A Multi-attribute Classification Method on Fresh Agricultural Products

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***Abstract*—By analyzing the current situation of inventory management of enterprises of fresh agricultural products in Handan city as an example and based on the nature of fresh agricultural products, this paper points out the defect and disadvantage of single classification standard of ABC classification method in inventory classification; and applies the improved classification method based on ABC classification method and multi-attribute strategic method. By selecting multiple standards as sorting criterion, such as storage facility, influence of stockout, seasonality and availability, the paper studies the classification method of inventory management in order to reduce the logistic cost of fresh agricultural products in logistic system.**

***Inde Terms*—fresh agricultural product, inventory management, ABC classification method, multi-attribute strategic method.**

I. INTRODUCTION

Fresh agricultural products mainly include vegetable, fruit, flower and plant, meat, egg, milk, aquatic products and other fresh primary products. They are generally called as "Three Fresh" (fruit and vegetable, meat and aquatic product). Being perishable and vulnerable is the main nature of fresh agricultural products. Besides, seasonality and regionalism, rigorous preservation conditions during storage and transportation and freshness-sensitive product value also constitute part of characteristics. Freshness is an important index to determine the value of fresh agricultural products.

This paper is the further study on inventory management of enterprises of fresh agricultural products basic on current situation of inventory management of these enterprises in Handan city which is located in middle and south area of Hebei Province and composed by 19 countries (downtown and country) and the important base of fresh agricultural products in Hebei province. With the rapid development of Chinese economy and entry into WTO, fresh agricultural product industry of Handan city encounters important opportunity and great challenge. How to provide the quality fresh agricultural products for customers at the lowest price becomes an important question for enterprises to solve. Inventory control is important to lower down the logistic cost of fresh agricultural products in logistic system because a large inventory not only occupies great amount of capital and reduces the profit of enterprise, but also may result in loss caused by the perishable nature of fresh agricultural products.

The main contribution of the work is to integrate ABC classification method with multi-attribute strategic method to develop a novel approach for classifying the fresh agricultural products. We apply the developed approach to recognize out the management priorities of different kinds of fresh agricultural products, which is helpful to reduce the logistic cost of fresh agricultural products in logistic system.

The rest of the paper is organized as follows. Section II reviews some related studies. Section III presents the proposed method for classifying the fresh agricultural products. Section VI concludes the work.

II. RELATED STUDIES

Inventory study of enterprises of fresh agricultural products is an important branch of inventory study of perishable products which are featured by being perishable. Being perishable means intrinsic value of products is decreased by corruption, damage, reduced utility value and marginal value [1]. Besides fresh agricultural products, perishable products in life also include ethyl alcohol, medicine, gasoline and so on. Without special storage device and reasonable inventory control strategy, perishable products would be greatly consumed.

Inventory study of perishable products started early in foreign countries. Scholars have made various kinds of expansion studies on the basics of inventory study of perishable products initiated by Ghare (1963) in 1960s, and greatly enriched the inventory control theory of perishable products. However, current inventory studies of perishable products only address general situations without detailed classification according to the features of various perishable products, as a result, current inventory theories of perishable products cannot be directly applied to the inventory optimization of specific perishable

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products [2]. Scholar Whitin (1957) is the first one to study the inventory of perishable products. He firstly studied the end of inventory cycle in which products are corrupted [3].

China is a late comer of inventory study of fresh agricultural products and the studies are scattered. At present, most studies of inventory control models by modern logistic theories and methodologies are based on the inventory theory of common products and perishable products. Li (2004) et al introduced a 3-parameter function Weibun to describe the properties of perishable products, which can provide excellent simulation of deterioration. They established the optimized subscription strategy model of perishable products within limited time, and then obtained the optimized subscription strategy by forward iterative approximation method [4]. Tekin et al (2001) derived the expressions for the key operating characteristics of a lost sales perishable inventory model, and found the age-based policy is superior to the stock level policy for slow moving perishable inventory systems with high service levels [5]. Coelho and Laporte (2014) discussed the main features of the problem arising in the joint replenishment and delivery of perishable products [6]. Herbon et al (2014) studied the perishable inventory management with dynamic pricing using RFID-supported devices [7]. Piramuthu and Zhou (2013) incorporated item-level quality information to build a perishable inventory management model, finding that the incorporation of item quality increases the resulting overall profit to the retailer [8]. Cai and Chen (2013) considered a supply chain in which a producer supplies a fresh product, through a thirdenvelopment analysisPL) provider, to a distant market where a distributor purchases and sells it to end customers [9]. Hadi-Vencheh and Mohamadghasemi (2011) proposed an integrated fuzzy analytic hierarchy process-data envelopment analysis (FAHP-DEA) for multiple criteria ABC inventory classification[10]. Pan and Hua studied an inventory model for a deteriorating item with price sensitive demand is developed under deterioration rate,which is assumed to follow weibull distribution with known parameter [11]. Xiu and Chen based on the characteristics that fresh agricultures product will deteriorate, they construct a time-varying consumer utility model considering the greenness and price of the fresh agricultural products with utility theory, which depicts the effect the fresh-keeping has on the consumers purchase decision [12].

By analyzing domestic and overseas studies of related field, it can be found that:

1) Foreign studies are usually related with practice while domestic studies are rather abstract and the theories are seldom related with the practical situations of enterprises.

2) In summary, the studies on the inventory of fresh agricultural products mainly address the balance between ordering volume and supply of enterprise. The aim is to achieve the balance of supply and demand in the enterprise with the emphasis on the control of inventory volume.

Currently, enterprises of fresh agricultural products do the classification by ABC method. According to the capital occupation of inventory, enterprises roughly classify the products into A, B and C type for management. ABC classification method has always been considered by enterprises as an effective fundamental analytical method. This method is easy to be operated and widely applied to multiple fields, such as production management, material management, equipment management, quality management, value engineering and sales management. However, as ABC classification method only has a single standard which is the accumulated amount of fresh agricultural products, it is only a kind of rough classification method. In real life, capital occupation alone cannot be treated as an objective standard to judge the importance of some kind of material. As there is a great variety of fresh agricultural products, one-shot classification is unreasonable and difficult to be controlled. ABC classification method alone cannot meet the actual requirements of analysis. Therefore, many scholars started to seek for other methods to make up the defect of ABC method. This paper introduces the improved classification method based on ABC method and multi-attribute method to optimize the inventory management of enterprises of fresh agricultural products, and has solved some following problems in the inventory management: 1) Reduce capital occupation and lower down the cost of inventory; 2) Promote the balance of supply and demand; 3) Realize scientific inventory management and lower down the cost of manpower and material.

Ⅲ. The Proposed Method

A. The Exiting Methods

I) ABC classification method

ABC method usually classifies the inventory into 3 types by the type and capital occupation (Table Ⅰ). The materials occupying great amount of capital are A type; medium amount B type and small amount C type. The amount becomes the measurement to determine the importance of materials. That is a material of lower price and greater usage amount may be more important than the material of higher price and smaller usage amount.

TABLE I
ABC CLASSIFICATION METHOD

	Number of Type	Accumulated Capital	Type Management
A	10%—20%	60%—80%	Give more importance
B	30%—40%	20%—30%	Give importance
C	50%—70%	5%—15%	Treating generally

II) Multi-attribute decision-making method

Multi-attribute decision-making method is designed to solve complicated and multi-criterion matters by qualitative and quantitative methods after further studying the relation between influencing factors and decision-making target [13-14]. We often meet the decision-making matters in real life, for example, choosing scenic spots and majors. Before making a final

decision, decision maker must consider multiple factors or criterions from many aspects and then makes the decision basic on these criterions.

As an effective tool to comprehensively evaluate various systems and optimize multi-criterion decision-making matters, multi-attribute decision-making method has been widely applied to domestic and overseas economy, society and engineering [15-17]. The application of multi-attribute decision-making method to inventory management can provide more precise decisions by qualitative and quantitative analysis on the influence of various factors on material management.

B. The Combined Method Based on ABC and Multi-Attribute Decision-Making Method

Based on the properties of fresh agricultural products and to provide a kind of practical inventory management method for enterprises of fresh agricultural products, this paper will discuss how to classify fresh agricultural products, and propose the suggestion for inventory management method of fresh agricultural products. The study aims to provide a kind of classification method combining qualitative and quantitative methods, and provide ideas for enterprises to improve the supply level of spot goods and save cost of capital by optimizing inventory through classification management. This paper classifies the fresh agricultural products by the following steps.

I) Applying ABC method to recognize Type A products

The paper conducts ABC classification of fresh agricultural products in inventory with capital occupation amount as the standard. Focus is given to the products of type A and type B. Managers may spend more time on the products occupying great amount of capital. According to the definition of ABC classification method, the classification of fresh agricultural products in inventory as capital occupation amount as standard is shown in Table Ⅱ:

TABLE II
ABC C LASSIFICATION OF FRESH AGRICULTURAL PRODUCTS IN STOCK

	Type of Fresh Agricultural Products	Accumulated Capitals	Type Management
A	10%—20%	60%—80%	Give more importance
B	30%—40%	20%—30%	Give importance
C	50%—70%	5%—15%	Treating generally

II) Classification of Type A by multi-attribute decision-making method

Those fresh agricultural products which occupy large amount of capital are the focus of inventory management. The second step of classification method introduced in this paper is to classify Type A products. Based on the actual inventory of fresh agricultural products of enterprises and by consulting experts, this paper has chosen 4 factors as the criterion of classification, which has great influence on the products. They are storage device, stockout influence, seasonality and availability.

(1) Storage device: as fresh agricultural products are putrescible and vulnerable, daily inventory management has high demand for storage device and many of them require cold storage. If without refrigeration house or refrigeration condition is poor, the products will corrupt and cannot be sold, which results in great loss and waste.

(2) Stockout influence: it means the production of fresh agricultural products cannot meet the demand of market, and thereby causes influence on enterprise. These influences may affect the capital, brand image and the life of residents.

(3) Seasonality: fresh agricultural products are seasonal products whose production, price and sales volume varies with seasons.

(4) Availability: it means the accessibility to these fresh agricultural products, for example, some products are far away and it may spend a few days in purchasing, so the time of purchasing is uncontrollable. Besides, some area fresh agricultural products are hard to be accessed when resources are tense due to climate factors and low production from farmers.

III) Establish a multi-attribute decision-making structural model

After classification criterions are chosen, we are able to establish a multi-attribute decision-making structural model. As there are a huge variety of fresh agricultural products, it will be time-consuming to conduct matrix operation for each one. Therefore, this paper has classified the fresh agricultural products into 5 types according to definition before establishing the multi-attribute decision-making structural model. These 5 types are vegetable & fruit, meat, aquatic products, egg and milk, flower and plant.

The following is the 3-layer multi-attribute decision-making structural model of fresh agricultural products with the importance of products as target layer. It is shown in Fig. 1:

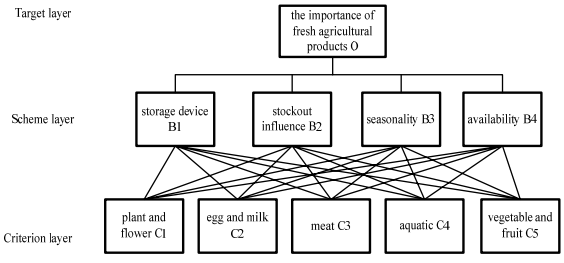

Figure 1. Importance 3-layer multi-attribute decision-making structural model of fresh agricultural products

In Fig.1, target layer is the importance of fresh agricultural products O; scheme layer includes 5 types of fresh agricultural products in Handan city: plant and flower C1, egg and milk C2, meat C3, aquatic C4, vegetable and fruit C5. Criterion layer includes storage device B1, stockout influence B2, seasonality B3 and availability B4.

VI) Establish judgment matrix and conduct consistency check

To determine the composition rule of matrix according to multi-attribute decision-making method, we will

separately establish a judgment matrix of criterion-layer-target-layer, scheme-layer-criterion-layer.

(1) Firstly, we investigated the inventory of enterprises of fresh agricultural products in Handan city and invited experts to give score according to these 4 criterions. The judgment matrix of criterion-layer B to target layer O is shown in table Ⅲ:

TABLE III
JUDGMENT MATRIX OF CRITERION LAYER B TO TARGET LAYER O

O--B	Storage Device B1	Stockout Influence B2	Seasonality B3	Availability B4
Storage Device B1	1	1/3	1/5	1/7
Stockout Influence B2	3	1	1/3	1/5
Seasonality B3	5	3	1	1/3
Availability B4	7	5	3	1

CI=0.039

Check 4-order random consistency index RI=0.90

$$CR \equiv \frac{CI}{RI} \equiv 0.043 < 0.1$$

Consistency check is passed.

(2) Calculate the weight vector of scheme layer to

TABLE IV
WEIGHT OF CRITERION LAYER TO TARGET LAYER

Criterion	Storage Device B1	Stockout Influence B2	Seasonality B3	Availability B4
Weight	0.0553	0.1175	0.2622	0.5650

Criterion layer and conduct consistency check:

1) Scheme layer to criterion layer—judgment matrix of storage device B1 is shown in table Ⅴ:

TABLE V
JUDGMENT MATRIX OF STORAGE DEVICE B1 SCHEME LAYER TO CRITERION LAYER

Storage Device B1	Flower C1	Egg and milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Flower C1	1	1/2	1/5	1/4	1/8
Egg and milk C2	2	1	1/3	1/2	1/4
Meat C3	5	3	1	2	1/2
Aquatic C4	4	2	1/2	1	1/3
Vegetable and fruit C5	8	4	2	3	1

The largest eigenvalue λ=5.0386 was obtained. After uniformization of eigenvectors, weights of corresponding scheme layer are shown in table Ⅵ:

TABLE VI
SCHEME LAYER TO CRITERION WEIGHT OF STORAGE DEVICE

Scheme	Flower C1	Egg and milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Weight	0.0479	0.0924	0.2619	0.1616	0.4361

CI(1)=0.00965

Check 5-order random consistency index RI=1.12

$$CR \equiv \frac{CI}{RI} \equiv 0.0086 < 0.1$$

Consistency check is passed.

2) Scheme layer to criterion—judgment matrix of stockout influence B2 is shown in table Ⅶ.

The largest eigenvalue λ=5.0280 was obtained. After uniformization of eigenvectors, weights of corresponding scheme layer are shown in tableⅧ:

CI(2)=0.0070

Check 5-order random consistency index RI=1.12

$$CR \equiv \frac{CI}{RI} \equiv 0.00652 < 0.1$$

TABLE VII
SCHEME LAYER TO CRITERION—JUDGMENT MATRIX OF STOCKOUT INFLUENCE B2

Stockout influence B2	Flower C1	Egg and milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Flower C1	1	2	5	3	7
Egg and milk C2	1/2	1	3	2	5
Meat C3	1/5	1/3	1	1/2	2
Aquatic C4	1/3	1/2	2	1	3
Vegetable and fruit C5	1/7	1/5	1/2	1/3	1

TABLE VIII
WEIGHT OF SCHEME LAYER TO STOCKOUT INFLUENCE

Scheme	Flower C1	Egg and milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Weight	0.0524	0.1524	0.0887	0.2619	0.4446

Consistency check is passed.

TABLE IX
SCHEME LAYER TO CRITERION-- JUDGMENT MATRIX OF SEASONALITY

Seasonality B3	Flower C1	Egg and Milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Flower C1	1	1/2	1/4	1/3	1/8
Egg and Milk C2	2	1	1/2	1/2	1/4
Meat C3	4	2	1	2	1/2
Aquatic C4	3	2	1/2	1	1/3
Vegetable and fruit C5	8	4	2	3	1

3) Scheme layer to criterion—judgment matrix of seasonality B3 is shown in table Ⅸ:

The largest eigenvalue λ=5.0399 was obtained. After uniformization of eigenvectors, weights of corresponding scheme layer are shown in table Ⅹ:

TABLE X
SCHEME LAYER TO CRITERION WEIGHT OF AVAILABILITY

Scheme	Flower C1	Egg and Milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Weight	0.0544	0.1036	0.2385	0.1580	0.4456

$$CI(3)=0.010$$

Check 5-order random consistency index RI=1.12

$$CR \equiv \frac{CI}{RI} \equiv 0.0089 < 0.1$$

Consistency check is passed.

4) Scheme layer to criterion—judgment matrix of availability B4 is shown in table Ⅺ:

TABLE XI
SCHEME LAYER TO CRITERION—JUDGMENT MATRIX OF AVAILABILITY B4

Availability B4	Flower C1	Egg And Milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Flower C1	1	1	1/3	1/2	1/4
Egg and Milk C2	1	1	1/3	1/2	1/4
Meat C3	3	3	1	2	1/2
AquaticC4	2	2	1/2	1	1/2
Vegetable and fruit C5	4	4	2	2	1

The largest eigenvalue λ=5.0394 was obtained. After uniformization of eigenvectors, weights of corresponding scheme layer are shown in table Ⅻ:

TABLE XII
SCHEME LAYER TO CRITERION WEIGHT OF AVAILABILITY

Scheme	Flower C1	Egg and Milk C2	Meat C3	Aquatic C4	Vegetable and fruit C5
Weight	0.0888	0.0888	0.2637	0.1688	0.3899

$$CI（4）=0.0098,$$

Check 5-order random consistency index RI=1.12

$$CR \equiv \frac{CI}{RI} \equiv 0.0088 < 0.1$$

Consistency check is passed.

(3) From the above results, we can calculate the combination weight of scheme layer C to target layer o through Matlab, as shown in table XIII:

TABLE XIII
COMBINATION WEIGHT TABLE OF SCHEME LAYER TO TARGET LAYER

Importance of fresh agricultural products O	Storage device B1	Stockout influence B2	Season -ality B3	Availab -ility B4	Combi -nation Weigh -t
α	0.0553	0.1175	0.2622	0.5650	
CI	0.00965	0.0070	0.010	0.0098	
Flower C1	0.0479	0.0524	0.0544	0.0888	0.0732
Egg and milk C2	0.0924	0.1524	0.1036	0.0888	0.1003
Meat C3	0.2619	0.0887	0.2385	0.2637	0.2364
Aquatic C4	0.1616	0.2619	0.1580	0.1688	0.1765
Vegetable and fruit C5	0.4361	0.4446	0.4456	0.3899	0.4135

Consistency check of combination weight vector is conducted as follow:

$$CI^*=[CI(1), CI(2), CI(3), CI(4)]^*\alpha=0.0095$$

$$RI^*=[1.12,1.12,1.12,1.12]^*\alpha=1.12$$

$$CR^* \equiv \frac{CI^*}{RI^*} \equiv 0.0085 < 0.1$$

Combination consistency check is passed.

It can be seen from the ranking of combination weights in table 14 that in the inventory management of fresh agricultural products, vegetable and fruit should be given focus and the next is meat, followed by aquatic products, egg and milk and flower.

VI. CONCLUSION

At present, enterprises of fresh agricultural products carry out inventory classification management by ABC classification method. According to the traditional ABC classification method, the classification standard is the capital occupation of inventory products. The singleness of classification standard makes this method one-sided and rough; there is a great variety of fresh agricultural products. If there is only the rough classification of A, B and C type, inventory manager will have no more energy for those most important fresh agricultural products. In this paper, we firstly made ABC classification by capital occupation, then carry out multi-attribute decision-making analysis of type A fresh agricultural products to obtain weight, and then grant corresponding weights to fresh agricultural products of each type. This classification method is more detailed and thereby avoids the phenomenon that some special products are neglected.

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