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Customer relationship value evaluation method for e-commerce platform based on fuzzy clustering

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Abstract: In order to improve the accuracy of customer relationship value evaluation on e-commerce platforms and reduce evaluation time, this paper proposes a fuzzy clustering-based customer relationship value evaluation method for e-commerce platforms. Firstly, consider the changes in customer relationships at different stages of the lifecycle and analyse the timeliness characteristics of customer relationships. Then, the Weibull distribution function is introduced to calculate the length of customer lifecycle. Finally, cluster the investment return on tangible assets of the enterprise, and invert the investment return on intangible assets of the enterprise. Use fuzzy clustering to evaluate the customer relationship value and obtain the final evaluation result. The results show that the method proposed in this paper can effectively improve evaluation efficiency and evaluation efficiency, with an evaluation time of only 2.8 seconds and an evaluation accuracy of up to 99.6%.

Keywords: fuzzy clustering; e-commerce platform; customer relationship value evaluation; life cycle length; return rate splitting method.

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1 Introduction

The evaluation of customer relationship value on e-commerce platforms refers to the comprehensive evaluation of customer behaviour, needs, and satisfaction to determine the value and contribution of customers on the e-commerce platform (Pan et al., 2023b). Customer relationship value assessment can help e-commerce platforms better understand customer needs, improve customer satisfaction, enhance customer loyalty, and thus enhance the platform's competitiveness and profitability. Meanwhile, customer relationship value assessment can also help e-commerce platforms optimise resource allocation, reduce unnecessary costs, and improve operational efficiency (Han, 2022). In addition, customer relationship value assessment can also provide decision-making

support for e-commerce platforms, such as developing marketing strategies and product pricing (Li, 2022). Therefore, in-depth research on customer relationship value evaluation on e-commerce platforms is of great significance for the development of the e-commerce industry.

Hao (2022a) proposes a customer relationship value evaluation method for commercial bank VIP wealth management business to classify customers, such as by factors such as asset size, investment preference, and risk preference. Select indicators such as customer asset size, product holdings, transaction frequency, risk preference, and customer satisfaction as the basis for calculating customer relationship value. The weights and calculation formulas of different indicators can be adjusted according to actual situations. Based on customer classification and value indicator selection, a customer relationship value evaluation model can be established. Commercial banks need to interpret and analyse the results of customer relationship value evaluation models, identify the strengths and weaknesses of customer relationships, and take corresponding measures to enhance customer relationship value. For customers with good customer relationships, we can further enhance customer loyalty and satisfaction by improving service quality, increasing product diversification, and giving gifts; For customers with poor customer relationships, methods such as improving services and adjusting investment portfolios can be used to recover customers and enhance customer relationships. This method can effectively improve customer satisfaction and loyalty, but it requires collecting a large amount of data and takes too long. Xu et al. (2023) proposes a customer relationship value evaluation method for e-commerce platforms based on optimisation models, collecting basic information and behavioural data of e-commerce platform customers, extracting collected data features, and determining key features for customer relationship value evaluation. According to the results of feature extraction, the random forest method is selected to build a customer relationship value evaluation model. The cluster analysis method is used to solve the evaluation model. This method can provide more personalised and high-quality services, and further improve their satisfaction and loyalty. However, this method still needs to be improved in the evaluation efficiency. Ma et al. (2023) proposes a customer relationship value evaluation method for e-commerce platforms based on the RFME model and AdaBoost classifier. Data mining is used to collect customer relationship related data on e-commerce platforms, and the collected data is cleaned. Using pre-processed data, an AdaBoost classifier model is constructed. After classifying and predicting customers using the AdaBoost classifier, the model output results are combined with the preset evaluation indicators, comprehensive evaluation of the value of customer relationships. This method can effectively improve the effectiveness of customer relationship value assessment, but the efficiency of customer relationship value assessment is not satisfactory.

In response to the low efficiency and accuracy of customer relationship value evaluation, this paper proposes a fuzzy clustering-based customer relationship value evaluation method for e-commerce platforms. The specific research ideas are:

Firstly, analyse the timeliness characteristics of customer relationships, consider the changes in customer relationships at different stages of the lifecycle, and introduce a Weibull distribution function to calculate the length of customer relationship timeliness and the length of customer lifecycle.

Then, based on the weighted average cost of capital, the investment return on tangible assets of the enterprise is clustered to invert the investment return on intangible assets of

the enterprise. Fuzzy clustering is used to evaluate the customer relationship value of e-commerce platforms.

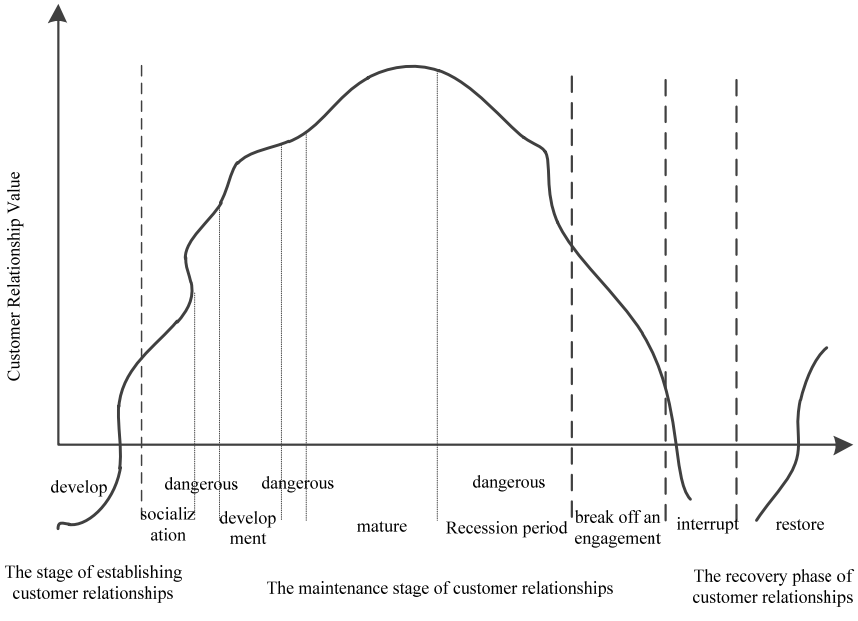
Finally, experimental verification was conducted using the accuracy of customer relationship value assessment and the time required for customer relationship value assessment as indicators, and conclusions were drawn.

2 Customer relationship value evaluation of E-commerce platform based on fuzzy clustering

2.1 Analysis of the timeliness characteristics of customer relationships

The customer relationship has a certain time limit, which is called the timeliness of the customer relationship, and the length of the timeliness affects the value of the customer relationship (Ke et al., 2021). This article adopts a four stage model to divide the lifecycle of customer relationships into seven stages, which are divided into three stages based on the value of customer relationships: the establishment stage, maintenance stage, and recovery stage, as shown in Figure 1.

Figure 1 Customer relationship lifecycle



Analysing Figure 1, it can be seen that the customer relationship lifecycle is divided into development period, socialisation period, growth period, maturity period, decline period, termination period, interruption period, and recovery period. Therefore, before evaluating the value of customer relationships, it is necessary to consider the changes in customer relationships at different stages of their lifecycle and introduce a Weibull distribution function to calculate the length of customer relationship timeliness.

2.2 Calculation of customer average life cycle length based on Weibull distribution function

The distribution of customer relationship life cycle includes hazard function and Survival function (Chen and Wu, 2021). If the time for the enterprise to establish a relationship with the customer has lasted to time *t*, the hazard function describes the loss rate of the customer at time *t*, and the Survival function describes the cumulative customer retention rate of the customer at time *t*. The life cycle distribution function can effectively study the dynamic customer retention rate of enterprises, and the hazard function of the Weibull distribution model can effectively reflect the changes in customer retention rate over time in different industries. Model involves parameters α, β selection of parameters α can reflect the length of customer lifecycle in different industries, α the larger the value, the longer the customer's lifecycle, and its variation pattern is determined by the shape parameter β decision.

When $0 < \beta < 1$, the danger function of the model is a decreasing curve over time. In fact, the dynamic customer retention rate in most industries is monotonically decreasing. At this point, the customer is in the inspection period of their lifecycle; As the frequency of transactions increases, both parties trust and are more satisfied with each other, and customer churn is alleviated (Peng and Zhang, 2023). At this point, the cumulative customer retention rate decreases slightly and eventually tends to a stable level. When $\beta = 1$, this is a special situation that indicates that the cumulative customer retention rate does not change over time, which is generally reflected in a few monopoly industries such as electricity, tobacco, gas energy, etc. Monopoly industries are supported by national policies, with low competition pressure and are mostly closely related to the daily needs of the people. For example, when residents use electricity for daily use, the electricity selling entity belongs to the state, and customers have no choice, so customers will not be lost throughout the entire life cycle.

When $\beta > 1$, there are fewer competitive enterprises in the market and customers have less choice, resulting in a lower customer churn rate (Pan et al., 2023a).

From this, it can be seen that by selecting the appropriate α, β, the Weibull distribution model can dynamically reflect the changes in customer numbers over time for different industries and enterprises. This article selects the Weibull distribution model to calculate the average lifecycle length of enterprise customer groups.

According to the analysis in the previous section, it is necessary to use the Weibull distribution function to calculate the average customer lifecycle length. The variation of customer stock over time is the distribution of the lifecycle of enterprise customers (Zhang, 2022). If the customer retention rate of a company follows a Weibull distribution, then the cumulative customer retention rate $r_{(t)}$ of the company can be expressed as:

$$r_{(t)} = e^{[-(\alpha t)^{\beta}]}, t > 0 \tag{1}$$

Among them, $r_{(t)}$ is the cumulative retention rate of customers at that time; α, β are all dimensionless undetermined constants, with α determining the range of function values;, β determines the distribution shape of the function, and e represents a constant.

In the Weibull distribution function, α reflects the average lifecycle length of the enterprise's customer base, and α. The larger the 888 value, the longer the customer's

lifecycle, and its variation pattern is β decision (Cheng, 2022). The simplified processing process is as follows:

$$r_{(t)} = e^{[-(\alpha t)^{\beta}]} \to ln\left[\frac{1}{r_{(t)}}\right] = (\alpha t)^{\beta} \to ln\left[\frac{1}{r_{(t)}}\right] = \beta ln\alpha + \beta lnt \tag{2}$$

In equation (2), specify:

$$y = lnln\left[\frac{1}{r_{(t)}}\right], c = \beta ln\alpha, x = lnt \tag{3}$$

In equation (3), it can be expressed as:

$$y = c + \beta x \tag{4}$$

Among them, c represents customer stock; y represents customer retention rate; x represents the number of customers. Transforming the Weibull distribution function from its original exponential form to a simple linear regression model can effectively reduce the complexity of mathematical calculations. The better the fit between the actual customer data and equation (4), the better the Weibull distribution fits the lifecycle distribution of the enterprise customer group (Hao, 2022b).

Due to the concentrated lifecycle of most customers, the longer the customer lifecycle, the higher the value of the enterprise's customer relationship (Zhang, 2022). Therefore, in the analysis, the time period between the establishment of the first transaction between the enterprise and the customer and the time when the cumulative customer retention rate is 50% is defined as the average customer life cycle of the enterprise customer group, and the corresponding time T is the customer's life cycle length. Therefore, according to Order $r_{(t)} = 0.5$, the customer relationship value evaluation function for constructing an e-commerce platform is:

$$WACC = exp\{[ln(-ln0.5)] / B\} / a; \tag{5}$$

α, β are all dimensionless undetermined constants, while α determines the range of function values; β determines the distribution shape of the function. By calculating this, we can obtain the average customer lifecycle length, which is the length of the timeliness of customer relationships.

Construct a customer relationship value evaluation function for e-commerce platforms, and use fuzzy clustering method to evaluate the value of enterprise customer relationships (Han, 2022).

2.3 Customer relationship value evaluation of E-commerce platform based on fuzzy clustering

Based on the average customer lifecycle length obtained from the previous section, a customer relationship value evaluation function for e-commerce platforms is constructed, and fuzzy clustering method is used to evaluate the enterprise customer relationship value. Applying fuzzy clustering on the basis of weighted average cost of capital, the investment return rate of intangible assets of a company is inverted by clustering the investment return rate of tangible assets (Lan et al., 2021). The tangible assets of a company mainly include current assets and fixed assets, and the value of these assets can

be directly obtained from the company's financial statements, so they have strong operability in evaluation practice. Meanwhile, the biggest feature of this method is that it considers the factors of intangible assets, making it more suitable for the evaluation of customer relationship assets. The formula for calculating the return on investment R_i is:

$$R_i = \frac{WACC - W_c \times R_c - W_f \times R_f}{W_i} \tag{6}$$

Among them, W_c represents the contribution value of customer intangible assets, R_c represents intangible assets, W_f represents customer investment return rate, and R_f represents the customer relationship sharing rate of intangible assets; the original evaluation function mostly uses the risk accumulation method and the weighted average cost of capital method to determine the Discount rate. The risk accumulation method involves many factors and does not have a unified calculation calibre. The weighted average cost of capital method considers the discount problem from the perspective of the overall income of the enterprise, and does not take into account the characteristics of customer relationship assets. Therefore, according to the characteristics of customer relationship assets, this paper selects the fuzzy clustering method to determine the Discount rate. The customer relationship value evaluation function based on fuzzy clustering is:

$$MPEE = \sum_{t=1}^{T} \frac{\left(E - E_c - E_l - E_f - E_o\right)_t \times W_i}{(1+r)^t} \tag{7}$$

Among them, *MPEE* represents the customer relationship value of the evaluated enterprise; E represents the enterprise's free cash flow; E_c represents the contribution value of current assets, E_1 represents the contribution value of long-term investments, E_o represents the contribution value of other assets, and E_c, E_1, E_o is obtained by multiplying the annual average value of each asset with its corresponding investment return rate; E_f represents the contribution value of fixed assets; W_i represents the customer relationship sharing rate; T is the average lifecycle length of the enterprise's customer base; r is the Discount rate. The application of fuzzy clustering evaluation function to evaluate the value of enterprise customer relationship needs to follow the following evaluation steps:

1 determine the average lifecycle length of the enterprise's customer base T

2 determine the proportion of intangible assets belonging to customer relationships in the enterprise W_i

3 predict the sales revenue, sales cost, business taxes and surcharges, period expenses, capital expenditure, depreciation and amortisation brought by existing customers within the life cycle, and calculate the future free cash flow E of the enterprise

4 predict the current assets contribution E_c, long-term investment contribution E_1, fixed assets contribution E_f and other assets contribution E_o of the enterprise within the life cycle, and obtain the intangible assets contribution of the enterprise by subtracting the relevant assets contribution from the enterprise's Free cash flow predicted in step 3

5 calculate the enterprise's discount rate r

6 Substitute the calculation results of all indicators into the evaluation function to obtain the customer relationship value of the enterprise.

To achieve customer relationship value evaluation on e-commerce platforms based on fuzzy clustering.

Table 1 Customer tracking survey data of electric from 2011 to 2019

Annual	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*
2011	119	100	89	76	69	64	62	59	55
	19	11	13	7	5	2	3	4	2
2012		134	117	103	90	81	70	62	55
		17	14	13	9	11	8	7	5
2013			113	92	79	68	59	52	44
			21	13	11	9	7	8	5
2014				84	67	52	41	32	25
				17	15	11	9	7	3
2015					70	51	38	29	22
					19	13	9	7	6
2016						62	47	36	29
						15	11	7	2
2017							70	53	40
							17	13	7
2018								84	69
								15	11
2019									70
									17
Total customers	119	234	319	355	375	378	387	407	409
Customer churn	73	28	48	50	59	61	64	68	58

3 Case analysis

3.1 Data sources

To obtain customer retention rate, it is necessary to conduct long-term tracking surveys on the changes in customer stock of enterprises. Currently, there are not many enterprises in China that publicly disclose changes in customer stock, and the vast majority of enterprises with shorter operating life in the market account for this. Therefore, it is difficult to obtain comprehensive customer stock information. This article adopts Google Dataset Search (https://toolbox.google.com/) to obtain basic customer data for the electrical equipment industry dataset from 2011 to 2019, and to track and investigate the changes in the number of electrical customers each year. The results are shown in Table 1.

Transform the data in Table 1 and further convert it to 2.

Table 2 Experience data table of customer maintenance time and customer retention rate of electric from 2011 to 2019

W	*Interval midpoint t*	*Number of customers*	*Number of lost customers*	*Customer churn rate*	*Conditional customer retention rate*	*Accumulated customer retention rate r (t)*	*y = [lnlnr(t)]*	*x = lnt*
8–9	8.5	55	2	3.64%	96.36%	30.64%	0.168	2.1
7–8	7.5	114	9	7.89%	92.11%	31.80%	0.136	2
6–7	6.5	168	15	8.93%	91.07%	34.53%	0.061	1.87
5–6	5.5	211	21	9.95%	90.05%	37.91%	–0.031	1.7
4–5	4.5	263	36	13.69%	86.31%	42.10%	–0.145	1.5
3–4	3.5	333	43	12.91%	87.09%	48.78%	–0.331	1.25
2–3	2.5	437	71	16.25%	83.75%	56.01%	–0.545	0.916
1–2	1.5	596	101	16.95%	83.05%	66.88%	–0.911	0.405
0–1	0.5	806	157	19.48%	80.52%	80.52%	–1.529	–0.69

From Table 2, it can be seen that in the early stages of the customer lifecycle, there are many unstable factors between enterprises and customers, and customer churn is a serious problem; as the products and services of enterprises gradually mature, customer relationships tend to stabilise, and the cumulative customer retention rate decreases to a small extent.

3.2 The process of evaluating customer relationship value on e-commerce platforms

The regression equation for the cumulative customer retention rate of e-commerce platforms is:

$$y = c + \beta x = -1.116 + 0.626x \tag{8}$$

Among them, parameter $c = -1.116$, $\beta = 0.626$, $\alpha = e^{c/\beta} = 0.168$.

According to the statistical test results in Table 2, the adjusted R2 is 0.998, indicating that equation (14) has a good fit for the change in customer retention rate of electric. Therefore, the Weibull distribution function of electric's customer retention rate over time is:

$$r_{(t)} = [\alpha^{-t\beta}] = e^{[-(0.168t)^{0.626}]}, t > 0 \tag{9}$$

According to order $r_{(t)} = 0.5$, the customer lifecycle length of T is 3.31, which means that Electric's customer lifecycle length is four years.

The predicted contribution value of fixed assets is shown in Table 3.

The detailed calculation of the four key influencing factors of electric: customer life cycle length, customer relationship sharing rate, relevant asset contribution and discount rate can give the evaluation results as shown in Table 4.

Table 3 Contribution value of fixed assets unit: 10,000 Yuan

Annual	*2020*	*2021*	*2022*	*2023*
Compensation return:				
Depreciation	10,399.47	10,399.47	10,399.47	10,399.47
Capital expenditure depreciation	1,218.73	13,627.37	26,929.14	32,354.79
Total compensation	11,618.20	24,026.84	37,328.61	42,754.26
Return on investment:				
Opening balance	130,493.52	143,249.92	343,021.23	350,364.91
Capital expenditure	24,374.60	223,798.15	42,237.27	66,275.74
Depreciation	11,618.20	24,026.84	34,893.59	17,961.80
Ending balance	143,249.92	343,021.23	350,364.91	398,678.84
Annual average balance	136,871.72	243,135.57	346,693.07	374,521.87
ROI	4.90%	4.90%	4.90%	4.90%
Total investment return	6,706.71	11,913.64	16,987.96	18,351.57

Table 4 Customer relationship value evaluation form of electric unit: 10,000 Yuan

Annual	*2020*	*2021*	*2022*	*2023*
Free cash flow	5,064,170.63	148,376.8	903,909.5	10,046,000.2
Less: contribution value of fixed assets	18,324.92	35,940.48	54,316.57	61,105.83
Contribution value of current assets	65,844.80	70,703.07	75,687.19	80,797.16
Long term investment contribution value	199.46	220.13	242.32	266.04
Contribution value of other assets	7.06	7.79	8.58	9.42
Equal to: contribution value of intangible assets	4,979,794.39	41,505.33	773,654.84	9,903,821.75
Multiply by: customer relationship sharing rate	0.103	0.103	0.103	0.103
Equal to: customer relationship contribution value	512,918.82	4,275.04	79,686.44	1,020,093.64
discounted rate	12.54%	12.54%	12.54%	12.54%
Discount period	0.5	1.5	2.5	3.5
Discount factor	0.9426	0.8376	0.7442	0.6613
Present value (10,000 Yuan)	483,477.28	3,580.77	59,302.65	674,587.92
Customer relationship value (100 million Yuan)		122.09		

In summary, according to the calculation results of the fuzzy clustering evaluation function, the customer relationship value of electric is 12.209 billion Yuan.

3.3 Accuracy of customer relationship value assessment

In order to verify the effectiveness of the method proposed in this article in evaluating customer relationship value, the accuracy of the Xu et al. (2023) method, the Ma et al. (2023) method, and the customer relationship value evaluation results under this method were statistically analysed. The calculation formula for the evaluation accuracy rate of P_{aa} is:

$$P_{aa} = \frac{A_{gg}}{H_f} \times 100\% \tag{10}$$

Among them, A_{gg} represents the number of times the customer relationship value evaluation was correct, H_f represents the total number of evaluations, and the accuracy results of customer relationship value evaluation are shown in Table 5.

Table 5 Accuracy of customer relationship value evaluation

Iterations/time	*Accuracy of customer relationship value assessment/%*		
	Xu et al. (2023) method	*Ma et al. (2023) method*	*Proposed method*
1,000	68.2	65.0	98.9
2,000	63.8	69.9	99.6
3,000	70.1	72.1	96.2
4,000	72.9	63.6	98.0
5,000	73.0	72.8	99.1

Analysis of Table 5 shows that the accuracy of customer relationship value evaluation using Xu et al. (2023) method varies between 63.8% and 73.0%, while the accuracy of customer relationship value evaluation using Ma et al. (2023) method varies between 63.6% and 72.8%. The accuracy of customer relationship value evaluation using this method varies between 96.2% and 99.6%, and the accuracy of customer relationship value evaluation using this method is consistently higher than other methods, this indicates the effectiveness of the method proposed in this article in evaluating customer relationship value.

3.4 Time consuming for evaluating customer relationship value on e-commerce platforms

In order to verify the efficiency of customer relationship value evaluation on e-commerce platforms under the method proposed in this article, the Xu et al. (2023) method, the Ma et al. (2023) method, and the time consumption of customer relationship value evaluation on e-commerce platforms using this method are shown in Table 6.

According to Table 6, when the number of iterations is 1,000, the customer relationship value evaluation time for the e-commerce platform using Xu et al. (2023) method is 32 seconds, the customer relationship value evaluation time for the e-commerce platform using Ma et al. (2023) method is 18 seconds, and the customer relationship value evaluation time for the e-commerce platform using this method is 0.5 seconds; When the number of iterations is 5,000, the customer relationship value evaluation time for the e-commerce platform using Xu et al. (2023) method is 159

seconds, the customer relationship value evaluation time for the e-commerce platform using Ma et al. (2023) method is 169 seconds, and the customer relationship value evaluation time for the e-commerce platform using this method is 2.8 seconds; The time consumption for evaluating customer relationship value on e-commerce platforms under this method is much lower than other methods, indicating that this method can effectively improve evaluation efficiency.

Table 6 Time consumption for evaluating customer relationship value on e-commerce platforms

Iterations/time	*Time consuming for evaluating customer relationship value on e-commerce platforms/s*		
	Xu et al. (2023) method	*Ma et al. (2023) method*	*Proposed method*
1,000	32	18	0.5
2,000	58	28	0.9
3,000	89	36	1.3
4,000	125	88	1.9
5,000	159	169	2.8

4 Conclusions

This article proposes a customer relationship value evaluation method for e-commerce platforms based on fuzzy clustering. Analyse the timeliness characteristics of customer relationships, construct a customer life cycle distribution model, use the Weibull distribution model to calculate the length of customer life cycle, cluster the investment return rate of tangible assets of enterprises to invert the investment return rate of intangible assets of enterprises, and use fuzzy clustering to evaluate the value of customer relationships on e-commerce platforms. The experimental results indicate that:

1 According to the calculation results of the fuzzy clustering evaluation function, the customer relationship value of Xuji Electric is 12.209 billion Yuan, and the accuracy of the customer relationship value evaluation method in this paper can reach up to 99.6%, verifying the effectiveness of the customer relationship value evaluation method in this paper.

2 When the number of iterations is 5,000, the customer relationship value evaluation time of the e-commerce platform proposed in this paper is 2.8 seconds; this indicates that the method proposed in this article can effectively improve evaluation efficiency.

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