Research on the Evaluation of Supermarket Chain Agricultural Products Supply Chain Performance Based on Improved FCE

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Abstract. In the context of rural revitalization, it is important to study the performance evaluation of agricultural products supply chain. Based on previous research, this paper refers to the more typical and advanced fuzzy comprehensive evaluation method used in supply chain performance evaluation, considers four aspects: customer, logistics, finance and information, establishes the corresponding evaluation index system, adopts the more common factor analysis method in objective assignment to calculate the weights, uses the fuzzy comprehensive evaluation method to evaluate the performance of the agricultural products supply chain of RT-Mart, and proposes to promote Based on the evaluation results, we propose three suggestions to improve the performance of agricultural products supply chain.

Keywords: agricultural supply chain · fuzzy comprehensive evaluation · performance evaluation

1 Introduction

The circulation of agricultural products in China is characterized by scattered upstream and downstream, and multiple layers in the middle. The third agricultural census data show that the number of small farmers in China accounts for more than 98% of the main agricultural business, the "small farmer economy" is still a significant feature. Intermediate circulation links to the wholesale market at all levels, the scale of new distribution methods is relatively small. Traditional farmers' markets still account for the mainstream of the circulation terminal link, accounting for as much as 56.5% in 2019. Farmers' markets and other intermediate wholesale markets are characterized by dense, mobile and difficult to manage, and face the risk of market closure many times during the epidemic, which directly affects the procurement chain of many small merchants, with both the production and marketing ends of agricultural products facing huge operational risks, and the risks of traditional agricultural products supply chain

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are obviously exposed, and the major trends of fresh direct procurement and farm-to-super docking are also revealed. Therefore, it is important to construct an agricultural products supply chain performance evaluation system centered on supermarket chains and evaluate its performance.

2 Review of the Current Status of Domestic and International Research

2.1 Status of Foreign Research

Sharma et al. collected data from 74 agricultural supply chain enterprises in North India and reviewed the performance indicators of agricultural supply chain. Seventy-nine sub-criteria were identified under 13 key indicators [1]. Raut et al. considered the same performance indicators other than economic performance proposed by Sharma et al. to measure the performance of management practices in Indian agro-industry and finally used structural equation modeling to test several hypotheses in the considered cases [2]. Gardas et al. identified performance indicators for green agro-supply chain and used ISM techniques to They modeled them and finally derived three most critical performance indicators with high impact, namely environmental management, regulatory pressure and competitive pressure [3]. Callado and Jack evaluated fresh fruit supply chain performance in Brazil using 49 indicators and found customer satisfaction to be the most critical performance indicator [4].

Kamble found that there is a lack of research on the impact of data analytics capabilities on the sustainability of agricultural supply chain performance, to fill this gap, scholars analyzed how supply chain resources, information visibility and data analytics capabilities are linked in a sustainable performance agricultural supply chain by summarizing 84 literature from 2000 to 2017, and proposed a supply chain visibility perspective from An applied framework for achieving sustainable performance from a supply chain visibility perspective is proposed [5]. Morteza et al. state that the driver for improving the performance of agricultural supply chains is the selection and distribution of optimal service packages, and in their study, scholars use fuzzy decision making and hierarchical analysis to validate this view [6]. Wucheng Zi et al. find that previous studies on improving food freshness have not considered the important factor of fairness, and examine the relationship between buyers and suppliers from a retailer fairness concern perspective explored the impact of collaborative cost sharing between buyers and suppliers on fresh produce supply chain performance [7]. Yue Li used hierarchical analysis to analyze the factors influencing fresh produce supply chain performance under the cloud logistics model and determined the degree of influence of each influencing factor [8].

2.2 Current Status of Domestic Research

Cao Ye used BP neural network to construct an evaluation index system from five aspects of agricultural supply chain: financial situation, operational capability, growth capability, customer satisfaction and agility [9]; Wang Yong used factor analysis to simplify multiple evaluation indexes of supply chain performance from cost, operation and service, considering that the dimensionality reduction function of factor analysis has the characteristics of wide application, good objectivity, low application difficulty and high extensiveness. The evaluation of the supply chain is carried out in three aspects: cost, operation and service [10]; Li Xingxing combines the characteristics of traditional single-type supply chain performance evaluation with the specific situation of cluster-type supply chain, and proposes a cluster-type supply chain performance evaluation and optimization method using DEA model [11]; Zhou Yefu considers the characteristics of short shelf life and perishability of agricultural products, draws on the supply chain performance evaluation index system based on the balanced scorecard theory, and uses the improved fuzzy integrated evaluation method to construct a fuzzy integrated evaluation. Comprehensive evaluation method to construct a fuzzy comprehensive evaluation model [12]; Wang Kaixuan et al. expanded the five-dimensional logistics service supply chain performance evaluation index system constructed by previous authors, and constructed a six-dimensional agricultural products supply chain evaluation index system based on the traditional four-dimensional balanced scorecard, and for the problem that the affiliation degree of fuzzy comprehensive evaluation method is difficult to determine, combined the gray clustering method with fuzzy comprehensive evaluation method to construct an agricultural products supply chain performance evaluation model [13].

2.3 Research Overview

The selection of performance evaluation indexes is the focus of supply chain performance evaluation research at home and abroad. In recent years, scholars at home and abroad have constructed corresponding index systems from the perspectives of visibility, sustainability and fairness for different research subjects, and used case study method, structural equation model, hierarchical analysis method, fuzzy comprehensive evaluation method and data envelopment analysis to conduct research.

Through literature review, scholars have pointed out that information technology plays an important role in the agricultural supply chain in the context of "Agriculture 4.0" in recent years, but the research on the evaluation of agricultural supply chain performance considering information technology indicators has yet to be supplemented, so this paper selects evaluation indicators reflecting the level of information technology on the basis of previous research. In addition, the current research mostly adopts hierarchical analysis method, which is a subjective and arbitrary method. Therefore, this paper adopts the more common factor analysis method in the objective assignment method to assign values to indicators, and innovates from the research method level.

3 Construction of Evaluation Index System

Consumer demand is the power source for the generation, operation and reconstruction of the supply chain. Supermarket chains in the downstream of the supply chain directly face the final consumers, so they should pay more attention to the satisfaction of customer demand, and the evaluation of supply chain performance should take into account the influence of consumer perception in the procurement process [14], so this paper selects customers as the first-level indicator. On this basis, the secondary indicators selected in this paper and their explanations are as follows: complaint behavior reflects the degree of customer satisfaction with supply chain agricultural products and services, and also reflects the changing trend of customer demand, so this paper selects customer complaint rate as the secondary indicator, which can reflect the outstanding problems affecting supply chain performance; the response speed to customer complaint behavior reflects the ability to handle complaints, which also affects the degree of customer satisfaction, so The response speed to customer complaints reflects the ability to handle complaints and also affects customer satisfaction, so the customer complaint handling time index is introduced; from the index availability, this paper selects the return ratio index to measure the supply chain agricultural products and service quality.

The realization of the customer dimension cannot be achieved without the support of logistics and storage links. Agricultural products are perishable and are very prone to quality problems in transportation, which will lead to the loosening or even interruption of the supply chain system [15], so this paper selects logistics as the primary index. The secondary indicators and their explanations are as follows: supply products are an important part of the supply chain, whether the timely supply of agricultural products directly affects the level of supermarket agricultural products supply chain performance, so the out-of-stock ratio indicator is selected; product freshness is the basic demand of consumers and the basic standard of supply chain agricultural products, this paper selects the product freshness indicator, which can comprehensively reflect the transportation and storage management level of supply chain node enterprises. Due to the strong timeliness, agricultural products need a high inventory turnover rate to reduce the loss caused by deterioration and damage in the storage process, so the inventory turnover index is introduced.

Financial indicators can intuitively reflect the operating conditions of supply chain node enterprises, and observing the inputs and outputs of financial indicators can help achieve the supply chain management goals of cost reduction and efficiency improvement, so finance is an important indicator for supply chain performance evaluation [16]. On the basis of selecting finance as the primary indicator, this paper selects some secondary indicators commonly used in supply chain performance evaluation, which are explained as follows: in order to measure the revenue level of sales revenue, this paper incorporates the net sales margin indicator into the evaluation system; the return on total assets is selected to reflect the profitability of supply chain node enterprises' own capital; in order to reflect the relationship between investment and return, the return on net assets indicator is selected.

In the context of "new retail", supermarket chains are undergoing the transformation of online and offline integration. The application of information technology is a means to collect and transmit information more accurately and quickly, and is also an important capability for the sustainable and stable development of modern agricultural supply chains. Therefore, when evaluating the performance of agricultural supply chain, we need to measure its ability to use emerging information technology [17]. To cope with this change, this paper selects information technology as the first-level index. The application of information system can effectively improve the accuracy and timeliness of information transmission and sharing, so the growth rate of information system application is taken as the second-level index.

Table 1. Summary of evaluation indicators

Tier 1 Indicators	Secondary indicators	Explanation of indicators
Customers	Customer complaint rate/%	Number of complaints as a percentage of the number of transactions
	Customer complaint resolution time/day	Time taken to resolve customer complaints
	Return rate/%	Number of returned products as a percentage of total products sold in the same period
Logistics	Out-of-stock ratio/%	Ratio of the number of out-of-stocks to the total number of shipments
	Product Freshness	The ratio of the number of products that have not deteriorated or been damaged during transportation and storage to the total number of products
	Inventory turnover rate/%	Ratio of cost of goods sold to average inventory
Finance	Net sales margin/%	Ratio of net income to operating income
	Total Return on Assets / %	Ratio of total compensation before interest and taxes to average total assets
	Return on Net Assets / %	Ratio of net income to average net assets
Informatization	Information system application growth rate / %	Ratio of incremental information system utilization to base period

Based on the above analysis, this paper constructs an evaluation index system with 4 primary indicators and 10 secondary indicators, and the summary of indicators is shown in Table 1.

4 Empirical Analysis

4.1 Introduction to the Method

Factor Analysis to Calculate Weights.
Factor analysis method of calculating weights is essentially normalizing the sum of the absolute values of the projections of indicators on each principal component as weights, i.e., each indicator is expressed as a linear combination of principal factors, and the normalization of the projection contribution of each indicator is treated as a weight [18].

The SPSS statistical software was used as the tool for determining the weights of factor analysis, and the steps were: first, to determine whether the data were suitable for factor analysis; second, to rotate the component matrix using the maximum variance method; finally, to calculate the index weights, the loading coefficients were divided by the square root of the corresponding characteristic roots to obtain the linear combination coefficients, and the linear combination coefficients were multiplied with the variance interpretation rate and then accumulated, divided by the cumulative variance interpretation rate to obtain the composite score The coefficients are normalized to obtain the weight values of each index.

Fuzzy Integrated Evaluation Method.

Fuzzy comprehensive evaluation method is an evaluation method based on fuzzy mathematics. This evaluation method applies the principle of fuzzy relationship synthesis to derive the comprehensive evaluation value based on the comprehensive consideration of the indicators of the evaluation object, and then compares the results. It is often used to evaluate things or objects that are constrained by multiple factors and systemic in nature, and is widely used in socio-economic, engineering and other fields [19].

The general steps of fuzzy comprehensive evaluation are

(1) Determine the set of rubrics and the set of factors, set the set of rubrics as $V = \{v_1, v_2, \ldots, v_m\}$, and the set of factors is determined according to the evaluation index system, note $U = \{u_1, u_2, \ldots, u_n\}$.
(2) Single-factor evaluation, single-factor evaluation of each indicator Ui ($i = 1, 2, \ldots, n$) in the factor set, i.e., determine the affiliation of $R|u_i$, from which the affiliation set, i.e., the single-factor evaluation set $r_i = (r_{i1}, r_{i2}, \ldots, r_{im})$, is obtained.
(3) Establish the fuzzy relationship matrix R,

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{p1} & r_{p2} & \cdots & r_{pm} \end{bmatrix} \tag{1}$$

(4) Determine the indicator weight A, denoted as A = {a1,a2,…,an}.
(5) Perform fuzzy synthesis, select the fuzzy synthesis operator, synthesize A with R, and obtain the fuzzy synthesis evaluation vector of each index as well as the overall evaluation vector, namely.

$$B = A^{\circ}R = (a_1, a_2, \ldots, a_p) \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{p1} & r_{p2} & \cdots & r_{pm} \end{bmatrix} = (b_1, b_2, \ldots, b_m). \tag{2}$$

4.2 Calculation Process

4.2.1 Determination of Evaluation Index Weights Based on Factor Analysis.

The agricultural products supply chain performance evaluation index system constructed in this paper has both quantitative and qualitative indicators, where the data of quantitative indicators are obtained from the financial statement of a branch of RT-Mart, and the

Table 2. Data on relevant indicators for the study sample 2017–2021

	Indicators	2017	2018	2019	2020	2021
Customers	Customer complaint rate/%	2.9	2.74	3.01	2.3	1.9
	Customer complaint resolution time/day	14.32	9.07	7.55	6.12	5.25
	Return rate/%	0.24	0.23	0.19	0.2	0.16
Logistics	Out-of-stock ratio/%	2.29	1.98	1.64	1.5	1.27
	Product Freshness	3.1	4.18	5.01	5.22	5.27
	Inventory turnover rate/%	9.24	10.96	11.27	11.85	10.96
Finance	Net sales margin/%	4.07	3.68	3.58	3.34	2.89
	Total Return on Assets / %	11.35	12.16	11.23	12.99	12.28
	Return on Net Assets / %	9.05	9.01	9.27	12.84	13.63
Informatization	Information system application growth rate/%	4.7	6.11	8.34	11.26	14.02

data of qualitative indicators are obtained through field research and random interviews, as shown in Table 2.

Considering the difference in magnitude between different data, the data were first standardized using the statistical software SPSS.

To determine whether the original data were suitable for factor analysis, KMO and Bartlett's sphericity tests were performed on the selected data. The test results are shown in Table 3. The KMO value of the selected data in this paper is 0.583, which is greater than 0.5 and still acceptable. The significance value is 0.000, which indicates that there is a significant correlation between the variables, and factor analysis can be performed.

The data were further processed using factor analysis, and the maximum variance method of rotation was selected to obtain the total variance explained and the rotated component matrices shown in Tables 4 and 5.

Based on the variance contribution and cumulative contribution of each public factor and the factor loadings of each indicator, the weights of each indicator can be obtained, as shown in Table 6.

Table 3. KMO and Bartlett's test

KMO Sampling suitability quantity		0.583
Bartlett's sphericity test	Approximate cardinality	204.495
	Degree of freedom	10
	Significance	0.000

Table 4. Total variance explained

Ingredients	Initial Eigenvalue			Extraction of the sum of squares of loads			Sum of squared rotating loads		
	Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %
1	7.947	79.471	79.471	7.947	79.471	79.471	4.709	47.091	47.091
2	1.082	10.818	90.289	1.082	10.818	90.289	4.32	43.198	90.289
3	0.866	8.661	98.95						
4	0.105	1.05	100						
5	6.28E−16	6.28E-15	100						
6	2.39E−16	2.39E-15	100						
7	8.85E−17	8.85E-16	100						
8	−2.24E-17	−2.24E-16	100						
9	−2.03E-16	−2.03E-15	100						
10	−8.16E-16	−8.16E-15	100						

Table 5. Component matrix after rotation

Variables	Ingredients	
	1	2
Customer complaint rate	0.262	0.947
Customer complaint resolution time	0.885	0.439
Return rate	0.751	0.484
Out-of-stock ratio	0.819	0.555
Product Freshness	−0.93	−0.367
Inventory turnover rate	−0.886	−0.176
Net sales margin	0.643	0.74
Total Return on Assets	−0.255	−0.733
Return on Net Assets	−0.392	−0.912
Growth rate of information system applications	−0.584	−0.777

Table 6. Table of index weights at each level

Tier 1 Indicators	Weighting of primary indicators	Secondary indicators	Secondary indicator weights
Customers	0.3005	Customer complaint rate/%	0.0952
		Customer complaint resolution time/day	0.1063
		Return rate/%	0.0989
Logistics	0.3002	Out-of-stock ratio/%	0.1100
		Product Freshness	0.1044
		Inventory turnover rate/%	0.0859
Finance	0.2912	Net sales margin/%	0.1101
		Total Return on Assets / %	0.0780
		Return on Net Assets / %	0.1031
Informatization	0.1082	Information system application growth rate/%	0.1082

Fuzzy Integrated Evaluation.

(1) Creating rubric sets and factor sets

The performance evaluation level 1 indicators in this paper include customer (U1), logistics (U2), finance (U3), and information technology (U4). Among them, customer indicators include secondary indicators of customer complaint rate (U11), customer complaint resolution time (U12) and return ratio (U13); logistics includes out-of-stock ratio (U21), product freshness (U22) and inventory turnover rate (U23); finance includes return on total assets (U31), return on net assets (U32) and net profit margin (U33); and information technology includes information system application growth rate (U41).

Therefore, the following set of factors is determined.

$U = \{U_1, U_2, U_3, U_4\}$

$U_1 = \{U_{11}, U_{12}, U_{13}\}$

$U_2 = \{U_{21}, U_{22}, U_{23}\}$

$U_3 = \{U_{31}, U_{32}, U_{33}\}$

$U_4 = \{U_{41}\}$

The weights of indicators at each level are:

A = (0.3005, 0.3002, 0.2912, 0.1082)

Set the set of comments as $V = \{V_1, V_2, V_3, V_4\}$ = {Excellent, Good, Poor, Very Poor} and assign the value V = {100, 75, 50, 25}.

(2) Single-factor evaluation

Twenty practitioners related to the case companies were selected to score the evaluation indicators, and the affiliation degree of each indicator was obtained using the 2017 data of the study sample, as shown in Table 7.

(3) Build fuzzy relationship matrix

The corresponding fuzzy relationship matrix can be obtained from Table 6.

$$R_1 = \begin{bmatrix} 0.7 & 0.15 & 0.05 & 0.1 \\ 0.4 & 0.2 & 0.25 & 0.15 \\ 0.15 & 0.55 & 0.15 & 0.15 \end{bmatrix} \tag{3}$$

Similarly, R2, R3 and R4 can be derived.

(4) Perform fuzzy synthesis

The four commonly used fuzzy synthetic operators are M(∧,∨), M(-,∨), M(∧, ⊕) and M(-, ⊕). In order to take into account each index, M(-, ⊕) (weighted average type)

Table 7. Statistical results of affiliation degree of each index

Evaluation Indicators	Number of experts who selected each indicator				Affiliation set
	V_1 (Excellent)	V_2 (Good)	V_3 (poor)	V_4 (very poor)	
Customer complaint rate/%	14	3	1	2	(0.7, 0.15, 0.05, 0.1)
Customer complaint resolution time/day	8	4	5	3	(0.4, 0.2, 0.25, 0.15)
Return rate/%	3	11	3	3	(0.15, 0.55, 0.15, 0.15)
Out-of-stock ratio/%	11	5	1	3	(0.55, 0.25, 0.05, 0.15)
Product Freshness	15	4	1	0	(0.75, 0.2, 0.05, 0)
Inventory turnover rate/%	6	10	3	1	(0.3, 0.5, 0.15, 0.05)
Net sales margin/%	9	5	2	4	(0.45, 0.25, 0.1, 0.2)
Total Return on Assets / %	4	6	8	2	(0.2, 0.3, 0.4, 0.1)
Return on Net Assets / %	8	5	2	5	(0.4, 0.25, 0.1, 0.25)
Information system application growth rate/%	10	3	5	2	(0.5, 0.15, 0.25, 0.1)

operator is chosen for calculation in this paper. A and R are synthesized to obtain the fuzzy integrated evaluation vector of each indicator as well as the overall evaluation vector, namely.

$$B = A^{\circ}R = (a_1, a_2, \ldots, a_p)\begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{p1} & r_{p2} & \cdots & r_{pm} \end{bmatrix} = (b_1, b_2, \ldots, b_m). \tag{4}$$

Using the 2017 data for the study sample, the following calculations were made. The evaluation vector of customer indicators is:

$$B_1 = 0.31694, 0.353766, 0.329153^{\circ}\begin{bmatrix} 0.7 & 0.15 & 0.05 & 0.1 \\ 0.4 & 0.2 & 0.25 & 0.15 \\ 0.15 & 0.55 & 0.15 & 0.15 \end{bmatrix}$$

$$= (0.412737, 0.299328, 0.153661, 0.134132) \quad (5)$$

Similarly, the evaluation vectors B_2, B_3 and B_4 for logistics, financial and information technology indicators can be derived as

$B_2 = (0.548015, 0.304122, 0.078601, 0.069258)$

$B_3 = (0.365299, 0.263352, 0.18031, 0.190898)$

$B_4 = (0.5, 0.15, 0.25, 0.1)$

The overall evaluation vector is.

$$B = 0.3005, 0.3002, 0.2912, 0.1082^{\circ} \begin{bmatrix} 0.412737 & 0.299328 & 0.153661 & 0.134132 \\ 0.548015 & 0.304122 & 0.078601 & 0.069258 \\ 0.365299 & 0.263352 & 0.18031 & 0.190898 \\ 0.5 & 0.15 & 0.25 & 0.1 \end{bmatrix}$$

$$= (0.449017, \ 0.274164, 0.149328, 0.127507) \quad (6)$$

Based on the previously set rubric set assignments, the overall rating values can be derived.

$$F = VB^T = \begin{bmatrix} 100 \ 75 \ 50 \ 25 \end{bmatrix} \begin{bmatrix} 0.449017 \\ 0.274164 \\ 0.149328 \\ 0.127507 \end{bmatrix} = 76.1180 \quad (7)$$

The overall rating for 2017 is 76.1180, which is between good and poor. The same can be obtained for the overall ratings of 74.6446, 73.4004, 72.8802 and 74.1885 for 2017–2020, respectively.

This agricultural supply chain performance level declines year by year from 2017–2020 and improves significantly in 2021, and in general, this agricultural supply chain still has a large potential for growth.

4.3 Analysis of Results

From the evaluation results, it can be seen that the degree of importance of the indicators of the agricultural products supply chain performance level is: Customer B_1 > Logistics B_2 > Finance B_3 > Information B_4. In order to promote the efficient and stable operation of the agricultural products supply chain, decision makers can focus on the key influencing factors as follows.

(1) Focus on consumer needs
As seen in the previous section, the perceptions and decisions of consumers at the far end of the supply chain have a great degree of influence on supply chain performance. Quick response to consumer demand is helpful for enterprises to understand market changes and improve agricultural logistics network in a targeted manner.

(2) Strengthen the construction of logistics facilities.
The perishable characteristics of agricultural products lead to the cold chain logistics facilities play an important role in the supply chain of agricultural products, increase the investment in the construction of cold chain logistics facilities can reduce the loss

of agricultural products in transit and storage process, so that the product quality can be improved, so that the consumer experience is enhanced, which helps to improve the product reputation and expand the consumer market.

(3) Increase the application of information systems.
The application of information system on the one hand helps to improve the speed of information dissemination, so that enterprises can quickly respond to market demand, on the other hand, it can reduce the rate of information errors and reduce the degree of information asymmetry to promote the close connection of the supply chain nodes.

5 Conclusion

Based on the previous research results on the evaluation of agricultural products supply chain performance, this paper constructs the agricultural products supply chain performance evaluation index system from the perspective of considering the information technology indicators, calculates the index weights by using the factor analysis method, which is more common in the objective assignment method, and uses the fuzzy comprehensive evaluation method to empirically analyze the agricultural products supply chain performance of RT-Mart stores, obtains the comprehensive performance evaluation score, and makes some suggestions from the perspective of key influencing The evaluation score was obtained, and some suggestions were made from the perspective of key factors.

The use of factor analysis in the paper to determine the index weights reduces the subjectivity of the study, and the evaluation results are more scientific and robust. However, the selection of evaluation indicators still needs to be continued to be improved in practical application. The research method and process can be useful for the evaluation of the supply chain of agricultural products in the same type of supermarket chains.

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