Research on Distribution Network Optimization of Fresh Agricultural Product Considering Combined Freshness-keeping

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Abstract

In order to meet the market's demand for quality and diversification of fresh agricultural product, a distribution network with network node that provides different grade of freshness-keeping service is designed. Combining the characteristic that fresh agricultural product freshness declines with time and the grade of freshness-keeping service, on the basis of constructing the freshness-keeping service level function, the demand function related to the sale price, freshness and freshness-keeping service is established. Then the 0-1 mixed integer programming model with the goal of maximizing profit is constructed. Results show that the combined freshness-keeping service of distribution network can improve the fresh agricultural product freshness-keeping level, and then improve fresh agricultural product freshness to stimulate consumer demand and maximize distribution network management profit.

Keywords

Fresh agricultural product; Combined freshness-keeping service; Distribution network.

1. Introduction

The problem of fresh agricultural products' preservation in distribution and circulation has always been the bottleneck that enterprises need to break through in operation. Fresh enterprises invest a large amount of money in the production area and stores to build preservation facilities，such as freezing and heat preservation，to improve the freshness of products and expand consumer demand. At present, food preservation mainly focuses on the operation part of the distribution network or some network nodes, which provide specific preservation services. However, there are still some problems such as high consumption rate of agricultural products and excessive increase of preservation cost. Therefore, the distribution of fresh agricultural products need to keep efficient fresh from the overall design of distribution network which consider different nodes that provide different levels of fresh service and form a distribution network combination preservation services. So that it can rapid response to market demand for the quality and diversity of fresh agricultural products.

The distribution of fresh agricultural products have been concerned by scholars. Freshness decreases gradually in processing, storage, transportation and sales. Scholars firstly paid attention to the influence of perishability of fresh agricultural products on distribution network. Literature [1-6] all studied the design of distribution network of fresh agricultural products on the basis of describing the freshness of agricultural products that attenuates with time or is related to temperature. Secondly, scholars have also noted that freshness preservation investment can improve the freshness of agricultural products which directly affects the market demand and the operating profit of the distribution network. So it is particularly important to invest capital to enhance freshness. From the aspect of the control of food wastage, Cai et al. [7] assumed that the deterioration of fresh products would reduce the its quantity and quality at the same time. Based on this assumption, they studied the optimization of fresh supply chain under the preservation efforts of suppliers. Cao Yu et al. [8] studied the optimal decision problem of fresh product supply chain on the basis of constructing fresh product freshness function related to supplier's preservation efforts and transportation time. The results showed that profit and freshness sensitivity coefficient changed in the same direction. Chen et al. [9] established a perishable product freshness function related to loss rate, preservation effort and time by integrating preservation effort decision, and studied the decision problem of overall revenue maximization. Shu-yun wang et al. [10] firstly introduced factors on fresh preservation efforts and time to describe all the quality of the product loss. Then the demand synthetically consider the influence of price and the freshness. Finally, average profit maximization as the objective function, the optimal decisions of fresh investment and other issues were studied. Xiong Feng et al. [11] proposed the freshness function of fresh agricultural products after the preservation efforts of cooperatives and core enterprises. Based on the influence of consumers' fresh preference and price sensitivity on market demand, they studied the investment decisions of preservation for supply chain members. Wang et al. [12] established a demand function linearly related to price, freshness improvement level and freshness preservation efforts, and pointed out that improving freshness can stimulate demand and improve economic benefits. The aforementioned literature shows that the fresh investment can improve the freshness of agricultural products, stimulate the demand and then drive the increase of network profits. However, the fresh-keeping service is replaced by the single-factor parameter of fresh-keeping effort, which blurs the supply source of fresh-keeping service. In addition, the function of different nodes in the distribution network which different levels provide fresh-keeping service is failed to distinguish. With the quality and diversification of consumer demand and the transformation and upgrading of distribution channels, the distribution network is finally manifested as a full-link distribution form of resource integration. Each network node provides diversified combination preservation services of different levels, which improves the freshness of fresh agricultural products, stimulates consumer demand, and creates new profit growth points [13-15]. Therefore, it is necessary to grasp the new changing rules of market demand, and explore the optimal combination of network node preservation service functions from the overall design of fresh agricultural products distribution network. The freshness of products and the operating profit of fresh enterprises are improved.

Firstly, This article analysis the relationship of agricultural product freshness and distribution network combination preservation service. Secondly, The fresh degree function affected by freshness service was constructed on the basis of service level functions. Then, the demand function related to the selling price, freshness and service of fresh agricultural products are proposed. Finally, the distribution network optimization model aiming at profit maximization is established.

2. Description

2.1 Problem Description

In the agricultural produce distribution network with different levels of fresh-keeping services, agricultural products can be sent to consumers through any sub-link. Each network node on the sub-link can provide diversified fresh-keeping services with different levels to meet consumers' diversified demands. With multiple agricultural producing area, multiple distribution centers, single species, a number of sales outlets in the distribution network with capacity limits, need to select distribution link and the corresponding traffic distribution. Distribution link and the corresponding freight amount are selected in the distribution network which constituted by multiple agricultural producing area, distribution centers, stores, single species, and capacity limits. the origin of agricultural products, distribution centers and sales outlets decide whether to offer services and the level of fresh-keeping service, which make the whole distribution network operating profit maximization.

2.2 Hypothesis

(1) Each distribution sub-link is independent of each other, that is, consumers lost from one distribution sub-link will not consume through other distribution sub-links.

(2) The traffic volume on each distribution sub-link must meet the minimum and maximum traffic volume limits.

(3) The demand of sales stores is approximately regarded as the final market demand. The market demand is linearly related to the selling price, freshness and freshness service of fresh agricultural products.

(4) All market demands can be met. The output is equal to the market demand. The inflow of each node is equal to the outflow. There is no shortage of goods, transportation delay and inventory backlog.

(5) Time of production, loading, unloading, and handling shall not be considered.

2.3 Parameter Determination

F : the set of producing areas， $F=\{1,2,3,...,f^{'}\}$， $f\in F$;

D : the set of distribution centers， $D=\{1,2,3,...,d^{'}\}$， $d\in D$;

S : the set of stores， $S=\{1,2,3,...,s^{'}\}$， $s\in S$;

Q : the set of distribution sub-link, $Q=\{q_1,q_2,q_3,...,q_m^{'}\}$, $q\in Q$; $Q=\{q_{fs},q_{fd},q_{ds}\}$, q_{fs} denotes from a producing area f to a store s, q_{fd} denotes from a producing area f to a distribution center d, q_{ds} denotes from a distribution center d to a store s;

SE : the set of fresh-keeping service level of producing areas, distribution centers and stores, $SE=\{1,2,3,...,se^{'}\}$， $se\in SE$;

R_s^0 : the initial demand of the store s ;

R : The total demand of all stores;

P : Selling price of fresh agricultural products;

e : demand price elasticity coefficient;

α : freshness value of fresh agricultural products;

β : Sensitivity coefficient of fresh agricultural products′ freshness;

TSE : Fresh-keeping service level function;

δ : Fresh-keeping service sensitivity coefficient;

L : Minimum freight amount limits for each distribution sub-link;

H : Maximum freight amount limits for each distribution sub-link;

G_f : The production in a factor f ;

$C_1^{'}$: Transportation cost of unit quantity and time;

$C_2^{'}$:The cost of fresh-keeping service;

h : Unit cost of production;

t_{fs} : The time from producing area f to store s ;

t_{fd} :The time from producing area f to distribution centers d ;

t_{ds} : The time from distribution centers d to a store s ;

T_1 : The commitment of delivery time from factory to store;

T_2 : The commitment of delivery time from distribution center to store;

$q_{fs}=1$: 0-1 integer variable， Represents whether send products from factor f to the store s， If send products from factor f to the store s, then $q_{fs}=1$; otherwise $q_{fs}=0$;

q_{fd} : 0-1 integer variable， Represents whether send products from factor f to the distribution centers d， If send products from factor f to the distribution centers d, then $q_{fd}=1$; otherwise $q_{fd}=0$;

q_{ds}: 0-1 integer variable, Represents whether send products from distribution centers d to the stores s, If send products from rom distribution centers d to the stores s then $q_{ds}=1$; otherwise $q_{ds}=0$;

Y_{fs}: The amount of transportation from factor f to store s;

Y_{fd}: The amount of transportation from factor f to distribution center d;

Y_{ds}: The amount of transportation from distribution center d to store s;

SE_{fse}:0-1 integer variable, represents factor f whether to provide the level of se Fresh-keeping service, if factor f provide se Fresh-keeping service, then $SE_{fse}=1$, otherwise $SE_{fse}=0$;

SE_{dse}:0-1 integer variable, represents the distribution center d whether to provide the level of se Fresh-keeping service, if the distribution center d provide se Fresh-keeping service, then $SE_{dse}=1$,otherwise $SE_{dse}=0$;

SE_{sse}:0-1 integer variable, represents the store s whether to provide the level of se Fresh-keeping service, if the store s provide se Fresh-keeping service, then $SE_{sse}=1$, otherwise $SE_{sse}=0$.

3. Model formulation And Solution

3.1 Fresh-keeping Service Level Function

In the distribution network of fresh products, each network node provides different levels of diversified fresh-keeping services. The more the fresh-keeping service content, the higher the fresh-keeping service level, that is, The realization of the single factor of fresh-keeping effort comes from the diversified combination of different fresh-keeping services levels. So the combines of different fresh-keeping services in the distribution network determine the fresh-keeping service level. The fresh-keeping service level expressed as a function of whether to choose the fresh-keeping service level of each node according to reference[16]. The basic form is

$$TSE' = \sum_{se \in SE} SE_{se} \times (1+k)^{se} \tag{1}$$

When fresh agricultural products are delivered to the store s, the function of total fresh-keeping service level provided by all nodes passing through is

$$TSE(SE_{fse}, SE_{dse}, SE_{sse}) = \delta \times \frac{\sum_{f \in F}\sum_{se \in SE} SE_{fse} \times (1+k)^{se} + \sum_{d \in D}\sum_{se \in SE} SE_{dse} \times (1+k)^{se} + \sum_{se \in SE} SE_{sse} \times (1+k)^{se}}{1 \times (1+k)^{se'} \times (f' + d' + s')}, \quad s \in S \tag{2}$$

k refers to the extent that the fresh-keeping quality increases with the increase of the fresh-keeping service level, $0<k<1$.

$0<\delta<1$, $\sum_{se \in SE} SE_{fse} \le 1, \sum_{se \in SE} SE_{dse} \le 1, \sum_{se \in SE} SE_{sse} \le 1, \ \forall f \in F, d \in D, s \in S$, represents that each factor, distribution center and store can only provide one level fresh-keeping service at most.

3.2 Freshness Function

Fresh produce is perishable and is freshest when picked from the field which freshness value can be set as 1. On the one hand, when fresh produce is transported from the factory to the market, the freshness will decrease with the passing of transportation time. On the other hand, in manufacturing, storage, transportation and other links, each network node provides different levels of fresh-keeping services with different contents, which can guarantee the freshness of fresh agricultural products to some extent. Although the freshness of fresh agricultural products cannot reach the level at the time of picking in the field, it can improve the freshness of fresh agricultural products when they are delivered to stores, that is, the maximum value of freshness attenuation of fresh agricultural products will decrease[17-18]. The more content of fresh-keeping service, the higher the level of fresh-keeping service, the quality of fresh-keeping service and the freshness of fresh agricultural products will be. According to literature [19-20], Considering that the fresh-keeping service level adopts the form of product and has a linear relationship with the target variable, the function of the freshness attenuation extreme value of fresh agricultural products when they are finally delivered to the store is set as

$$\gamma_s = \left[1 - m \times TSE(SE_{fse}, SE_{dse}, SE_{sse})\right]\gamma_0, \quad s \in S \tag{3}$$

γ_0 represents the maximum value of freshness attenuation when fresh agricultural products are delivered to stores without providing fresh-keeping service. The greater the value is, the lower the freshness value of fresh agricultural products is when delivered to stores. m is the sensitivity coefficient of freshness attenuation extremum of fresh-keeping service and $0 < m < 1$.The formula shows that the higher the level of fresh-keeping service is, the smaller the maximum value of freshness attenuation is. By substituting the function of fresh-keeping service level into the above equation, it can be obtained

$$\gamma_s = \left[1 - m \times \delta \times \frac{\sum_{f \in F}\sum_{se \in SE} SE_{fse} \times (1+k)^{se} + \sum_{d \in D}\sum_{se \in SE} SE_{dse} \times (1+k)^{se} + \sum_{se \in SE} SE_{sse} \times (1+k)^{se}}{1 \times (1+k)^{se'} \times (f' + d' + s')}\right]\gamma_0, \quad s \in S \tag{4}$$

Based on this, the freshness of fresh agricultural products is expressed as a function of whether a distribution sub-link is selected or not, and the corresponding transport time and freshness preservation service. Referring to literature [20], the assumption method of describing freshness attenuation with time acceleration is described, and the freshness function $\alpha(t)$ in this paper is set as

$$\alpha(t_s) = \alpha_0 - \gamma_s \left(\frac{t}{T}\right)^{0.5} \tag{5}$$

For each store s

$$t_s = \sum_{f \in F} q_{fs} \times t_{fs} + \sum_{f \in F}\sum_{d \in D} q_{fd} \times t_{fd} + \sum_{d \in D} q_{ds} \times t_{ds}, \quad s \in S \tag{6}$$

$$T_s = \sum_{f \in F} q_{fs} \times T_1 + \sum_{f \in F}\sum_{d \in D} q_{fd} \times q_{ds} \times T_2, \quad s \in S \tag{7}$$

α_0 represents the initial freshness value of fresh agricultural products, $0 < \alpha_0 < 1$indicates that fresh agricultural products are not in the freshest state in the picking place when they are distributed from the factory, which is more in line with the actual situation, and $0 < \gamma_s \le \gamma_0 \le \alpha_0$.

Therefore, when delivered to stores s, the function of fresh agricultural products freshness is decreased with the passing of transportation time and improved with the enhancement of fresh-keeping service

$$\alpha(t_s) = \alpha_0 - \left[1 - m \times \delta \times \frac{\sum_{f \in F}\sum_{se \in SE} SE_{fse} \times (1+k)^{se} + \sum_{d \in D}\sum_{se \in SE} SE_{dse} \times (1+k)^{se} + \sum_{se \in SE} SE_{sse} \times (1+k)^{se}}{1 \times (1+k)^{se'} \times (f' + d' + s')}\right] \times \gamma_0 \times \left(\frac{\sum_{f \in F} q_{fs} \times t_{fs} + \sum_{f \in F}\sum_{d \in D} q_{fd} \times t_{fd} + \sum_{d \in D} q_{ds} \times t_{ds}}{\sum_{f \in F} q_{fs} \times T_1 + \sum_{f \in F}\sum_{d \in D} q_{fd} \times q_{ds} \times T_2}\right)^{0.5}, \quad s \in S \tag{8}$$

3.3 Demand Function

According to hypothesis(3), the demand is affected by the selling price, freshness, and freshness service of fresh agricultural products and is linearly correlated. Referring to literature [21], the basic form of demand function is established as follows

$$R = R^0 - P \times e + \alpha(t) \times \beta \times R^0 + TSE(SE_{fse}, SE_{dse}, SE_{sse}) \times \delta \times R^0 \tag{9}$$

The freshness function and freshness service level function of each store s are substituted into the demand function, and the demand function of each store $s \in S$ is

$$R_s = R_s^0 - P \times e + \left\{ \alpha_0 - \left[1 - m \times \delta \times \frac{\sum_{f \in F} \sum_{se \in SE} SE_{fse} \times (1+k)^{se} + \sum_{d \in D} \sum_{se \in SE} SE_{dse} \times (1+k)^{se} + \sum_{se \in SE} SE_{sse} \times (1+k)^{se}}{(1+k)^{se'} \times (f' + d' + s')} \right] \times \gamma_0 \times \left(\frac{\sum_{f \in F} q_{fs} \times t_{fs} + \sum_{f \in F} \sum_{d \in D} q_{fd} \times t_{fd} + \sum_{d \in D} q_{ds} \times t_{ds}}{\sum_{f \in F} q_{fs} \times T_1 + \sum_{f \in F} \sum_{d \in D} q_{fd} \times q_{ds} \times T_2} \right)^{0.5} \right\} \times \beta \times R^0$$
$$+ \left[\delta \times \frac{\sum_{f \in F} \sum_{se \in SE} SE_{fse} \times (1+k)^{se} + \sum_{d \in D} \sum_{se \in SE} SE_{dse} \times (1+k)^{se} + \sum_{se \in SE} SE_{sse} \times (1+k)^{se}}{1 \times (1+k)^{se'} \times (f' + d' + s')} \right] \times \delta \times R^0 \tag{10}$$

Then, the total demand for all stores is

$$R = \sum_{s \in S} R_s \tag{11}$$

3.4 Transport Cost Function

In real life, the modes of transportation selected by each distribution sub-link are generally different, such as automobile transportation and train transportation. In general, when the starting and ending distances are the same and the same quantity of goods will be transported. Although the time of transportation by automobile is shorter than that by train, the cost of transportation by automobile is higher than that by train. With the shortening of transportation time, the transportation cost increases, and the increasing speed becomes larger and larger, that is, the transportation cost per unit quantity per unit time increases rapidly, so there is an accelerating and increasing relationship between the transportation cost per unit quantity per unit time and the shortening of transportation time. This relation has the same change property as the common change rate exponential form [22]. Therefore, the exponential form can effectively describe the change characteristics of unit quantity and unit time transport cost with transport time.In this paper, the transportation cost per unit quantity per unit time is expressed as an exponential function of transportation time, the basic form is as follows:

$$C_1' = A \times \frac{1}{a^t} \tag{12}$$

A and a is constant and $A > 0$， $a > 1$， The total transportation cost function is

$$C_1 = \sum_{f \in F} \sum_{s \in S} q_{fs} \times \left(A \times \frac{1}{a^{t_{fs}}} \right) \times t_{fs} \times Y_{fs} + \sum_{f \in F} \sum_{d \in D} q_{fd} \times \left(A \times \frac{1}{a^{t_{fd}}} \right) \times t_{fd} \times Y_{fd} + \sum_{d \in D} \sum_{s \in S} q_{ds} \times \left(A \times \frac{1}{a^{t_{ds}}} \right) \times t_{ds} \times Y_{ds} \tag{13}$$

3.5 Cost Function of Fresh-keeping Services

Combined with the actual situation, when the origin, distribution center, and store provide different levels of freshness services, the more freshness service content, the higher the freshness service level, the higher the freshness service level, the higher the freshness service cost paid, and the cost increase rate gradually It becomes larger, that is, when the level of fresh-keeping services reaches a certain level, it needs to be further improved and needs to pay more costs, which has the same changing nature as the common change rate index form [22]. In this regard, this article expresses the cost of fresh-keeping services as an exponential form function on which grades of fresh-keeping services are selected at each node, that is, the basic form of the fresh-keeping service cost function is

$$C_2' = \sum_{se \in SE} SE_{se} \times b^{se}, \quad \forall f \in F, d \in D, s \in S \tag{14}$$

Among them $\sum_{se \in SE} SE_{se} \le 1$， b is a constant and $b > 1$, then the total fresh-keeping service cost function of all nodes is:

$$C_2=\sum_{f\in F}\left(\sum_{se\in SE}SE_{fse}\times b^{se}\right)+\sum_{d\in D}\left(\sum_{se\in SE}SE_{dse}\times b^{se}\right)+\sum_{s\in S}\left(\sum_{se\in SE}SE_{sse}\times b^{se}\right) \tag{15}$$

Among them $\sum_{se\in SE}SE_{fse}\le 1, \sum_{se\in SE}SE_{dse}\le 1, \sum_{se\in SE}SE_{sse}\le 1, \ \forall f\in F, d\in D, s\in S$, it means that each node of the origin, distribution center, and store can only provide at most one grade of fresh-keeping service.

3.6 Production Cost

The production volume of each origin f is:

$$G_f=\sum_{s\in S}q_{fs}\times Y_{fs}+\sum_{d\in D}q_{fd}\times Y_{fd}, \ \forall f\in F \tag{16}$$

The total production cost is:

$$C_3=\sum_{f\in F}G_f\times h=\sum_{f\in F}\left(\sum_{s\in S}q_{fs}\times Y_{fs}+\sum_{d\in D}q_{fd}\times Y_{fd}\right)\times h \tag{17}$$

Among them h is a constant and $h>0$.

3.7 Objective Function

Comprehensive consideration of transportation costs C_1、service cost C_2、production cost C_3, Constructing an optimized model for the distribution network of fresh agricultural products with maximum profit Z. Let sales revenue be $W=P\times R$, then the objective function is:

$$\text{Max } Z=P\times R-C_1-C_2-C_3 \tag{18}$$

Substituting the relevant function becomes:

$$\begin{aligned}\text{Max } Z=P\times\sum_{s\in S}R_s-&\left[\sum_{f\in F}\sum_{s\in S}q_{fs}\times\left(A\times\frac{1}{a^{t_{fs}}}\right)\times t_{fs}\times Y_{fs}+\sum_{f\in F}\sum_{d\in D}q_{fd}\times\left(A\times\frac{1}{a^{t_{fd}}}\right)\times t_{fd}\times Y_{fd}+\sum_{d\in D}\sum_{s\in S}q_{ds}\times\left(A\times\frac{1}{a^{t_{ds}}}\right)\times t_{ds}\times Y_{ds}\right]\\-&\left[\sum_{f\in F}\left(\sum_{se\in SE}SE_{fse}\times b^{se}\right)+\sum_{d\in D}\left(\sum_{se\in SE}SE_{dse}\times b^{se}\right)+\sum_{s\in S}\left(\sum_{se\in SE}SE_{sse}\times b^{se}\right)\right]\\-&\sum_{f\in F}\left(\sum_{s\in S}q_{fs}\times Y_{fs}+\sum_{d\in D}q_{fd}\times Y_{fd}\right)\times h\end{aligned} \tag{19}$$

Meet the following constraints:

(1) The delivery time of fresh agricultural products from the place f of origin to the store d isn't longer than the delivery period promised to be sent from the place of production to the store:

$$q_{fs}\times t_{fs}\le T_1, \ \forall f\in F, s\in S \tag{20}$$

(2) The delivery time of fresh agricultural products from the origin f through the distribution center d to the store s is not greater than the promised delivery time from the origin through the distribution center to the store:

$$q_{fd}\times q_{ds}\times(t_{fd}+t_{ds})\le T_2, \forall f\in F, d\in D, s\in S \tag{21}$$

(3) When each distribution sub-link is adopted, the sub-link only has traffic and meets the minimum and maximum traffic restrictions:

$$L\times q_{fs}\le Y_{fs}, \ L\times q_{fd}\le Y_{fd}, \ L\times q_{ds}\le Y_{ds}, \ \forall f\in F, d\in D, s\in S \tag{22}$$

$$H \times q_{fs} \geq Y_{fs}, \ H \times q_{fd} \geq Y_{fd}, \ H \times q_{ds} \geq Y_{ds}, \ \forall f \in F, d \in D, s \in S \quad (23)$$

The minimum transportation volume L and the maximum transportation volume H are constant and $H > L > 0$.

(4) For any origin f, the total transportation volume is equal to the production volume and both are more than 0:

$$\sum_{s \in S} q_{fs} \times Y_{fs} + \sum_{d \in D} q_{fd} \times Y_{fd} = G_f > 0, \ \forall f \in F \quad (24)$$

(5) For any distribution center d, the inflow is equal to the outflow and both are more than 0:

$$\sum_{f \in F} q_{fd} \times Y_{fd} = \sum_{s \in S} q_{ds} \times Y_{ds} > 0, \ \forall d \in D \quad (25)$$

(6) For any store s, the inflow is equal to the demand and is greater than 0:(

$$\sum_{f \in F} q_{fs} \times Y_{fs} + \sum_{d \in D} q_{ds} \times Y_{ds} = R_s > 0, \ \forall s \in S \quad (26)$$

The above-mentioned fresh agricultural product distribution network optimization model is a 0-1 mixed integer programming model, and the variable factors involved are more complicated. Because genetic algorithm has the characteristics of strong global search ability, strong adaptability and good robust performance, in order to make the final result closer to reality, this paper uses MATLAB (R2018a) to implement the genetic algorithm and simulate the model.

4. Numerical Example Analysis

A fresh food company's distribution network is composed of 2 agricultural products producing areas, 3 distribution centers and 6 sales stores. In the processing, warehousing, transportation and other links, each network node provides fresh-keeping services, such as personalized packaging fresh-keeping, constant temperature fresh-keeping, Atmosphere preservation, vacuum preservation, etc., different preservation services are superimposed to form different levels of preservation services. The more preservation services, the higher the preservation service level, and the higher the preservation service level of fresh agricultural products. As shown in table 1, and each node of the origin, distribution center, and store can only provide at least one level of freshness service.

Table 1 Distribution network fresh-keeping service levels

Level(se)	Explanation
First level($se = 1$)	Provide personalized packaging preservation, constant temperature preservation and other preservation services.
Second level($se = 2$)	Provide personalized fresh-keeping services such as package fresh-keeping, constant temperature fresh-keeping, modified atmosphere fresh-keeping, etc.
Third level($se = 3$)	Provide personalized packaging preservation, constant temperature preservation, modified atmosphere preservation, vacuum preservation and other preservation services.

The initial demand of 6 stores is shown in Table 2.

Table 2 Initial demand of each store

R_1^0	R_2^0	R_3^0	R_4^0	R_5^0	R_6^0
450	500	600	400	650	550

Table 3 and Table 5 show the transportation time between the origin, distribution center, and stores.

Table 3 Delivery time from the origin to the store

$f \to s$	1	2	3	4	5	6
1	30	20	30	40	20	30
2	20	40	30	20	30	40

Table 4 Delivery time from origin to distribution center

$f \to d$	1	2	3
1	40	20	30
2	30	30	20

Table 5 Delivery time from distribution center to store

$d \to s$	1	2	3	4	5	6
1	50	40	40	30	20	60
2	60	50	70	40	50	30
3	30	60	70	50	40	40

Drawing on literature [16] and literature [20], the specific assignment of other relevant parameters is shown in Table 6.

Table 6 Related parameters

k	m	β	δ	γ_0	α_0	T_1	T_2
0.02	0.20	0.50	0.50	0.80	0.90	40	100
P	e	A	a	b	h	L	H
60	1.20	40	1.14	20	10	200	1500

According to the above information, the parameters are substituted into the relevant expressions, and MATLAB R2018a is used for programming and calculation. The program runs for 15 minutes and the relevant results are obtained. The demand, total demand and production volume of each sales place are shown in Table 7 below. The selection of the freshness service level of the fresh agricultural products distribution network is shown in Table 8. The design of the distribution network is shown in Figure 1 below. Profits and other major expenses are collected， the breakdown of support is shown in Table 9 below.

Table 7 Demand of each store, total demand and production volume of each origin

R_1	R_2	R_3	R_4	R_5	R_6	R	G_1	G_2
1600	1533	2159	1423	2355	1978	11048	4337	6711

Table 8 Selection of fresh-keeping service level of fresh agricultural products distribution network

Network node	First-level fresh-keeping service	Second-level fresh-keeping service	Third-level fresh-keeping service
Origin F_1	1	0	0
Origin F_2	1	0	0
Distribution center D_1	0	0	1
Distribution center D_2	0	0	1
Distribution center D_3	0	1	0
Store S_1	0	0	0
Store S_2	0	0	1
Store S_3	0	1	0
Store S_4	1	0	0
Store S_5	0	0	0
Store S_6	0	0	1

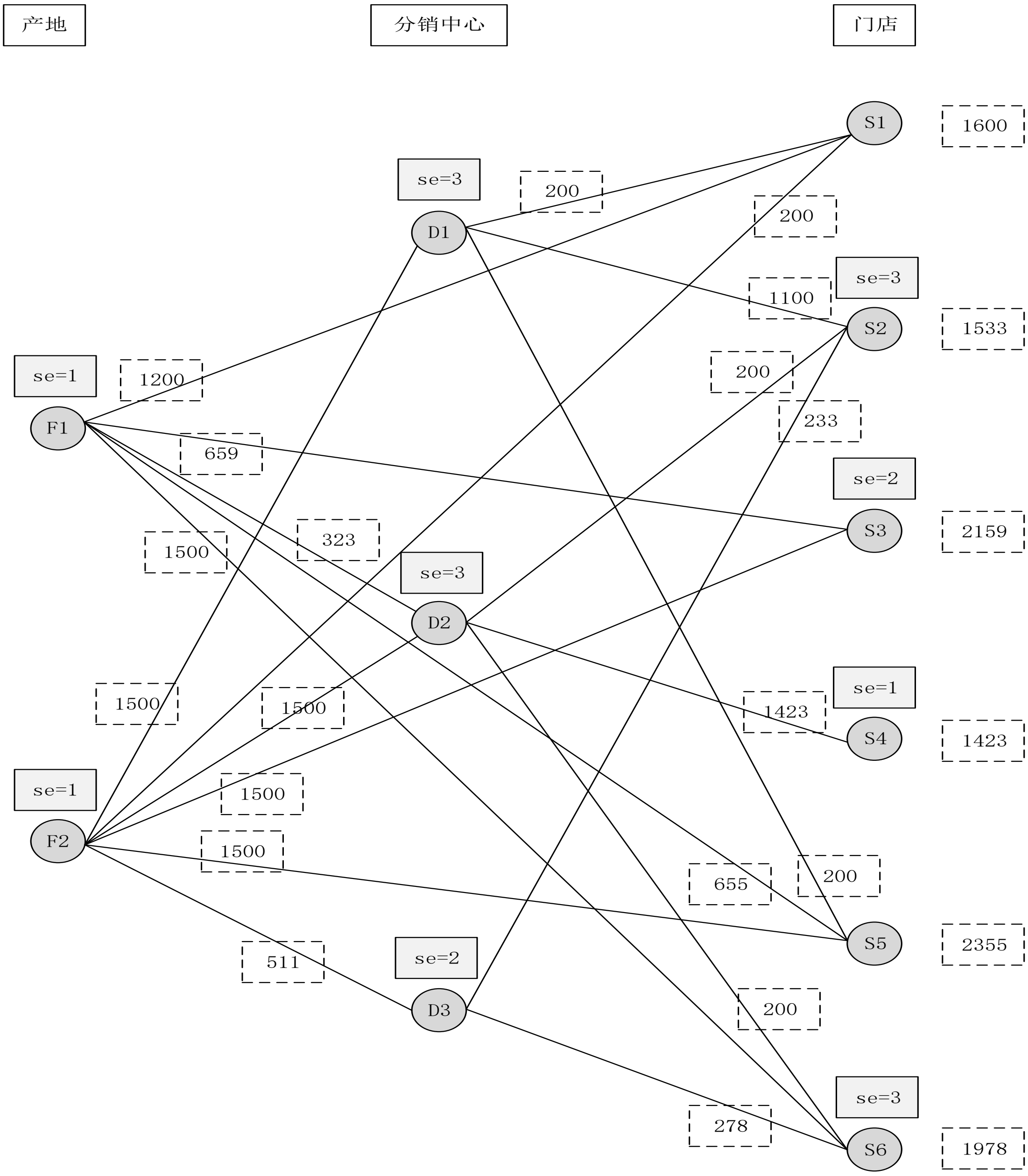

Figure 1 Relative optimal solutions of decision variables in the distribution network of fresh agricultural products

Table 9 Breakdown of profits and other major expenses

Profit	Sales revenue	transportation cost	Service cost	Cost of production
159360.13	662880.00	360179.87	32860.00	110480.00

In summary, the high-level fresh-keeping service can bring consumers high-quality products, that is, the different levels of diverse combinations of fresh-keeping services provided by each node in the distribution network can improve the fresh-keeping service level of fresh agricultural products and reduce the freshness Decreasing the extreme value, thereby improving the freshness of fresh agricultural products, stimulating consumer demand, and improving the distribution network operating profit, which provides a theoretical reference for the effective management of fresh enterprises.

5. Conclusion

The freshness of fresh agricultural products has the characteristics of decay with the passage of time and enhancement and improvement of fresh-keeping services, but the current preservation efficiency of localized fresh-keeping services in the current distribution network is limited. Therefore, this paper combines the freshness of fresh agricultural products and the diversity of freshness service level characteristics of the distribution network, based on the design of the freshness service level function, constructs the freshness function affected by the freshness service, establishes the sales price of fresh agricultural products, Demand functions related to freshness and fresh-keeping services, a 0-1 mixed integer programming model with the goal of maximizing profit was constructed, and numerical simulation was used to verify the feasibility and effectiveness of the model. Studies have shown that the combination of distribution network preservation services can improve the preservation effect, stimulate and meet the needs of quality and diversified consumption, and maximize the distribution network operating profit. The simulation research in this paper is based on the assumption of no inventory backlog, but in real life, the loss problem caused by the high inventory backlog is widespread. Therefore, relevant actual case data can be collected to make further research on the joint decision-making of fresh-keeping services and inventory in the fresh agricultural products distribution network. In order to broaden the application field of this study.

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