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SOME EXPERIENCE IN HUMAN NUTRITION AND INSTITUTIONAL MENU PLANNING AND PROGRAMMING — MODELS, SOLUTION METHODS, APPLICATIONS

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Abstract. This paper presents results of a ten-year study done in the field of modelling and solving the problem of human nutrition. In solving the problem of institutional menu planning, a two phase approach is proposed: Phase I — comprising of the determination of how many times the given meal has to be used in the given planning period, and Phase II — comprising the precise definition of each of the daily menus used, taking care of all nutritional, economical and other constraints pertinent to the highly complex domain of human nutrition. The Phase I model reduces to linear, integer goal programming model with about 250 unknowns and about 300 constraints. The model used in Phase II is a nonlinear, 0-1 goal programming model, consisting of, typically, from 50 000 to 100 000 of unknowns and of about 200 constraints. The solution method is based on modified, iterative Monte Carlo procedure using a hypergeometric distribution for the random variable representing the unknown. The model has been successfully used for a number of years for programming and planning of human nutrition in military environment. However, the usefulness of the approach appears to be of some importance in the case of the hospitals and other institutions feeding a large number of persons.

Key words and phrases: Human nutrition, integer goal programming, Monte Carlo method

1. INTRODUCTION

One of the very first operations research models has been the minimum-cost diet problem [STIGLER, 1945], that reduces to simple linear programming model and has been successfully applied to the feed-mix problem in the case of livestock feeding. Human nutrition appears to be a rather complex problem asking for more sophisticated modelling. Namely, the basic fact is that the attribute human always makes the problem almost mathematically intractable. Individual preferences of human beings are so unpredictable making generalizations and models almost impossible. The search of operations research literature shows very few endeavors to apply operations research methods to the human nutrition planning problem, [BALINTFY, 1975] using an integer programming and [ANDERSON, EARLE, 1983] using a linear goal programming in institutional menu planning. A team of researchers at the Laboratory for Operations Research, Faculty of Organizational Sciences, University of Belgrade, started a study, almost ten years ago, on human nutrition problems as applied to large human collectives, as exemplified by the army units, hospitalized patients, refugee camps and other institutions, typically found in Third World countries.

The thorough study of the human nutrition planning process has shown that the nutritional quality of meals provided in such institutions is generally, pretty low. The main characteristic of the manual institutional menu planning process is the utmost care to remain under the given budget constraints, providing the required caloric values of menus and neglecting the biochemical and other nutritional required caloric values of menus and neglecting the biochemical and other nutritional required caloric values of menus and neglecting the biochemical and other nutritional requirements. It is evident that this affects negatively the health and general well being of the population concerned, and therefore lowers their working ability. One could expect that, in spite of the given budget constraints, a higher nutritional quality of institutional menus could be achieved. In solving the problem of institutional menu planning, a two phase approach is proposed: Phase I — comprising of the determination of how many times the given meal has to be used in the given planning period, and Phase II — comprising the precise definition of each of the daily menus used, taking care of all nutritional, economical and other constraints pertinent to the highly complex domain of human nutrition. Motivated by the importance of this problem, the authors tried to employ operations research methods for its solution, by developing for Phase I integer goal programming model and for Phase II a nonlinear, 0-1 goal programming model, consisting of, typically, from 50 000 to 100 000 of unknowns and of about 200 constraints. The solution method is based on modified, iterative Monte Carlo procedure using a hypergeometric distribution for the random variable representing the unknown, in the case of Phase I model, and original heuristic algorithm for Phase II model.

2. MATHEMATICAL MODEL OF INSTITUTIONAL MENU PLANNING

The first problem in formulating the mathematical model of institutional menu planning, is a choice of the basic planning unit, i.e. a model variable. The classical LP models of livestock feeding are based on determination of the optimal mix of food types, yielding the minimal costs and satisfying the set of nutritional and other relevant constraints. Obviously, such an approach to human nutrition planning would be highly inadequate. The first attempt to formulate mathematically a model of human nutrition planning is given in [PETRIĆ, KRČEVINAC, 1983]. Here, a two phase approach has been proposed: Phase I — comprising of the determination of how many times the given meal has been used in the given planning period, and Phase II — comprising the precise definition of each of the menus used, taking care of all nutritional, economical and other constraints pertinent to the highly complex domain of human nutrition.

2.1. Mathematical model of human nutrition planning (Phase I)

The set of meals available $\{J_j\}$, $j = \overline{1,n}$, is identified and suitably partitioned into following groups:

- breakfast meals, $(j = \overline{1,n_1})$
- soups, $(j = \overline{n_1+1,n_2})$
- lunch — main meals, $(j = \overline{n_2+1,n_3})$
- lunch salads, $(j = \overline{n_3+1,n_4})$
- lunch desserts, $(j = \overline{n_4+1,n_5})$
- supper — main meals, $(j = \overline{n_5+1,n_6})$
- supper salads, $(j = \overline{n_6+1,n_7})$
- supper desserts, $(j = \overline{n_7+1,n_8})$
- salt — daily amount, $(j = n_8+1 = n)$.

By denoting x_j — the unknown number of times a given meal is used in given planning period, the following linear goal programming model has been formulated:

$$\text{Min } f^0 = \sum_{s=1}^{h+g+1} p_s(d_s^- + d_s^+)$$

subject to:

$$\sum_{j=1}^{n} c_j x_j + d_1^- - d_1^+ = C,$$

$$\sum_{j=1}^{n} a_{ij} x_j + d_s^- - d_s^+ = a_i^{**}, \qquad (i = \overline{1,h};\ s = \overline{2,h+1}),$$

$$\sum_{j=1}^{n} d_{jk} x_j + d_s^- - d_s^+ = d_k^* t, \qquad (k = \overline{1,g};\ s = \overline{h+2,h+g+1}),$$

$$t = \sum_{k=1}^{r}\sum_{j=1}^{n} d_{jk} x_j,$$

$$\sum_{j=n_{l-1}+1}^{n_l} x_j = u_l, \qquad (l = \overline{1,q}); \quad n_0 = 0, \tag{1}$$

$$\underline{a}_i^* \le \sum_{j=1}^{n} a_{ij} x_j \le \overline{a}_i^* \qquad (i = \overline{h+1,m}), \tag{2}$$

$$\underline{b} \le \sum_{j=1}^{n} b_j x_j \le \overline{b}, \tag{3}$$

$$\underline{d}_k \cdot t \le \sum_{j=1}^{n} d_{jk} x_j \le \overline{d}_k \cdot t, \qquad (k = \overline{g+1,r}), \tag{4}$$

$$\underline{a}_j \le x_j \le \overline{a}_j, \qquad (j = \overline{1,n}), \tag{5}$$
$$x_j \ge 0, \qquad x_j \text{ — integer}, \qquad (j = \overline{1,n})$$

where:

n — is a total number of meals,

c_j — is a price of a meal, $(j = \overline{1,n})$,

d_s^-, d_s^+ — are deviation variables denoting:

1. for $s = 1$, budgeted cost deviation,
2. for $s = \overline{2, h+1}$, special nutrient content deviations, and
3. for $s = \overline{h+2, h+g+1}$, deviations from the required percentage portion of chosen meals in caloric value of food intake,

g — is a total number of required special food groups to contribute to the caloric value of food intake,

p_s — is a priority of the goal s, $(s = \overline{1, h+g+1})$,

C — is a budgeted cost per person in a planning period,

h — is a total number of specially required nutrients,

a_{ij} — is a quantity of nutrient i in the meal j, $(i = \overline{1,m}$; $j = \overline{1,n})$,

m — is a total number of nutrients,

a_i^{**} — is a planned portion of special nutrient i in food intake, $(i = \overline{1,h})$,

d_{jk} — is a caloric value of the food group k in meal j, $(j = \overline{1,n}$; $k = \overline{1,r})$,

r — is a total number of food groups,

d_k^* — is a required percentage portion of special food group k in caloric value of food intake, $(k = \overline{1,g})$,

t — is a total caloric value of food intake in planning period,

u_l — is a total number of meal group l in the planning period, $(l = \overline{1,q})$,

q — is a total number of meal groups,

$\underline{a}_i^*$, $\overline{a}_i^*$ — are lower and upper bound of the nutrient i in food intake respectively, $(i = \overline{h+1, m})$,

b_j — is a caloric value of meal j $(j = \overline{1,n})$,

$\underline{b}$, $\overline{b}$ — are lower and upper bound of caloric value of food intake in a planning period, respectively,

$\underline{d}_k$, $\overline{d}_k$ — are lower and upper bound of percentage portion of food group k in caloric value of food intake, respectively, $(k = \overline{g+1, r})$,

$\underline{a}_j$, $\overline{a}_j$ — are lower and upper bound of number of times that meal j is used in the planning period, $(j = \overline{1,n})$.

The concept of meal, as used in this model, follows the standard, manual practice of institutional menu planning, where meal can be either single, (like plain pancakes, from batter), or complex, (like cup of herbal tea brewed, boiled egg and half an inch slice of brown bread). Further, based also on practical reasons, specifically in the case of nutrition of hospitalized patients, nutrients and foods available are treated in two classes: special and the rest, [MARTIĆ, 1989]. The special nutrient and/or foods are modelled differently from the rest of them.

The above model allows for the choice of meals to be used in the planning period and determination of the number of times of their usage, achieving the goal of minimal deviations from the available funds and satisfying all nutritional and other constraints. The results obtained with this model confirm its usability, generality and flexibility. Typically, the total number of meals considered ranges from 150 to 250, and the number of constraints is from about 200 to 300.

The results of the above model, besides the basic plan of meal usage in a planning period, allow for the computation of the per day cost of food intake per person, the average nutrient content of food intake per person and the percentage portion of food groups in food intake. By modifying various model parameters, most often modifying $\underline{a}_j$, $\overline{a}_j$ that are lower and upper bound of number of times that meal j is used in the planning period, $(j = \overline{1,n})$, nutritionists – planners can experiment with the model to obtain the most satisfying result. Upon the acceptance of the optimal plan obtained in the Phase I, it represents the basic input to the Phase II.

2.2. MATHEMATICAL MODEL OF DAILY MENUS (PHASE II)

The optimal institutional menu plan obtained in Phase I has to be transformed into detailed version, that specifies precisely each of the daily menus in planning period. Daily menus have to provide for satisfactory variety of meals, avoiding monotonous repetitions of meal combinations and reflecting the common tastes and habits of the population concerned. Further, the use of models in creating daily menus makes possible to permit the choice between a set of a few menus available daily, which is psychologically very stimulative in the case of collective nutrition and still takes care of relevant economic constraints.

Normally, the daily menu comprises 15 to 20 meals, grouped in the following way:

a) 1 to 3 meals for breakfast
b) 1 to 2 soups
c) 3 to 4 main meals for lunch
d) 1 to 3 lunch salads
e) 1 to 2 lunch desserts
f) 2 to 4 main meals for supper
g) 1 to 2 supper salads
h) 1 to 2 supper desserts.

The main goal of the daily menu planning model is, from results of Phase I, from the set of meals selected to be used and respective number of repetitions of given meal usage in planning period, to specify the content and other relevant details for each of daily menus. More formally, it is necessary to determine whether the meal j is to be used as the k-th component of a daily menu for the i-th day of planning period. The model, given below is a further improvement of the mathematical model of daily menu planning, given first in [MARTIĆ, Petrić, 1986] and improved version in [MARTIĆ, 1989].

$$\text{Min } f^0 = \sum_{i=1}^{m} d_i^- + d_i^+$$

subject to:

$$\sum_{l=1}^{q} \sum_{j=n_{l-1}+1}^{n_l} \sum_{k=k_{l-1}+1}^{k_l} y_{jk}^i b_j \frac{1}{k_l - k_{l-1}} + d_i^- - d_i^+ = e, \quad (i = \overline{1,m}),$$

$$\sum_{i=1}^{m} \sum_{k=k_{l-1}+1}^{k_l} y_{jk}^i \frac{1}{k_l - k_{l-1}} = x_j, \quad (j = \overline{n_{l-1}+1, n_l};\ l = \overline{1,q}), \tag{6}$$

$$\sum_{j=n_{l-1}+1}^{n_l} y_{jk}^i \in \{0,1\}, \quad (k = \overline{k_{l-1}+1, k_l}), \quad (l = \overline{1,q}), \quad (i = \overline{1,m})$$

$$\sum_{k=1}^{k_q-1} \sum_{k^*} \sum_{j=1}^{n-1} \sum_{j^*=j+1}^{n} z_{jj^*} \cdot y_{jk}^i y_{j^*k^*}^i \leq 1, \quad (i = \overline{1,m}), \quad k^* \in S_k, \tag{7}$$

$$\sum_{k=1}^{k_q} \sum_{j=1}^{n} |y_{jk}^r - y_{jk}^i| > R, \quad (i = \overline{1, m-1}), \quad (r = \overline{i+1, m}),$$

$$y_{jk}^i \in (0,1), \qquad (i = \overline{1,m};\ j = \overline{1,n};\ k = \overline{1,k_q}).$$

where:

m — is a number of days in planning period,

d_i^-, d_i^+ — are negative and/or positive deviations of the caloric value of i-th daily menu from the planned caloric value, $(i = \overline{1,m})$,

e — is an average daily caloric value of food intake in planning period, computed based on Phase I results,

q — is a total number of meal groups,

n_l — is a sequence number of the last meal in the l-th meal group, $(l = \overline{1,q})$,

k_l — is a sequence number of the last component in a daily menu, where a meal from the l-th group $(l = \overline{1,q})$ can be assigned,

y_{jk}^i — is an 0-1 unknown, denoting whether the j-th meal is assigned as the k-th component in the i-th daily menu or not, $(i = \overline{1,m};\ j = \overline{1,n};\ k = \overline{1,k_q})$,

x_j — is a planned number of usage of the j-th meal in planning period, as obtained from Phase I, $(j = \overline{1,n})$,

b_j — is a caloric value of j-th meal, $(j = \overline{1,n})$

R — is a minimal number of different meals in any pair of daily menus,

$Z = \{z_{jj^*}\}$ — is a matrix of parameters denoting whether a meal j can be associated with a meal j^* in a given daily menu, taking into account technological constraints of meal preparation, matters of taste and the similar, $(j = \overline{1,n};\ j^* = \overline{1,n})$

$$z_{jj^*} = \begin{cases} 0 & \text{if meals } j \text{ and } j^* \text{ can be associated} \\ 1 & \text{if it is not advisable to associate meals } j \text{ and } j^* \\ 2 & \text{if it is strictly forbidden to associate meals } j \text{ and } j^* \end{cases}$$

S_k — is a set of components of a daily menu asking that the compatibility with the k-th component of a daily menu has to be checked, $(k = \overline{1,k_q})$

The main improvement of the above model is in the addition of the rather complex constraint (7), which defines the compatibility of meals in a daily menu. The model minimizes the sum of deviations of caloric value from the corresponding planned value for each of daily menus. The objective could be modified by adding a goal which assures that daily menus are approximately equal. The nutrition experts agree that, in Phase II modelling, it is allowed to take care only of caloric values of meal combinations and that other nutritive requests will be automatically satisfied.

The mathematical model given is of rather large dimensions for real human nutrition planning problems. Typically, depending on the length of planning period, it has from 50 000 to 100 000 0-1 unknowns and about 150 to 250 of type (6) active constraints.

3. SOLUTION METHODS

By formulating a two-phase approach and using two types of models, the choice of solution method depends on the type of model.

3.1. Phase I solution methods

Phase I model can be solved by using any of well introduced integer goal programming methods. However, in solving large models that appear in practice, the presence of active constraints of type (1) led to significant problems in obtaining a feasible solution. A practical request to develop human nutrition planning software for use on PC computers put an additional constraint in finding the adequate solution method.

By getting an idea on use of Monte Carlo method in solving optimization problems, [Conley, 1980; Conley, 1981], we decided to start experimenting with it and investigating its usability in solving human nutrition planning problem in phase I. The essence of Monte Carlo method consists in generating realizations of a random variable representing feasible solution of Phase I model. From the generated subset of feasible solutions, one finds that which minimizes the spread $(d^- + d^+)$. The basic problems appearing in practical application of Monte Carlo method lays in the choice of a probability distribution of random variable. It is proposed in [CONLEY, 1980] to use a uniform distribution providing homogeneous treatment of the whole set of feasible solutions. However, in the presence of active constraints, the use of uniform distribution does not yield satisfactory results. More specifically, in generating realizations that will satisfy constraint (5), there is quite small probability that it will satisfy constraint (1), as well. Thus, the obtained subset of feasible solutions has only a few elements. Apparently, a chance to find an optimal solution in a thus subset obtained is extremely small. Further, by investigating a normal distribution it is found that in case of inadequately chosen initial guess there is a high chance to reach a solution far from the real optimum. The fact required further thorough study of the applicability of Monte Carlo method to human nutrition planning problem and choice of probability distribution that better reflects the essence of this problem.

It has been found, [MLADENOVIĆ, PETRIĆ, 1984] that the use of hypergeometric distribution gives satisfactory results. Let Y_j denote a random variable having hypergeometric distribution, defined as:

$$Y_j = X_j - \underline{a}_j, \qquad (j = \overline{1,n})$$

where X_j is a random variable denoting the number of times a meal j is used in planning period, and $\underline{a}_j$ is corresponding given lower bound.

Then for each meal group $(l = \overline{1,q})$, one can define the following:

$$\begin{aligned} r_j &= \overline{a}_j - \underline{a}_j, \qquad (j = \overline{n_{l-1}+1, n_l}), \\ s_l &= \sum_{k=n_{l-1}+1}^{n_l} r_j, \qquad (l = \overline{1,q}), \\ v_l &= u_l - \sum_{k=n_{l-1}}^{n_l} \underline{a}_j, \qquad (l = \overline{1,q}). \end{aligned} \tag{8}$$

Parameter r_j shows the allowed spread of values for variable x_j. The total number of allowed usage of all meals from the group l is represented by the parameter s_l. Parameter v_l denotes an excess of number of usages of all meals in group l over a total requested minimal number of usages.

Modelling of random variables having hypergeometric distribution can be described in terms of random drawing differently colored balls out of the box. There are in total s_l balls of $(n_l - n_{l-1})$ different colors. There are r_j balls in each color group. One has to draw without replacement v_l balls in total. A number of balls of color j that are drawn from the box corresponds to realization y_j of random variable Y_j. According to hypergeometric distribution, the probability that random variable Y_j shall take realization y_j $(0 \leq y_j \leq r_j)$ is:

$$P(y) = P(Y_j = y_j) = \frac{\binom{r_j}{y_j} \cdot \binom{s_l - r_j}{v_l - y_j}}{\binom{s_l}{v_l}}, \quad (l = \overline{1,q};\ j = \overline{n_{l-1}+1, n_l}).$$

Mathematical expectation of random variable Y_j is: $E(Y_j) = v_l r_j / s_l$. Taking into account the way how realizations y_j are obtained, it follows:

$$\sum_{j=n_{l-1}+1}^{n_l} y_j = v_l, \qquad (l = \overline{1,q}).$$

By replacing v_l in relation (8) one obtains:

$$u_l = v_l + \sum_{j=n_{l-1}+1}^{n_l} \underline{a}_j = \sum_{j=n_{l-1}+1}^{n_l} y_j + \underline{a}_j = \sum_{j=n_{l-1}+1}^{n_l} x_j.$$

This is completely the same as relation (1) in the set of constraints of Phase I mathematical model. This indicates that by modelling random variables using hypergeometric distribution, it is assured that all active constraints in mathematical model will be satisfied.

By repeating the procedure described for all q meal groups, one random solution of human nutrition planning problem is obtained. This solution is feasible if it satisfies constraints (2), (3) and (4) as well. For the feasible solution obtained, the value of all deviation variables is computed yielding a value of the objective function. A detailed algorithm of this procedure is given in [MARTIĆ, 1989]. By experimenting it has been found that it is enough to obtain about 300 to 500 random feasible solutions, in order to get the satisfactory solution of human nutrition planning problem.

The study of appropriate probability distribution to be used in generating realizations of random variable indicated that a modified uniform distribution can be used also, by reducing the allowed interval of values from $(\underline{a}_j, \overline{a}_j)$ to (g_j, h_j). The lower and upper bounds are modified so that constraints (1) are a prirori satisfied. However, the use of modified uniform distribution is affected by the modelling sequence of random variable x_j. In [MLADENOVIĆ, PETRIĆ, 1984] the following three modelling sequences are recommended:

(i) the variables are modelled in the sequence of their indices in a given meal group l $(x_{n_{l-1}+1}, x_{n_{l-1}+2}, \ldots, x_{n_l})$,

(ii) the modelling sequence is determined by randomly generating permutations of variable indices,

(iii) modeling is performed in sequence of increasing values of differences $(h_j - g_j)$.

For the variable that is modelled first $g_j = \underline{a}_j$ and $h_j = \overline{a}_j$. For each next variable, in the sequence selected, the corresponding h_j and g_j values are determined so that the sum of lower bounds for the variables with nonassigned random realization has to be less than, and the sum of corresponding upper bounds has to be greater than or equal to u_l. For the last variable modelled, $g_j = h_j$. By repeating this procedure all q meal groups, a random solution, satisfying constraint (1), is obtained. Further steps are same as in the case of hypergeometric distribution. For details see [MARTIĆ, 1989].

The use of hypergeometric or modified uniform distribution in Monte Carlo methods is very suitable in case of models with active constraints, as is human nutrition planning problem, assuring a priori satisfaction of these constraints and obtaining a sufficiently large set of feasible solutions to get a satisfactory solution of an optimization problem. In case of hypergeometric distribution, due to very low variance of random variable, solutions cluster around expected value. In case of modified uniform distribution, sometimes one faces the situation that the obtained set of feasible solutions does not contain the optimal solution.

In [CONLEY, 1981], an iterative variant of Monte Carlo method using a uniform probability distribution in solving integer programming problems has been proposed. Upon obtaining the first satisfactory solution of optimization problem using Monte Carlo method, further improvement can be achieved by modifying, in each iteration step, the interval $(\underline{a}_j, \overline{a}_j)$ where the optimal solution is located. However, in integer programming problems where the interval mentioned is small, it is not possible to employ the iterative procedure as proposed in [CONLEY, 1981]. In [ZAFIROVIĆ, 1984] an improved version of iterative Monte Carlo method is proposed, which can be successfully used in integer programming problems with narrow intervals $(\underline{a}_j, \overline{a}_j)$.

3.2. PHASE II SOLUTION METHOD

For the solution of a nonlinear, 0-1 goal programming model as formulated in Phase II, an algorithm based on original heuristic has been developed. Due to large size of the model, as well as the presence of a large number of active constraints, the use of standard 0-1 solution methods was not efficient. Also, the use of Monte Carlo method ensured the satisfaction of constraints of type (6), but the presence of the strict constraints of type (7) prohibited finding of the feasible solutions. It has to be noted that matrix Z is not a sparse one. Details of heuristic algorithm are given in [MARTIĆ, 1989]. Here,only a short description is given.

In the first step meals from the group lunch — main meal are distributed in m subgroups, with $(k_l - k_{l-1})$ meals in each subgroup, where l denotes a sequence number of this meal group. The subgroups are formed in accordance with the cycle of meal usage. The procedure starts with meal group l, which has a densely populated matrix Z. Further, certain constraints of technological preparation of meal have to be considered in the course of subgroup formation. For example, two main meals for lunch asking for preparation in oven cannot be assigned to the same combination, i.e. daily menu. In other words, the choice of the first main meal influences the choice of the rest of them.

Lunch salads are assigned to the main meals in two-step procedure. In the first step, a lunch salad is assigned that is comparable with more than one main meal already chosen. In the second step, the most compatible lunch salad is assigned to the rest of main meals that have no lunch salad assigned in step one.

The menu combinations, consisting of a lunch — main meal and the assigned, compatible lunch salad, are further sorted into an ascending order of their caloric values. The meals from the meal group — lunch desserts are sorted in a descending order of their caloric values. Then, a lunch dessert with the lowest caloric value is assigned to the main meal — lunch salad combination, with the highest caloric value. Following the same principle the assignment of soups is performed, completing the procedure of obtaining m different menus for lunch.

A similar procedure is used in forming supper and breakfast menus. A determination of a daily menu, i.e. the combination of the breakfast, lunch and supper menus is performed by requesting that each of the daily menus in planning period is having approximately the same caloric value and that constraint (8) is satisfied.

4. EXPERIENCE AND CONCLUDING REMARKS

The practical ten-year experience obtained indicates a high level of functionality and usefulness of the methodology and software package developed. The use of this approach to collective human nutrition planning assures higher quality of food intake complying with all nutritive requirements and other relevant constraints, and providing nutrition with cost that minimally deviate from the budgeted value.

The reality and usefulness of models and solution methods developed for human nutrition planning have been thoroughly tested in military environment for soldiers nourishing. Due to specific military requirements a software package for PC computers has been developed and corresponding data base of nutritive and other relevant values, designed and loaded. The software package consists of a set of programs allowing for the data base maintenance, model management and solution, and report generation.

The use of software package developed has been found functional in practice by enabling:

(i) obtaining a satisfactory plan of daily menus in given planning period,

(ii) fast and effective study of changes in planning assumptions (like price changes, nutritive requirements changes, food availability changes and similar),

(iii) fast and effective generation of reports relevant for managing human nutrition process and indicating the quality of nutrition of the given population (like average content of nutritive and other food ingredients, average costs of various types, percentage portion of all food groups and similar),

(iv) computation of quantities of food stuff as needed for realization of a nutrition plan obtained and food purchase management,

(v) minimization of food wastage,

(vi) a detailed analysis of nutrient content, caloric value, recipes and other relevant information concerning all meals, meal groups and daily menus in planning period.

The practical use of this methodology in military environment has been formalized in terms of a number of menu planning manuals (4000 thousand pages in total), which are used in practice routinely. A specific variant of a model and corresponding data base has been used for diet planning for hospitalized patients in military hospitals. By allowing interactive use of software package, a diet plan for different classes of patients can be generated. In total, 35 different diet plans have been considered and the results obtained indicate high level of practicality of this approach. Currently, the use of methodology and software package developed in menu analysis for some large hotels is under investigation.

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