Evaluation and Management of Elderly Canteen Providers Based on TOPSIS Modeling

Meiyan Lin[1,a*], Weizhi Tong[2,b]

{mylin17@szu.edu.cn[a], 2200132015@email.szu.edu.cn[b]}

College of Management, Shenzhen University, Shenzhen, PR China, A414, Mingli Building, Lihu Campus, Shenzhen University, 1066 Xueyuan Avenue, Taoyuan Street, Nanshan District, Shenzhen, Guangdong, China[1]
College of Management, Shenzhen University, Shenzhen, PR China, 1214 Wutong Tree, Lihu Campus, Shenzhen University, No.1066 Xueyuan Avenue, Taoyuan Street, Nanshan District, Shenzhen City, Guangdong Province, China[2]

Abstract. The purpose of this paper is to study how to evaluate the suppliers of elderly canteens scientifically and fairly in order to protect the dietary safety of an increasing number of elderly people. Based on the research results of scholars at home and abroad, the study formulates the evaluation index system that should be adopted by the elderly canteens and uses the AHP-entropy combination weighting method to determine the weights of the indicators. It then constructs an evaluation model using the TOPSIS method to comprehensively evaluate the various suppliers in order to select the most suitable partners. The study shows that the most concerned indicator in the selection of suppliers by the elderly canteens is "product quality," while the "reputation" indicator is less concerned. Therefore, the elderly canteens pay more attention to the supplier's "reputation" when choosing suppliers. Additionally, the research results of this paper can also provide reference and a theoretical basis for other elderly canteens' supplier selection.

Keywords: elderly canteen, supplier evaluation, evaluation index, AHP-entropy combined weights.

1 Introduction

The current situation of China's aging population is as follows: According to the 2022 Annual National Development Bulletin of the Aging Career published by the Ministry of Civil Affairs, the number of elderly people aged 60 years and above in the country reached 28,040,000 by the end of 2022, accounting for 19.8% of the total population. Additionally, the population of elderly individuals aged 65 years and above stood at 209,780,000, making up 14.9% of the total population. The dependency ratio for the elderly population aged 65 and over is 21.8%.

However, a significant number of elderly individuals face mobility issues, preventing them from carrying out basic tasks such as grocery shopping and cooking. To address the challenge of ensuring proper nutrition for the elderly, some communities have established dedicated canteens that provide three nutritious meals a day. These canteens prioritize food safety to guarantee that the elderly can enjoy their meals in a safe and healthy manner. The term "elderly canteen" encompasses various forms, including specialized canteens in elderly day care centers and community canteens that offer meal assistance services for the elderly.

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Shenzhen, as a national pilot city for comprehensive reform in the elderly service industry, took proactive measures as early as 2019 by issuing the Work Program on Accelerating Meal Assistance Services for the Elderly. The program aimed to promote the implementation of elderly meal assistance policies by attracting more social entities to provide such services through government guidance and moderate subsidies. To date, Shenzhen has established 195 canteens and subsidized meal sites for the elderly. These include both government-operated facilities and those developed through partnerships with enterprises, such as the well-known Shenzhen restaurant chains Noodle King and Red Lai Village. Eligible elderly individuals can utilize allowances when dining at these establishments, while regular customers pay the original prices.

The procurement of agricultural and sideline products for the elderly canteens is vital for maintaining a reliable food supply chain and ensuring the food safety of all elderly diners, as well as the general consumers. The selection of excellent suppliers plays a crucial role in guaranteeing the quality and safety of the food provided in these canteens. However, there are some challenges in the supplier selection process for elderly canteens. Many canteens frequently change suppliers due to issues related to product quality or price. The emphasis on supply price often leads to price competition among different suppliers. While a canteen may ultimately find a low-priced supplier and achieve short-term cost savings, relying solely on price as a selection criterion can be a double-edged sword. Suppliers may be compelled to lower their prices at the expense of compromising the quality of their products, thereby giving rise to potential food safety concerns. Therefore, it is crucial for elderly canteens to adopt scientific methods to identify long-term suppliers who offer a balance between competitive pricing and high-quality products, while also considering factors such as delivery speed and reputation.

The literature related to this paper focuses on two main areas: supplier evaluation indicators and supplier selection methods. The earliest study of supplier evaluation indicators was in 1966, when Dickson compiled 23 supplier selection indicators by dividing the information provided by purchasing managers and purchasing agents and ranked their importance [1]. Ye explores the supplier's production capacity, business management capability, external environment [2]. Peng believes that supplier evaluation indicators need to be identified using a scientific methodology that is suitable for enterprises in need of them [3]. Based on the theory of supply chain synergy, Li completed the construction of the supplier evaluation index system, and combined the index system with the actual needs of enterprises to design a dynamic evaluation model applicable to manufacturing suppliers [4]. Combined with relevant research theories, it can be found that the selection of suppliers should be adapted to the requirements of the demand side. In this paper, according to the characteristics of the elderly canteens, the consideration of the supplier's service ability and reputation of these indicators is added.

As for the methods of supplier selection, Simić summarized the relevant papers of domestic and foreign scholars for the last 50 years in 2017, and concluded that the frequency of the use of various supplier selection methods [5]. Hajiaghaei-Keshteli uses the Pythagorean Fuzzy TOPSIS method to evaluate vendors and compares it to the traditional TOPSISI method with consistent results [6]. Zhong improves the CRITIC method and uses short-term transaction data for a coal-electricity-integrated firm to evaluate its coal suppliers [7]. Among the methods of supplier selection, both quantitative and qualitative methods alone have certain limitations, so this study uses a combination of qualitative and quantitative methods to determine the

indicator weights. In addition, based on the advantages of the TOPSIS method, which utilizes the raw data more fully and has less information loss, this paper will use the TOPSIS method to construct the model when conducting the evaluation of suppliers.

Finally, in the past, the supplier evaluation and selection problems rarely involve food suppliers, and mainly supermarkets as the main supplier selection problems, about the canteen, restaurant supplier selection problems are rare, but the elderly canteen, community canteens as a hot topic in recent years, its food safety issues can not be ignored, the evaluation and selection of the supplier is also the top priority, therefore, this paper on the evaluation of suppliers of the elderly canteen and the selection of the study is aimed at the elderly canteens supplier selection problems to provide a suitable solution.

2 Evaluation index system for suppliers of canteens for the elderly

The evaluation metrics constructed for supplier selection vary across industries. Not all indicators are suitable for supplier selection in a certain industry. This paper comprehensively refers to the design of evaluation indexes for related food supplier selection problems, and takes into account the characteristics of the elderly canteen itself to construct a reasonable supplier evaluation system for the elderly canteen. In this paper, we believe that the most important indexes for elderly canteens to select suppliers are the five main indexes: product quality, product price, delivery level, service ability and reputation. Therefore, the supplier evaluation index system of the elderly canteen in this paper consists of five primary indexes, under which secondary indexes are set respectively, and the supplier selection is made through the comprehensive evaluation of 12 indexes, as shown in Table 1.

Table 1. Evaluation index system for elderly canteen suppliers.

Level 1 indicators	Level 2 indicators
Product quality	Freshness of products
	Product qualification rate
	Traceability of products
	Product quotation
Product price	Price stability
	Payment cycle
Delivery level	On-time delivery rate
	Product distribution capability
Service capacity	Ordering method
	Returns & exchange service
Reputation	Customers claim
	Historical record of non-compliance

3 Empirical analysis

Taking an elderly canteen in X city as an example, the current supplier selection situation of this elderly canteen is obtained through interviews. The elderly canteen currently has five alternative suppliers, and the following uses the supplier evaluation index system constructed in the previous section, as well as the AHP-entropy combination of weights method to

determine the weights and the TOPSIS comprehensive evaluation method to carry out a comprehensive evaluation of the five suppliers and make the final choice.

3.1 Determination of subjective weights for evaluation indicators

The subjective weights are determined using the AHP method [8], which is mainly based on the expert scoring method, in which the relevant experts (the head of procurement and scholars in the field of supply chain management) compare the relative importance of each evaluation index between the two, and establish a judgment matrix (the judgment matrix of the first-level indexes is shown in Table 2), so as to calculate the subjective weights of each evaluation index.

Table 2. Judgment matrix of supplier-level evaluation indicators.

Level 1 indicators	Product quality	Product price	Delivery level	Service capacity	Reputation
Product quality	1	3	5	5	9
Product price	1/3	1	3	2	7
Delivery level	1/5	1/3	1	1/2	3
Service capacity	1/5	1/3	2	1	3
Reputation	1/9	1/7	1/3	1/3	1

According to the judgment matrix, the weights of the first-level indicators and the weights of the second-level indicators corresponding to each first-level indicator were calculated respectively, and the consistency test was performed to obtain the subjective weight table of the overall indicators, as shown in Table 3.

Table 3. Subjective weighting table for overall indicators.

Level 1 indicators	Level 1 indicator weights	Level 2 indicators	Level 2 indicator weights	Combined subjective weights
Product quality	0.517	Freshness of products	0.64	0.331
		Product qualification rate	0.26	0.134
		Traceability of products	0.1	0.052
Product price	0.238	Product quotation	0.69	0.164
		Price stability	0.23	0.055
		Payment cycle	0.08	0.019
Delivery level	0.089	On-time delivery rate	0.83	0.073
		Product distribution capability	0.17	0.015
Service capacity	0.117	Ordering method	0.13	0.015
		Returns & exchange service	0.87	0.102
Reputation	0.039	Customers claim	0.17	0.007
		Historical record of non-compliance	0.83	0.033

From Table 3, it can be concluded that the most important indicator for elderly canteens in selecting suppliers is product freshness, followed by product offer, which is in line with the consistent supplier selection criteria; however, the two indicators of reputation, customer complaints and history of breach of contract, are given too little weight.

3.2 Determination of objective weights for evaluation indicators

In order to get the initial data of the five alternative suppliers, we interviewed the head of procurement of this elderly canteen in City X, who scored each supplier based on their historical data, and obtained the supplier indicator data in Table 4 (where S1-S5 denote each supplier):

Table 4. Scale of values for alternative supplier indicators.

Level 1 indicators	Level 2 indicators	S1	S2	S3	S4	S5
Product quality	Freshness of products	9	8	8	9	9
	Product qualification rate	90%	91%	90%	87%	92%
	Traceability of products	8	9	7	9	9
Product price	Product quotation	94%	89%	87%	91%	90%
	Price stability	8	9	9	7	9
	Payment cycle	111%	90%	120%	88%	103%
Delivery level	On-time delivery rate	90%	91%	89%	90%	88%
	Product distribution capability	9	8	8	9	8
Service capacity	Ordering method	9	9	9	9	9
	Returns & exchange service	90%	86%	83%	89%	88%
Reputation	Customers claim	13%	23%	24%	19%	21%
	Historical record of non-compliance	20%	16%	29%	10%	25%

The initial data of suppliers in Table 4 were combined according to Eq.(1)

$$Y_{ij} = \left(y_{ij} \right)_{m \times n} \tag{1}$$

normalization is performed to obtain the standardized matrix Table 5:

Table 5. Standardized matrix of supplier indicators.

Level 1 indicators	Level 2 indicators	S1	S2	S3	S4	S5
Product quality	Freshness of products	0.2093	0.1861	0.1861	0.2093	0.2093
	Product qualification rate	0.2000	0.2022	0.2000	0.1933	0.2044
	Traceability of products	0.1905	0.2043	0.1667	0.2043	0.2143
Product price	Product quotation	0.2084	0.1973	0.1929	0.2018	0.1996
	Price stability	0.1905	0.2142	0.2142	0.1667	0.2143
	Payment cycle	0.2168	0.1758	0.2344	0.1719	0.2012
Delivery level	On-time delivery rate	0.2009	0.2031	0.1987	0.2007	0.1964
	Product distribution capability	0.2143	0.1905	0.1905	0.2143	0.1905
Service capacity	Ordering method	0.2000	0.2000	0.2000	0.2000	0.2000
	Returns & exchange service	0.2064	0.1973	0.1903	0.2041	0.2018
Reputation	Customers claim	0.1300	0.2300	0.2400	0.1900	0.2100
	Historical record of non-compliance	0.2000	0.1600	0.2900	0.1000	0.2500

The entropy weighting method is used below to calculate the objective weights of each indicator as shown in Table 6.

As can be seen from Table 6, except for the two secondary indicators of credibility, which have smaller weights, the weights of the other secondary indicators do not differ much.

Table 6. Objective weights of the entropy weighting method for each indicator.

Level 2 indicators	$hj = 1 - Hj$	Objective weights	Subjective weights x objective weight	Portfolio weighting
Freshness of products	0.6294	0.0801	0.2065	0.3261
Product qualification rate	0.6474	0.0824	0.0110	0.1358
Traceability of products	0.6539	0.0832	0.0043	0.0532
Product quotation	0.6311	0.0803	0.0132	0.1620
Price stability	0.6671	0.0849	0.0047	0.0574
Payment cycle	0.6153	0.0783	0.0015	0.0183
On-time delivery rate	0.6457	0.0821	0.0060	0.0737
Product distribution capability	0.6199	0.0789	0.0012	0.0146
Ordering method	0.6476	0.0824	0.0012	0.0152
Returns & exchange service	0.6349	0.0808	0.0082	0.1014
Customers claim	0.8210	0.1044	0.0007	0.0090
Historical record of non-compliance	0.6476	0.0824	0.0027	0.0334

3.3 Determination of weights for combinations of evaluation indicators

Based on the subjective and objective weights of the evaluation indicators derived above, and then based on the following Eq.(2)

$$q_j = \frac{w_j \times e_j}{\Sigma_{j=1}^{n} w_j \times e_j} \; j = (1,2,\ldots,\ n) \tag{2}$$

The combination weights of the evaluation indicators can be calculated, as shown in Table 7.

Table 7. Combination weights of each indicator entropy combination weight method.

Level 2 indicators	Subjective weights	Objective weights	Subjective weights x objective weight	Portfolio weighting
Freshness of products	0.331	0.0801	0.2065	0.3261
Product qualification rate	0.134	0.0824	0.0110	0.1358
Traceability of products	0.052	0.0832	0.0043	0.0532
Product quotation	0.164	0.0803	0.0132	0.1620
Price stability	0.055	0.0849	0.0047	0.0574
Payment cycle	0.019	0.0783	0.0015	0.0183
On-time delivery rate	0.073	0.0821	0.0060	0.0737
Product distribution capability	0.015	0.0789	0.0012	0.0146
Ordering method	0.015	0.0824	0.0012	0.0152
Returns & exchange service	0.102	0.0808	0.0082	0.1014
Customers claim	0.007	0.1044	0.0007	0.0090
Historical record of non-compliance	0.033	0.0824	0.0027	0.0334

3.4 Comprehensive evaluation of suppliers by the TOPSIS methodology

Based on the supplier standardization matrix and combination weights obtained in the previous section, the following TOPSIS method is used to calculate the product of the

standardization matrix and combination weights [9], resulting in the weight matrix for each evaluation indicator, as shown in Table 8. Then the ideal and negative ideal solutions of each index are calculated, and finally the relative distance of each supplier to the ideal solution of the government is calculated.

Table 8. Weighted normalization matrix.

Level 1 indicators	Level 2 indicators	S1	S2	S3	S4	S5
Product quality	Freshness of products	0.0683	0.0607	0.0607	0.0683	0.0683
	Product qualification rate	0.0272	0.0275	0.0272	0.0263	0.0278
	Traceability of products	0.0101	0.0109	0.0089	0.0109	0.0114
Product price	Product quotation	0.0338	0.0320	0.0312	0.0327	0.0323
	Price stability	0.0109	0.0123	0.0123	0.0096	0.0123
	Payment cycle	0.0040	0.0032	0.0043	0.0031	0.0037
Delivery level	On-time delivery rate	0.0148	0.0150	0.0146	0.0148	0.0145
	Product distribution capability	0.0031	0.0028	0.0028	0.0031	0.0037
Service capacity	Ordering method	0.0030	0.0030	0.0030	0.0030	0.0030
	Returns & exchange service	0.0209	0.0200	0.0193	0.0207	0.0205
	Customers claim	0.0012	0.0021	0.0022	0.0017	0.0019
Reputation	Historical record of non-compliance	0.0067	0.0053	0.0097	0.0033	0.0084

Following the steps of TOPSIS, ideal solutions as well as negative ideal solutions were identified for each indicator of the alternative as shown in Table 9:

Table 9. Ideal and negative ideal solutions.

Level 2 indicators	Ideal solution	Negative ideal solution
Freshness of products	0.0683	0.0607
Product qualification rate	0.0278	0.0263
Traceability of products	0.0114	0.0089
Product quotation	0.0312	0.0338
Price stability	0.0123	0.0096
Payment cycle	0.0043	0.0031
On-time delivery rate	0.0150	0.0145
Product distribution capability	0.0031	0.0028
Ordering method	0.0030	0.0030
Returns & exchange service	0.0209	0.0193
Customers claim	0.0012	0.0022
Historical record of non-compliance	0.0033	0.0097

Next, the distance between each supplier and the optimal and worst target values can be calculated based on (3-5) below, which in turn calculates the relative progress of each supplier, as shown in Table 10:

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2}\ (i = 1,2,3,\ldots,\ m) \tag{3}$$

$$D_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2}\ (i = 1,2,3,\ldots,\ m) \tag{4}$$

$$x_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{5}$$

Table 10. Relative progress of posting by supplier.

Supplier	D+	D-	Relative posting progress x
S1	0.00002246	0.00007525	0.7701
S2	0.00006566	0.00003609	0.3547
S3	0.00010914	0.00001631	0.1300
S4	0.00001381	0.00010632	0.8850
S5	0.00002884	0.00008019	0.7355

From the comparison of the relative progress of each supplier, it can be learnt that S4>S1>S5>S2>S3; therefore, supplier S4 should be the best partner of the elderly canteen. According to Table 2, the weights of "product quality" and "product price" in the evaluation of suppliers are 0.517 and 0.238 respectively, which are the two items with the largest weights, and according to the data in Table 4, it can also be seen that the weights of "product quality" and "product price" in the evaluation of suppliers are 0.517 and 0.238 respectively. According to the data in Table 4, it can be seen that supplier S4's "product quality" and "product price" are relatively advantageous in the two first-level indicators of the second-level indicators, so it is a reasonable choice for supplier S4 to be evaluated as the best supplier.

In the analysis of the weights of the evaluation indicators, it can be seen through the determination of the subjective weights of the first-level indicators that the weight of the "product quality" indicator is 0.517, which shows that this indicator is the most important reference factor for elderly canteens to choose their suppliers, and it also shows that in the current environment where the whole country attaches importance to the issue of food safety, the quality of qualified products has become the basic prerequisite for elderly canteens to choose their suppliers. It also shows that under the current environment where the whole nation is concerned about food safety, the quality of products has become the basic premise for elderly canteens to choose when to select suppliers.

The weighting of the "reputation" indicator is only 0.039, indicating that canteens do not pay enough attention to the "reputation" indicator when choosing suppliers. The main reason is that most of the suppliers of agricultural and sideline products to be selected by the canteens are small enterprises or self-employed, therefore, the corporate reputation of these suppliers is generally not strong enough to become the main evaluation criterion for the canteens when they select suitable suppliers; moreover, the definition of the evaluation indicator of "reputation" is relatively vague, and there is no uniform standard for evaluation, which may have a negative impact on the canteens. In addition, the definition of the evaluation index "reputation" is relatively vague and there is no uniform standard in the evaluation, which may cause some difficulties for the elderly canteens in selecting suppliers.

4 Conclusion

In this paper, we comprehensively consider all aspects of the characteristics of the elderly canteen and construct a supplier evaluation index system for the elderly canteen. We also propose how to select and evaluate suppliers based on the TOPSIS method. Taking an elderly

canteen in X city as an example, we carry out empirical analyses and calculate the advantages and disadvantages of each supplier to determine the best supplier selection for this elderly canteen. This provides references for supplier management issues in this elderly canteen and other canteens in the future. Additionally, the research method and evaluation system of this paper serve as a reference for other supplier selection problems, such as supermarket supplier selection. In the future, we will continue to conduct in-depth research, improve the evaluation index system, gather more accurate and reliable data, and enhance the credibility of the supplier evaluation results.

In response to the results derived from this paper, we also propose some countermeasures. First, it is recommended that senior canteens further emphasize product quality as the basic premise for selecting suppliers. A quality management mechanism can be established with suppliers to ensure that product quality meets the standards. Secondly, redefine and clarify the evaluation index of "credibility", and clarify the relevant evaluation criteria with suppliers. Consideration can be given to using suppliers' operation history, customer satisfaction and partnership as the basis of the evaluation index.

This paper also has some limitations that can be addressed through further refinement. Firstly, the evaluation system for supplier selection in elderly canteens lacks comprehensive research, resulting in some deficiencies that need improvement. Secondly, the current supplier evaluation index system is specifically designed for elderly canteens, focusing on the evaluation and selection of agricultural and sideline product suppliers. In the future, the indicator system can be further modified and enhanced to increase its applicability to a broader range of scenarios.

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