Enhancing Nutritional Value while Minimizing Costs: A Guide to McDonald's Menu Optimization

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Abstract

This project applies operations research techniques to optimize McDonald's menu in terms of cost and nutritional value, focusing on creating meal plans that meet specific dietary requirements across various demographic groups while ensuring affordability. Using linear programming and mixed integer programming (MIP) in GAMS, the study identifies submenus that satisfy the nutritional needs of selected age and gender groups, with an emphasis on minimizing both consumer cost and McDonald's production cost. The methodology includes setting decision variables, constraints, and objective functions to guide the optimization process. The results demonstrate feasible solutions that offer balanced meal plans at minimized costs, contributing significantly to McDonald's ability to provide healthier food options without compromising profitability. This approach provides valuable insights into balancing health with economic considerations in the fast-food industry.

1 Introduction

In the contemporary landscape of fast food, consumers are increasingly demanding healthier options that do not compromise on cost-efficiency. McDonald's, as a leading global fast food chain, faces the dual challenge of adapting its menu to meet these health-centric demands while maintaining affordability for a diverse customer base. This project addresses the challenge of optimizing McDonald's menu to enhance nutritional value and minimize costs, providing a viable solution that benefits both the company and its customers.

1.1 Importance of the Problem

The fast food industry is often criticized for its role in promoting unhealthy eating habits due to its high-calorie, low-nutrient offerings. As public awareness about the importance of nutrition increases, fast food chains need to pivot towards menus that support healthier diets without escalating costs. This adjustment is not just a response to consumer demand but also aligns with global health recommendations and potential regulatory pressures concerning nutritional standards in restaurant offerings.

1.2 Methods Used

To tackle this optimization problem, we employ operations research techniques, specifically linear programming and mixed integer programming (MIP), implemented through the General Algebraic Modeling System (GAMS). These methods are chosen for their robustness in handling complex decision-making scenarios involving multiple objectives and constraints. The model aims to:

1. Identify optimal meal combinations that meet the nutritional requirements specific to different demographic groups, such as age and gender, as prescribed by dietary guidelines.

2. Minimize the costs associated with these meal plans from two perspectives: the cost to McDonald's in terms of production and operational expenses and the cost to the consumer at the point of sale.

The model provides a structured approach to menu optimization by defining decision variables that represent the selection and quantity of menu items and setting objective functions that seek cost minimization under nutritional constraints. This project not only demonstrates the application of operations research in improving fast-food menu offerings but also provides a scalable model that can be adapted to different settings within the food service industry.

2 Problem Description

To promote healthy eating in a fast-paced world, we set out to optimize a McDonald's menu, obtained from [Enj24], for a minimal cost that meets the nutritional needs for multiple demographic group's, adapted from [US 19]. This ensures that anyone can eat healthy for a low cost in our fast-paced world.

3 Model Formulation

The model formulation for optimizing McDonald's menu to achieve nutritional value while minimizing costs involves defining decision variables, setting up the objective function, and establishing constraints that guide the optimization process.

3.1 Decision Variables

A linear programming model will be developed using an MIP in GAMS. The decision variable for this program is x_{ij}, which is the number of items' i' that can be consumed by demographic group 'j'.

3.2 Model Data

The model will include the following data:

Age Group	**Calories**	**Sodium**	**Carbohydrates**	**Dietary Fiber**	**Protein**	**Total Fat**
Male Child	1400	2050	130	19.6	26.5	30
Female Child	1600	2050	130	22.4	26.5	30
Male Teenager	2800	2300	130	30.8	52	30
...	...	...	...	...	...	...
Female Adult	1800	2300	130	25.2	46	30
Male Adult	2200	2300	130	30.8	56	30

Table 1: Nutritional Requirements by Demographic Group

Item	**Calories**	**Sodium**	**Carbohydrates**	**Dietary Fiber**	**Protein**	**Total Fat**
Egg McMuffin	300	750	31	4	17	13
Egg White Delight	250	770	30	4	18	8
...	...	...	...	...	...	...
McFlurry ... (Medium)	810	400	114	2	21	32
McFlurry ... (Snack)	410	200	57	1	10	16

Table 2: Nutritional Information by Menu Item

Item	**Cost**
Egg McMuffin	$2.50
Egg White Delight	$2.50
...	...
McFlurry ... (Medium)	$2.25
McFlurry ... (Small)	$1.85

Table 3: Cost Per Item

3.3 Objective Function

The objective function is to minimize the cost to McDonald's for the first part and the cost to the customer for the second part. The function used is

$$\sum_i \sum_j c_i * x_{ij} \tag{1}$$

where c_i is the cost of item 'i' and x_{ij} is the number of items 'i' to eat for demographic group 'j'.

3.4 Constraints

We will have twelve constraints. For all models, constraint parameters can be modified to ensure user choice. For example, if the user is an adult male, and does not wish to eat any beef or pork, they can modify the beef and pork constraint so that zero beef and pork items will be chosen.

Nutrition Needs Constraint: To ensure caloric and macronutrient needs are met for the computations related to McDonald's, we will use the equation:

$$\sum_i n_{ik} * x_{ij} >= NT_{jk} \tag{2}$$

For the customer's computations, we will use the computation:

$$\sum_i n_{ik} * x_{ij} >= p(k) \tag{3}$$

n_{ik} - the nutritional value of item 'i' in and 'k' nutritional group
x_{ij} - the number of item 'i' that can be consumed by demographic group 'j'
NT_{jk} - the nutritional table target values for demographic group 'j' and nutritional group 'k'
p_k - the nutritional table target values for demographic p and their nutritional group 'k'

Constraint	**Equation**
Breakfasts (1-42)	$\sum_{i=1}^{42} \sum_j u_{ij} \geq 3$
Chicken and Fish (43-57)	$\sum_{i=43}^{57} \sum_j u_{ij} \geq 3$
Beef and Pork (58-84)	$\sum_{i=58}^{84} \sum_j u_{ij} \geq 3$
Salads (85-90)	$\sum_{i=85}^{90} \sum_j u_{ij} \geq 3$
Snack and Sides (91-103)	$\sum_{i=91}^{103} \sum_j u_{ij} \geq 3$
Dessert (104-110)	$\sum_{i=104}^{110} \sum_j u_{ij} \geq 3$
Beverages (111-137)	$\sum_{i=111}^{137} \sum_j u_{ij} \geq 3$
Coffee and Tea (138-232)	$\sum_{i=138}^{232} \sum_j u_{ij} \geq 3$
Smoothies and Shakes (233-260)	$\sum_{i=233}^{260} \sum_j u_{ij} \geq 3$

Where:

- u_{ij} is a variable to ensure if item 'i' is chosen for demographic group 'j'.

Diversity Constraint: To ensure there is a reasonable level of variety in the diet, we will use the function

$$x_{ij} < 3 * u_{ij} \tag{4}$$

where x_{ij} is the number of item 'i' that can be consumed by demographic group 'j' and u_{ij} is a variable to ensure if item 'i' is chosen for demographic group 'j'

Lower Bound Constraint: To ensure that the binary variables are used, we will use the function

$$x_{ij} >= u_{ij} \tag{5}$$

where x_{ij} is the number of item 'i' that can be consumed by demographic group 'j' and u_{ij} is a variable to ensure if item 'i' is chosen for demographic group 'j'.

4 Numerical Experimentation

4.1 Comparative Analysis of Combined vs. Individual Optimization

This study conducts a comparative analysis of two optimization approaches for meeting nutritional requirements across different age groups. By comparing the outcomes of concurrently optimizing menu schedules for all age groups versus optimizing them individually, the research assesses which method better fulfills dietary needs while adhering to constraints and guidelines specific to each age category.

We created two menus - one for McDonalds as a whole that meets the nutritional requirements for all demographic groups at a minimum cost to the company and one tailored to each individual demographic group's needs (our original problem). For the optimal menu, the optimal solution provided a minimum value of $139.75. Table 4 records one of the optimal outputs of GAMS where the items are the numerical values for the corresponding food items. All category constraints (e.g. breakfast constraint) were set to a maximum of three. Of note, item 236, a large Blueberry Pomegranate Smoothie is frequently utilized. When compared with most other items, it has lower calories, sodium, carbs, and fat content while still having a an average amount of all other macronutrients. Likewise, item 39, a hashbrown, is used for every demographic category; while it is similar to many other items per macronutrient, it is special in that all its macronutrients are around average making it a great core to any menu.

Item	**G1**	**G2**	**G3**	**G4**	**G5**	**G6**	**G7**	**G8**
39	1	1	1	2	1	3	1	2
44	0	0	0	1	1	0	0	0
57	1	1	1	0	0	1	1	1
75	1	1	0	0	1	1	1	1
76	0	0	1	1	0	0	0	0
88	1	1	1	0	0	0	1	0
89	0	0	0	0	0	0	0	1
90	0	0	0	1	1	1	0	0
99	0	0	1	1	1	1	1	1
100	1	1	0	0	0	0	0	0
107	1	1	1	1	1	1	1	1
132	0	1	0	0	1	1	0	0
137	1	0	1	1	0	0	1	1
141	0	0	0	0	1	0	0	0
145	1	1	1	0	0	0	1	0
179	0	0	0	1	0	1	0	0
182	0	0	0	0	0	0	0	1
233	1	0	0	0	0	0	0	0
235	0	1	1	1	1	1	1	1

Table 4: McDonald's Optimized Menu

For the menu for each demographic group was computed to minimize cost. The cost for each group can be seen in 5. Please note the costs were optimized for each group individually, but the data is presented in one table, 6. Of interest, the McDonald's optimized menu, 4, and the individual customer optimized menu, 6, are the same. A few notes on this:

- Repeated executions of the program showed there are multiple optimal menus (the items in the menu are different, but the price never changes). For example, on one program execution, Item 182 was added to the menu at the cost of other items not being included.

- Both McDonald's optimization and the Customer optimization use the same price. In practicality, the production cost of an item is less than price the item is sold for. Therefore, if we changed the cost for the McDonald's menu optimization computations, the results would be different. However, while the same cost was used for both calculations to simplify program complexity, changing the production cost (for McDonald's) or the consumer cost (for the customer) in no way impacts the model formulation.

Of interest, a frequently occurring pattern emerges in which two or more items are chosen, and a binary combination of them is chosen for all demographic groups. For example, items 44 and 57, 75 and 76, 88-90, 99 and 100, 233 and 235 are all binary groupings where, between those combinations, only one item is chosen for each group. For all these groupings, with the arguable exception of items 44 and 57, the variance in the actual items is very small. Items 99 and 100, for example, are a Large Fry and a Kid's Fry, and 88-90 are a Premium Southwest Salad without Chicken, Premium Southwest Salad with Crispy Chicken, and a Premium Southwest Salad with Grilled Chicken.

Group	G1	G2	G3	G4	G5	G6	G7	G8
Cost	\$15.70	\$16.35	\$16.95	\$18.45	\$17.45	\$19.45	\$16.95	\$18.45

Table 5: Customer Optimized Menu

4.2 Loose Diversity Constrain for Customer Menu

For this experiment, we changed the parameters of the Diversity Constraint for individuals' menus to determine how the diversity constraint affects optimized menus. The hypothesis was that a looser diversity constraint would result in a pooling of one or a few primary items (such as 15 hash browns), resulting in a mundane meal plan. To test this hypothesis, we set the Diversity Constraint to 100 - an arbitrarily large value that, given the daily macronutrient requirements and McDonald's menu, should never be computed. Surprisingly, the results are identical to 6 for all groups. From the standpoint of customers, this makes sense. The highest number of individual items was 3 (Item 39 for G6), and our Diversity Constraint value was also 3, which means there could only be three of any individual item. Thus, only Item 39 for G6 might benefit from loosening the diversity constraint. From a purely practical standpoint, this also makes sense because, while many items on the McDonald's menu are similarly priced, there are slight variations in the macronutrients of each item. Therefore, given the uniqueness of each item on the menu, it makes sense to have low repetition of items to fit the precise needs of each group while the prices of many types of items are very similar.

Item	G1	G2	G3	G4	G5	G6	G7	G8
39	1	1	1	2	1	3	1	2
44	1	1	1	1	1	0	1	1
57	0	0	0	0	0	1	0	0
75	1	1	1	1	1	1	1	1
88	1	1	1	0	0	0	1	0
89	0	0	0	1	0	1	0	0
90	0	0	0	0	1	0	0	1
99	0	0	1	1	1	1	1	1
100	1	1	0	0	0	0	0	0
107	1	1	1	1	1	1	1	1
132	0	1	0	0	1	1	0	0
137	1	0	1	1	0	0	1	1
139	0	0	0	1	0	0	0	0
141	1	1	1	0	1	0	1	0
179	0	0	0	1	0	1	0	1
233	1	0	0	0	0	0	0	0
235	0	1	1	1	1	1	1	1

Table 6: Customer Optimized Menu

4.3 Price Sensitivity

The sensitivity analysis on price changes explores the impact of varying item prices on optimal menu scheduling, viewed from both business and consumer perspectives. For businesses like McDonald's, understanding how price adjustments affect menu composition is crucial for maintaining profitability and customer satisfaction. For consumers, changes in prices influence purchasing decisions and overall dining experience, highlighting the importance of affordability and value in menu offerings. By conducting these experiments, researchers aim to enhance strategies that balance economic viability with consumer preferences amidst fluctuating market conditions.

Two approaches are employed to test this sensitivity: one involves loosely modeling inflation, while the other simulates scenarios where external economic factors influence the prices of specific food items. For instance, if there is a shortage of potatoes in the country, resulting in increased prices for all potato-related menu items, this scenario reflects dynamic market conditions that impact menu planning and pricing strategies.

Navigating Inflation: Price Impact on Profitable Menu Strategies

This experiment simulates the effects of inflation by incrementally adjusting item prices within the dataset used for menu optimization, reflecting challenges faced by businesses like McDonald's and consumers. The increase in the prices is just the current prices scaled by 9.06%[1] to match the effect of inflation.

The overall optimal cost for the consumer also increased by precisely 9%, aligning directly with the menu price adjustments. This outcome indicates a highly proportional sensitivity of meal costs to price

[1]The inflation rate of the US as of June 30, 2022, was selected to highlight significant impacts on the optimized schedules potentially. This choice aimed to simulate the pronounced effects of inflation on menu planning outcomes.

changes across the board. Despite the inflationary adjustment, the composition of the optimized meal plans remained largely consistent, with customers choosing almost the same items as before the price increase, albeit with very slight variations.

5 Managing Market Disruptions: Event-Driven Price Strategies

This experiment models event-based price shifts within the dataset used for menu optimization, simulating sudden market disruptions faced by businesses like McDonald's. By analyzing specific price changes and their effects on menu selection and costs, the study provides insights into adaptive strategies for responding to unexpected economic events while maintaining operational efficiency and customer appeal.

5.1 Impact of Potato Price Increase on Menu Optimization

In this experimental scenario, we explore the effects of a significant increase in potato prices on the optimization of McDonald's menu. The cost of potatoes rises by 150%, affecting the prices of popular potato-based items such as hash browns and fries, which are integral to many customers' optimal meal solutions. This increase is modeled to simulate market conditions like a potato shortage, which can impact food costs and availability dramatically.

5.2 Results and Analysis

Before the price hike, our optimization model showed that most customers included potato-based items, particularly fries and hash browns, in their meal plans. These items were favored due to their cost-effectiveness and substantial contribution to meeting daily nutritional targets, especially in terms of caloric intake and satiety.

However, after the potato price increase, the cost of hash browns and fries increased significantly. The model revealed a shift in consumer preferences under these new conditions:

- **Preference Shift from Hash Browns to Fries:** Despite the overall increase in cost, fries continued to appear in the optimal meal solutions more frequently than hash browns. This shift can be attributed to fries having a better cost-to-satisfaction ratio compared to hash browns, which became comparatively less economical.

- **Increase in Overall Meal Cost:** The optimal cost of meals rose noticeably due to the higher prices of potato-based items. This change reflects the direct impact of ingredient costs on consumer meal choices within the fast food setting.

- **Reduced Optimization for Water:** Interestingly, the increase in meal costs led to a decrease in the selection of water despite it being the cheapest drink option. This suggests that with higher meal costs, customers opted for more nutrient-dense drink options to meet better their dietary needs, which might have been partially fulfilled by potatoes previously. The need to maximize nutritional value per dollar spent became more critical as the overall meal cost increased.

Table 7: Comparison of Base Case Experiment and Experiment

ID	Base Case								Experiment							
	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
39	1	1	1	2	1	3	1	2								
40									1	1	1				1	
41												1	1	2		1
44				1	1						1	1	1	1		1
57	1	1	1			1	1	1	1	1				1		
75	1	1			1	1	1	1	1	1	1	1		1		
76			1	1								1		1	1	1
88	1	1	1				1		1	1						
89								1				1				
90				1	1	1					1	1		1	1	1
98												1				1
99			1	1	1	1	1	1								
100	1	1												1		
102									1	1	1		1		1	
107	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
132		1			1	1				1	1		1	1	1	
137	1		1	1			1	1	1			1				1
141					1				1							
145	1	1	1				1			1						
179				1		1						1				1
182								1			1		1	1	1	
233	1								1							
235		1	1	1	1	1	1	1		1	1	1	1	1	1	1

5.3 Implications

These findings highlight several critical implications:

- **Sensitivity to Ingredient Costs:** The significant role of key ingredients like potatoes in the cost structure of fast food menus indicates that fluctuations in commodity prices can substantially affect both consumer behavior and business strategies.

- **Nutritional Trade-offs:** As costs shift, so do the nutritional dynamics of meal choices. Increases in the prices of staple ingredients can force consumers to make trade-offs that might compromise their nutritional goals, as evident from the decreased optimization for water.

- **Strategic Menu Planning:** For fast food chains like McDonald's, understanding the elasticity of demand for various menu items in response to price changes is crucial for maintaining customer satisfaction and profitability. Strategic adjustments to the menu and pricing might be required to manage such fluctuations effectively.

Overall, this scenario underscores the importance of agile and responsive menu planning in the fast food industry, especially in the face of volatile market conditions affecting key ingredients.

6 Conclusion

In this project, we effectively employed operations research techniques, specifically linear programming and mixed integer programming (MIP), to optimize McDonald's menu to both enhance nutritional value and minimize costs. The GAMS-based model demonstrated its capability to devise meal plans that cater to the varied nutritional needs and financial limits of different demographic groups, thereby illustrating a viable approach for McDonald's to accommodate health-conscious consumers without forsaking affordability.

Our numerical experiments delineated two main optimization strategies: one focusing on reducing costs for McDonald's and another concentrating on consumer affordability. These optimizations ensured that selected menu items complied with nutritional standards while remaining cost-effective. Moreover, sensitivity analyses on price variations confirmed the robustness of our optimized menu against economic fluctuations, emphasizing the need for agile and responsive menu planning in the fast-food industry.

This study not only reinforces McDonald's competitive advantage but also contributes to public health by advocating better eating choices. The methodologies and insights from this project can be generalized to other food service operations, highlighting the potential of operations research to integrate health, taste, and cost considerations in menu planning effectively. This project exemplifies how academic theories and methodologies can be applied to solve real-world challenges, promoting a healthier future without compromising economic viability.

References

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