A model for evaluating menu performance in collective nutrition organizations based on the DEA method

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Abstract:

Introduction/purpose: In the paper, a model for evaluating menu performance in collective nutrition organizations is presented, enabling quantification of the efficiency of each individual dish.

Methods: The Data Envelopment Analysis (DEA) method has been applied to evaluate the efficiency of dishes.

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Results: The model has been successfully tested on the menu of the collective nutrition restaurant for cadets at the Military Academy in Belgrade (MAB). The evaluation included 20 existing dishes and 11 substitute dishes formed using the Food Replacement Table (FRT), allowing insight into the efficiency of each individual dish. In line with the specified criteria, 10 out of a total of 31 dishes have been evaluated as efficient (7 existing and 3 replacement dishes). By replacing inefficient existing dishes with new efficient dishes, the overall efficiency of the menu will increase, implying greater satisfaction of food users and reduction of the waste of prepared and uneaten meals.

Conclusion: A proposed model can be applied in practice because it provides objective and measurable values for assessing the performance of dishes, aiming to optimize the menu assortment in collective nutrition organizations and reduce the shortcomings of subjective decision making in selecting substitute meals. This model can be further improved by the use of other different methods for determining the weights of the criteria and ranking.

Key words: menu evaluation, restaurant management, DEA method, collective nutrition.

Introduction

Planning and implementing efficient nutrition for personnel pose highly complex challenges in collective nutrition organizations, such as the military, police, healthcare institutions, educational establishments, and others. Nutrition for personnel represents the most critical task within the logistics support function of the Serbian Armed Forces (SAF).

Research indicates that military logisticians, even in the most powerful armed forces globally, encounter numerous issues in logistics planning. These challenges include difficulties in forecasting, lengthy processes, mismatched demands, and limited visibility of logistical resources. Quartermaster services responsible for food supply tasks are not exempt from these problems and difficulties.

In the U.S. regulation 'The Army Food Program' (AR 30–22, 2019), necessary policies are outlined to ensure that soldiers are provided with safe, nutritionally balanced, sufficiently diverse, and appealing meals, appropriately timed. Meanwhile, according to the Rulebook on quartermastership in the Ministry of Defense (MD) and the SAF, nutrition for personnel is to be provided in a prescribed, regular, and health-approved manner. This nutrition should be based on scientific knowledge, technical and technological capabilities, acquired experience, scientific principles, and dietary traditions that align with the psychophysical demands and coordinated requirements of command and management. The goal is to ensure the quality and complete satisfaction of the energy and biological needs of the members of the SAF.

The most valuable resource of the military is the soldier (the individual), capable of executing assigned tasks. As such, they deserve the best available support for life and work. Proper human nutrition allows for a balanced intake of nutrients and protective materials necessary for proper functioning, recovery, development, and defense of the human body against external influences.

Food influences biochemical processes at the cellular level, stimulates willpower and positive thinking, reduces tension, and enhances mood. Deviations from this balance can lead to overnutrition or inadequate nutrition, negatively impacting health, psychophysical fitness, work capacity, and overall lifespan.

Numerous epidemiological studies have shown that food is, in most cases, a factor that either causes or exacerbates civilization-related diseases (Bleich et al, 2015; De Ridder et al, 2017; Schulze et al, 2018). In this context, the responsibility of logisticians is to learn from the past, analyze the present, and predict the future in order to provide the best support to military personnel. Proper planning and organization of collective nutrition for military members enable the development of capabilities to achieve the proclaimed short-term, medium-term, and long-term goals of the military organization. These goals stem from the broader interests of society and impact the stability and overall development of the state.

Menus for younger populations, such as students and cadets in military schools, receive special attention (Budowle et al, 2023; Schinkel et al, 2023). Furthermore, the ongoing research at the MAB focuses on improving the nutrition of cadets at the MAB restaurant, primarily through research projects VA-DH-4/17-19 and VA-TT-1/20-25.

To achieve complete, diverse, consistent, and high-quality nutrition, dietary plans are developed. These plans define norms for food allocation, the structure of food items, and recipes based on scientific, medical, nutritional, and culinary foundations.

On the basis of the conducted research and regular monitoring of food service implementation at the MAB by experts, it has been observed that a portion of prepared meals, according to the approved menu and the reported number of cadets, was not utilized for consumption. The main reason is the mismatch between the type of food products and the sensory properties of meal components with user preferences.

This phenomenon has negative effects in terms of resource utilization and engagement for preparing meals that go unused. Additionally, it results in deficits of programmed nutrients and protective substances that users either did not intake or replaced inadequately through surrogate meals. Such imbalances can lead to the degradation of psychophysical abilities (including cognitive and motivational aspects) and, over an extended period, contribute to the development of chronic illnesses. Treating these illnesses requires further resource allocation.

To rationalize resource usage and enhance user satisfaction, two approaches are commonly applied.

The first approach involves logistical experts of Quartermaster Service (QMS) partially minimizing the number of prepared meals that are unpopular among users based on experiential assessment. While this reduces costs, it does not fully achieve the goal of collective nutrition, as some users may still remain dissatisfied.

The second approach is normatively regulated. It involves developing a monthly menu by considering all factors affecting nutrition implementation. This menu allows for the substitution of meals specified in the Meal Application Cycle (MAC)[1] to create a realistically achievable and functional monthly menu. When certain meals cannot be implemented, logistical experts of QMS, considering available ingredients, technical-technological conditions, and personnel resources, subjectively choose the most suitable replacements, either for entire meals or for components with similar energy and biological value.

The mentioned approaches are quite experiential and subjective, and in current practice, there is no adequate model that would provide logistical experts with support in making objective decisions regarding the optimal selection of substitute meals from the group of existing meals in the NP or meals modified by replacing some of the components according to the FRT, which is an integral part of it. The verification of the proposed model was conducted at the MAB.The overview of the applied methodology is given in Figure 1.

Generally, menu planning is a multi-criteria problem that requires consideration of a wide range of quantitative and qualitative criteria, often accompanied by various forms of uncertainty, insecurity, imprecision, and subjectivity on the part of decision makers. This can make the decision-making process quite complex, challenging, and time-consuming.

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[1] The MAC cycle is prescribed by the Nutrition Plan (NP) in the SAF. By adhering to the meal application cycle, the average planned energy and biological value of meals are ensured, along with the consumption of the planned food products.

Therefore, the application of specific multi-criteria optimization methods and linear programming techniques serves as a useful tool for comprehensively identifying relevant criteria for evaluating meal performance and creating a model for optimizing menus in collective nutrition organizations, all while aligning with established norms to enhance user satisfaction.

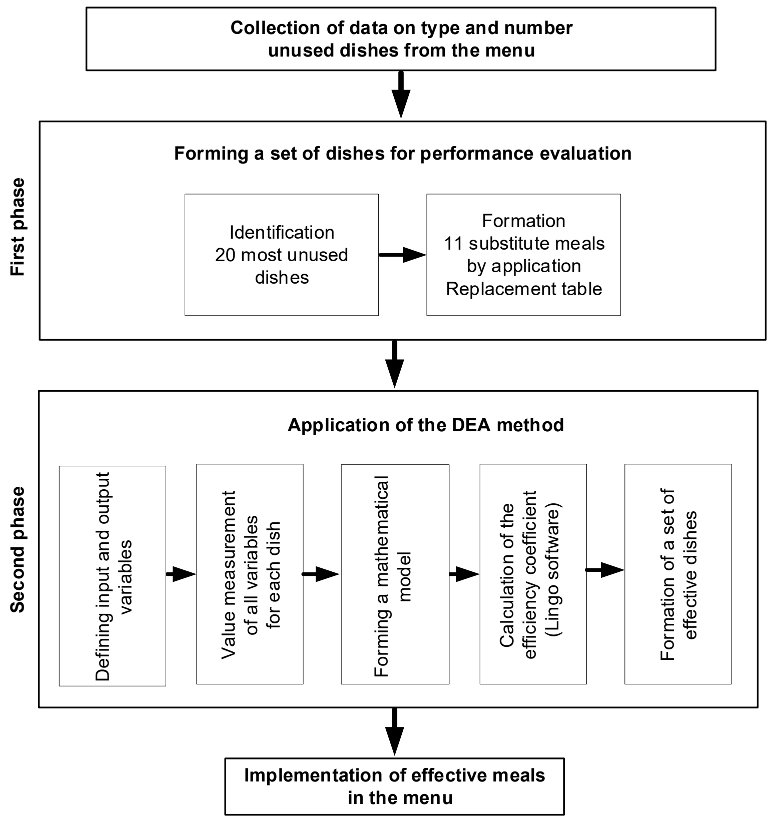

Figure 1 – Phases and steps for the application of the proposed model

To mitigate the shortcomings of subjective decision making and obtain more objective and measurable assessments of meal performance and menu optimization, this study proposes a model based on the DEA method which relies on mathematical programming to assess the relationships between relevant input and output parameters, quantifying their efficiency. As a result, it provides real-time insights into the performance of each individual dish from the observed set of dishes.

Background

In this chapter, we provide an overview of previous research (literature), describe the menu, and present the necessary theoretical foundation for the DEA method. This method is used to develop a model for evaluating the performance of dishes in the menu of collective nutrition organizations.

Review of the previous research and literature

Researchers have always worked on creating menu optimization models to enhance efficiency, guest satisfaction, and profits (Taylor et al, 2009).

Menu engineering models allow for systematic evaluation by comparing individual dishes based on pre-defined criteria. Earlier approaches to menu evaluation focused on the cost contribution of food items and the popularity of the 'product mix'.

Miller conducted the first menu analysis using a four-quadrant matrix, where he tracked the value defined as the sales velocity via vectors related to dish popularity and sales levels (Miller, 1996). Kasawana and Smith applied the 'Boston Consulting Group Portfolio Analysis' as the basis for the 'Menu Engineering Matrix approach', incorporating profitability (measured by contribution margin) but excluding the possibility of mutual influence between low food costs and high gross profit (Kasavana & Smith, 1982).

Pavesic recognized the connection between low food costs and high gross profit, replacing gross profit with the weighted ratio of gross profit to contribution margin. Pavesic also treated 'dish popularity' as an indirect third variable (Pavesic, 1983). Hayes and Huffman attempted to allocate all costs, including labor and fixed costs, to individual menu items in their profit and loss analysis (Hayes & Huffman, 1985). Later, Miller developed a matrix model for analyzing menu profitability based on food costs and the product mix, without considering production costs (Miller, 1996).

Bayou and Bennett constructed a model for profitability analysis and attempted to allocate variable costs, such as labor, to assess the financial strength of each dish (Bayou & Bennett, 1992). Le Bruto, Quain, and Ashley modified the 'Kasawana and Smith model' (KSM) by allocating labor costs separately as fixed and variable components for each menu item (LeBruto et al, 1995).

The limitation of all matrix models lies in the assumption that indirect costs are equally allocated to all menu items (Morrison, 1996). To overcome this limitation, Cohen included five factors (food costs, price, labor costs, popularity, and contribution margin) and normalized input values into scalar variables on a scale of 1-10 (Cohen et al.,1998). This approach did not consider other production factors and did not explain how labor costs were measured. Horton modified KSM by incorporating the value of 'estimated labor' into the contribution margin (gross profit) (Horton, 2001). Taylor, Raynolds and Brown introduced a non-parametric statistical approach that addressed the shortcomings of the previous models related to labor measurement and data analysis. Tom and Annaraud applied fuzzy techniques within KSM to handle uncertainties in menu alternative evaluation through linguistic variables, providing relevant information for decision makers in multi-criteria decision making (Tom & Annaraud, 2017).

For food to fulfill its nutritional mission, it needs to provide both short-term (subconscious sensory perception during and immediately before and after a meal, motivating repeated consumption of the chosen meal) and long-term satisfaction (conscious feelings of health, vitality, capability, and enthusiasm for life and work). Previous studies and works have not sufficiently leveraged feedback obtained from food consumers, which is a necessary parameter in the architecture of a nutrition system that is relevant and up-to-date in the context of new knowledge in the science of nutrition and comprehensive user needs.

The common characteristic of the previous research works is that they inadequately exploited the advantages of objective methods that allow measuring the relative efficiency of individual dishes from the set of existing menu items and selected substitute dishes formed in accordance with FRT. These methods consider a broader spectrum of relevant criteria (economic, organizational, technical, nutritional, gastronomic, etc.) including those reflecting user satisfaction.

The first application of the DEA method in practice was carried out for military purposes, by the authors themselves, to evaluate the efficiency of equipment maintenance and recruitment processes (Charnes et al, 1984), followed by subsequent applications by other authors for measuring financial efficiency (Bowlin, 1987, 1989), combat unit capabilities (Crino, 1996) and other defense-related aspects (Bowlin, 2004; Hanson, 2016).

DEA has also been successfully used in the restaurant industry in restaurant ranking (Hadad et al, 2007). An extended the CRS-DEA model from the work of (Taylor et al, 2009) to a variable returns-to-scale (VRS) DEA model was used under a metafrontier framework and simultaneously determined which items should be retained on a menu based on efficiency as determined by VRS-DEA in order to increase financial performance (Fang & Hsu, 2014). The DEA method has been successfully applied in the integration of menu analysis and revenue management approaches in order to improve strategy formulation (Lai et al, 2019), then for the formation of the CDMA model for menu analysis as a tool to support management in making strategic decisions (Nemeschansky et al, 2020), and for developing an innovative SBM-DEA model to evaluate the menu item efficiency with a better discrimination power and determine the input targets for each menu item by comparing the efficiency frontier.

The new approach presented in this study enables the evaluation of dish performance using the DEA method based on nine relevant input/output variables. These variables include organoleptic and digestive characteristics of dishes, which have not been previously used in combination with organizational, nutritional, and technical-technological variables. The goal is to enhance the existing menu assortment by replacing inefficient dishes with more suitable ones, thereby increasing user satisfaction with the food and improving the efficiency of food-related tasks within the organization.

The description of a menu

A menu represents the list of dishes offered by a restaurant and results from synthesizing the needs of the target user group on one hand, and the restaurant's ability to prepare food in an affordable manner according to defined standards on the other. The menu is structured based on the restaurant's production capabilities (technical, technological, and organizational) and available resources, as well as user preferences for restaurant services.

Menus can be categorized as follows: Fixed menus - characteristic of à la carte restaurants; Daily menus - for breakfast, lunch, and dinner; Weekly menus - spanning a week; Ten-Day menus - common for pension-style consumption; Monthly menus - used in student cafeterias, preschools, hospitals, etc; Cyclical menus - repeated in specific time intervals and Seasonal menus - designed for tourist seasons or specific times of the year. In military and related organizational systems where collective nutrition occurs, an annual menu specifies the types of dishes, their monthly cycles, and criteria for creating monthly menus.

User food needs arise from their daily activities (psychophysical engagement) and dietary habits. These needs represent the energy-biological value of daily nutrition and the expected sensory perception during and after meals. If a nutritionally balanced menu does not align with users' expectations regarding sensory properties (taste, texture, digestibility), meal components, and preparation methods, satisfaction may be lacking. This can discourage subsequent meal consumption, disrupting the user's health equilibrium. Additionally, inefficient menus can lead to wasted resources and potential health risks due to inadequate nutrient intake or harmful substitutes.

Optimizing menus ensures a balanced compensation for energy-biological expenditures, avoiding excesses or deficiencies. It also provides subjective satisfaction during meals and maintains overall well-being. An optimized menu allows efficient utilization of restaurant capacities and resources, satisfying both user expectations and restaurant management. Measurement of efficiency of units of similar type, not only help in identifying the shortcomings of the unit, but also helps in the development of the unit by eradicating or minimizing those shortcomings.

DEA method

In 1978, DEA methodology was introduced to calculate the relative efficiency of units based on multiple outputs and multiple inputs (Charnes et al, 1978).

DEA is a mathematical programming approach based on numerical data. It is successfully used for evaluating heterogeneous entities (such as organizational or production units). Some notable advantages of DEA are that it can accommodate multiple input and output variables, even when they have different units, it can work with both qualitative and quantitative data, and it acts as an effective decision-making tool in directing the attention of management to the area that can be improved (Xie et al, 2021).

Notably, the first paper titled "Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through" (Charnes et al, 1981) marked the beginning of its application. The increasing number of published scientific papers attests to the significance of the method and its practical value.

DEA was considered an excellent mathematical programming and a powerful management tool that can be used to measure, evaluate, and analyze the efficiency of the state, government, and military units (Okromtchedlishvili, 2022).

As of 2021, there have been a total of 17,164 papers using DEA methodology (in its original or improved form) listed in the Web of Science database.There has been a substantial growth in published works (Figure 2).

The application of the method is particularly suitable for assessing efficiency in cases where the complex nature of the relationship between multiple inputs and multiple outputs makes it impossible to apply other approaches for efficiency evaluation (Cooper et al, 2007).

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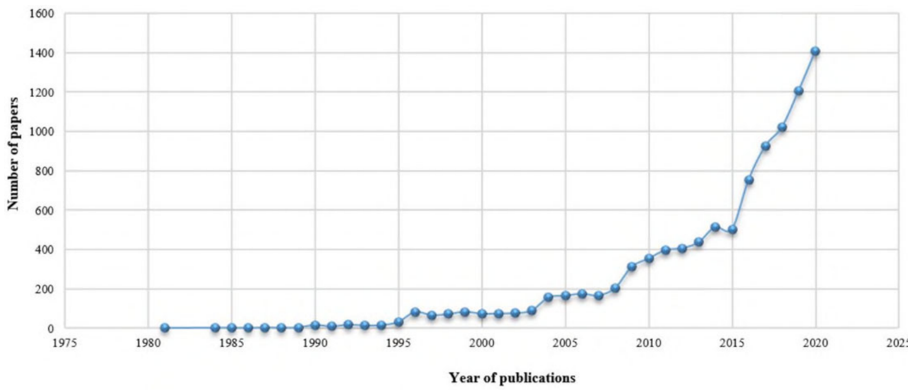

Figure 2 – DEA publications since 1980

The concept of the DEA method

The main advantage of the DEA method is that it does not require assumptions about the functional form of the production function, which excludes the estimation of parameter values (non-parametric method). In relation to other methods, the efficiency of input and output weights should not be known "a priori", because entities are grouped into efficient or inefficient depending on their relative geometric location in relation to an empirically set efficiency limit that is based on best practice, and not on averaging.

There are several methods similar to Data Envelopment Analysis (DEA) for measuring efficiency. A few notable ones are: Stochastic Frontier Analysis (SFA)[2], Free Disposal Hull (FDH)[3], Multiple-Criteria Decision Analysis (MCDA)[4], Ratio Analysis[5] and Tobit and OLS Regression Models[6].

The name “DEA” stems from the way the method identifies the “frontier” used to assess the performance of all subjects under evaluation.

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2 This method uses statistical techniques to estimate the efficiency of decision-making units (DMUs) by separating random errors from inefficiency effects.

3 FDH is a non-parametric method like DEA but does not assume convexity of the production possibility set, making it more flexible in certain applications.

4 MCDA evaluates efficiency by considering multiple criteria and often involves stakeholder preferences to weigh different factors.

5 This method involves calculating ratios of outputs to inputs to assess efficiency, which is simpler but less comprehensive than DEA.

6 These models can be used in conjunction with DEA to analyze the determinants of efficiency, providing additional insights into the factors influencing performance.

The authors of DEA propose a solution that overcomes subjectively imposed preferences of decision makers. They suggest that each Decision Making Unit (DMU) should have the freedom to determine the weight coefficients to maximize its own efficiency and present itself in the best light. All weight coefficients must be greater than 0 and the efficiency score for any DMU cannot exceed 1. DEA simplifies the scaling problem, expressing efficiency as a number between 0 and 1. Units achieving a score of 1 are considered efficient and lie on the efficiency boundary. Deviations from 1 indicate excess inputs or insufficient outputs. A DMU is efficient if it does not satisfy two conditions (Charnes et al, 1978): a) it is possible to increase any output without increasing any input or decreasing any other output; and b) it is possible to decrease any input without decreasing any output or increasing any other input.

DEA analyzes each DMU to determine whether its inputs can be achieved from below (i.e., achieving a given output with fewer inputs) and whether its outputs can be achieved from above (i.e., producing a larger output with a given input) based on the values of other units' inputs and outputs. If a unit can be achieved, it is relatively inefficient; otherwise, it contributes to forming the efficiency boundary, which represents the equivalent of the production frontier. For each inefficient DMU, DEA identifies the content and level of inefficiency for each input and output. The level of inefficiency is determined by comparing it to either a single reference DMU or a convex combination of other reference DMUs that lie on the efficiency boundary.

These reference DMUs use proportionally the same input levels and produce proportionally the same or greater output levels. In simpler terms, DEA helps to understand how much an inefficient DMU deviates from the best-performing units. It is like finding the optimal balance between inputs and outputs to achieve efficiency.

Efficiency can be achieved by projecting onto the efficient frontier, as shown in Figure 3.

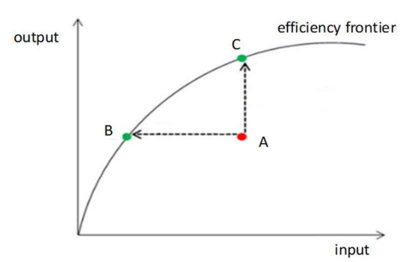

Figure 3 – Approximate representation of the limit of efficiency

This representation is approximate because it assumes only one input and output, one inefficient unit, and no change in the efficiency boundary. The Figure depicts the efficiency boundary where the efficient units B and C lie, while the inefficient unit A can approach the efficiency boundary by reducing its input or increasing its output.

There ara two fundamental models used in measuring efficiency: CCR (Charnes, Cooper, and Rhodes) and BCC (Banker, Charnes, and Cooper). The CCR model assumes that DMUs operate with constant return to scale, meaning that increasing inputs must result in a proportional increase in outputs. This efficiency includes both pure technical efficiency (how well inputs are transformed into outputs) and scale efficiency (how efficiently the DMU operates at its chosen scale).The efficiency frontier provided by CCR models takes the shape of a convex cone). The BCC model also known as the DEA model with variable returns to scale focuses on pure technical efficiency, ignoring the impact of the scale. In the BCC model, a specific DMU is compared only to other units with similar scales of operation. It provides a measure of efficiency that considers the impact of inputs and outputs without assuming constant returns to the scale. In the mentioned context, the CCR model was used in this paper.

DEA CCR model

DEA models can generally have two forms: input or output oriented (Figure 4).

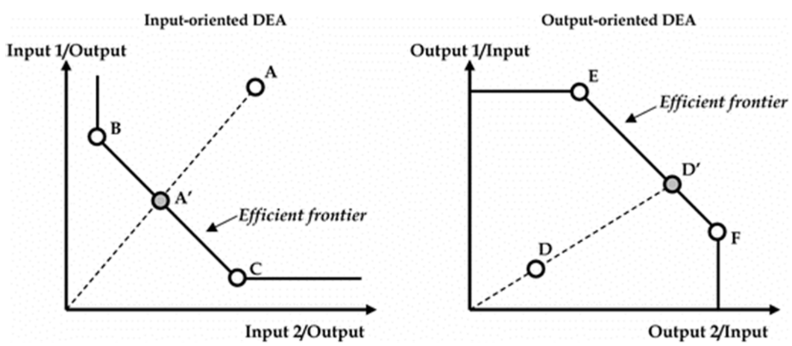

Figure 4 – Input and output-oriented CCR models

The efficiency frontier or envelope consists of the efficient units C, B, D, and E. The difference lies only in the way inefficient units are enveloped.

Input-oriented approach (input minimization or contraction) focuses on achieving the desired output while using the least amount of input resources. The output-oriented approach (output maximization or expansion) aims to maximize the outputs while maintaining a specified level of input resources.

The input-oriented CCR model is obtained by converting a non-linear to a linear problem, which is then solved by the method of linear programming, by applying a system of linear equations (1):

$$DEA_{input} = \min \sum_{i=1}^{m} w_i x_i - input$$

st:

$$\begin{aligned} & \sum_{i=1}^{m} w_i x_{ij} - \sum_{i=m+1}^{m+s} w_i y_{ij} \geq 0, \; j = 1,...,n \\ & \sum_{i=m+1}^{m+s} w_i y_{i-output} = 1 \\ & w_i \geq 0, \;\; i = 1,...,m+s \end{aligned} \tag{1}$$

The DMU consists of *m* input parameters for each alternative x_{ij}, *s* represents the output parameters for each alternative y_{ij}, taking into account the weights of the parameters denoted by w_i, and *n* represents the total number of DMUs.

The output-oriented CCR model, where the optimization criterion is the maximization of the value of the objective function (efficiency), is solved by applying a systems of linear equations (2):

$$DEA_{output} = \max \sum_{i=m+1}^{m+s} w_i x_i - output$$

st:

$$\begin{aligned} & -\left(\sum_{i=1}^{m} w_i x_{ij} \right) + \sum_{i=m+1}^{m+s} w_i y_{ij} \leq 0, \; j = 1,...,n \\ & \sum_{i=1}^{m} w_i y_{i-intput} = 1 \\ & w_i \geq 0, \;\; i = 1,...,m+s \end{aligned} \tag{2}$$

To obtain the efficiency index for each DMU, it is necessary to apply expression (3):

$$Efficiency = \frac{\max OUTPUT}{\min INPUT} \tag{3}$$

Although input- and output-oriented models have different optimization criteria, the problem is unique and the following expression applies:

$$FX^0 = \max_{x \in D} FX$$
$$FX^0 = \min_{x \in D} \left[-F(X) \right] \quad (4)$$

where *D* is the domain of admissible solutions.

Application of the model

During the observed period in the 2023 calendar year, based on the indicators tracking lunch meals, according to the 'Record of Prepared and Unused Meals', 20 dishes in the menu were identified as not being frequently chosen by users. These dishes are numbered from 1 to 20 in order from the least desirable to more desirable. In collaboration with a nutritionist, a group of 11 new dishes was formed by replacing certain components of the meals numbered from 21 to 31.

For effective interpretation, acceptance, and utilization of the results obtained from the DEA analysis, a final group of relevant criteria reflecting the performance of each individual dish in the menu was identified based on questionnaires and expert surveys. The collected data were selected according to the following categories: food price (Official prices from the Serbian Armed Forces and the Ministry of Defense during the observed period, based on valid contracts with suppliers and market scans for fresh seasonal fruits and vegetables); technological preparation requirements (represents the number and complexity of work operations needed to prepare the dish - e.g., sorting, peeling, slicing, breading, frying, etc. Values were obtained through surveys with the restaurant staff involved in food preparation and are presented on a scale from 1 to 100); technical equipment requirements for dish preparation (Represents the number and complexity of devices used in dish preparation - e.g., peeling machines, cutting machines, sautéing equipment, cooking kettles, convection ovens, etc. Values were obtained through surveys with the restaurant staff involved in food preparation and are presented on a scale from 1 to 100); preparation time (represented on a scale from 1 to 100 based on the experience of restaurant chefs); technical-technological requirements for food storage (includes the use of storage capacities and equipment for preserving food until consumption); nutritional quality index of dishes (a comprehensive indicator considering the nutritional contribution of proteins, carbohydrates, and fats in the total calories intake during dish consumption.

Unlike the purely energy-focused calorific value, this index synthesizes the structural, protective, and energy contributions of the dish to the body. The Nutritional Quality Index of Dishes was calculated based on the methodology for calculation the Nutrient Rich Food Index (Drewnowski, 2009) and it relies on data regarding the nutritional composition of dishes including proteins, fats, and carbohydrates, from the NP.); sensory properties of dishes[7]; digestibility of dishes[8], and post-meal feeling[9].

Based on formulas (1) and (2), systems of linear equations were formed for 31 dishes[10]. By solving these linear equations using the Lingo 20.0 software package[11], the values for the minimum Input and maximum Output are obtained for the first dish 'Potato Moussaka' (Figure 5).

The efficiency index for the first dish 'Potato Moussaka' is E= 0.7637242/1,309373= 0.583275. In the same manner, the values were obtained for the remaining dishes.

By applying formula (3), the efficiency coefficients were calculated for each dish (Figure 6).

After calculating the efficiency coefficient and conducting the analysis, it can be observed that, in line with the specified criteria, 10 out of a total of 31 dishes have been evaluated as efficient (*E=1*).

[7] Includes texture, aroma, taste, and appearance of the dish. Ratings for criteria 7, 8, and 9 were obtained through surveys with a representative sample of cadets from all classes and genders.

[8] Subjective perception of digestion and satiety after consuming the meal by food users.

[9] Common implications include post-lunch energy levels, heavier-to-digest dishes may reduce post-meal energy and agility.

[10] The mathematically posed task can be described as follows: determine the values of the weights of (independently variable) inputs and outputs so that the DMU has the highest relative efficiency (dependently variable) in the output orientation or inefficiency in the input orientation, and that the weighted sum of the inputs of the observed DMU is equal to one and other DMUs greater than or equal to zero.

[11] The first specialized software for DEA was developed at the University of Massachusetts in 1989 under the name IDEAS.Today, numerous software programs are widely known and applied.

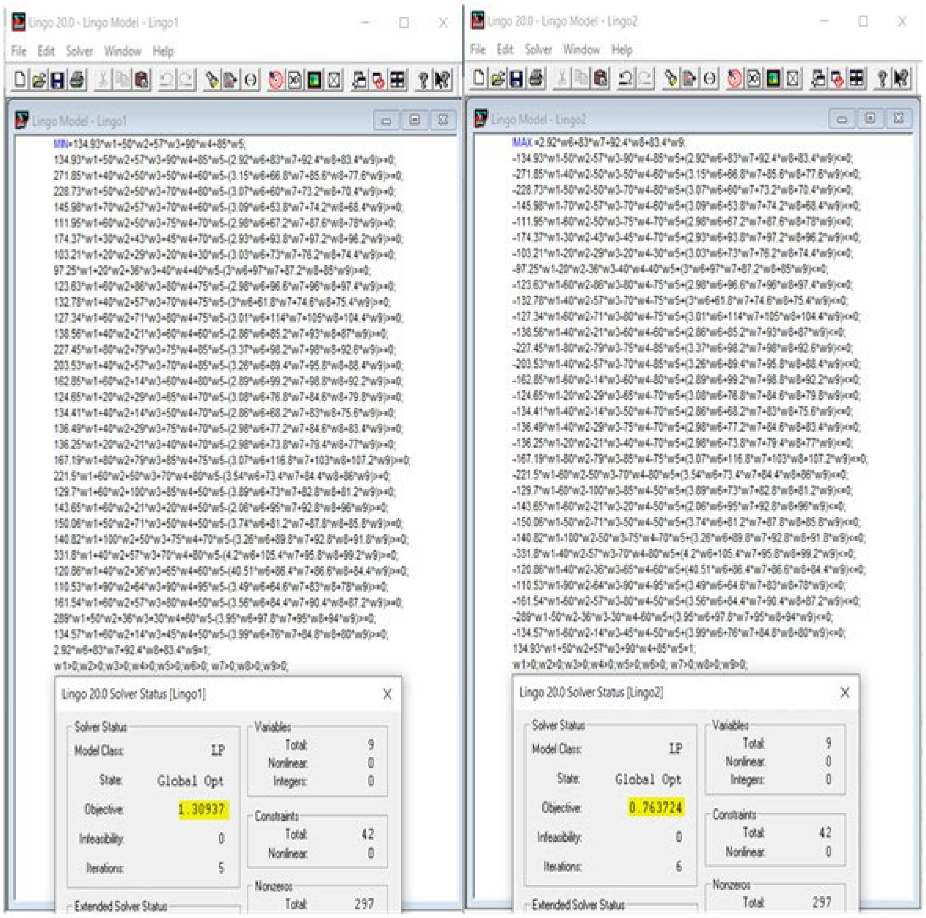

Figure 5 – A system of linear equations of the input and output-oriented CCR model

Ord. no.	Name of the dish on the menu/ Criterion	Price of food products	Technological requirements for preparation	Technical requirements for dish preparation	Cooking time	Technical and technological requirements for food storage	*Nutritional quality index*	*Sensory properties*	*Digestibility*	*Feeling after lunch (zeal for work)*	*min INPUT*	*max OUTPUT*	*E = max OUTPUT/min INPUT*
		I	II	III	IV	V	*VI*	*VII*	*VIII*	*IX*			
1.	Potato Moussaka	134,93	50	57	90	85	2,92	*83*	*92,40*	*83,40*	1,309373	0,763724	0,583275
2.	Trout and salted potatoes	217,85	40	50	50	60	3,15	*66,8*	*85,60*	*77,60*	1,630336	0,613371	0,376223
3.	Roast lamb, stewed peas, and roasted potatoes	228,73	50	50	70	80	3,07	*60*	*73,20*	*70,40*	2,126991	0,470148	0,221039
4.	Mackerel and salted potatoes	145,98	70	57	70	60	3,09	*53,8*	*74,20*	*68,40*	1,751512	0,570935	0,325967
5.	Fried fish, stewed carrots, and stewed rice	111,95	60	50	75	70	2,98	*67,2*	*87,60*	*78,00*	1,145900	0,872676	0,761564
6.	Turkey fillet, stewed rice, and stewed sweet cabba	174,37	30	43	45	70	2,93	*93,8*	*97,20*	*96,20*	1,210845	0,825869	0,682060
7.	Military bean stew with canned pork goulash	103,21	20	29	20	30	3,03	*73*	*76,20*	*74,40*	1,000000	1,000000	1,000000
8.	Bean soup with smoked bacon	97,25	20	36	40	40	3,00	*97*	*87,20*	*85,00*	1,000000	1,000000	1,000000
9.	Parisian schnitzel, stewed green beans, and salted potatoes	123,63	60	86	80	75	2,98	*96,6*	*96,00*	*97,40*	1,109415	0,901376	0,812478
10.	Greek meatballs	134,78	40	57	70	75	3,00	*61,8*	*74,60*	*75,40*	1,535281	0,651347	0,424252
11.	Viennese schnitzel, stewed peas, and mashed potatoes	127,34	60	71	80	75	3,01	*114*	*105,00*	*104,40*	1,066089	0,938008	0,879859
12.	Hunter's potatoes with meat	138,56	40	21	60	60	2,86	*85,2*	*93,00*	*87,00*	1,000000	1,000000	1,000000
13.	Breaded fish, mashed spinach, and fried potatoes	227,45	80	79	75	85	3,37	*98,2*	*98,00*	*92,60*	1,943255	0,514601	0,264814
14.	Breaded fish and fried potatoes	203,53	40	57	70	85	3,26	*89,4*	*95,80*	*88,40*	1,633790	0,612074	0,374634
15.	Stuffed peppers and mashed potatoes	162,85	60	14	60	80	2,89	*99,2*	*98,80*	*92,20*	1,000000	1,000000	1,000000
16.	Roast pork, sauerkraut, and mashed potatoes	124,65	20	29	65	70	3,08	*76,8*	*84,60*	*79,80*	1,000000	1,000000	1,000000
17.	Potato stew with beef	134,41	40	14	50	70	2,86	*68,2*	*83,00*	*75,60*	1,000000	1,000000	1,000000
18.	Roast pork, stewed peas, and roasted potatoes	136,49	40	29	75	70	2,98	*77,2*	*84,60*	*83,40*	1,154228	0,866380	0,750614
19.	Beef with vegetables	136,25	20	21	40	70	2,98	*73,8*	*79,40*	*77,00*	1,000000	1,000000	1,000000
20.	Karađorđe's schnitzel, stewed green beans, and roasted potatoes	167,19	80	79	85	75	3,07	*116,8*	*103,00*	*107,20*	1,363154	0,733593	0,538159
21.	Lamb in milk with mashed potatoes and stewed carrots	221,50	60	50	70	80	3,54	*73,4*	*84,40*	*86,00*	1,802074	0,554916	0,307932
22.	Larded beef and lentils with potatoes	129,70	60	100	85	50	3,89	*73*	*82,80*	*81,20*	1,329773	0,752008	0,565516
23.	Baker's potatoes with sausage	143,65	60	21	20	50	2,06	*95*	*92,80*	*96,00*	1,000000	1,000000	1,000000
24.	Grilled mackerel fillet and risotto with eggplant	150,06	50	71	50	50	3,74	*81,2*	*87,80*	*85,80*	1,349072	0,741251	0,549452
25.	Pork chop and grilled vegetables	140,82	100	50	75	70	3,26	*89,8*	*92,80*	*91,80*	1,319026	0,758135	0,574769
26.	Turkey fillet in cream with gnocchi	331,80	40	57	70	80	4,20	*105,4*	*95,80*	*99,20*	1,510142	0,662189	0,438495
27.	Beef stew with mashed potatoes	120,86	40	36	65	60	4,51	*86,4*	*86,60*	*84,40*	1,000000	1,000000	1,000000
28.	Cauliflower and eggplant moussaka	110,53	90	64	90	95	3,49	*64,6*	*83,00*	*78,00*	1,188796	0,841187	0,707596
29.	Minced beef roll and risi e bisi	161,54	60	57	80	50	3,56	*84,4*	*90,40*	*87,20*	1,362762	0,733804	0,538468
30.	Baked broccoli with chicken	289,00	50	36	30	60	3,95	*97,8*	*95,00*	*94,00*	1,168148	0,856056	0,732832
31.	Sautéed beef liver and mashed potatoes	134,57	60	14	45	50	3,99	*76*	*84,80*	*80,00*	1,000000	1,000000	1,000000

Figure 6 – Criterion and coefficient values

Conclusion

In the process of planning logistics support, logistics units must continuously observe, study, and analyze user requirements from various angles. They generally make numerous decisions based on subjective perception and experientially chosen criteria to respond rationally to user demands within the available resource capacities of the logistics system (Milenkov et al, 2020).

To reduce the shortcomings of subjective decision making and obtain a more objective and measurable assessment of dish performance, as well as to optimize menu assortments in collective nutrition organizations, this study proposes a model for evaluating dish efficiency using the DEA method which relies on mathematical programming to assess the relationship between relevant input and output parameters, quantifying their efficiency.

The application of the proposed model identified 10 efficient dishes (7 existing and 3 replacement dishes) out of 31 considered. The replacement dishes assessed as efficient can be incorporated into the menu, replacing some of the lowest-ranked 13 inefficient existing dishes. By doing so, the overall efficiency of the menu will increase, implying greater satisfaction of food users. Ranking can be based on the obtained efficiency coefficient values (from the lowest to the highest ones) or by creating a more precise model for multi-criteria optimization using rough numbers or fuzzy logic (Bozanic et al, 2023; Badi et al, 2024). This approach could serve as a basis for further research and enhancement of the model presented in this study.

Considering that the model's output criteria focus on user satisfaction after meals, while the input criteria relate to technical-technological and material requirements for dish preparation, and recognizing that user dietary habits and perceptions continually evolve from scientific, technical-technological, and sociological perspectives, this model can effectively be used for periodic, objective dish evaluation. It serves as a tool for logistics support personnel (QMS) to adjust menus based on user dietary habits, staff expertise, facility equipment, market conditions, and the material capabilities of the SAF.

Also, the presented model can be very effectively applied when it is necessary to create a menu according to the defined effects it should have on the target group of users (by favoring certain criteria, such as nutritional composition, digestibility, energy for physical work after a meal, possibility of preparation in extraordinary circumstances, necessity to bring the organism to a state of optimal psychophysical performance for the realization of planned activities and enable adequate recovery afterwards) in collective nutrition facilities for public sector (evaluating meal programs in public institutions like prisons and police facilities to ensure they are both nutritious and cost-effective), as well as school catering (assessing the efficiency of school meal programs to provide balanced nutrition within budget constraints), corporate catering (analyzing the efficiency of meal services in corporate settings to optimize costs and employee satisfaction), healthcare (evaluating the efficiency of meal plans in hospitals and nursing homes to ensure nutritional needs are met cost-effectively) and hospitality industry (assessing the efficiency of restaurant menus to balance cost, customer satisfaction, and nutritional value).

By minimizing the negative effects of menu misalignment with user needs (on the one hand) and resource constraints (on the other), this approach can enhance user satisfaction and reduce material waste resulting from unused prepared meals.

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Un modelo para evaluar el desempeño del menú en organizaciones de nutrición colectiva basado en el método DEA

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CAMPO: investigación de operaciones, logística, gestión de ingeniería
TIPO DE ARTÍCULO: artículo científico original

Resumen:

Introducción/objetivo: En el artículo se presenta un modelo para evaluar el desempeño del menú en organizaciones de nutrición colectiva, que permite cuantificar la eficiencia de cada plato individual.

Métodos: Se ha aplicado el método de Análisis Envolvente de Datos (DEA) para evaluar la eficiencia de los platillos.

Resultados: El modelo ha sido probado con éxito en el menú del restaurante de nutrición colectiva para cadetes de la Academia Militar de Belgrado (MAB). La evaluación incluyó 20 platillos existentes y 11 platillos sustitutos formados utilizando la Tabla de Reemplazo de Alimentos (FRT), lo que permite conocer la eficiencia de cada platillo individual. De acuerdo con los criterios especificados, 10 de un total de 31 platillos han sido evaluados como eficientes (7 platillos existentes y 3 de sustitución). Al reemplazar los platillos existentes ineficientes por platillos nuevos y eficientes, la eficiencia general del menú aumentará, lo que implicará una mayor satisfacción de los usuarios de los alimentos y una reducción del desperdicio de comidas preparadas y no consumidas.

Conclusión: El modelo propuesto puede aplicarse en la práctica porque proporciona valores objetivos y medibles para evaluar el desempeño de los *platillos, con el objetivo de optimizar la variedad del menú en organizaciones de nutrición colectiva y reducir las deficiencias de la toma de decisiones subjetiva en la selección de comidas sustitutivas. Este modelo se puede mejorar aún más mediante el uso de otros métodos diferentes para determinar las ponderaciones de los criterios y la clasificación.*

Palabras claves: evaluación de menús, gestión de restaurantes, método DEA, nutrición colectiva.

Модель оценки эффективности меню на предприятиях общественного питания, основанная на методе DEA

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РУБРИКА ГРНТИ: 27.47.19 Исследование операций,
82.01.00 Общие вопросы организации и управления
ВИД СТАТЬИ: оригинальная научная статья

Резюме:

Введение/цель: В статье представлена модель оценки эффективности меню на предприятиях общественного питания, позволяющая количественно оценить эффективность каждого отдельного блюда.

Методы: Для оценки эффективности блюд был применен анализ свертки данных (DEA).

Результаты: Модель была успешно протестирована на меню столовой для кадетов Военной академии в Белграде. Оценка включала 20 существующих блюд и 11 заменяемых блюд, составленных с использованием Таблицы замены продуктов, что позволило получить представление об эффективности каждого отдельного блюда. В соответствии с указанными критериями 10 из 31 блюда были оценены как эффективные (7 существующих и 3 заменяемых блюда). Заменив неэффективные существующие блюда новыми эффективными блюдами, общая эффективность меню увеличится, что приведет к большему удовлетворению *пользователей питания и сокращению отходов приготовленных, но не съеденных блюд.*

Вывод: Предложенная модель может быть применена на практике, так как она предоставляет объективные и измеримые значения для оценки эффективности блюд, направленные на оптимизацию ассортимента меню на предприятиях общественного питания. Также такая модель уменьшит недостатки, связанные с субъективным принятием решений при выборе заменяемых блюд. Эта модель может быть дополнительно улучшена за счет использования и других методов для определения весовых коэффициентов и ранжирования.

Ключевые слова: оценка меню, управление предприятием общественного питания, метод DEA, общественное питание.

Модел за евалуацију перформанси јеловника у организацијама колективне исхране заснован на методи DEA

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ОБЛАСТ: операциона истраживања, логистика, инжењерски менаџмент
ВРСТА ЧЛАНКА: оригинални научни рад

Сажетак:

Увод/циљ: У раду је приказан модел за евалуацију перформанси јеловника у организацијама колективне исхране, који омогућава квантификацију ефикасности сваког појединачног јела.

Методе: За оцену ефикасности јела примењена је метода DEA.

Резултати: Модел је успешно тестиран на менију ресторана колективне исхране кадета Војне академије у Београду. Евалуација је обухватила 20 постојећих јела и 11 заменских јела формираних коришћењем Таблица замене, омогућавајући увид у ефикасност сваког појединачног јела. У складу са наведеним критеријумима, 10 од укупно 31 јела оцењено је као ефикасно (7 постојећих и 3 заменска). Заменом неефикасних постојећих јела новим ефикасним јелима повећаће се укупна ефикасност јеловника, чиме ће се *повећати задовољство корисника хране и смањити расипање припремљених а непоједених јела.*

Закључак: Предложени модел може се применити у пракси, јер даје објективне и мерљиве вредности за процену перформанси оброка ради оптимизације асортимана менија у организацијама колективне исхране и смањења недостатака субјективног одлучивања у избору заменског оброка. Овај модел се може додатно унапредити употребом других различитих метода за одређивање тежине критеријума и рангирања.

Кључне речи: евалуација менија, ресторански менаџмент, метода DEA, колективна исхрана.

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