 2.108 |
| Beverages | 2.00 | .417 | .241 | .237 | .543 | .357 |
| Vegetables | 2.037 | 1.170 | 1.050 | 1.125 | .957 | 1.112 |
| Legumes and Nuts | .144 | .170 | .125 | .166 | .131 | .159 |
| Grain & Cereal Products | .850 | .816 | .724 | .627 | .696 | .724 |
| Fruits | .587 | .464 | .490 | .496 | .276 | .450 |
| Fats, Oils and Salad Dressing | .129 | .174 | .160 | .155 | .132 | .160 |
| Sugar and Sweets | .350 | .281 | .246 | .278 | .129 | .254 |
| Soups and Gravies | — | .019 | .009 | .021 | .010 | .017 |
| Condiments | .979* | .130 | .101 | .133 | .107 | .125 |
| Miscellaneous | — | .031 | .017 | .018 | .036 | .026 |

*Includes only specifically listed items

TABLE 3
FEBRUARY 1972 PROPOSED FCI

| Component | Unit | Quantity Per 100 | Unit Price | Value of Component |
|--|-------|---------------------|---------------|-----------------------|
| Bacon, Slab, Sliced | Pound | 9.00 | | |
| Beef, Fresh, Carcass OR | " | 59.70 | | |
| Beef, Boneless* | " | 40.60 | | |
| Ham, Smoked, Boneless | " | 7.20 | | |
| Pork Loin, Fresh, Bladeless OR | " | 14.00 | | |
| Pork, Boneless, (50% roasts, 50% chop) | " | 9.41 | | |
| Chicken, Fresh, Rtc (Whole) OR | " | 11.00 | | |
| Chicken, Rtc, Cut-up | " | 8.46 | | |
| Turkey, Rtc, Whole OR | " | 4.00 | | |
| Turkey, Boneless, Raw | " | 2.46 | | |
| Fish, Portions, Haddock and Cod | " | 6.25 | | |
| Butter, Patties (70% Patties/30% Print) | " | 10.00 | | |
| Cheese, Cheddar, Natural | " | 3.125 | | |
| Eggs, Fresh, in Shell (Medium or Larger) | Dozen | 10.00 | | |
| Apples, Fresh, Eating | Pound | 13.00 | | |
| Bananas, Fresh | " | 13.00 | | |
| Oranges, Fresh | " | 13.00 | | |
| Strawberries, Frozen | " | 5.00 | | |
| Cabbage, Fresh | " | 13.00 | | |
| Carrots, Fresh | " | 11.00 | | |
| Celery, Fresh | " | 11.00 | | |
| Lettuce, Fresh, Head | " | 20.00 | | |
| Onions, Dry | " | 12.00 | | |
| Potatoes, White, Fresh, Sk | " | 75.00 | | |
| Tomatoes, Fresh | " | 14.00 | | |
| Shortening, Compound, GP | " | 10.00 | | |
| Apples, Canned | " | 4.00 | | |
| Beans, Canned, w/Pork | " | 2.00 | | |
| Beans, Green, Canned | " | 4.00 | | |
| Cherries, Rtp, Canned | " | 3.125 | | |
| Beans, Green, Frozen | " | 8.29 | | |
| Broccoli, Frozen | " | 10.34 | | |

*With the new beef roasts and steaks, boneless beef values are computed as follows:

| | | |
|-------------|-------|-------|
| Grill Steak | Pound | 8.93 |
| Pot Roast | " | 10.56 |
| Ground | " | 21.11 |

TABLE 3 (Cont'd)

FEBRUARY 1972 PROPOSED FCI

| Component | Unit | Quantity Per 100 | Unit Price | Value of Component |
|--|-------------|-----------------------------|-----------------------|-------------------------------|
| Corn, Whole Grain, Frozen | Pound | 7.28 | | |
| Potatoes, French Fried, Frozen | " | 12.75 | | |
| Juice, Orange, Frozen (3 + 1) | " | 1.17 | | |
| Juice, Pineapple, Canned | " | 1.40 | | |
| Juice, Tomato, Canned | " | 1.40 | | |
| Peaches, Sliced, Canned | " | 5.25 | | |
| Peas, Green, Canned | " | 2.00 | | |
| Pineapple, Sliced, Canned | " | 7.00 | | |
| Tomatoes, Canned | " | 14.25 | | |
| Cake Mix, Yellow | " | 13.50 | | |
| Flour, Wheat, Pastry | " | 12.00 | | |
| Rice, Parboiled | " | 4.00 | | |
| Spaghetti | " | 3.00 | | |
| Sugar, Granulated | " | 31.25 | | |
| Jam, Strawberry | " | .938 | | |
| Jelly, Grape | " | .938 | | |
| Oil, Salad | " | 5.00 | | |
| Catsup | " | 5.00 | | |
| Coffee, Regular and Ground | " | 12.50 | | |
| Cereal, Cornflakes | " | 3.00 | | |
| Bread, White, Plain | " | 49.50 | | |
| Milk, Whole, Fresh | " | 200.00 | | |
| Subtotal | | | | = _____ |
| Condiments and Accessory Foods – Add 1.5% of Subtotal | | | | = _____ |
| Grand Total (Value of Basic Daily Food Allowance for 100 Persons) | | | | = _____ |
| Divide by 100 (Value of Basic Daily Food Allowance for One Man) | | | | = _____ |

TABLE 4

**FCI PROPOSED BY THE OFFICE OF THE ASSISTANT SECRETARY
OF DEFENSE FOR INSTALLATIONS AND LOGISTICS**

| Component | Unit | Quantity Per 100 | Unit Price | Value of Component |
|---------------------------------------|-------|---------------------|---------------|-----------------------|
| Bacon, Slab, Smoked OR | Pound | 7.00 | | |
| Bacon, Slab, Sliced | " | 7.00 | | |
| Beef, Fresh, Carcass, OR | " | 68.00 | | |
| Beef, Boneless* | " | 46.24 | | |
| Ham, Smoked, Boneless | " | 6.3 | | |
| Pork Loin, Fresh, Bladeless OR | " | 13.00 | | |
| Pork, Boneless (50% roasts/50% chops) | " | 8.74 | | |
| Chicken, Fresh, Rtc, (Whole) OR | " | 15.00 | | |
| Chicken, Rtc, Cut-up | " | 11.54 | | |
| Fish Fillet, Flounder | " | 4.00 | | |
| Butter, Patties | " | 10.00 | | |
| Cheese, Cheddar, Natural | " | 3.125 | | |
| Eggs, Fresh, In Shell | Dozen | 10.00 | | |
| Apples, Fresh, Eating | Pound | 17.00 | | |
| Bananas, Fresh | " | 5.00 | | |
| Oranges, Fresh | " | 18.00 | | |
| Cabbage, Fresh | " | 14.75 | | |
| Carrots, Fresh | " | 13.00 | | |
| Celery, Fresh | " | 12.00 | | |
| Lettuce, Fresh, Head | " | 13.00 | | |
| Onions, Dry | " | 15.00 | | |
| Potatoes, White, Fresh | " | 98.00 | | |
| Tomatoes, Fresh | " | 13.00 | | |
| Lard, Service or Shortening, GP | " | 10.00 | | |
| Apples, Canned | " | 5.25 | | |
| Beans, Green, Canned | " | 8.25 | | |
| Cherries, RSP, Canned | " | 4.00 | | |
| Corn, Whole Grain, Canned | " | 10.50 | | |
| Juice, Orange, Canned | " | 1.875 | | |
| Juice, Pineapple, Canned | " | 1.875 | | |
| Juice, Tomato, Canned | " | 3.75 | | |
| Peaches, Sliced, Canned | " | 3.25 | | |
| Pears, Halved, Canned | " | 2.25 | | |
| Peas, Green, Canned | " | 6.125 | | |
| Pineapple, Sliced, Canned | " | 4.00 | | |
| *Grill Steak | " | 10.17 | | |
| Pot Roast | " | 12.2 | | |
| Ground Beef | " | 12.025 | | |
| Beef Patties | " | 12.025 | | |

TABLE 4 (Cont'd)

**FCI PROPOSED BY THE OFFICE OF THE ASSISTANT SECRETARY
OF DEFENSE FOR INSTALLATIONS AND LOGISTICS**

| Component | Unit | Quantity Per 100 | Unit Price | Value of Component |
|--|-------------|-----------------------------|-----------------------|-------------------------------|
| Tomatoes, Canned | Pound | 14.50 | | |
| Flour, Wheat, Hard | " | 37.50 | | |
| Noodles, Egg | " | 2.00 | | |
| Rice, Parboiled | " | 3.00 | | |
| Spaghetti | " | 3.00 | | |
| Sugar, Granulated | " | 31.25 | | |
| Jam, Strawberry | " | 1.875 | | |
| Jelly, Grape | " | 1.875 | | |
| Oil, Salad | " | 2.8875 | | |
| Catsup | " | 4.76 | | |
| Vinegar | " | 3.1725 | | |
| Cocoa, Natural | " | 3.125 | | |
| Coffee, Regular and Ground | " | 9.375 | | |
| Cereal, Cornflakes | " | 2.00 | | |
| Bread, White, Plain | " | 37.50 | | |
| Milk, Whole, Fresh | Pint | 200.00 | | |
| Subtotal | | | | = _____ |
| Condiments and Accessory Foods – Add 1.5% of Subtotal | | | | = _____ |
| Grand Total (Value of Basic Daily Food Allowance for 100 Persons) | | | | = _____ |
| Divide by 100 (Value of Basic Daily Food Allowance for One Man) | | | | = _____ |

the current FCI are not extreme. First, 3 pounds of canned corn are substituted for 3 pounds of asparagus; and secondly, the condiment allowance is reduced from 2% to 1.5%. These changes still adhere to the letter of the NRL, and no new liberties are taken as to interpretation.

Focusing attention on proposed means of developing still further alternative FCI's based on the NRL, one notes that the Navy Ration Law specifies 14 components (articles), 13 of which have prescribed issue factors associated with them. Of the 13, 4 comprise a single choice (butter, eggs, sugar, cheese) and the other 9 provide one or more "or's" as a choice. In some cases, the choice is among different types of food items (cocoa or coffee or tea), in other cases the choice is among form (fresh or canned or dry). Complicating the issue further, is the fact that the components refer to generic groupings (like "meat, poultry, fish") to which a large number of food items can be associated. The objective in designing a FCI is to associate with each NRL component one or more specific food items such that while the items for each overall component have the NRL specified issue quantity associated with them, the choice of items and their issue factors reflects food utilization patterns in the DoD.

The proposed approach to achieving this is illustrated in Figure 1 and 2. In both figures the starting point for the generation of the index is naturally the NRL article. As previously mentioned, most articles have a number of associated choices. The first problem, therefore, is to determine how much of the issue factor specified for each choice to incorporate into the index. The means chosen is to determine what percentage of the total utilization (in lbs/ration) for items falling into the generic class identified by the NRL article are utilized on the sub-group of items falling into the choice category, e.g., what percent of utilization of NRL article 3, vegetables, are of fresh vegetables. (This percentage figure can also be interpreted as the number of ration equivalents per hundred rations). As Figure 1 indicates, of the 1.271 lbs/ration of vegetables utilized in DoD, 0.706 lb/ration or 55.6% are fresh vegetables. The product of this figure (55.6%) and the NRL issue factor for this choice (fresh vegetables -- 44 oz) is the total issue factor (24.5 oz/ration) for the FCI items chosen to represent this NRL choice group. In a similar fashion, issue factors would be derived for dried and for canned vegetables, thus insuring that the three choice groups provide a full ration of vegetables in the FCI.

As illustrated in Figure 1, one could stop at this point and choose the items to represent the NRL article choice group from a listing of items representing 75% by weight of the total food quantity utilized. For example, of the approximately 50 most used items representing 75% of total food utilized, 11 are vegetables and 7 are fresh vegetables. The total utilization of these 7 fresh vegetables amounts to 0.628 lbs/ration. By dividing the utilization quantity for each of these 7 vegetables by this total, one can determine a percentage factor which can be associated with the item, e.g., fresh potatoes with a usage of 0.324 lbs/ration comprises 51.6% of the total utilization quantity for all 7 fresh vegetable items in the top 75% of utilization. The product of this percentage factor (51.6%) and the issue factor for the NRL article choice group (24.5 oz/ration) yields

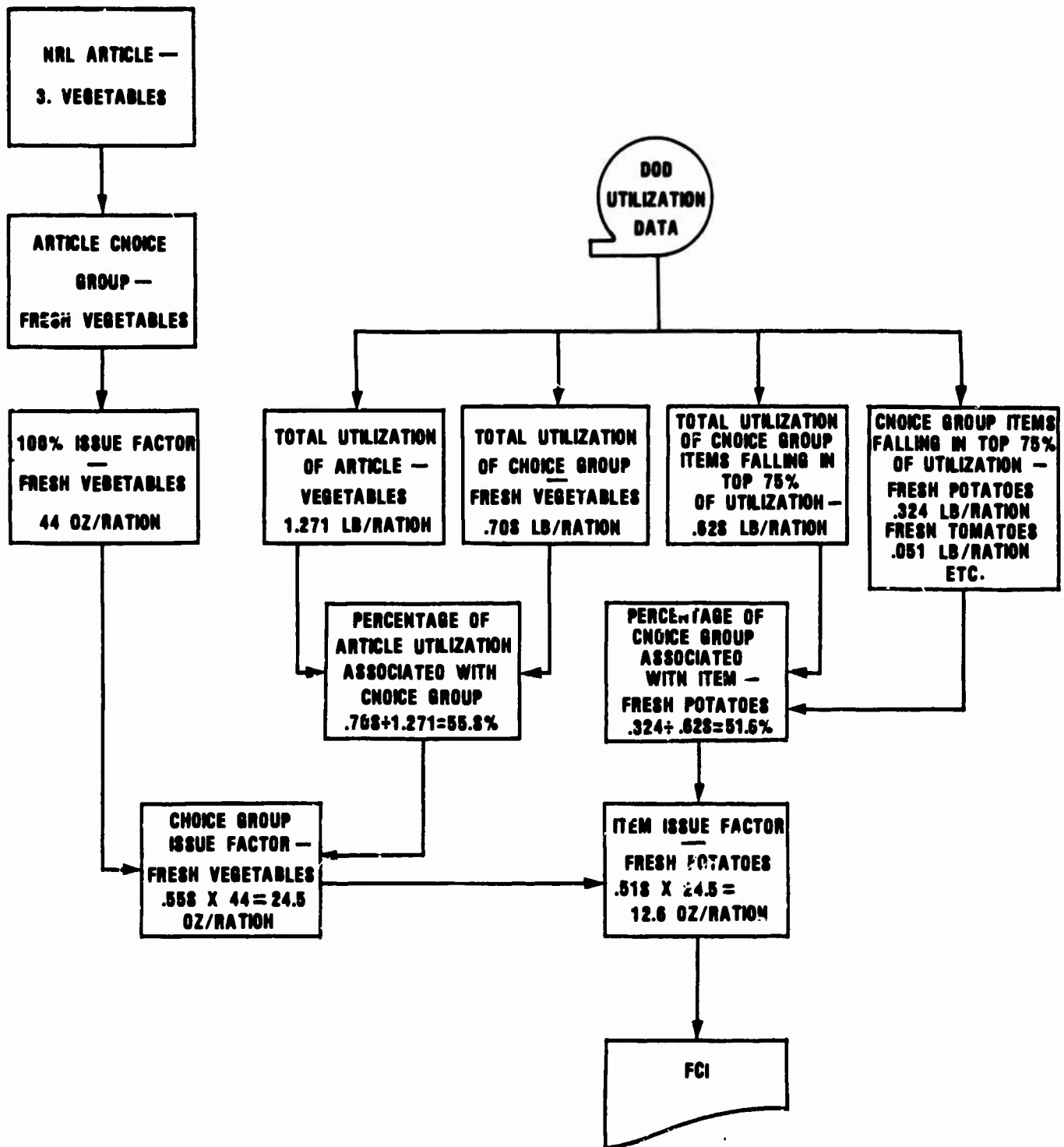


FIGURE 1. FLOW CHART FOR THE DEVELOPMENT OF A NAVY RATION LAW BASED FCI USING ITEMS COMPRISING THE TOP 75% OF DOD FOOD UTILIZATION.

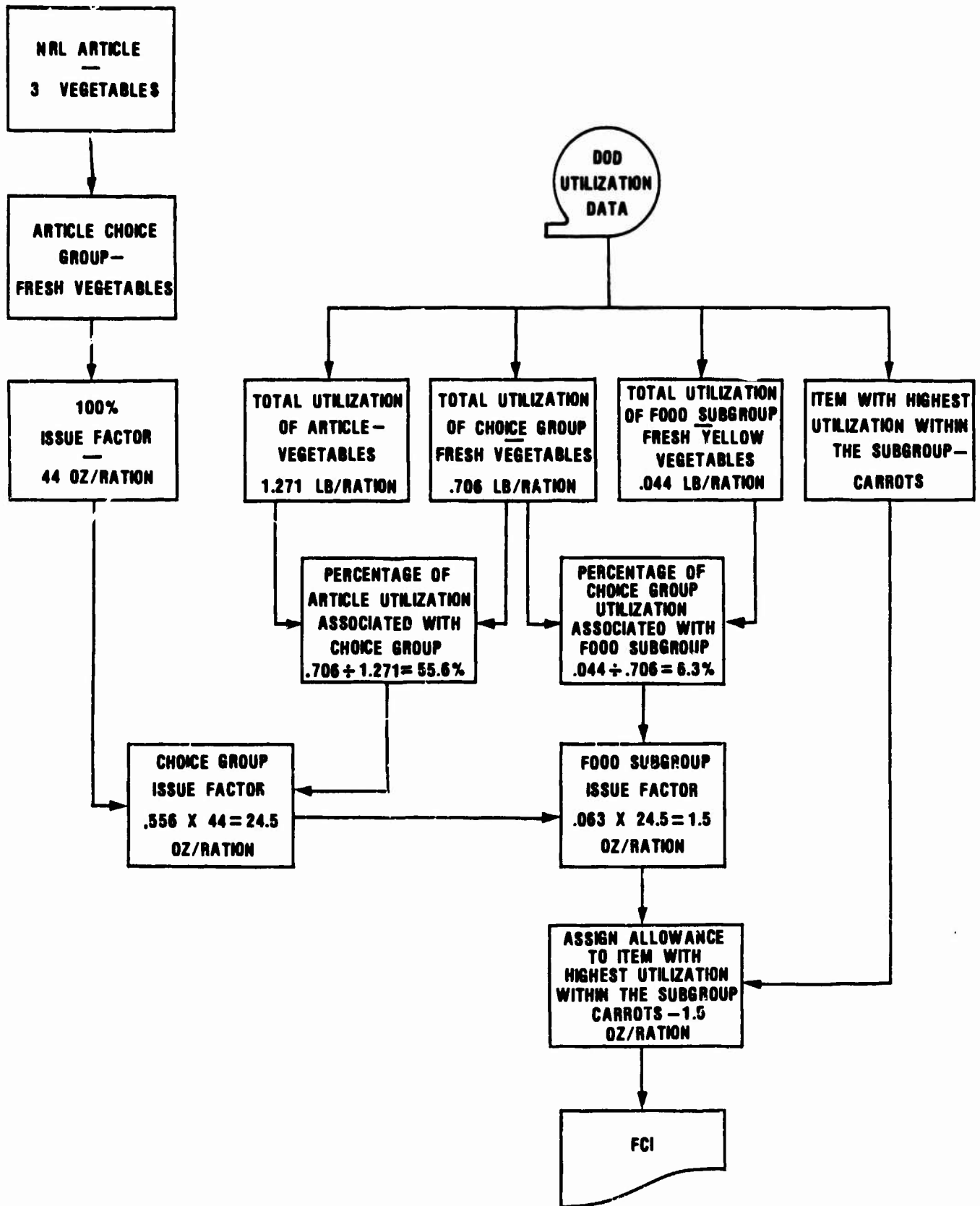


FIGURE 2. FLOW CHART FOR THE DEVELOPMENT OF A NAVY RATION LAW BASED FCI USING FOOD SURGROUPS.

the issue factor (12.6 oz/ration) for the FCI item, fresh potatoes. The results of this procedure are shown in the FCI presented in Table 5. Using a listing of items representing only the top 75% of total utilization implies the possibility that due to low utilization a particular article choice will not be represented. Care should be taken that at least one item representing each NRL article is incorporated into the FCI.

The choices indicated for each NRL article narrow the field of consideration to an extent; nevertheless, they are still broad enough to encompass a number of identifiable groups of items. For example, the NRL article 3 choice, fresh vegetables, has associated with it yellow, dark green, leafy, and other vegetables. Given that it is considered important to insure representation within the FCI of a series of subgroups associated with each NRL article choice group, then a method similar to the one discussed above and illustrated in Figure 2 would be used to determine how much of the choice group issue factor to assign to each food group. That is, having determined the issue factor for the choice group, one proceeds to aggregate items into the various subgroups that may be associated with each NRL article choice group. The quotient of each individual subgroup's utilization per ration (fresh, yellow vegetables, 0.044 lbs/ration) divided by the total utilization per ration for all items encompassed by the NRL choice group (fresh vegetables, 0.706 lbs/ration) yields a percentage (6.3%) which when multiplied by the issue factor for the NRL article choice group fresh vegetables - (24.5 oz/ration) yields the issue factor (fresh, yellow vegetables, 1.5 oz/ration) for the food group. The choice of the representative subgroup item to be incorporated into the FCI is the group item with the highest usage per ration (carrots). Using subgroupings similar to those suggested in "Patterns of Food Utilization in DoD" TR 75-65-OR/SA and shown in Table 6, this procedure yields the FCI shown in Table 7.

Table 8 presents a summary of the nutrient content of each of the FCI's suggested to this point. It may be noted that each is more than adequate as far as meeting The Surgeon General's Daily Dietary Allowances. ⁽³⁾ In addition, Table 8 provides a comparison of BDFA's as calculated from each FCI using June 1974 DPSC prices. Both the OASD suggested FCI and the NRL FCI using food subgroups provide similar BDFA's. The task group FCI suggested in February 1972 clearly represents a higher level of feeding; a level, however, which has been identified in a report on the basic level of military feeding. ⁽⁴⁾

With respect to this level of feeding, it should be pointed out that one advantage of the NRL based FCI using food subgroups is that it can be adjusted to a desired level of feeding by substituting a more expensive, higher preference item for the group item with the highest usage. This process of substitution is continued until the BDFA provided by the FCI equals the desired level of feeding.

(3) Department of the Army, Navy, and Air Force "Medical Service - NUTRITIONAL STANDARDS" AR 41-25/BUMEDINST 10110.30/AFR 160-95, August 1972.

(4) Brandier, P., et al. "The Basic Level of Feeding-A Comparison of Military and Comparable Civilian Food Utilization" USA Natick Laboratories TR 75-43-OR/SA.

TABLE 5**NAVY RATION LAW TYPE FCI BASED ON ITEMS
COMPRISING THE TOP 75% OF DOD FOOD
UTILIZATION (NRL #1)**

| Component | Unit | Quantity per Hundred Rations |
|-------------------------------------|-------------|---|
| Bread, White, Fresh | Pound | 33.099 |
| Rolls, Bread, Fresh | Pound | 9.681 |
| Flour, Wheat, Bread | Pound | 32.220 |
| Beef, Ground, Frozen | Pound | 13.971 |
| Chicken, Cut-up, Frozen | Pound | 11.597 |
| Beef, Patties, Frozen | Pound | 6.191 |
| Beef, Oven Roast, Boneless, Frozen | Pound | 5.692 |
| Beef, Pot Roast, Boneless, Frozen | Pound | 5.291 |
| Beef, Grill Steak, Boneless, Frozen | Pound | 4.800 |
| Pork, Spareribs, Frozen | Pound | 3.188 |
| Beef, Swiss Steak, Boneless, Frozen | Pound | 3.056 |
| Turkey, Raw, Boneless, Frozen | Pound | 2.981 |
| Frankfurters, Frozen | Pound | 2.733 |
| Beef, Diced, Frozen | Pound | 2.625 |
| Pork, Sausage, Frozen | Pound | 2.621 |
| Veal, Sliced, Boneless, Frozen | Pound | 2.574 |
| Pork, Slices, Boned, Frozen | Pound | 2.331 |
| Bacon, Sliced, Frozen | Pound | 7.110 |

TABLE 5 (Cont'd)**NAVY RATION LAW TYPE FCI BASED ON ITEMS
COMPRISING THE TOP 75% OF DOD FOOD
UTILIZATION (NRL #1)**

| Component | Unit | Quantity per Hundred Rations |
|---------------------------------------|-------------|---|
| Ham, Cooked, Smoked, Boneless, Frozen | Pound | 2.576 |
| Ham, Canned | Pound | 5.858 |
| Potatoes, White, Fresh | Pound | 78.814 |
| Tomatoes, Fresh | Pound | 12.415 |
| Cabbage, Fresh | Pound | 11.558 |
| Lettuce, Fresh | Pound | 24.875 |
| Onions Dry | Pound | 9.020 |
| Celery | Pound | 8.149 |
| Carrots, Fresh | Pound | 8.057 |
| Potatoes, White, Frozen | Pound | 36.100 |
| Tomatoes, Canned | Pound | 15.438 |
| Beans, White, Canned | Pound | 7.268 |
| Potatoes, White, Instant | Pound | 4.306 |
| Watermelon, Fresh | Pound | 9.284 |
| Oranges, Fresh | Pound | 20.528 |
| Apples, Fresh | Pound | 19.812 |
| Bananas, Fresh | Pound | 16.820 |
| Grapefruit, Fresh | Pound | 8.915 |

TABLE 5 (Cont'd)**NAVY RATION LAW TYPE FCI BASED ON ITEMS
COMPRISING THE TOP 75% OF DOD FOOD
UTILIZATION (NRL #1)**

| Component | Unit | Quantity per Hundred Rations |
|--------------------------|-------------|---|
| Juice, Orange, Canned | Pound | 1.848 |
| Juice, Tomato, Canned | Pound | 1.749 |
| Juice, Pineapple, Canned | Pound | 2.254 |
| Juice, Apple, Canned | Pound | 1.705 |
| Juice, Orange, Frozen | Pound | .689 |
| Coffee, Roasted | Pound | 12.500 |
| Milk, White, Fresh | Pint | 167.950* |
| Milk, Chocolate, Fresh | Pint | 31.950* |
| Butter | Pound | 10.000 |
| Spaghetti | Pound | 10.000 |
| Cheese, Cottage | Pound | 3.125 |
| Eggs, Shell | Dozen | 10.000 |
| Shortening Compound | Pound | 10.000 |
| Salad Dressing | Pound | 10.000 |
| Sugar, Granulated | Pound | 26.338 |
| Sugar, Powdered | Pound | 4.912 |

Condiments: Add 1.5% of the Subtotal

*Consistent with DOD Appropriation

TABLE 6
SUBGROUPS USED IN DEVELOPING AN FCI BASED ON THE NRL

Beef, Frozen
Veal and Lamb, Frozen
Pork, Frozen
Poultry and Rabbit, Frozen
Fish, Frozen
Shellfish, Frozen
Sausages, Frozen
Smoked and Salted Meats and Cold Cuts
Canned and Dehydrated Meats
Bread, Rolls and Crackers
Flour and Mixes
Dry and Dehydrated Vegetables
Dry Legumes, Nuts and Nut Butter
Tomatoes, Canned
Legumes, Canned
Yellow Vegetables and Potatoes, Canned
Leafy Vegetables, Dark-Green Vegetables, Other Vegetables, Canned
Potatoes, Fresh
Tomatoes, Fresh
Dark-Green Vegetables, Fresh

TABLE 6 (Cont'd)

SUBGROUPS USED IN DEVELOPING AN FCI BASED ON THE NRL

Yellow Vegetables, Fresh

Leafy Vegetables, Fresh

Other Vegetables, Fresh

Potatoes, Frozen

Dark-Green Vegetables, Frozen

Yellow Vegetables, Frozen

Other Vegetables, Frozen

Legumes, Frozen

Dried, Canned and Preserved Fruit

Citrus Fruit, Fresh

Other Fruit, Fresh

Fruit, Frozen

Canned Juice

Frozen Juice and Instant Juice

Coffee, Cocoa and Tea

Milk

Butter

Pasta

Cereal

TABLE 6 (Cont'd)

SUBGROUPS USED IN DEVELOPING AN FCI BASED ON THE NRL

Rice

Cheese

Eggs

Salad Oil and Dressings

Other Fats and Oils

Sugar

TABLE 7
NAVY RATION LAW TYPE FCI BASED ON FOOD SUBGROUPS
(NRL #2)

| Component | Unit | Quantity per Hundred Rations |
|-------------------------------------|-------|---------------------------------|
| Beef, Ground, Frozen | Pound | 20.049 |
| Beef, Grill Steak, Boneless, Frozen | Pound | 6.888 |
| Beef, Oven Roast, Boneless, Frozen | Pound | 8.169 |
| Veal, Slices, Boned, Frozen | Pound | 3.010 |
| Pork, Spareribs, Frozen | Pound | 5.518 |
| Pork, Ham, Boneless, Frozen | Pound | 3.850 |
| Chicken, Cut-up, Frozen | Pound | 12.725 |
| Cod, Portions, Frozen | Pound | 2.336 |
| Shrimp, Raw, Breaded, Frozen | Pound | 2.362 |
| Frankfurters, Frozen | Pound | 4.757 |
| Bacon, Sliced, Frozen | Pound | 8.050 |
| Boiogna, Frozen | Pound | 1.538 |
| Ham, Canned | Pound | 5.856 |
| Bread, White, Fresh | Pound | 42.488 |
| Flour, Wheat | Pound | 32.220 |
| Potatoes, White, Instant | Pound | 3.045 |
| Beans, White, Dry | Pound | 1.263 |
| Tomatoes, Canned | Pound | 6.938 |
| Beans, White, Canned | Pound | 8.588 |

TABLE 7 (Cont'd)**NAVY RATION LAW TYPE FCI BASED ON FOOD SUBGROUPS
(NRL #2)**

| Component | Unit | Quantity per Hundred Rations |
|---------------------------|-------------|---|
| Corn, Whole Grain, Canned | Pound | 4.125 |
| Beets, Canned | Pound | 3.038 |
| Potatoes, White, Fresh | Pound | 70.330 |
| Tomatoes, Fresh | Pound | 11.406 |
| Peppers, Sweet, Fresh | Pound | 4.756 |
| Carrots, Fresh | Pound | 9.600 |
| Onions, Dry | Pound | 23.731 |
| Lettuce | Pound | 33.069 |
| Potatoes, White, Frozen | Pound | 13.563 |
| Broccoli, Frozen | Pound | 4.400 |
| Corn, Whole Grain, Frozen | Pound | 4.381 |
| Vegetables, Mixed, Frozen | Pound | 7.556 |
| Beans, Green, Frozen | Pound | 6.200 |
| Peaches, Canned | Pound | 17.638 |
| Apples, Fresh | Pound | 27.856 |
| Oranges, Fresh | Pound | 14.425 |
| Strawberries, Frozen | Pound | 4.328 |
| Juice, Pineapple, Canned | Pound | 7.556 |

TABLE 7 (Cont'd)

**NAVY RATION LAW TYPE FCI BASED ON FOOD SUBGROUPS
(NRL #2)**

| Component | Unit | Quantity per Hundred Rations |
|----------------------------------|-------------|---|
| Juice, Orange, Frozen | Pound | .689 |
| Coffee, Roasted | Pound | 12.500 |
| Milk, White, Fresh | Pint | 200.000* |
| Butter | Pound | 10.000 |
| Spaghetti | Pound | 3.944 |
| Cereal, Prepared, Individual | Pound | 3.806 |
| Rice | Pound | 2.250 |
| Cheese, Cottage | Pound | 3.125 |
| Eggs, Shell | Dozen | 10.000 |
| Shortening Compound | Pound | 10.000 |
| Salad Dressing | Pound | 10.000 |
| Sugar, Granulated | Pound | 31.250 |
| Condiments: Add 1.5% of Subtotal | | |

*Consistent with DOD Appropriation

TABLE 8

COST AND NUTRITION SUMMARY OF FCI'S BASED ON THE NRL

| | Current FCI | GASD(I&L) FCI | NRL #1 (Top 75%) | NRL #2 (Sub- groups) | Feb 72 FCI |
|---------------------|-------------------------|------------------|---------------------|----------------------------|------------------------|
| BDFA ⁽¹⁾ | \$2.296 ⁽²⁾ | \$2.271 | \$2.225 | \$2.270 | \$2.359 ⁽³⁾ |
| Energy (Cal) | 4839 | 4848 | 5067 | 4914 | 4914 |
| Protein (g) | 160 | 160 | 166 | 162 | 154 |
| Fat (g) | 204(38%) ⁽⁴⁾ | 204(38%) | 218(39%) | 207(38%) | 222(41%) |
| Calcium (mg) | 1723 | 1721 | 1614 | 1646 | 1830 |
| Iron (mg) | 26.8 | 26.6 | 25.6 | 26.4 | 23.5 |
| Vit A (IU) | 12002 | 11980 | 9281 | 11720 | 12054 |
| Thiamine (mg) | 2.7 | 2.7 | 2.5 | 2.6 | 2.4 |
| Riboflavin (mg) | 3.5 | 3.4 | 3.3 | 3.5 | 3.3 |
| Niacin (mg) | 33.8 | 33.9 | 35.2 | 34.4 | 31.4 |
| Ascorbic Acid (mg) | 202.1 | 200.6 | 223.7 | 210.1 | 240.6 |

⁽¹⁾ Using "market" butter

⁽²⁾ \$2.244 using CCC butter

⁽³⁾ \$2.415 using "choice" meat prices

⁽⁴⁾ Indicates % of calories provided by fat in the FCI food items.

Two further alternatives can be proposed which are the result of repeating the previous chain of calculations using expenditure data (in \$/ration) rather than utilization data (in lbs/ration). The rationale for such a set of indices is simply the logic of using cost experience to generate a cost-control mechanism such as a FCI. This proposal must be rejected for the following reason: when one analyzes expenditure data, it will be noted that an appreciable percentage of the items representing the greatest expenditures are items with high unit costs but utilized in moderate quantities. If one had the freedom to adjust the quantity to be included in the FCI of such high cost items to a level proportionate to their actual utilization, there would be no problem. However, the NRL prescribes the amounts to be utilized, resulting in food cost indices yielding higher than reasonable BDFA's.

One fact must be clarified at this point; that is, the use of food utilization data to distribute prescribed NRL issue quantities will not necessarily yield a FCI which completely agrees with the pattern of food utilization in DoD. This is due to the fact that the basic quantities as specified by the NRL can only be adjusted in a minor fashion. Therefore, for example, while DoD utilization of eggs is 2.2 eggs per ration, the NRL issue factor for eggs is 1.2 eggs per ration; and no adjustment factor can be imposed to exceed this amount so long as there is conformance to the NRL.

Of the two methods developed, the index based on the highest usage item in each listed food subgroup seems more reasonable than a FCI based on the top 75% usage items. Among the desired characteristics of a FCI are that it represent a balanced nutritional formulation and that it be representative of the full range of those items actually being used. The exclusive use of those items comprising the top 75% of usage ignores some of the essential but lower use items. As has been noted, in order to insure that all NRL articles are represented in the top 75% FCI alternative one may have to dip below the top 75% of usage items for a representative index component. The top 75% of DoD food utilization encompasses 57 items. If one must continually dip down for additional index components to represent low usage articles or article choices, the FCI will soon become unwieldy. It must also be remembered that one subset of all possible food subgroup choices is the subset that yields the top 75% of usage items. That is, the food subgroup methodology is flexible enough that it can be adjusted to yield the top 75% FCI, while the reverse is not possible. Finally, the food subgroup methodology permits the simple adjustment to level of feeding while the top 75% methodology does not.

B. FCIs Based On DOD Food Utilization Patterns - As has been mentioned, a large scale detailed survey of DoD food usage by service has recently been carried out and reported in "Patterns of Food Utilization in the DoD" US Army Natick Laboratories TR-75-65-OR/SA. One of the major objectives of this survey is to provide a data base for the development of a FCI. The specific system designed for the analysis of the data, in fact, incorporates features that enable the rapid generation of FCIs under different assumptions.

In attempting to develop a FCI from military food utilization data (without conforming to the NRL), the most reasonable approach seems to be to divide the entire data base of over 500 different items utilized into generic groupings and then choose one or more individual items to represent each group. The particular choice as to groupings is not a unique one but rather is a matter of judgement. The groupings chosen for the purposes of this report are shown in Table 9. Having grouped the data, one chooses one or more representative items based on their importance to the daily ration. Importance to the daily ration can be measured in two ways, in terms of usage per ration or expenditure per ration. Within either of these contexts one can also take one of two approaches. The first approach is to consider all groups of equal importance and choose perhaps two representative items for each group. The second approach is to order the data in descending order of magnitude to determine the 50 or so items responsible for 75% of total usage or expenditure per ration. (The use of the latter method often results in some group being represented by 4 or 5 items while another group may not be represented at all.)

Having assembled the list of items to be included in the FCI, the next task is to determine the issue factors. The calculation of issue factors is determined by the constraints one chooses to place on the FCI. Food utilization data provide essentially three pieces of information with respect to each food group:

1. The total usage in lb/ration,
2. The total expenditure in cost/ration, and
3. The relative proportions of either usage or expenditure between members of the food group.

If one selects the first approach to item choice, i.e., two items for each and every group, then one can get exact mathematical solutions by imposing any two of the above three as constraints. This results from the fact that in this case there are two equations in two unknowns, a determined situation for each food group. Three pairings of constraints are possible: (1) cost and proportion, (2) usage and proportion, and (3) usage and cost.

In the latter situation the exact solution for a particular food group may yield mathematically correct and exact figures which have no physical significance; that is, negative issue factors for one of the FCI items representing the food group may result. In these cases an approximate solution must be obtained by imposing a third, non-negativity constraint on the issue factors. If it is desired to take cognizance of all three constraints, the situation becomes overdetermined (3 equations in 2 unknowns) and one can either take an average of the exact solutions for the cost/proportion and usage/proportion constrained situations, or utilize a least squares best fit in the absence of an exact solution. Appendix I provides derivation of the mathematical expressions for the factors for all cases referred to above.

TABLE 9

MAJOR GROUPS UTILIZED IN DEVELOPING URL TYPE FCI'S

Beef, Cuts, Frozen

Remainder of Beef

Veal, Lamb, and Rabbit

Pork, Diced and Sliced, Frozen

Remainder of Pork and Sausages and Cold Cuts

Poultry

Fish and Shellfish

Eggs

Butter

Milk and Milk Drinks

Cream and Ice Cream and Cheese

Tea, Coffee and Cocoa

Juices and Soft Drinks

Potatoes

Remainder of Vegetables, Fresh

Remainder of Vegetables, Frozen

Remainder of Vegetables, Canned

Legumes and Nuts and Remainder of Vegetables, Dehydrated

Bread, Rolls, and Biscuits and Other Baked Goods

Pasta and Cereals and Cereal Pastes and Rice and Barley

TABLE 9 (Cont'd)

MAJOR GROUPS UTILIZED IN DEVELOPING URL TYPE FCI'S

Flour and Mixes

Fruits, Fresh and Frozen

Fruits, Canned and Dehydrated

Margarine

Salad Oil and Dressings and Other Fats and Oils

Sugar and Syrup, Honey, and Molasses

Jam and Jellies and Candy and Puddings and Pie Fillings, etc.

Miscellaneous Items and Condiments

Appendix 2 provides examples of each of these five methods of FCI generation, as well as an example of one adjusted to a particular level of feeding, which will be discussed later. In addition, the BDFA's and nutrient contents yielded by these FCI's are also detailed. Each example contains the same items for in each case the same methods (i.e., incorporating the two most utilized food items in the food group) were used to chose the index items. As will be noted in Appendix 1, the expressions for the issue factors in the weighted least squares case permits one to place more or less emphasis on any particular defining relation. In this example the cost relationship was weighted 0.5, usage 0.3, and proportion at 0.2. The choice of weighting factors (W_i) is one of the necessary judgments that has to be made to reflect management emphasis on each of these three defining relations. In this particular case the greatest emphasis is placed on maintaining cost distribution between food groups and the least emphasis on maintaining the item proportions within each food group. All of these indexes are costed using June 1974 DPSC prices. It may be noted that the three indexes that placed the greatest emphasis on cost (cost/proportion, cost/usage, and weighted least squares) provide similar BDFA's while the other two provide somewhat lower BDFA's. It should be pointed out that in the case of the usage/cost and weighted least squares FCI's, the strict mathematical relations yielded negative issue factors for some items, and empirical judgments was exercised in choosing positive issue factors such that the BDFA level was maintained at the total DoD expenditure level as determined in the aforementioned report on DoD food utilization. Nutrient levels for all FCI's exceeded The Surgeon General's minimum requirements. In the case of fat content these levels are a few percent higher than the suggested maximum.

If one chooses to use the second approach to item choice, i.e., utilizing a list of items comprising the top 75% of total expenditure, the neat mathematical solutions just described do not apply. Nevertheless, a FCI can be derived as diagrammed in Figure 3, which depicts a solution constrained by cost and proportion. The items comprising the top 75% of expenditure to be incorporated into the FCI are categorized into the chosen food groups with 1 to N items per group. One then adds up the expenditures per ration for each FCI item in the group and divides this sum into the expenditure per ration for each individual FCI item. This will assign a percent figure to each FCI item in the group and, moreover, these percentages will total 100%. As these FCI items represent entire food groups, one multiplies the percent associated with the FCI item by the total expenditure per ration for the food group. (In the event certain food groups are not represented in the index by a specific item, their expenditures per ration are added to related groups which are represented. This ensures that 100% of the cost of the ration will be distributed). The resulting product represents an expenditure per ration for the item normalized to represent its particular proportion of its food group. If one divides this normalized expenditure per ration by the cost/lb. of the item, the FCI item issue factors are obtained. The issue factors are such that the sum of the products of the FCI item issue factors and their cost/lb. equals the total cost of an average ration at a given point in time, while still maintaining the relative proportions between food groups and between items within food groups. In this particular instance the 1 April 1974 DPSC price list, as revised by Change Notices 1 & 2, dated 1 May 1974 and 1 June 1974, respectively was used. The results of this calculation are shown in Table 10. As this table indicates, the BDFA provided by the index equals the level of expenditure (\$2.28) for DoD utilization per ration priced at June 1974 DPSC prices. Nutrient levels also exceed the minimum standards set by The Surgeon General.

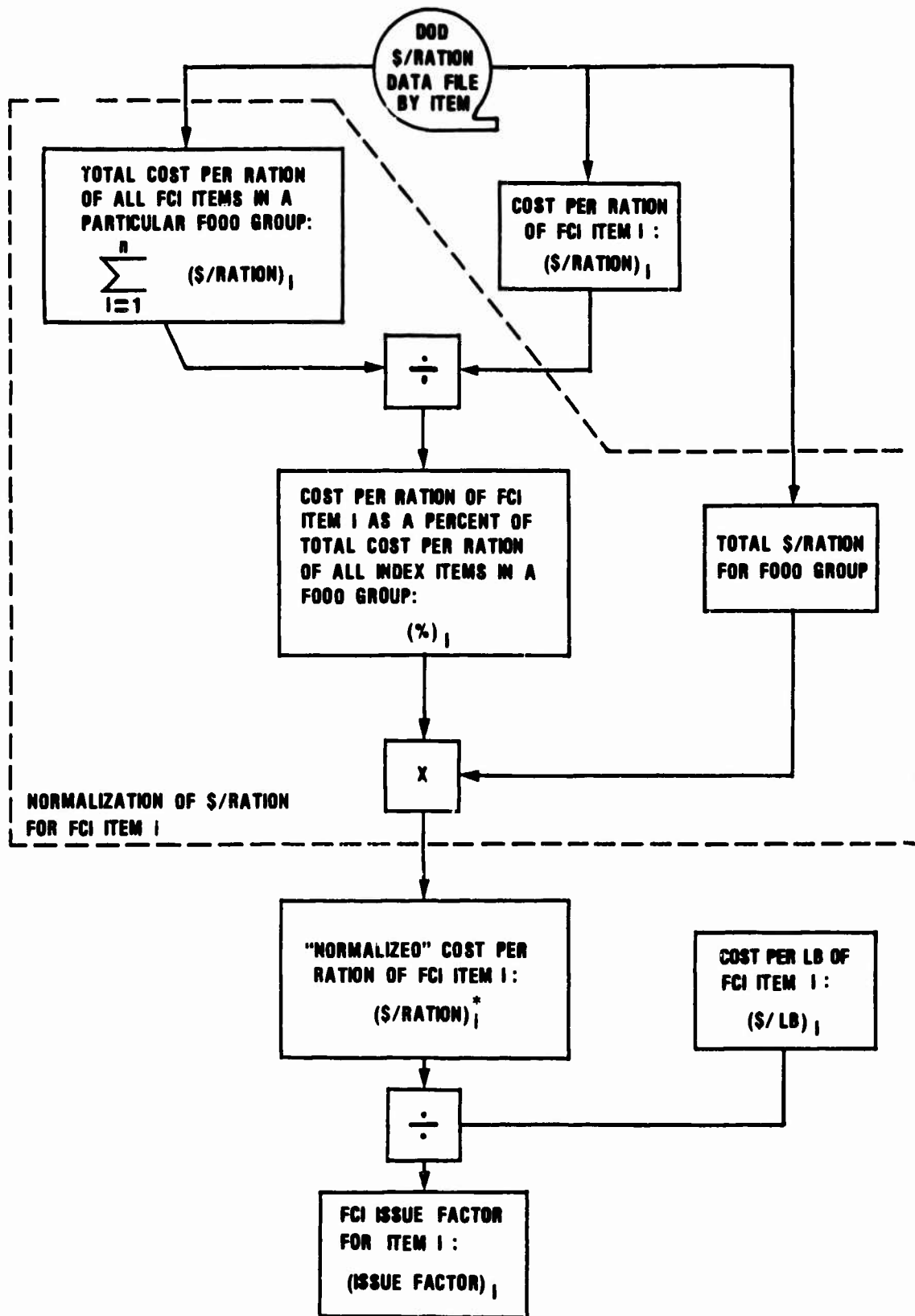


FIGURE 3. FLOW CHART FOR THE DEVELOPMENT OF A UNIFORM RATION LAW TYPE FCI USING ITEMS COMPRISING THE TOP 75% OF OOD FOOD EXPENDITURES.

TABLE 10**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE TOP
75% OF DOD FOOD EXPENDITURE**

| Component | Issue Factor (Lbs/100 Rations) |
|-------------------------------|---|
| Beef, Grill Steak | 4.356 |
| Beef, Oven Roast | 5.164 |
| Beef, Pot Roast | 4.801 |
| Beef, Swiss Steak | 2.774 |
| Beef, Minute Steak | .681 |
| Beef, Tenderloin | .466 |
| Beef, Corned | 1.537 |
| Beef, Corned, Canned | .533 |
| Beef, Ground | 16.333 |
| Beef, Diced | 3.068 |
| Beef, Patties | .542 |
| Veal, Sliced, Boneless | 2.663 |
| Veal, Roast | .480 |
| Bacon, Sliced | 7.043 |
| Frankfurters | 2.913 |
| Ham, Cooked, Smoked, Boneless | 2.954 |
| Pork, Spareribs | 3.398 |
| Pork, Roast, Boned | 2.046 |

TABLE 10 (Cont'd)**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE TOP
75% OF DOD FOOD EXPENDITURE**

| Component | Issue Factor (Lbs/100 Rations) |
|-----------------------------|---|
| Pork, Ham, Boneless | 2.372 |
| Pork, Loin, Boneless | 1.408 |
| Pork, Slices, Boned | 2.147 |
| Pork, Sausage | 2.793 |
| Ham, Canned | 5.980 |
| Chicken, Cut-up | 11.351 |
| Turkey, Raw, Boneless | 2.917 |
| Turkey, RTC | 1.404 |
| Cod, Portions | 1.760 |
| Shrimp, Raw, Breaded | 2.759 |
| Shrimp, Peeled and Deveined | .558 |
| Lobster | .567 |
| Eggs, Shell | 22.820 |
| Butter | 6.766 |
| Milk, White, Fresh | 163.231 |
| Milk, Chocolate | 22.288 |
| Milk, Nonfat, Dry | 1.095 |
| Ice Cream | 2.312 |

TABLE 10 (Cont'd)**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE TOP
75% OF DOD FOOD EXPENDITURE**

| Component | Issue Factor (Lbs/100 Rations) |
|---------------------------------------|---|
| Cheese, American | 2.312 |
| Cheese, Cheddar | .979 |
| Cheese, Cottage | 3.201 |
| Coffee, Roasted | 4.215 |
| Juice, Orange, Frozen | 12.738 |
| Potatoes, White, Fresh | 34.730 |
| Potatoes, White, Frozen, French Fries | 9.472 |
| Potatoes, White, Instant | 3.674 |
| Potato Chips | .730 |
| Tomatoes, Fresh | 10.057 |
| Lettuce, Fresh | 20.146 |
| Corn, Whole Grain, Frozen | 9.625 |
| Tomatoes, Canned | 21.844 |
| Beans, White, Canned | 18.201 |
| Bread, White, Fresh | 31.290 |
| Rolls, Bread, Fresh | 9.156 |
| Rice | 7.766 |
| Flour, Wheat | 36.155 |

TABLE 10 (Cont'd)

**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE TOP
75% OF DOD FOOD EXPENDITURE**

| Component | Issue Factor (Lbs/100 Rations) |
|----------------------------|---|
| Oranges | 30.866 |
| Apples | 29.798 |
| Margarine | 1.527 |
| Salad Oil | 1.930 |
| Salad Dressing | 3.431 |
| Shortening Compound | 7.271 |
| Shortening Compound, Fluid | 1.754 |
| Sugar Granulated | 20.899 |
| Syrup, Maple | 4.135 |
| Catsup, Tomato | 14.511 |
| Add 1.5% for Condiments | |
| | |
| BDFA | \$2.282 |
| Energy | 4818cal |
| Protein | 177g |
| Fat | 207g (39%) |
| Calcium | 1724mg |
| Iron | 26.6mg |

TABLE 10 (Cont'd)

**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE TOP
75% OF DOD FOOD EXPENDITURE**

| Component | |
|------------------|---------|
| Vitamin A | 7631IV |
| Thiamine | 2.9mg |
| Riboflavin | 3.5mg |
| Niacin | 34.3mg |
| Ascorbic Acid | 240.5mg |

Another alternative representing a usage and proportion constrained situation can be derived by simply substituting usage data (in lbs/ration) for cost or expenditure data (in cost/ration) and utilizing the resulting "normalized" usage per ration as the issue factor for each FCI item. (In this case no further division is necessary to convert a cost per ration figure to a lb/ration issue factor). This index is presented in Table II. Again, the FCI provides more than adequate levels of nutrition. The BDFA provided, however, is considerably lower than the previous examples. This is due to the fact that the highest usage items in most food groups are usually the less costly ones, and all adjustments made maintain usage quantities and not costs.

The most appropriate methodology to be used in deriving a FCI to represent the totality of DoD food utilization would be the method which considers the greatest number of factors, that is, the weighted least squares method. Any of the other methods which consider only two of the three factors (cost, usage, proportion) ignore the other significant effect. The weighted least squares method also offers two other associated advantages: (1) it permits greater emphasis to be placed on a particular factor while still considering the other factors as well, and (2) the solution minimizes the error in the necessarily approximate solution to n equations in $n-1$ unknowns.

All of the previous discussions have reference to the utilization of historical data representing the existing level of military feeding to develop a FCI. US Army Natick Laboratories TR 75-43-OR/SA, "The Basic Level of Feeding: A Comparison of Military and Comparable Civilian Food Utilization" raises the issue of setting a level of military feeding in an objective fashion. Implementation of this concept would require the development of a FCI to provide this new level of military feeding (which may be greater or less than the historical level). This could be accomplished in a very simple fashion by resetting the food group cost level, referred to in Appendix I of this report as C_G to a new level, C_L , reflecting the new level of military feeding. If we call the current total cost to feed T_C and the new level of feeding T_L , then a new food group cost C_L could be set as follows:

$$C_L = C_G \times (T_L / T_C)$$

Substituting this new value C_L for the C_G value in the expressions derived in Appendix I would yield an alternative FCI adjusted to the new level of feeding.

This approach is a simplified one because it assumes that the pattern of expenditure between food groups will remain the same regardless of the amount of money available. That is, with more money one buys proportionately more of each group of food items. This is, of course, not always the case. It is well known that additional funds are often expended in upgrading the quality of the food rather than the amount; for example, using the additional funds to substitute steak for hamburger. Despite this fact, given that the change in the level of military feeding is of the order of 10% or less, changes in the pattern of expenditure with respect to food groups would be minimal. Also, the cost level for each group is being adjusted, not the usage level. This cost adjustment would be the result of making a quality change rather than a quantity change within a food group. Therefore, the utilization of the aforementioned technique would be essentially valid for the cost/usage constrained situation. That is, since it is quite likely that the relative proportions of the items representing the food group will be altered, imposing the proportion constraint would be inappropriate and the cost/usage constrained FCI would be the most logical one to use.

TABLE 11**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE
TOP 75% OF DOD FOOD UTILIZATION**

| Component | Issue Factor (Lbs/100 Rations) |
|-------------------------------|---|
| Bacon, Sliced | 6.902 |
| Beef, Grill Steak | 5.145 |
| Beef, Swiss Steak | 3.275 |
| Beef, Oven Roast | 6.100 |
| Beef, Pot Roast | 5.672 |
| Beef, Diced | 2.359 |
| Beef, Ground | 12.558 |
| Beef, Patties | 5.584 |
| Frankfurters | 3.837 |
| Ham, Canned | 7.874 |
| Ham, Cooked, Smoked, Boneless | 3.889 |
| Pork Slices, Boneless | 2.104 |
| Pork Sausage | 3.680 |
| Pork Spareribs | 4.476 |
| Veal, Slices, Boneless | 3.551 |
| Chicken, Cut-up | 16.675 |

TABLE 11 (Cont'd)

**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE
TOP 75% OF DOD FOOD UTILIZATION**

| Component | Issue Factor (Lbs/100 Rations) |
|------------------------|---|
| Turkey, Boneless, Raw | 4.286 |
| Butter | 6.766 |
| Cheese, Cottage | 8.561 |
| Eggs, Shell | 22.024 |
| Ice Cream | 5.848 |
| Milk, Chocolate | 30.426 |
| Milk | 159.152 |
| Apples, Fresh | 11.834 |
| Bananas, Fresh | 10.049 |
| Grapefruit, Fresh | 5.326 |
| Oranges, Fresh | 12.261 |
| Watermelons, Fresh | 5.546 |
| Cabbage, Fresh | 7.608 |
| Carrots, Fresh | 5.306 |
| Celery, Fresh | 5.363 |
| Lettuce, Fresh | 16.382 |
| Onions, Dry | 5.936 |
| Potatoes, White, Fresh | 33.610 |
| Tomatoes, Fresh | 8.177 |

TABLE 11 (Cont'd)**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE
TOP 75% OF DOD FOOD UTILIZATION**

| Component | Issue Factor (Lbs/100 Rations) |
|--------------------------------|---|
| Potatoes, White, Fried, Frozen | 9.166 |
| Juice, Orange, Frozen | 2.771 |
| Juice, Orange, Canned | 2.860 |
| Bread, Fresh, White | 36.448 |
| Rolls, Fresh | 10.663 |
| Shortening Compound | 10.849 |
| Beans, White, Canned | 20.114 |
| Juice, Apple, Canned | 2.638 |
| Juice, Pineapple, Canned | 3.488 |
| Juice, Tomato, Canned | 2.707 |
| Potatoes, White, Instant | 3.558 |
| Tomatoes, Canned | 15.940 |
| Flour, Wheat | 25.242 |
| Sugar, Granulated | 16.434 |
| Sugar, Powdered | 3.065 |
| Coffee, Roasted | 4.414 |

TABLE 11 (Cont'd)

**UNIFORM RATION LAW TYPE FCI BASED ON ITEMS COMPRISING THE
TOP 75% OF DOD FOOD UTILIZATION**

| Component | Issue Factor (Lbs/100 Rations) |
|-----------------------|---|
| Beverage Base | 16.823 |
| Catsup, Tomato | 9.926 |
| Salad Dressing | 5.119 |
| Syrup, Maple | 5.885 |
| Add 2% for Condiments | |
| BDFA | \$2.092 |
| Energy | 4585cal |
| Protein | 169g |
| Fat | 203g (42%) |
| Calcium | 1569mg |
| Iron | 24.5mg |
| Vitamin A | 8555IU |
| Thiamine | 2.2mg |
| Riboflavin | 3.3mg |
| Niacin | 31.2mg |
| Ascorbic Acid | 155.1mg |

As noted previously, Appendix 2 provides an example of such a FCI. Nutrient levels provided by this Index also exceed The Surgeon General's minimum requirements; however, fat content exceeds the recommended maximum allowance. If comparisons are desired between this FCI and that recommended in February 1972, care must be taken to use the issue factors for steak and oven roast indicated in the footnote of the Appendix. The issue factors were calculated using "choice" quality meat prices as opposed to "good" quality meat prices. Only under this condition do both these indexes provide equivalent BDFA's.

One point must be emphasized: these mathematical models are only tools to be used in developing FCI's. At many steps in their utilization, sound professional judgement is required either to provide fundamental input, such as the groupings of food items or to provide for an alternative solution such as in the event that negative issue factors are indicated. In addition, if one chooses to use a least squares model in which only approximate solutions to the constraint equations are possible, then professional judgement would be necessary to alter issue factors such that the total cost exactly equals a specific value or level.

C. Reference Menus Based FCI's. - As was pointed out previously, the possibility of developing a mathematically optimized reference menu incorporating the latest scientific information on the preferences of enlisted personnel represents an attractive basis for the development of a FCI. By incorporating nutritional constraints, such a FCI could not only provide a BDFA capable of meeting all nutritional requirements but would additionally enable the menu planner to maximize satisfaction of stated customer preferences within the desired level of feeding. While the current state-of-the-art in mathematical programming is unable to solve the problem of maximizing preference for a selective menu within given cost and nutritional constraints, this scientific preference data can be used in an empirical fashion by senior service menu planners in much the same fashion as other more intuitive sources of preference data to develop higher preference menus than currently used.

In any case, once the menu has been developed it can be recapitulated (i.e., all of the recipes converted into the requisite ingredients) to provide data on the proposed food utilization per ration on an item-by-item basis. This data is indistinguishable in form from the data gathered by the DoD food utilization survey which provided historical food utilization per ration on an item-by-item basis. Therefore, all the mathematical methods developed and discussed previously under "Food Utilization Patterns in DoD" can be applied in this case to generate FCI's by merely substituting menu recap data for the DoD food usage data.

One final alternative, referred to in the proceeding section of this report, would be to take advantage of computer processing capability to cost the entire reference menu rather than just a representative sample of items. The difference in cost of this entire menu and that of the least squares adjusted index will not be great since one of the constraints on the latter is that total group costs be maintained. This equivalency of cost, however, is a strong function of the cost relationships that maintain at the time the least squares FCI was developed. Fluctuation in price relationships over time will naturally affect the ability of the shorter index to track the entire menu. This condition is not unique to this particular situation as the use of a sample to measure the whole always involves a certain margin of error.

SECTION V

CONCLUSIONS

1. The intention of this study is neither to examine the necessity of a ration law nor to recommend a specific food cost index, but rather to explore and evaluate a number of methods for food cost index development. Evaluations normally contain an element of ranking since most evaluations are relative rather than absolute. In this situation circumstances exist which require that these evaluations be made within the boundaries of certain constraints. That is, the Navy Ration Law is an existing statute, and the ranking of NRL-based FCI's relative to other types of FCI's would be unsuitable since this report does not evaluate the NRL itself versus other laws or regulations that could be used to define the ration entitlement. Any evaluation, therefore, must proceed with the separate consideration of the relative merits of FCI's that are constrained by the NRL and those that are not.

2. Within the context of the NRL, four FCI's are presented, two representing efforts prior to the URCS program. As pointed out, the correlation between the current FCI and actual DoD food utilization is low. This index also fails to recognize such accepted food service practices as the use of frozen fruits, vegetables, and juices, or prepared cake mixes. The February 1972 FCI, currently slated for adoption in FY 76, represents an advance over the aforementioned FCI in that it better reflects utilization patterns and incorporates more of the current high use food process types, such as frozen foods and cake mixes. In addition, this FCI (as modified by several recent changes) coincidentally costs out at a level deemed appropriate in a study on the basic level of feeding.⁽⁵⁾ However, one basic assumption by the task group responsible for its development was that military department differences preclude uniform consumption patterns, and hence while food utilization patterns are considered, they do not play a dominant role in the formulation of this FCI. This again results in a FCI which does not accurately reflect actual consumption figures. The two new FCI types suggested by this study depart from the aforementioned premise and assume that the DoD food utilization pattern can be constructed and used as a basis for a FCI insuring that the resulting FCI relates to actual consumption practices within NRL constraints.

The central problem to achieving full representation of the range of food items being used is that the NRL itself ignores certain components of the actual ration being served, (e.g., soft drinks, ice cream, and margarine) and limits the quantities of other items (e.g., eggs) to levels that are unrepresentative of current utilization. As a result, no NRL based FCI can truly reflect actual feeding practices. However, of all of the four NRL-based FCI's, the food subgroup FCI makes the greatest attempt to adhere to recent food usage experience. The major factor that seems to argue in favor of the February 72 FCI is that it provides a BDFA close to the desired level of feeding. However, the agreement between the level of feeding represented by this FCI and the desired basic level of feeding is a product of chance rather than design, and the food subgroup methodology also permits the adjustment to a desired level of feeding. Therefore, it is concluded that an FCI development methodology based on use of the best food utilization data available and following the food subgroup approach is preferred among those FCI's that conform to the NRL.

⁽⁵⁾Brandler, P., et al "The Basic Level of Feeding: A Comparison of Military and Comparable Civilian Food Utilization" US Army Natick Laboratories TR 75-43-OR/SA.

3. The choice of the most appropriate methodology for the development of a FCI is a function of the constraints placed upon its formulation. If it is assumed that a law with prescribed allowances for specific food components exists, as for example the current NRL or some updated version, then it is concluded that the food subgroup methodology found to be most logical for the NRL would be most appropriate. If on the other hand the law does not specify a specific set of food allotments, then the problem is one of developing a methodology for formulating an appropriate FCI which is nonconstrained as to prescribed food issues. The approaches suggested in the previous section on DoD Food Utilization Patterns and Reference Menus all fall into this latter category.

As has been noted, the methodologies for deriving FCI's from DoD food utilization data or from a reference menu recap are equivalent. That is, the suggested mathematical models do not recognize any difference between a data base derived from utilization data and one derived from a reference menu. Of the two data bases, utilization data or reference menus, the reference menu approach seems to offer the greatest number of advantages. A reference menu can directly incorporate the latest scientific information on the specific preference of servicemen. It can be scientifically optimized with respect to preference within any constraints deemed relevant, including cost and nutrition. In the event that a change in the level of feeding (in terms of \$/ration) is considered appropriate, an optimized menu can be formulated without any artificial assumptions. This approach has intuitive as well as practical appeal in view of the fact that a menu is a visible and tangible basis for an index, being more so than a list of foods that have little discernible association with menus. Utilization data on the other hand is historical in viewpoint rather than forward looking and is at best an indirect indicator of consumer preferences. In addition, historical usage data cannot help but reflect certain undesirable influences that military food service has sometimes been subject to but is constantly trying to improve: vagaries in supply, inconsistent local menu planning, wastage, low customer acceptance, and limited professional supervision. A FCI derived from such a data base generally represents a continuation of the status-quo.

It is concluded that a reference menu represents the most attractive means of developing a FCI. However, there is no attendant requirement that any service impose that menu on any base food service operator as a requirement. It would merely be provided as a professionally prepared scientific guide or standard capable of yielding the optimum in customer preference within the constraints of the desired basic level of feeding and adequate nutrition. Since preference data relates to menu items (i.e., recipes) and not to the raw foods, it is necessary to make the conversion by recapitulating the reference menus into their constituent raw foods. A FCI based on such a recap thus is designed expressly to meet "consumer requirements." Given the option of a more scientific approach such as the usage of a reference menu, the logical choice seems clear.

It must be remembered, however, that the intuitively attractive advantages of preference data over utilization data for FCI development have never been validated by actual experience. In addition, the mathematical algorithms necessary to perform the desired optimization for selective menus have not been fully developed as yet. Therefore, it must be concluded that the adoption of the preference approach must await the completion of a program to develop the necessary methodology and to validate the advantages postulated.

5. In either case (DoD utilization or reference menu) the most appropriate methodology to be used in deriving a FCI to represent the totality of either DoD food utilization or a reference menu would be the method which considers the greatest number of factors, that is, the weighted least squares method. Any of the other methods which consider only two of the three factors (cost, usage, proportion) ignore the other significant effect. The exception to this general conclusion, as has previously been pointed out, is the case of adjusting DoD food utilization data for an increase in the level of feeding in which the proportion relations would no longer be maintained and the usage/cost model is, therefore, more valid. As is apparent, increasing the level of feeding in a reference menu situation implies redesigning the menu to the higher level of feeding and then rederiving the FCI with a least squares technique.

The use of manual techniques for BDFA calculations naturally limits the number of items that can reasonably be included in a FCI. However, modern computer techniques permit the rapid costing of entire menus. In the event of the future adoption of a reference menu as a standard of feeding, the costing of the entire menu is naturally a more effective method of ensuring sufficient funds for its provision than any representative sample of items, no matter how derived. However, the decision to adopt entire menu computer costing is a JRCs system decision and goes beyond the scope of this document.

SECTION VI

Recommendations

1. Due to the requirements for professional judgement at numerous decision points in the development of a FCI, it is recommended that a standing committee, comprised of representatives from each service, medical/nutritional advisors and food utilization/preference advisors, be formed to periodically review the food cost index. The objective of this committee should be to keep the FCI current with consumer requirements, nutritional standards, and generally accepted U.S. feeding standards. Proposed amendments should be submitted to the committee from all interested sources, and the committee should meet at scheduled periods, probably no less frequently than every year or two. The reviewing offices (for subsistence policy and for funding) and the procedure for forwarding the committee's recommendations would be specified. Further, the time allowed for each reviewing office to act on the recommendations should be stated in order to avoid unwarranted delays in taking action on such recommendations. The instructions governing the FCI development and revision should be recorded in DOD Directive 1338.10. This committee could operate as a subcommittee or permanent task group within the Uniform Ration Cost System Committee which is recommended in "Uniform Ration Cost System - Summary Report," U.S. Army Natick Laboratories TR-75-69-OR/SA.

2. The preference menu basis for the FCI should be further developed and tested. In view of the fact that a large number of menus can be developed unless the boundary limits are well defined, a frame of reference should be applied in terms of a cost constraint (for a particular date) and nutritional standards. Initially this type of menu should be developed "manually" by professional dietitians with access to DoD food preference data. Progress has been made in developing mathematical programming techniques so that computer-based analyses can provide time-saving assistance to professionals undertaking this type of activity. For example, the frequency of serving menu items in a cyclic menu can be determined on the basis of maximizing preference subject to stated constraints. Research should continue in the area of expanding this capacity to encompass selective menus and food compatibilities. Research on the use of preference menus, as opposed to their development should also be continued, including test at installations to determine their general suitability both as to being a reference for food service operations and as a basis for a FCI.

3. As concluded previously, the preference menu approach seems to represent the most attractive alternative to formulating a FCI. However, the current statutory requirements of the NRL as well as the specific reservations with respect to reference menus mentioned previously require a time-phased approach to its possible implementation. As a result the following is recommended:

a. Until the NRL has been rescinded, implement a FCI developed under the direction of the DoD Food Planning Board using the food subgroup methodology, based on DoD food utilization data collected in the URCS program.

b. In subsequently adopting a Uniform Ration Law (URL), place greatest initial emphasis on the use of food utilization data and the least squares technique in developing a FCI.

c. As soon as technically feasible, supplement the utilization data with DoD food preference data and start to incorporate the results of the recommended preference menu research into the periodic reviews and revisions of the URL FCI, again using the weighted least squares technique.

d. Following test and validation of the reference menu approach, adopt it as a basis for development of the FCI, using the weighted least squares technique.

e. As soon as shown to be practicable from the standpoint of service requirements, institute entire reference menu costing, (rather than the shorter FCI) as a basis for determining the monetary value of the basic daily food allowance.

f. Continue research into the use of mathematical optimization techniques for analytical solution of the BDFA subject to selected nutritional, preference or cost constraints.

APPENDIX I

Mathematical Derivation of FCI Issue Factors Under Different Constraints

The solutions presented below are derived for the case in which two items are chosen to represent each food group. The methods, however, can be extended to cover situations in which three or more representative items are desired.

- Definitions:
- X_1 = The FCI Issue factor for item 1 in lb./ration
 - X_2 = The FCI Issue factor for item 2 in lb./ration
 - A_1 = The actual utilization of item 1 in lb./ration
 - A_2 = The actual utilization of item 2 in lb./ration
 - C_1 = The unit cost of item 1 in \$/lb.
 - C_2 = The unit cost of item 2 in \$/lb.
 - L_G = The total utilization in lb./ration for the food group of which items 1 & 2 are members
 - C_G = The total expenditure in \$/ration for the food group of which items 1 & 2 are members

The three possible constraints are:

1. Total usage: The sum of the two FCI item issue factors equals the total utilization for the food group of which the items are members.

$$X_1 + X_2 = L_G$$

2. Total expenditure: The sum of the two extended FCI item values equals the total expenditure for the food group of which the items are members.

$$X_1 C_1 + X_2 C_2 = C_G$$

3. Relative proportion: The ratio of the amount specified in the FCI for item 1 to the amount specified for item 2 equals the ratio of their actual utilization.

$$\frac{X_1}{X_2} = \frac{A_1}{A_2}$$

which reduces to

$$X_1 A_2 - X_2 A_1 = 0$$

(A) Solution to Usage/Proportion Constrained Problem:

$$X_1 + X_2 = L_G$$

$$X_1 A_2 - X_2 A_1 = 0$$

Solving by determinants:

$$x_1 = \frac{\begin{vmatrix} L_G & 1 \\ 0 & -A_1 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ A_2 & -A_1 \end{vmatrix}}, \quad x_2 = \frac{\begin{vmatrix} 1 & L_G \\ A_2 & 0 \end{vmatrix}}{\begin{vmatrix} 1 & 1 \\ A_2 & -A_1 \end{vmatrix}}$$

or

$$x_1 = \frac{A_1 L_G}{A_1 + A_2}, \quad x_2 = \frac{A_2 L_G}{A_1 + A_2}$$

(B) Solution to the Cost/Proportion Constrained Problem

$$x_1 C_1 + x_2 C_2 = C_G$$

$$x_1 A_2 - x_2 A_1 = 0$$

Solving by determinants:

$$x_1 = \frac{\begin{vmatrix} C_G & C_2 \\ 0 & -A_1 \end{vmatrix}}{\begin{vmatrix} C_1 & C_2 \\ A_2 & -A_1 \end{vmatrix}}, \quad x_2 = \frac{\begin{vmatrix} C_1 & C_G \\ A_2 & 0 \end{vmatrix}}{\begin{vmatrix} C_1 & C_2 \\ A_2 & -A_1 \end{vmatrix}}$$

or

$$x_1 = \frac{A_1 C_G}{A_1 C_1 + A_2 C_2}, \quad x_2 = \frac{A_2 C_G}{A_1 C_1 + A_2 C_2}$$

(C) Solution to the Cost/Usage Constrained Problem

$$x_1 C_1 + x_2 C_2 = C_G$$

$$x_1 + x_2 = L_G$$

Solving by determinants:

$$x_1 = \frac{\begin{vmatrix} C_G & C_2 \\ L_G & 1 \end{vmatrix}}{\begin{vmatrix} C_1 & C_2 \\ 1 & 1 \end{vmatrix}}, \quad x_2 = \frac{\begin{vmatrix} C_1 & C_G \\ 1 & L_G \end{vmatrix}}{\begin{vmatrix} C_1 & C_2 \\ 1 & 1 \end{vmatrix}}$$

or

$$X_1 = \frac{C_G - C_2 L_G}{C_1 - C_2}, \quad X_2 = \frac{C_1 L_G - C_G}{C_1 - C_2}$$

(D) Solution to the Cost/Usage/Proportion constrained problem using an average of the Cost/Proportion and Usage/Proportion problem solutions.

For Usage/Proportion

$$X_1 = \frac{A_1 L_G}{A_1 + A_2}$$

For Cost/Proportion

$$X_1 = \frac{A_1 C_G}{A_1 C_1 + A_2 C_2}$$

The average solution is one half the sum of the two.

$$X_1 = 1/2 \left[\frac{A_1 L_G}{A_1 + A_2} + \frac{A_1 C_G}{A_1 C_1 + A_2 C_2} \right]$$

In both cases

$$X_2 = \frac{A_2 X_1}{A_1}$$

Therefore substituting for X_1 :

$$X_2 = \frac{A_2}{2} \left[\frac{L_G}{A_1 + A_2} + \frac{C_G}{A_1 C_1 + A_2 C_2} \right]$$

(E) Solution to the Cost/Usage/Proportion Problem Using a Weighted Least Squares Technique.

The three constraining equations are:

$$X_1 + X_2 = L_G$$

$$X_1 C_1 + X_2 C_2 = C_G$$

$$X_1 A_2 - X_2 A_1 = 0$$

Only approximate solutions can be derived for this group of equations. Therefore, let us define an error term for each equation:

$$X_1 + X_2 - L_G = e_L$$

$$X_1 C_1 + X_2 C_2 - C_G = e_C$$

$$X_1 A_2 - X_2 A_1 = e_P$$

One would like to minimize the sum of the squares of these errors, but in such a fashion that different weighting can be assigned to each error term so as to permit a ranking with respect to importance. This can be accomplished by defining a quality Q as follows:

$$Q = W_L e_L^2 + W_C e_C^2 + W_P e_P^2$$

Substituting the expressions for the e 's:

$$Q = W_L (X_1 + X_2 - L_G)^2 + W_C (X_1 C_1 + X_2 C_2 - C_G)^2 + W_P (X_1 A_2 - X_2 A_1)^2$$

A necessary condition for a relative minimum is the vanishing of the partial derivatives with respect to X_1 and X_2 . This exercise yields a pair of normal equations which can be solved for X_1 and X_2 .

Taking Partial Derivatives

$$\frac{\partial Q}{\partial X_1} = 2W_L (X_1 + X_2 - L_G) + 2C_1 W_C (X_1 C_1 + X_2 C_2 - C_G) + 2A_2 W_P (X_1 A_2 - X_2 A_1) = 0$$

$\frac{\partial Q}{\partial X_1}$

$$\frac{\partial Q}{\partial X_2} = 2W_L (X_1 + X_2 - L_G) + 2C_2 W_C (X_1 C_1 + X_2 C_2 - C_G) - 2A_1 W_P (X_1 A_2 - X_2 A_1) = 0$$

$\frac{\partial Q}{\partial X_2}$

The Normal Equations are therefore:

$$X_1 (W_C C_1^2 + W_L + A_2^2 W_P) + X_2 (W_C C_1 C_2 + W_L - A_1 A_2 W_P) = C_G W_C C_1 + W_L L_G$$

$$X_1 (W_C C_1 C_2 + W_L - A_1 A_2 W_P) + X_2 (W_C C_2^2 + W_L + A_1^2 W_P) = C_G W_C C_2 + W_L L_G$$

The solutions to the latter pair of equations are:

$$X_1 = \frac{(W_C C_1 C_G + W_L L_G) (W_C C_2^2 + W_L + W_P A_1^2) - (W_C C_1 C_2 + W_L - W_P A_1 A_2) (W_C C_2 C_G + W_L L_G)}{(W_C C_1^2 + W_L + W_P A_2^2) (W_C C_2^2 + W_L + W_P A_1^2) - (W_C C_1 C_2 + W_L - W_P A_1 A_2)^2}$$

$$X_2 = \frac{(W_C C_1^2 + W_L + W_P A_2^2) (W_C C_2 C_G + W_L L_G) - (W_C C_1 C_G + W_L L_G) (W_C C_1 C_2 + W_L - W_P A_1 A_2)}{(W_C C_1^2 + W_L + W_P A_2^2) (W_C C_2^2 + W_L + W_P A_1^2) - (W_C C_1 C_2 + W_L - W_P A_1 A_2)^2}$$

$$(W_C C_1^2 + W_L + W_P A_2^2) (W_C C_2^2 + W_L + W_P A_1^2) - (W_C C_1 C_2 + W_L - W_P A_1 A_2)^2$$

APPENDIX II

FCI's Based on DOD Expenditure & Utilization Data
 Issue Factor (lbs./100 rations)
 Weighted

| Computation Criterion → Component | Usage/ Proportion | Cost/ Proportion | Average Usage/Prop. Cost/Prop. | Least Sq. | | Usage/Cost Adjusted to Level of Feeding |
|--------------------------------------|----------------------|---------------------|--------------------------------------|---------------------------------------|----------------|---|
| | | | | Cost (.5) Usage (.3) Prop. (.2) | Usage/ Cost | |
| Bacon, Sliced | 6.902 | 7.043 | 6.972 | 6.665 | 6.660 | 5.938 |
| Beef, Grill Steak | 9.238 | 7.735 | 8.487 | 9.238 | 7.500 | 9.199 |
| Beef, Oven Roast | 10.953 | 9.171 | 10.062 | 10.953 | 12.691 | 13.992 |
| Beef Ground | 14.205 | 16.060 | 15.133 | 11.878 | 15.133 | 5.672 |
| Beef Patties | 6.295 | 7.117 | 6.706 | 9.874 | 6.706 | 13.763 |
| Ham Canned | 15.147 | 15.023 | 15.085 | 15.387 | 15.085 | 11.479 |
| Pork Slices, Boneless | 2.104 | 2.147 | 2.126 | 2.343 | 2.346 | 3.068 |
| Pork Spareribs | 8.609 | 8.539 | 8.574 | 8.256 | 8.574 | 13.024 |
| Veal, Slices, Boneless | 2.826 | 2.852 | 2.839 | 2.871 | 2.871 | 3.169 |
| Veal, Ground | .725 | .731 | .728 | .680 | .680 | .383 |
| Chicken, Out-up | 11.668 | 12.439 | 12.053 | 10.342 | 10.246 | 8.870 |
| Turkey, Raw, Boneless | 2.999 | 3.197 | 3.098 | 4.346 | 4.421 | 5.796 |
| Fish Portions, Cod | 2.451 | 2.763 | 2.607 | 2.607 | 2.607 | 2.690 |
| Shrimp, Raw, Breaded | 3.842 | 4.331 | 4.087 | 4.087 | 4.087 | 4.217 |

APPENDIX II (Cont'd)

FCI's Based on DOD Expenditure & Utilization Data
Issue Factor (lbs./100 rations)

| Computation Criterion → Component | Usage/ Proportion | Cost/ Proportion | Average Usage/Prop. Cost/Prop. | Weighted Least Sq. | | Usage/Cost Adjusted to Level of Feeding |
|--------------------------------------|----------------------|---------------------|--------------------------------------|---------------------------------------|----------------|---|
| | | | | Cost (.5) Usage (.3) Prop. (.2) | Usage/ Cost | |
| Butter | 6.766 | 6.766 | 6.766 | 6.766 | 6.766 | 7.172 |
| Margarine | 1.527 | 1.527 | 1.527 | 1.527 | 1.527 | 1.619 |
| Cheese, American | 2.453 | 3.037 | 2.745 | 3.506 | 3.508 | 3.837 |
| Cheese, Cottage | 3.395 | 4.204 | 3.799 | 2.342 | 2.340 | 2.011 |
| Eggs, Shell | 22.024 | 22.819 | 22.422 | 22.422 | 22.422 | 24.189 |
| Ice Cream | 8.561 | 8.285 | 8.423 | 8.423 | 8.423 | 8.782 |
| Milk Chocolate | 30.426 | 30.527 | 30.476 | 30.429 | 47.542 | 32.358 |
| Milk | 159.152 | 159.681 | 159.417 | 159.167 | 142.036 | 169.262 |
| Apples, Fresh | 14.141 | 18.160 | 16.151 | 22.629 | 16.151 | 16.695 |
| Oranges, Fresh | 14.651 | 18.815 | 16.733 | 6.377 | 16.733 | 17.297 |
| Lettuce, Fresh | 25.443 | 20.148 | 22.796 | 30.034 | 30.492 | 29.339 |
| Potatoes, White, Fresh | 36.405 | 44.987 | 40.696 | 35.002 | 16.315 | 9.996 |
| Tomatoes, Fresh | 12.700 | 10.057 | 11.379 | 8.063 | 7.651 | 8.804 |
| Corn Whole, Grain, Frozen | 5.705 | 5.532 | 5.619 | 3.976 | 3.604 | 7.647 |
| Peas, Frozen | 4.788 | 4.566 | 4.677 | 3.611 | 3.582 | 5.068 |
| Potatoes, Fried, Frozen | 9.928 | 12.269 | 11.099 | 11.680 | 30.018 | 36.337 |
| Vegetables, Mixed, Frozen | 4.923 | 4.775 | 4.849 | 6.644 | 7.024 | 2.982 |

APPENDIX II (Cont'd)

FCI's Based on DOD Expenditure & Utilization Data
Issue Factor (lbs./100 rations)

| Computation Criterion → Component | Usage/ Proportion | Cost/ Proportion | Average Usage/Prop. Cost/Prop. | Weighted | | Usage/Cost Adjusted to Level of Feeding |
|--------------------------------------|----------------------|---------------------|--------------------------------------|--|----------------|---|
| | | | | Least Sq. Cost (.5) Usage (.3) Prop. (.2) | Usage/ Cost | |
| Bread White, Fresh | 30.221 | 31.291 | 30.756 | 30.676 | 38.548 | 32.733 |
| Rolls, Fresh | 8.841 | 9.154 | 8.998 | 8.503 | .514 | 6.687 |
| Shortening Compound | 9.811 | 11.126 | 10.468 | 14.653 | 10.468 | 10.802 |
| Beans, White, Canned | 11.470 | 10.937 | 11.203 | 12.644 | 12.676 | 11.190 |
| Corn, Whole Grain, Canned | 2.480 | 3.144 | 2.812 | 8.338 | 9.941 | 12.059 |
| Juice Pineapple, Canned | 8.356 | 14.269 | 11.312 | 22.209 | 11.312 | 11.740 |
| Peaches, Canned | 8.176 | 10.846 | 9.511 | 9.511 | 9.511 | 9.836 |
| Pineapple, Canned | 8.047 | 10.675 | 9.361 | 9.361 | 9.361 | 9.682 |
| Tomatoes, Canned | 13.214 | 16.755 | 14.985 | 7.400 | 5.753 | 3.635 |
| Cake Mix, Yellow | 4.900 | 5.585 | 5.242 | 7.064 | 8.249 | 9.888 |
| Flour, Wheat | 20.341 | 23.182 | 21.762 | 18.231 | 16.993 | 15.353 |
| Rice, Parboiled | 4.933 | 5.089 | 5.011 | 6.248 | 6.358 | 5.163 |
| Spaghetti | 3.115 | 3.213 | 3.164 | 1.804 | 1.690 | 3.260 |
| Sugar, Granulated | 14.646 | 14.641 | 14.644 | 14.640 | 14.607 | 16.555 |
| Cocoa | .124 | .120 | .122 | .574 | .583 | .125 |
| Coffee, Roasted | 4.291 | 4.166 | 4.228 | 3.839 | 3.831 | 4.353 |

APPENDIX II (Cont'd)

FCI's Based on DOD Expenditure & Utilization Data

| Computation Criterion→ Component | Issue Factor (lbs./100 rations) Weighted | | | | | Usage/Cost Adjusted to Level of Feeding |
|-------------------------------------|---|---------------------|--------------------------------------|--|----------------|---|
| | Usage/ Proportion | Cost/ Proportion | Average Usage/Prop. Cost/Prop. | Least Sq. Cost (.5) Usage (.3) Prop. (.2) | Usage/ Cost | |
| Beverage Base | 22.930 | 39.157 | 31.044 | 9.239 | 31.044 | 32.218 |
| Jam, Strawberry | 2.548 | 2.912 | 2.730 | 3.628 | 3.629 | 4.147 |
| Jelly, Apple | 2.944 | 3.364 | 3.154 | 1.865 | 1.864 | 1.345 |
| Salad Dressing | 4.630 | 5.250 | 4.940 | -- | 4.940 | 5.097 |
| Syrup, Maple | 5.244 | 5.243 | 5.244 | 5.250 | 5.283 | 3.420 |
| BDFA | \$2.236 | \$2.289 | \$2.262 | \$2.284 | \$2.288 | \$2.413* |
| Energy (cal) | 4581 | 5023 | 4802 | 4665 | 4890 | 5059 |
| Protein (g) | 164 | 169 | 166 | 166 | 166 | 169 |
| Fat (g) | 202 (41%) | 212 (41%) | 207 (41%) | 220 (43%) | 214 (41%) | 226 (42%) |
| Calcium (mg) | 1613 | 1663 | 1638 | 1663 | 1676 | 1751 |
| Iron (mg) | 23.4 | 24.7 | 24.1 | 24.0 | 25.4 | 24.5 |
| Vit. A (IU) | 7095 | 7264 | 7180 | 7128 | 7173 | 6773 |
| Thiamine (mg) | 2.3 | 2.4 | 2.3 | 2.3 | 2.4 | 2.3 |
| Riboflavin (mg) | 3.2 | 3.3 | 3.2 | 3.2 | 3.2 | 3.2 |
| Niacin (mg) | 29.7 | 31.5 | 30.6 | 30.0 | 31.2 | 30.7 |

*If "choice" beef prices had been used, the issue factor for Grill Steak would be 7.3 lbs, and 13.3 lbs for Oven Roast to yield the same cost.

APPENDIX II (Cont'd)

FCI's Based on DOD Expenditure & Utilization Data

| | Issue Factor (lbs./100 rations) | | | | Usage/Cost Adjusted to Level of Feeding |
|--------------------|---------------------------------|---------------------|--------------------------------------|--|---|
| | Usage/ Proportion | Cost/ Proportion | Average Usage/Prop. Cost/Prop. | Least Sq. Cost (.5) Usage (.3) Prop. (.2) | |
| Ascorbic Acid (mg) | 116.5 | 135.0 | 125.8 | 103.4 | 116.7 |
| | | | | | 120.4 |

Add 2.5% For Condiments

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5. *ibid.*

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4. Department of the Army, Navy, and Air Force, "Medical Services - NUTRITIONAL STANDARDS," AR 40-25/BUMEDINST 10110.3D/AFR 160-35, August, 1972.
5. Defense Supply Agency, "Composition of Foods Used By the Armed Forces," DSAH 1338.1, May, 1964.
6. Section 6082, Title 10, US Code "Navy Ration: Composition"
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8. Richardson, R.P., et al. "Uniform Ration Cost System - Summary Report" US Army Natick Laboratories TR 75-69-OR/SA.