

The Application of Mathematical Modeling in e-Commerce Mode in Digital Marketing Mode

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Abstract: “Digital economy is the main economic form following agricultural economy and industrial economy. It is a new economic form with data resources as the key element, modern information network as the main carrier, integrated application of information and communication technology and digital transformation of total factor as the important driving force to promote more unity of fairness and efficiency. The rapid development speed, wide radiation scope and unprecedented impact of the digital economy are driving profound changes in the way of production, life style and governance, and becoming a key force in reorganizing global factors and resources, reshaping the global economic structure and changing the pattern of global competition. At the same time, in the wave of digital technology, many enterprises accelerate the transformation, and optimize the digital marketing methods constantly. On the one hand, the technological upgrading brought about the 5G era, and the development of big data provides fertile soil for the development of digital industry marketing. On the other hand, with the continuous concentration of Internet media resources, the Internet for industrial marketing can help people collect the data from all aspects of the audience, making the resources needed for precision marketing more conveniently to obtain. With data mining, text analysis and other technologies, the audience's age, gender, browsing habits and other data are collected, and the consumer preferences are outlined, which achieve an overwhelming way to replace the previous extensive marketing methods. The e-commerce model of network camp model is analyzed through mathematical modeling of the marketing function. The product price, advertising investment, sales model design and logistics serve as the four variables of marketing network sales key explanatory variables. The price exert the biggest influence on network marketing, followed by advertising investment, logistics investment and design investment.

1. Introduction

China's economy has shifted from high growth stage to high quality developmental stage. The country is in the transformation of the mode of development, in the optimization of economic structure and in the transformation of growth momentum. The Internet and digital are the most distinctive characteristics of the era. With the rapid development of Chinese Internet and digital technology, “new infrastructure” is built to speed up the layout. The high quality development preface, Internet and digital tools have changed people's way of life. China is moving steadily forward to the digital age. Compared with that of the original model, the main significance of enterprises after digitization lies in the ability to obtain accurate user needs, more sufficient cash flow, flexible control of supply chain, and automatic link between products and services, etc. How to adopt the appropriate network marketing means and how to use the sales idea of mathematical modeling will be a major trend of the future development of the marketing mode under the e-commerce model, which also has very important practical significance and high theoretical value. The purpose of mathematical modeling application is mainly to plan the mode of e-commerce network digital marketing, with profit maximization as the overall strategic goal, this paper mainly discusses the digital marketing model under the e-commerce mode on the basis of the profit function and the deviation analysis method.

2. The Significance of the Digital Marketing Model

2.1 Coordinate with Digital Consumer Purchases

The digital technology of unique advantages is used to collect and analyze the purchase data of consumers, accurately locate the shopping preferences, tendencies and needs of different consumers, customize the platform, and automatically generate and push relevant products, so as to effectively meet the personalized actual shopping needs of different consumers. On the one side is the formation of consumer digital trends, on the other side, the emergence of new products. Enterprises are facing an unprecedented digital challenge. According to the first half of 2021 alone, 79,000 new products were launched in China, creating less than 1% of disruptive innovations, while some new products are surviving for less than 10 days. Therefore, the coordination of consumer digital purchase is mainly manifested in two aspects.[1]

2.2 Coordinate with Digital Consumer Purchases

Digital marketing enables enterprises to jump out of the traditional marketing thinking of increasing sales through sales team, advertising and promotion, and turns them to the modern marketing thinking of creating, communicating and delivering value for the target market, namely CCDV (Create, Communicate, and Deliver Value) marketing thinking. Through the innovative application of various digital technologies, products and services, enterprises can carry out a series of digital marketing activities, including investigation, publicity, planning, packaging, brand communication, consumption guidance, product promotion, discount promotion, and so on. At the same time, it is conducive to the reasonable analysis and planning of product production or procurement costs, product packaging material costs, express logistics and transportation costs, storage and transit costs, enterprise operating costs, etc. In this way, a basic price system is formed. On this basis, with the application of digital marketing model as the focus, non-unnecessary costs are reduced, and the price comparison with the homogeneous products is achieved in the market. With the help of single profit maximization, continuous adjustment, the floating pricing of the final product is formed.[2]

3. Digital Marketing Functions in Mathematical Modeling

The profit of digital marketing is mainly determined by the difference between sales revenue and sales cost. The sales revenue depends on the product of the net unit price of goods and its sales volume. The marketing cost is mainly divided into variable marketing cost, fixed cost, marketing and other costs, so the profit function of digital marketing can be expressed as follows:

$$F = [(P-d)-C_1] * Q - C_2 - C_n \quad (1)$$

F represents the total profit in digital marketing, P represents the price of market sales, Q represents the quantity of goods in digital marketing; d represents the discount in goods marketing, C_1 represents the variable cost per goods; C_2 represents the fixed cost of goods in digital marketing; and C_n represents the marketing and other costs of goods in the market. It can be concluded from the function that if and only if $(P-d) > C_1$, the commodity may have a certain profit margin or profit, that is, the sales price of the commodity in digital marketing needs to be greater than or equal to the variable production cost. If $(P-d) < C_1$, the sales of the commodity are in a loss and cannot cover the fixed and variable costs of the commodity. In order to analyze the profit model in digital marketing in a more detailed way, this paper needs to introduce the sales equations affecting the sales volume to study the commodity sales reaction in digital marketing. Assuming that the sales quantity is mainly determined by the two variables of controllable factors and uncontrollable factors of the enterprise, the sales function in marketing can be expressed as follows:

$$Q = f(X_1, X_2, \dots, X_n, Y_1, Y_2, \dots, Y_n) \quad (2)$$

Among them, X_1, X_2, \dots, X_n indicate predictability in digital marketing, Y_1, Y_2, \dots, Y_n indicate unpredictability in digital marketing.

Variable X includes the price of goods in the market, promotion discount, variable cost of goods and marketing cost; while variable Y includes market stability, homogeneous product price, consumer income, digital technology and other factors. When these unpredictability factors change, so does the market purchase rate. Although the enterprise cannot control the influence of the variable Y on the sales volume, the enterprise can comprehensively manage the whole process of product production and sales based on the digital marketing mode. The company can also realize the data precipitation, guide the production, improve the output and quality, and promote the product sales. It can be carried out mainly from the following aspects. Agricultural growth data will be collected through the Internet of things monitoring the whole production cloud platform, which is conducive to establish the growth model; based on the digital agriculture system, the system background big data mining and analysis, using the traceability system to find the problems in product production, intelligent, information cloud computing system, production management cost and time cost are reduced.

Based on the above measures, we assume that the uncontrollable market sales variable Y has been fully predicted, so the sales function of type (2) can be rewritten as follows:

$$Q=f(X_{1a}, X_{2a}, \dots, X_t | Y_{1a}, Y_{2a}, \dots, Y_n) \quad (3)$$

The above formula indicates that when the uncontrollable market sales variable Y has been fully predicted, that is, Y is a function that the sales volume is affected by the controllable variable X. Then, the sales function can be expressed as follows:

$$Q=f(P, d, C_1, C_2) \quad (4)$$

Where Q represents the quantity of goods in digital marketing; P represents the price of market sales, d represents the discount in product marketing, C_1 represents the variable cost of each item; and C_2 represents the fixed cost of goods in digital marketing. Since the marketing cost of goods mainly includes product publicity, employee salary, traceability system management cost and other factors, then formula (4) can be rewritten as follows:

$$Q=f(P, d, C_1, A, M, T) \quad (5)$$

Among them, A indicates the input cost of publicity in digital marketing, M indicates the salary of employees in promotion, T indicates the traceability management cost, (P, d, C_1, A, M, T) are the key marketing factors for the success of digital marketing.

How to transform type (5) into the optimal marketing combination is the core of the limited allocation of marketing resources. To deal with the issue, we have used the earned value method for further analysis.

4. Application of the Deviation Analysis Method

4.1 Introduction of the Deviation Analysis Method

Deviation analysis is also known as earning value method or deviation analysis method. Earning value analysis method is a method used more in the implementation of engineering projects, and is an effective method to comprehensively control the project progress and cost. The Earned Value Management (EVM) method, as an advanced project management technology, was originally determined by the US Department of Defense in 1967. So far, the international advanced engineering companies have generally adopted the earned value method for engineering project cost, progress comprehensive analysis and control.

Basic parameters of the deviation analysis method:

Finished Project Budget Cost (BCWP) = Unit price

Planning work budget cost (BCWS) = planned project quantity budget unit price

Actual finished cost (ACWP) = Actual unit price of completed work

Evaluation index of the deviation analysis method:

Cost deviation CV=BCWP-ACWP

Progress deviation SV=BCWP-BCWS

Expense Performance CPI=BCWP / ACWP

Progress Performance SPI=BCWP / BCWS

It can be seen that the earned value method mainly applies the progress and cost control of project management, and its core content is to analyze and rectify the two core contents of progress and cost. The project progress and the sales volume of digital products have the same quantity attribute, and the project unit price and cost and the sales price of digital products are same in terms of common price attribute. This means that a slight improvement of the deviation analysis method can be applied to the price and quantity deviation analysis of various sales businesses of digital marketing. Taking the digital sales of red dates in Cangzhou, Hebei province as an example, the application of the deviation analysis method in brand precision marketing is completely feasible.

4.2 Mathematical Modeling of the Precision Marketing Price of Red Dates Based on the Deviation Analysis Method

Basic parameter definition:

Actual sales of red dates are planned sales volume

PPWP (Project red dates Price for Work Performed) = Actual unit price

Plan to sell red dates plan sales

PPWS (Project red dates Price for Work Scheduled) = Scheduled sales volume planned unit price

Actual sales of red dates

APWP (Actual red dates Price for Work Performed) = Actual unit price for actual sales volume

Definition of the evaluation index:

Price Deviation PV (Price Variance) = PPWP-APWP

Volume deviation SV (Schedule Variance) = PPWP-PPWS

Price Performance Index PPI=PPWP / APWP

Progress Performance Index SPI=PPWP / PPWS

Calculation meaning of the evaluation index:

Price deviation (Price Variance-PV): PV refers to the difference between PPWP and APWP during the inspection period, and the calculation formula is $PV=PPWP-APWP$. When PV is negative, it means that the implementation effect is not good, that is, the actual consumption cost exceeds the budget value and it is overspent. On the contrary, when the PV is positive, it means that the actual consumption cost is lower than the budget value, which indicates the savings or high efficiency. If $PV=0$, it means that the project performs as planned.

Sales deviation (Schedule Variance-SV): SV refers to the difference between the check date, PPWP and PPWS. The calculation formula is $SV=PPWP-PPWS$. When SV is positive, progress indicates advance, and that SV is negative indicates progress delay. If $SV=0$, it is indicated that the progress is as planned.

Price performance Index (Price Performed Index-CPI): PPI is the ratio of the earned value to the actual expense value. $CPI=PPWP / APWP$, $CPI>1$ means below budget, $PPI<1$ means over budget, and $CPI=1$ means that the actual expenses match the budgeted cost. If $CPI=1$, it indicates that the project cost performs as planned.

Progress Performance Index (Schedule Performed Index-SPI): SPI refers to the ratio of project earned value to planned value, that is, $SPI=PPWP / PPWS$. $SPI>1$ indicates advance, $SPI<1$ indicates delay, and $SPI=1$ means actual progress is equal to the planned progress.

4.3 Application of Mathematical Modeling of Precision Marketing of Cangzhou Jujube I

It is assumed that six companies are A, B, C, D, E and F, among which A and B are large jujube sales enterprises; C and D are medium-sized jujube sales enterprises; E and F are small jujube sales enterprises. And A, C and E enterprises carry out precision marketing, and B, D and F are the control group.

According to the implementation plan of Cangzhou golden jujube brand precision marketing, the price range of golden jujube gift box is: 150~200 (including) yuan / box, which belongs to the warning range; 200~230 (including) yuan / box, which belongs to the safety range; 230 yuan / box

above, which belongs to the high range. And the fourth quarter (October-December) for the jujube sales high-frequency period.

4.3.1 Basic Data Extraction

Table 1 is Built Based on the Sales Data of a, B, C, d, e, and f, the Six Companies in the Fourth Quarter of 2021, That is, Sales Data of Each Company in the Fourth Quarter of 2021.

Table 1 Sales Data Of All Companies in the Fourth Quarter of 2021 .

Company	Planned sales (Box)	Actual sales (Box)	Plan unit price (Yuan/box)	Actual unit price (Yuan / box)
A	15000	15794	229	219
B	16000	13472	239	249
C	8000	9489	215	189
D	7500	5795	230	259
E	5000	5788	215	209
F	6400	5703	209	239

4.3.2 Calculation of Parameters and Indicators

Take the sales performance of the 6 companies in Table 1 as an example. The calculated basic parameters and evaluation indicators of the deviation analysis method are shown in Table 2.

Table 2 Basic Parameters And Evaluation Indicators of Each Company in the Fourth Quarter. of 2021

Company	PPWP	PPWS	APWP	PV	SV	PPI	SPI
A	3616826	3435000	3458886	157940	181826	1.05	1.05
B	3219808	3824000	3354528	-134720	-604192	0.96	0.84
C	2040135	1720000	1793421	246714	320135	1.14	1.19
D	1332850	1725000	1500905	-168055	-392150	0.89	0.77
E	1244420	1075000	1209692	34728	169420	1.03	1.16
F	1191927	1337600	1363017	-171090	-145673	0.87	0.89

4.3.3 Mathematical Model Analysis

According to fig.1 and fig.2, the listed business evaluation indicators are analyzed, and it is obvious that according to the relevant marketing data of A, C and E enterprises for precision marketing, the PV and SV of the three companies are all positive, while the PPI and SPI are > 1 . It also saved the marketing cost and improved the sales expectation in advance; however, the control group B, D and F all failed to meet the expectations and exceeded the budget.

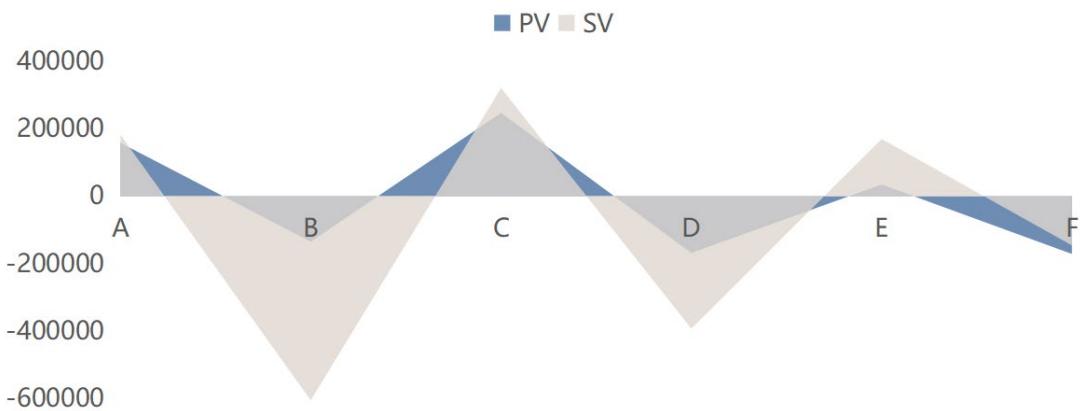


Fig.1: Price Deviation and Sales Deviation of Each Company in the Fourth Quarter of 2021

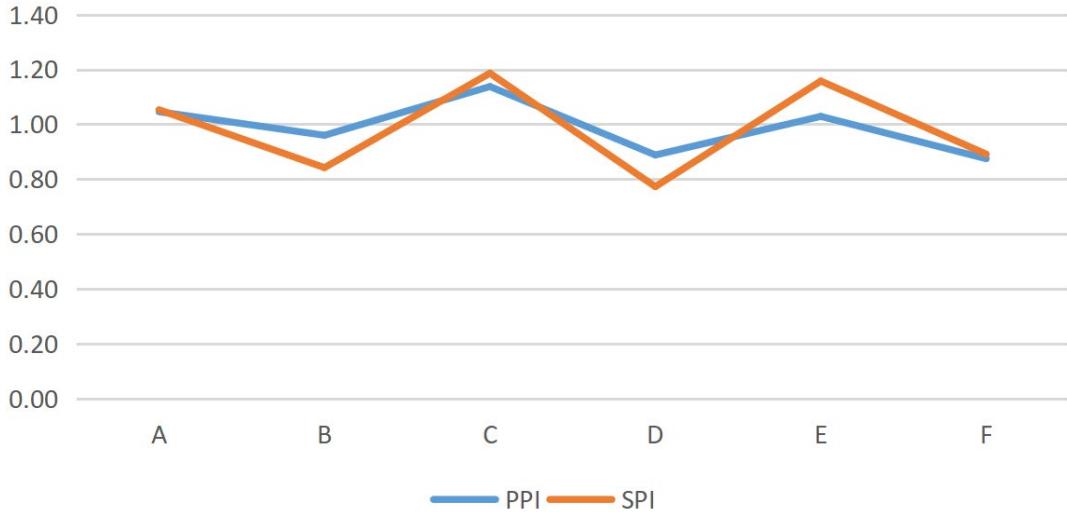


Fig.2: Price Performance Index and Progress Performance Index of All Companies in the Fourth Quarter of 2021

4.4 Application of Mathematical Modeling of Precision Marketing of Cangzhou Jujube II

Assuming that Company A is a large jujube sales enterprise in Cangzhou City, due to the impact of COVID-19 epidemic in 2020-2021, the production and sales levels of the enterprise have decreased significantly, and the enterprise has decided to carry out the reform of digital marketing mode. Since the data of 2020-2021 cannot be compared, the sales data of enterprises in 2019-2020 and 2021-2022 are now compared and analyzed.

4.4.1 Mathematical Model Analysis

Table 3 and 4 Are Constructed According to the Enterprise Sales Data of 2019-2020 and 2021-2022, Respectively.

Table 3: Sales Data for 2019-2020

Month	Planned sales (Box)	Actual sales (Box)	Plan unit price (Yuan/box)	Actual unit price (Yuan / box)
1	7000	7598	239	219
2	6000	7300	215	229
3	6000	5489	215	209
4	7500	7795	269	259
5	5000	4788	249	249
6	7000	8189	175	169
7	6000	5598	175	159
8	8500	7982	200	219
9	7700	6893	200	189
10	8100	8342	225	239
11	7000	5598	230	229
12	10000	9457	225	229

Table 4: Sales Data for 2019- 2020

Month	Planned sales (Box)	Actual sales (Box)	Plan unit price (Yuan/box)	Actual unit price (Yuan / box)
1	7000	7598	239	219
2	6000	7300	215	229
3	6000	5489	215	209
4	7500	7795	269	259
5	5000	4788	249	249
6	7000	8189	175	169
7	6000	5598	175	159
8	8500	7982	200	219
9	7700	6893	200	189
10	8100	8342	225	239
11	7000	5598	230	229
12	10000	9457	225	229

4.4.2 Calculation of Parameters and Indicators

The calculated basic parameters and evaluation indicators of the deviation analysis method are shown in Table 5[3].

Table 5: Basic Parameters and Evaluation Standards for 2019- 2020 and 2021-2022

Year	Month	PPWP	PPWS	APWP	PV	SV	PPI	SPI
2019-2020	1	1815922	1673000	1663962	151960	142922	1.09	1.09
	2	1569500	1290000	1671700	-102200	279500	0.94	1.22
	3	1180135	1290000	1147201	32934	-109865	1.03	0.91
	4	2096855	2017500	2018905	77950	79355	1.04	1.04
	5	1192212	1245000	1192212	0	-52788	1.00	0.96
	6	1433075	1225000	1383941	49134	208075	1.04	1.17
	7	979650	1050000	890082	89568	-70350	1.10	0.93
	8	1596400	1700000	1748058	-151658	-103600	0.91	0.94
	9	1378600	1540000	1302777	75823	-161400	1.06	0.90
	10	1876950	1822500	1993738	-116788	54450	0.94	1.03
	11	1287540	1610000	1281942	5598	-322460	1.00	0.80
	12	2127825	2250000	2165653	-37828	-122175	0.98	0.95
2021-2022	1	1460025	1350000	1421091	38934	110025	1.03	1.08
	2	1405065	1410000	1189821	215244	-4935	1.18	1.00
	3	1145520	1075000	1113552	31968	70520	1.03	1.07
	4	1600822	1553500	1533842	66980	47322	1.04	1.03
	5	1537942	1295000	1359802	178140	242942	1.13	1.19
	6	1294755	1045000	1170855	123900	249755	1.11	1.24
	7	1067472	1134000	954512	112960	-66528	1.12	0.94
	8	1326825	1237500	1291443	35382	89325	1.03	1.07
	9	1390800	1400000	1244766	146034	-9200	1.12	0.99
	10	1894725	1687500	2012619	-117894	207225	0.94	1.12
	11	1334330	1175000	1300262	34068	159330	1.03	1.14
	12	2484890	2350000	2421446	63444	134890	1.03	1.06

4.4.3 Mathematical Model Analysis

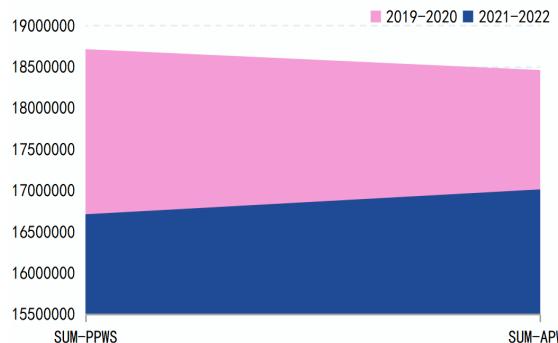


Fig.3: Total Planned Sales Volume and Actual Sales Volume for the Years of 2019- 2020 and 2021-2022



Fig.4: Average Evaluation Indicators for 2019-2020 and 2021-2022

According to Fig.3 and Fig.4, first, the difference between total planned sales and actual sales for 2019-2020 has a relatively steady rise in 2021-2022, despite that the overall turnover is not higher than in 2019-2020. However, it can intuitively clarify the upward trend of 2021-2022; 2019-2020 > 1 but average progress value performance indicator <1. Compared with the average value performance index of 2021-2022, the average value performance index and the average progress value performance index are both > 1.5; When comparing the monthly average price deviation with the sales deviation in each year, positive year for 2021-2022, not only did it greatly reduce costs,

but the enterprise has also over-fulfilled the original plan ahead of schedule. It is far more conducive to enterprise development than meeting the cost reduction and causing enterprise inefficiency in 2019-2020.

5. Conclusions

The mathematical model of digital precision marketing based on profit function and deviation analysis is feasible in theory. In the digital era of sharing and giving universal benefits, the connection is greater than the comparison between owning digital economy and traditional economy. One is scarce because of resource monopoly, and the other is abundant because of resource sharing. The traditional economy encourages unlimited desire, and the digital economy pursues friendly relations. The marginal cost of traditional economy increases, and the marginal cost of digital economy is zero. Traditional economic capital competition has widened the gap between the rich and the poor, yet the digital economy shares dividends and benefits the public. At the same time, through the digital platform, the platform can reconstruct the latest scene, and even reconstruct the business model, create a closed-loop small ecology, and change the original profit model. The development of the Internet and big data makes enterprise marketing “a process from people finding information to information itself”. However, the introduction of a mathematical model, the establishment of an evaluation index and a set of evaluation system haven’t been achieved overnight, and cannot be accomplished overnight. We also need to recognize the difference between the digital field and the sales field, whether the profit function, the deviation analysis can be effectively used in the digital precision marketing, and we should also expect the digital marketing experts and scholars to do more in-depth research and analysis.

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