Optimization of Health Food Advertising Model Based on Linear Programming Model

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Abstract: With the deepening of sustainable development, more and more consumers and entrepreneurs are aware of the importance of healthy living and healthy eating. However, with the rapid development of science and technology, people's healthy consumption habits have not been positively affected. Especially in the face of constant changes in advertising media, many health food companies are still thinking about how to effectively combine health food advertising, so that health food advertising really finds their own target customers, so as to encourage consumers to make green choices for health food. In order to solve the above problems, this paper uses Matlab software combined with the mathematical model of multi-objective linear programming to discuss the practicability and economy and provides a creative implementation method for health food enterprises to effectively put health care advertising in the new market. And through the solution results of Linprog function to the multi-objective linear programming model, we can clearly see the combination delivery strategies of different health advertisements under different risk-bearing capacities. It can be seen that linear programming model is a simple and reliable method of health advertising portfolio planning, which can be widely used in the actual operation of health advertising portfolio optimization.

Keywords: Health Mobile Advertisement; Linear Programming Model; Optimization of Health Food Advertising Model; Linprog Function

1. Introduction

With the continuous improvement of people's living standards, in today's sustainable development, a healthy diet has attracted more and more consumers' attention [1]. However, studies on social media have found that, compared with the convenience and entertainment brought by social media, the widespread use of social media has not effectively raised consumers' health awareness [2,3]. In particular, consumers show negative attitudes towards healthy diet and lifestyle. In other words, consumers' eating habits are not simply guided by their personal wishes but also influenced by external information, such as advertising and news. Thus, more and more researchers have begun to focus on how to use social media to help consumers make conscious healthy eating choices [4].

To be more specific, with the popularity of mobile phones and other mobile applications, traditional media has been strongly impacted at the same time, advertisers are constantly searching for new ways of communication [5-7]. There are significant differences between mobile advertising and traditional advertising in form, communication mode, audience coverage and interactivity. Mobile advertising, as the name suggests, is often delivered via smartphones, tablets and other mobile devices [2]. This includes in-app ads, SMS ads, push notifications, social media ads, etc. Traditional advertising is mainly through television, radio, newspapers, magazines, outdoor advertising (such as bus ads, and billboards) and other media. In terms of interactivity, mobile advertising allows for a higher degree of interaction. For example, users can click on ads to get more information, download apps, make purchases, etc. Traditional advertising is less interactive, usually one-way transmission, users can only watch or listen to the radio to receive information, and interaction is usually more limited. In terms of targeting, mobile advertising can use the user's geographical location, interests, habits, and other data for accurate delivery. For example, ads can

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display content related to local businesses based on a user's location; Traditional advertising is more widely targeted, usually through a wide range of media coverage to reach the target audience as much as possible, the effect is relatively less accurate than mobile advertising. In terms of cost-effectiveness, mobile advertising usually has more flexible budget options, which can adjust the investment according to the advertising effect (such as click rate, conversion rate, etc.), which is relatively more cost-effective; Traditional advertising: production and delivery costs are higher, especially TV and radio advertising. The coverage is wide but the effectiveness measurement and adjustment is not as flexible as mobile advertising. Therefore, current advertising researchers and advertisers are concerned about how to accurately deliver advertisements to target customers at the right time and place [8].

To sum up, unlike in the traditional advertising era, modern advertisers and researchers pay more attention to mobile advertising. In order to find target customers, mobile advertising pays more attention to customer mobility, that is, customer location information and temporal and spatial characteristics [8,9]. For health advertisers, studying mobile advertising is also studying their target customers, and only by accurately targeting their target customers can mobile advertising play its maximum effectiveness [10,11]. In the process of practice, compared with placing healthy food advertisements in places such as cinemas and shopping areas, placing them in areas such as gyms and sports centers, it can attract consumers who are concerned about healthy eating.

Therefore, the problem of this study is how to place health food advertisements in the designated areas, so as to effectively cover the consumers in the selected areas and control the cost of health advertisers. In particular, this study creatively combines linear programming research with health food research by constructing a multi-objective linear programming model and obtains practical and economical health food advertising portfolio strategy by using Matlab and Linprog functions. This method is easy to use and can get direct results quickly. It can be widely used in various research and practical applications.

2. Research Foundation

With the rise of digital transformation and big data technology, the health advertising portfolio optimization model has evolved to be more complex and dynamic [12,13]. In other words, with the spread of the Internet and mobile devices, the channels through which consumers are exposed to ads have diversified, and advertisers have had to deal with an increasingly complex advertising ecosystem. This complexity promotes the deepening of investment research on advertising portfolio optimization. Specifically, computer-related methods commonly used in advertising portfolio investing include linear programming [14], genetic algorithms [15], neural networks [16], and machine learning models [17]. These methods can help advertisers optimize ad spend and improve ROI across complex, multi-dimensional portfolios. These new methods not only take into account the synergies of multi-channel advertising, but also integrate real-time data, machine learning, and artificial intelligence technologies to enable more accurate budget allocation and performance prediction [18]. However, different methods are suitable for different situations and show different advantages and disadvantages as the environment changes.

2.1 Linear Programming

Linear programming (LP) is an important branch of operations research, which has been studied earlier, developed rapidly, applied widely, and developed mature methods [19]. It is a mathematical method to assist people in scientific management and a mathematical theory and method to study the extreme value problem of linear objective function under linear constraints. As an important branch of operations research, linear programming is widely used in military operations, economic analysis, management, and engineering technology [20]. It provides the scientific basis for rational use of limited human, material, and financial resources to make the best decision.

When linear programming is extended to the field of advertising research, with the increase of advertising channels, how to measure the contribution of each channel accurately has become a research hotspot. The traditional "last contact attribution model" has been unable to meet the needs of a complex

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multi-channel environment. Researchers with investments in health advertising optimization have proposed a multi-channel attribution model that considers the interactions between channels [21,22]. This model can not only evaluate the contribution of each channel more accurately but also reveal the synergistic effect between different channels, which provides a more scientific basis for the optimization of the advertising portfolio. More importantly, in practice, the multi-channel attribution model has become a standard tool for advertising optimization. Through this model, advertisers can allocate their budgets more rationally, avoid over-reliance on one channel, and enhance the overall effectiveness of advertising.

2.2 Genetic Algorithms

Genetic Algorithm (GA) was first proposed by John holland in the United States in the 1970s. Specifically, genetic algorithms are designed and proposed according to the law of evolution of organisms in nature. It is a computational model of biological evolution process that simulates the natural selection and genetic mechanism of Darwinian biological evolution, so genetic algorithm is also a method to search for the optimal solution by simulating the natural evolution process. The algorithm converts the process of solving the problem into a process similar to the crossover and variation of chromosome genes in biological evolution by means of mathematics and computer simulation. When solving complex combinatorial optimization problems, compared with some conventional optimization algorithms, it is usually able to obtain better optimization results faster. Genetic algorithm has been widely used in combinatorial optimization, machine learning, signal processing, adaptive control and artificial life [23].

Applied to the research of advertising portfolio investment, the theoretical basis and application scenarios of genetic algorithm provide flexible optimization tools for advertisers, which can cope with the needs of complex budget allocation, multi-objective optimization and dynamic adjustment. In particular, issues in ad portfolio investing often involve multi-channel, multi-dimensional optimization, such as how to allocate budgets across channels such as search engine advertising, social media advertising, and display advertising to maximize advertising effectiveness. This kind of problem is complicated and involves multi-objective and multi-constraint conditions, which is difficult for traditional optimization methods to solve effectively, but genetic algorithms can be competent. However, the successful use of genetic algorithms also has very strict requirements [15]. For example, the computational cost is high: the genetic algorithm needs several iterations, and each iteration needs to evaluate a large number of candidate solutions, which makes the computational cost of the algorithm high; Parameter adjustment is complex: the performance of genetic algorithm depends on the setting of parameters such as cross rate and variation rate. Different parameter Settings will affect the convergence speed of the algorithm and the quality of the optimal solution. Finding the appropriate parameter configuration usually requires experimentation and tuning. Uncertain convergence speed: Although the genetic algorithm can find the global optimal solution, its convergence speed is unstable, and it may need more iterations to find the ideal solution, especially in the case of large solution space or high complexity; And sensitive to fitness function: the optimization effect of genetic algorithm depends on the design of fitness function. If the fitness function design is not reasonable, the optimization result may deviate from the actual advertising investment target.

2.3 Neural Networks and Machine Learning Models

With the maturity of big data and artificial intelligence technologies, some researchers have pointed out that machine learning and neural network methods have been applied more and more widely in advertising portfolio optimization [24,25]. In particular, machine learning algorithms such as random forests, support vector machines, and neural networks can handle complex non-linear relationships and predict underlying trends in advertising effectiveness. While the application of machine learning methods in ad portfolio optimization marks a shift from rule-driven to data-driven strategies, both machine learning and neural networks have overfitting risks, limited interpretability, and computation-intensive issues. Therefore, it is difficult to quickly spread to various fields in a short time.

As mentioned above, linear programming, as a classical optimization algorithm, can be widely applied to the research of advertising optimization portfolio investment. By constructing linear objective function and linear constraints, it can find the optimal solution in advertising budget allocation, channel selection and other scenarios. Compared with other complex optimization algorithms (such as genetic algorithms, neural networks, etc.), linear programming has unique advantages.

3. The Establishment of the Mathematical Model

3.1 Problem Description

With the improvement of health awareness, the health food market has attracted increasing attention from consumers. The role of health product advertising as a hidden price has long been recognized in economics and marketing, but the impact of these personalized hidden prices on corporate profits and consumer welfare has not been explored. A Health food brand hopes to increase brand awareness and market share by placing advertisements in fitness centers. In order to achieve this goal, the brand needs to develop a set of reasonable advertising strategies. This plan aims to maximize the revenue of the entire advertising plan while controlling the overall risk level to meet the budget constraints.

Considering that the linear programming model is used to solve resource allocation and optimization problems in advertising portfolio optimization investment, it plays an important role in advertising delivery strategy. Especially in combination with the rapid development of AI technologies such as computers, through the combination of machine learning, big data technology, and algorithm improvement, innovation can be achieved based on traditional linear programming models to improve advertising effectiveness and return on investment. That is to say, machine learning can predict key metrics such as click-through rates and conversion rates of ads through historical ad delivery data. These predictions can be used as input parameters in a linear programming model to help optimize the allocation of advertising budgets. For example, machine learning-based models can more accurately predict how different audience groups will respond to advertisements, allowing linear programming models to make optimal decisions for different target groups. More importantly, in the complex advertising portfolio optimization problem, solving linear programming directly may face the problem of high computational complexity and long solving time. By combining heuristic algorithms (such as genetic algorithm, ant colony algorithm, etc.) with linear programming, the solution process can be accelerated and the solution close to the optimal solution can be found. The introduction of a heuristic algorithm not only improves the computational efficiency but also can deal with the complexity brought by high dimensional data. Therefore, this paper focuses on the establishment of multi-objective linear function models. By establishing key and effective multi-objective linear function models, advertising portfolio optimization provides a solid and powerful model foundation and provides a new perspective for the effective combination of machine learning and other algorithms in the future.

The research focuses on how A health food brand can effectively advertise in fitness centers. Suppose A health food brand has an amount of H to place n kinds of advertisements in the fitness center s_i (i=1,2,3,…,n), the average rate of return of these n kinds of advertisements in this period is k_i, and the risk loss rate r_i. The more diversified the advertising, the smaller the total risk, which is measured by the largest risk in the s_i of the investment. Suppose that (1) the average rate of return k_i and the risk loss rate r_i of various advertisements are known; (2) The more dispersed the advertising, the smaller the total risk; Overall risk is measured by the greatest risk in the portfolio; (3) When placing the i type of advertisement, A healthy food brand need to pay the transaction fee, and the rate is q_i; (4) When the purchase amount does not exceed the given value c_i, the transaction fee is calculated based on the purchase c_i.

3.2 Optimization of Mathematical Model

Objective function:

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$$Q = \max\sum_{i=0}^{n}(k_i - q_i)x_i \quad (1)$$

$$\min \{ \max\_(1 \leq i \leq n) \{ r\_i\ x\_i \} \} \quad (2)$$

and:

x_i ----the funds used to place i types of healthy food advertisements

k_i ----the average rate of return of this type of healthy food advertisement during this period

q_i ----the transaction fee when placing the i type of healthy food advertisement

r_i ----the risk loss rate of this type of healthy food advertisement in this period

Q ----the total revenue of healthy food advertising s_i delivered during the period

Q max ----maximum total revenue generated from healthy food advertising

Q min ----minimum total revenue generated from healthy food advertising

Constraints:

(1) The total amount of investment is M, and each input is non-negative;

(2) $k_i > r_i$ (k_i and r_i are greater than 0).

$$\sum_{i=0}^{4}(1 + q_i)x_i = H, x_i \geq 0, i = 1,2,\ldots,n \quad (3)$$

The above optimization model is a mathematical model for multi-objective optimization of linear programming problems. By solving this, we can get the best combination of health advertisements.

4. Case Study

Suppose A health food brand has a fund of 100,000 yuan to advertise health food in the fitness center, the specific income (k_i), risk loss rate (r_i), rate (q_i) and transaction fee (c_i) of each health food advertisement is shown in Table 1 below. It is worth noting that A health food brand can also, according to the specific situation of the market, temporarily not put new advertisements in the fitness center, and instead invest money in the bank, waiting for the market to improve and then make specific investment plans. In other words, when the market environment is not good and A health food brand temporarily deposits the funds to the bank, the bank deposit interest rate is k_0=5% and there is no risk and no transaction fee.

Table 1. Specific Indicators of All Types of Advertising

s_i	k_i/%	r_i/%	q_i/%	c_i/%
S1	22	2.3	2	101
S2	21	1.8	1	168
S3	23	3.4	3.5	56
S4	28	6.8	5.5	48

Based on the above situation, we can basically assume: since the investment amount of 100000 yuan (H=100000) is quite large, and the norm c_i in reality is small relative to H, $q_i c_i$ is even smaller, so it is assumed that each input amount x_i is greater than the corresponding c_i.

4.1 Model Building

Decision variable: The capital of advertising s_i is x_i (i=0,1,2,3,4), and the total revenue Q

Objective function: maximum net benefit (max), minimum total risk (min)

Constraint: The total investment is H, and each input is non-negative

Objective function:

$$Q = max\sum_{i=0}^{4}(k_i - q_i)x_i \quad (4)$$

$$min \{ max_{1 \leq i \leq n} \{ r_i x_i \} \} \quad (5)$$

Constraint:

$$\sum_{i=0}^{4}(1 + q_i)x_i = H, x_i \geqslant 0, i = 1,2,\ldots,n. \quad (6)$$

4.2 Model Improvement

Considering the different risks that advertisers can bear in reality, that is, the risk rate is less than or equal to the risk value that advertisers can bear, it can be regarded as satisfying the "total risk as small as possible" for such advertisers,

Risk rate meets:

$$\frac{r_i x_i}{H} \leq a \quad (7)$$

Therefore, we can discuss the investment methods acceptable to advertisers with different risk tolerances by situation, assuming that low-risk investors are a=5%, medium-risk investors are a=15%, etc.

In summary, the objective function and constraints are:

$$max\sum_{i=0}^{n}(k_i - q_i)x_i \quad (8)$$

$$\frac{r_i x_i}{H} \leq a, i = 1,2,\ldots,n, \quad (9)$$

$$\sum_{i=0}^{n}(1 + q_i)x_i = H, \quad (10)$$

$$x_i \geq 0, i = 1,2,\ldots,n. \quad (11)$$

4.3 Analysis of Calculation Results

Matlab is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numerical computation. Matlab is mainly used for numerical operations, but with a large number of additional toolboxes, it is also suitable for different fields of application, such as control system design and analysis, image processing, deep learning, signal processing and communication, financial modeling, and analysis. Matlab software is used to calculate the linear programming problem. More specifically, we use the linprog function to find the problem of optimal combination. Because linprog function of Matlab is a linear programming solver, its principle is to use the simplex method to solve linear programming problems. This function can optimize arbitrarily large linear programming problems, finding the minimum or maximum in the required time. Specifically, the function transforms a linear programming problem into a standard form and uses methods from linear algebra to solve the problem. In practical applications, this function can help users find the optimal solution faster and solve large-scale complex problems effectively, and the calculation results are shown in Figure 1 and Table 2.

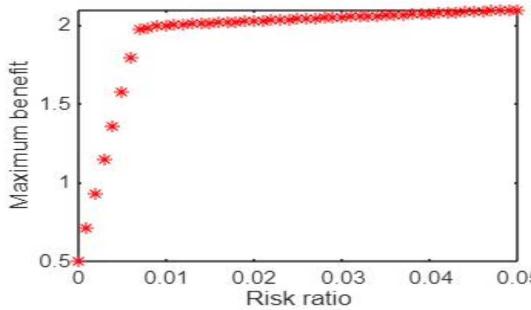

Figure 1. Calculation Result

To be more specific, according to Table 2 and Figure 1, risk and return coexist, when the risk rate does not exceed 1%, the greater the risk rate, the greater the return. When the risk rate does not exceed 1%, the return increases rapidly with the risk increase. When the risk exceeds 1%, the return increases slowly with the increase of risk. Therefore, for enterprises with no special requirements for risk and return, a risk rate of 1%

Table 2. Portfolio Outcome

Type	S_0	S_1	S_2	S_3	S_4
1	8.536	0.434	0.556	0.294	0.147
2	7.072	0.869	1.111	0.588	0.284
3	5.608	1.304	1.667	0.882	0.441
4	4.143	1.739	2.222	1.176	0.588
5	2.679	2.173	2.778	1.470	0.735
6	1.215	2.608	3.333	1.764	0.882
7	0	3.043	3.889	1.818	1.029

can be chosen as the optimal investment portfolio. The specific investment plan is x0=12151 yuan, x1=26087 yuan, x2=33333 yuan, x3=17647 yuan, x4=8824 yuan.

Next, when the investment amount is 50,000 yuan (H=50000), we verify the validity of our experiment by considering different investment parameters, as shown in Table 3. Similarly, with the linprog function, we get the following result. Based on the Figure 2, a risk rate of 3% can be chosen as the optimal investment portfolio. The specific investment plan is x0=0 yuan, x1=12000 yuan, x2=20000 yuan, x3=5455 yuan, x4=11060 yuan.

Table 3. New Indicators of All Types of Advertising

s_i	k_i/%	r_i/%	q_i/%	c_i/%
S_1	28	2.5	1	102
S_2	21	1.5	2	199
S_3	23	5.5	4.5	52
S_4	25	2.6	6.5	40

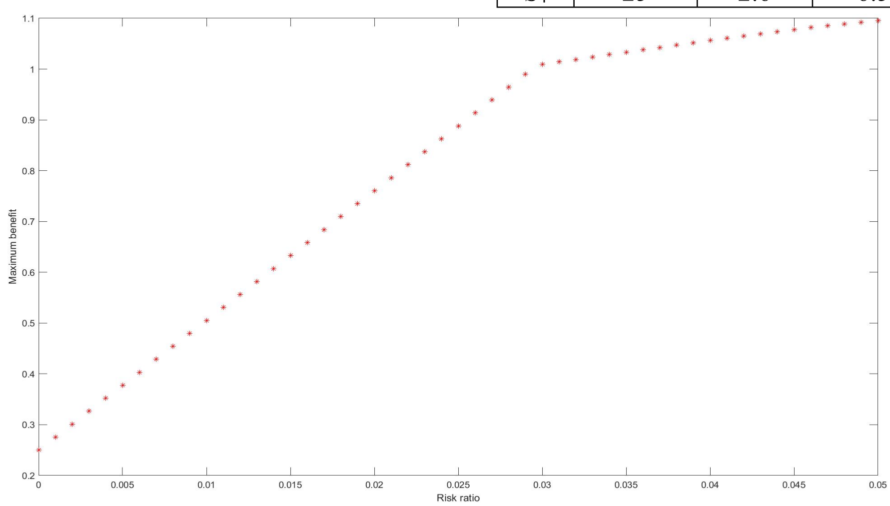

Figure 2. Result of New Indicators

More importantly, according to the solution results of different advertising investment parameters in different situations, it can be seen that the multi-objective linear

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programming model proposed in this paper can reflect the constraint relationship between the risk and return of the investment of health product advertising portfolio with full consideration of the real environment, and can use key data to show the actual optimization results in a short time.

5.Discussion and Conclusion

5.1 Conclusion

In this paper, the effects of the market environment and different health advertising characteristics on the market portfolio layout of health food companies are comprehensively considered, and a multi-objective optimization linear programming mathematical model is established to measure economy and practicability.

Firstly, it is complicated for health food companies to help consumers establish healthy living and eating habits with the help of health advertisements. Health food companies not only need to consider the characteristics of target customers faced by different media and advertisements but also need to reasonably optimize their health advertising portfolio according to the characteristics of target customers. Only by taking into account the external environment's development characteristics and the enterprise's specific situation can a healthy advertising portfolio suitable for consumers and enterprises' development be successfully promoted on the right platform at the right time.

Secondly, economy and practicality are important factors that health food companies must consider when investing in a health advertising portfolio. As mentioned in this paper, health food companies should fully consider the market environment factors before portfolio investment, and then effectively and reasonably carry out portfolio investment in health advertising according to their specific conditions. Therefore, this paper proposes a mathematical model of multi-objective optimal linear programming, which provides a solution for the optimal health advertising portfolio investment of health food advertising companies, and provides a practical way for health food advertising companies to open up new markets and attract target customers effectively.

Then, the planning method proposed in this paper should be applied to real cases. According to the application of the linear programming model in health advertising portfolio investment, intuitive investment plans can be obtained. The case study shows that under the condition of no special risk and return preference, A health food advertising company can choose the optimal portfolio investment scheme x0=12151 yuan, x1=26087 yuan, x2=33333 yuan, x3=17647 yuan, x4=8824 yuan.

Last but not least, linprog function is mainly solved by simplex method or interior point method. The simplex method is an algorithm based on vertices. It finds the optimal solution by iterating continuously to find the adjacent vertices of the current solution. Specifically, the simplex method starts with a feasible solution and then selects a feasible solution in the corner of the current feasible domain as the next solution, and judges whether the optimal solution is reached according to the judgment rule. The interior point method is a kind of algorithm based on the central path, it constructs the central path, transforms the problem into the form of solving a series of linear equations, continuously reduces the objective function in the process of solving, and adds its constraints as a penalty function to the objective function. Therefore, the interior point method has the advantages of global optimal solution and stability, but the solution speed is relatively slow. When using linprog functions, the user needs to provide the objective function, as well as equality and inequality constraints, including constraint coefficients and constraint constants.

5.2 Limitation and Future Research

Although this study explores the optimization of the healthcare food advertising mix by constructing a multi-objective linear model, there are some research limitations and suggestions for future research. First of all, this study mainly provides practical and economical solutions for the advertising combination of health care food through linprog function. Future studies can also try to use some other methods, such as ε-constraint method and Pareto frontier algorithm, so as to explore the optimal solutions under different methods. Second, this study only studied one case, and future studies can expand the research field by comparing two or more cases.

Finally, future research can also expand the scope of research beyond the health advertising portfolio, and try to associate the multi-objective linear programming model with the research on the investment and construction of health products and supply chain management, so as to provide an innovative research perspective for the development of the whole chain of health food.

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