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Research Article

Risk Evaluation of Cold Logistics Chain Based on Cloud Model

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Abstract: Perishable food is very important for people, because it can provide healthy and safe foods. However, difficulties arise in ensuring that, as long as there is something wrong in one aspect of the chain, this can result in a loss of quality and revenue. In this paper, we establish the indicators system of risk for the cold logistics chain and construct comprehensive evaluation model based on cloud model. Finally, a case will be used to verify the correctness and practicalness of the model.

Keywords: Cloud model, cold logistics chain, comprehensive evaluation, indicators of risk

INTRODUCTION

As know to all, Supply Chain Management (SCM) is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses and stores, so that merchandise is produced and distributed at the right quantities, to the right locations and at the right time, in order to minimize system wide costs while satisfying service level requirements.

One of the branches of SCM is Cold Chain Management (CCM). The purpose of the CCM is managing activities related to perishable products like medicine, blood, dairy, meat, food, vegetables, mushrooms, flowers and fruit products and so on which must be distributed in a special time and kept in the particular environment condition. Since the spoilage of the perishable products leads to waste and toxicosis, researching all stages of Cold Chain (CC) is necessary (Amir and Reza, 2012).

Cold-chain: A "cold chain", also named low-temperature logistics system and is comprised of equipments and processes which keep perishable products under conditioned environment. Just as described in the previous paragraph, these perishable products can be categorized into two types: living products (fruits, vegetables, live seafood, flowers, etc.) and non-living products (meat, dairy products, processed food products, medicines, blood, frozen products, etc.), which all require appropriate atmosphere to defy microbial spoilage. The cold chain includes all aspects of the transfer of food from the producer to the consumer. Logistics is the key of the cold chain. Therefore, many scholars call it 'cold logistics chain'. It includes refrigeration, freezing, warehousing, transportation, distribution, packaging, processing, multimodal transport and other series of value-added services (Guojun and Rong, 2009).

Since it needs to maintain low temperatures throughout the cold chain, the cold logistics chain has very high conditions for its facilities. For logistics companies, they must have cold storage and specially designed trucks or cold containers to providing these services. It needs a large number of invested capitals. In general, the features of cold chain are shown as below:

- The investment cost of Cold logistics chain is high
- Operation cycle demand is very short
- Operation needs to have strong technology
- Food quality control is difficult
- Cold logistics chain operation still needs a lot of other special condition

The risk of cold chain: Most of perishable food can provide people with healthy, heterogeneous and safe foods. This trend suggests that consumers may have a great need for cold foods in the future. However, difficulties arise in ensuring that, as foods are made, stored and sent from the factory to customers in each cycle of the supply chain, or cold chain, the process will be effective and affordable. That is to say, as long as there is something wrong in one aspect of the chain, this can result in a loss of quality and revenue and, in many cases, leads to spoilage. Therefore, in order to maintain quality and reduce costs, purchasing some equipment, such as refrigeration trucks and refrigerated display cabinets, is very necessary. Some of the facilities, e.g., cold storage warehouses, are also very important. In addition, some special skills of operations and good working orders are the key to supporting the

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Table 1: The risk evaluation indicator system of cold logistics chain

Purpose indicator	I indicators	II indicators
Risk evaluation indicator of cold logistics chain U_0	The risk of purchase U_1	The quality of primary agricultural products (raw materials) u_{11}
		The price of primary agricultural products (raw materials) u_{12}
		The failure of delivery of supplier u_{13}
	The risk of production management U_2	The accuracy of the forecast in marketing demand u_{21}
		Comprehensiveness of the production of health system u_{22}
		The lag standardized construction u_{23}
	The risk of facilities and equipment U_3	The low quantity of facilities and equipment u_{31}
		The frequency of sudden power failure u_{32}
	The risk of technology U_4	The development and application of operating technologies u_{41}
		The application of Management Information System (MIS) u_{42}
	The risk of human resources U_5	The ratio of high-level talented person occupies the whole staff u_{51}
		The lag of human resources quality cultivation mechanism u_{52}
	The risk of environmental U_6	Natural disasters/war u_{61}
		The change of climate/weather u_{62}
		The lag of laws and regulations construction u_{63}
		The level of urban traffic congestion u_{64}

entire cold chain. If not, all of that would pose a great risk to the cold chain. So the risk evaluation of cold chain logistics is necessary (Kai-Ying and Yi-Cheng, 2011).

Research goal: This study will construct the evaluation index system of risk for the cold logistics chain and then, introduce the theory of cloud model, furthermore, establish comprehensive evaluation model of cloud model. Finally, a case will be used to verify the correctness and practicalness of the model.

THE EVALUATION INDEX SYSTEM OF RISK FOR THE COLD LOGISTICS CHAIN

The risk exists in any links of the cold chain. For different perspectives, there are different types of risk. This paper will identify factors of risk by analyzing the sources of risk.

The risk from purchase: For the object of the cold chain is food, risk from the primary agricultural products procurement should be given adequate attention. If there is something wrong at the beginning of the procurement such as a problem of raw materials, then the goal of the entire cold chain will be doomed to fail.

The risk from production management: In general, the production of food or simple processing is carried out under specific conditions, such as temperature, humidity and health conditions. So production management is very important for cold chain.

The risk from facilities and equipment: As previously described, refrigeration trucks, refrigerated display cabinets, cold storage warehouses etc., are essential. The suitable quantity of facilities and equipment are the basic guarantee to achieve the goal of cold chain. What's more, the supply of energy (electricity in general), which used for cooling, is also very important. The sudden power failure will bring very large risks.

The risk from technology: Compared to the general Supply Chain (SC), cold chain has a stricter require for operating technologies, such as post-harvest treatment, pre-cooling, refrigeration, packaging e.g., Development and use of these technologies is critical to the cold chain. From the perspective of information flow, the technology of Management Information System (MIS) is as important as operating techniques, or even more important.

The risk from human resources: The quality of employees directly affects the degree of the risk about cold chain system. For example, if someone doesn't have a basic knowledge of cold chain, may mistake the temperature of the storage for fruits and vegetables and cause irreversible mistake for the quality of fruits and vegetables.

The risk from environmental: Changes in the environment can affect the risk of cold logistics chain. But these changes could be divided into two kinds: routine and unexpected. The former can be predicted, it has limited impact on the system. The latter risk is important for the system and needs to make appropriate emergency measures.

According to above analysis, establish the risk evaluation index system of cold logistics chain, is shown as Table 1.

MATHEMATICAL MODEL

The theory of cloud model: Cloud is a quantitative and qualitative uncertainty conversion model, which was proposed by Professor Deyi Li based on the traditional fuzzy set theory and probability statistics.

The definition of cloud: Cloud is an uncertainty conversion model between a qualitative concept and its quantitative representation, which is expressed by natural language values. That is to say, the cloud model is an uncertainty model used to achieve the conversion between qualitative and quantitative.

Suppose U is a quantitative domain expressed by precise values and C is a qualitative concept on the domain. If the quantitative value $x \in U$ and x is a random realization to the qualitative concept C, whose membership degree μ(x)ε[0,1] for C is a random number with stable tendency:

$$\mu : U \to [0,1], \forall x \in U, x \to \mu(x)$$

Then, the distribution of x on the domain is called as cloud and each x is called as droplet (Deyi and Yi, 2005).

The number features of normal cloud: Cloud is made up of many cloud droplets and a single cloud droplet is a specific realization of the qualitative value in number. Its abscissa value represents the quantitative value corresponding to qualitative concept and the ordinate value expresses the membership degree of the quantitative value on behalf of the qualitative concepts. The three number features of cloud are expectation E_x, entropy E_n and hyper entropy H_e:

E_x: Expectation best representatives the value of the qualitative concept and it is usually the x value corresponding to the gravity of cloud reflected the center value of corresponded qualitative concept.

E_n: Entropy represents the measure to the fuzzy degree of the qualitative concept, the size of which directly determines the number of elements that can be accepted by the qualitative concept on the domain and also reflects the margin of qualitative value based on both this and that.

H_e: Super entropy expresses the uncertainty measurement of entropy and that is the entropy of entropy. The size of super entropy indirectly reflects the cloud's thickness.

The $3E_n$ rules of cloud refer to that the total contribution of all elements on the domain U to the qualitative concept C is 1. That is, 99.7% of the cloud droplets will fall into the range (E_x - $3E_n$, E_x + $3E_n$). Thus, cloud fell on the outside of this scope are small probability events for a qualitative linguistic values concept and it can be ignored.

Cloud Generation (CG): Normal cloud model is a new model which combines normal distribution of probability theory with the bell-shaped membership functions of fuzzy sets.

Cloud Generation (CG) is a specific algorithm which realizes with the computer. There are two kinds: Forward Normal Cloud Generator, Backward Cloud Generator (CG^{-1}).

The Forward Normal Cloud Generator is a mapping from qualitative to quantitative. It produces the cloud droplets according to the number features (E_x, E_n, H_e) of normal cloud. Backward Cloud Generator is a model which can transform quantity value into the qualitative concept. It may transform a certain number of precise information into qualitative concept which expressed by the number features (E_x, E_n, H_e).

The generation algorithm of forward normal cloud generator is as follows:

- $E_{ni}^{'} = NORM(E_n, H_e^2)$
  Generating the random number $E_n^{'}$ that the expectation is E_n and the variance is H_e^2
- $x_i = NORM\ (E_x, E_{ni}^{'2})$
  Generating the normal random number x_i that the expectation is E_x and the variance is $E_{ni}^{'2}$
- $\mu_i = \exp[-(x_i - E_x)^2/2E_{ni}^{'2}]$
  Generating the cloud droplets (x_i, μ_i)

The generation algorithm of backward Cloud Generator (CG^{-1}) is as follows: According to x_i, calculate the sample mean, the first-order sample absolute center distance and the sample variance of set of data and then according to the requirements as follows calculate the number features (E_x, E_n, H_e) of normal cloud (Deyi and Yi, 2005):

$$\begin{cases} \overline{X} = \frac{1}{n}\sum_{i=1}^{n} x_i, A = \frac{1}{n}\sum_{i=1}^{n}\left|x_i - \overline{X}\right|, S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{X})^2; \\ E_x = \overline{X}; \\ E_n = \sqrt{\frac{\pi}{2}} \times \frac{1}{n}\sum_{i=1}^{n}\left|x_i - E_x\right|; \\ H_e = \sqrt{S^2 - E_n^{\ 2}} \end{cases} \tag{1}$$

Virtual cloud: The number features of each cloud can calculate with together for some purpose, the results will form a new set of number features. Virtual Cloud is a new cloud that expressed by the new number features (E_x, E_n, H_e).

According to different application purpose, the Virtual Cloud has two types: Floating Cloud and Synthesized Cloud (Luo *et al*., 2008).

The algorithm of floating cloud is as follows:

$$\begin{cases} E_x = \dfrac{E_{x_1}A_1 + E_{x_2}A_2 + \cdots + E_{x_n}A_n}{A_1 + A_2 + \cdots + A_n} \\ E_n = \dfrac{A_1^2}{A_1^2 + A_2^2 + \cdots + A_n^2} * E_{n_1} + \dfrac{A_2^2}{A_1^2 + A_2^2 + \cdots + A_n^2} * E_{n_2} + \cdots + \dfrac{A_n^2}{A_1^2 + A_2^2 + \cdots + A_n^2} * E_{n_n} \\ H_e = \dfrac{A_1^2}{A_1^2 + A_2^2 + \cdots + A_n^2} * H_{e_1} + \dfrac{A_2^2}{A_1^2 + A_2^2 + \cdots + A_n^2} * H_{e_2} + \cdots + \dfrac{A_1^2}{A_1^2 + A_2^2 + \cdots + A_n^2} * H_{e_n} \end{cases} \quad (2)$$

The algorithm of synthesized cloud is as follows:

$$\begin{cases} E_x = \dfrac{E_{x_1}E_{n_1}A_1 + E_{x_2}E_{n_2}A_2 + \cdots + E_{x_n}E_{n_n}A_n}{E_{n_1}A_1 + E_{n_2}A_2 + \cdots + E_{n_n}A_n} \\ E_n = E_{n_1}A_1 n + E_{n_2}A_2 n + \cdots + E_{n_n}A_n n \\ H_e = \dfrac{H_{e_1}E_{n_1}A_1 + H_{e_2}E_{n_2}A_2 + \cdots + H_{e_n}E_{n_n}A_n}{E_{n_1}A_1 + E_{n_2}A_2 + \cdots + E_{n_n}A_n} \end{cases} \quad (3)$$

where, n denotes the number of basic cloud, A_i (i = 1, 2, …, n) is the weight of indicator.

Comprehensive evaluation based on cloud model: According to Table 1, we can see that the risk evaluation of cold logistics chain is a multi-level comprehensive evaluation, which is the process of getting the evaluation results of objective indicators by the evaluation results of sub-indicators.

Determine the necessary collection: Comprehensive evaluation model in the fuzzy mathematics use quantitative methods to make remarks on the sub-indicators. With the cloud model theory, qualitative methods can be used to represent the sub-indicators on the reviews. There are three basic sets in model:

- $U = \{U_0, U_1, U_2, ..., U_n\}$

  It is indicator set, where U_0 is the purpose indicator $U_i = \{u_{i1}, u_{i2}..., u_{im}\}$, i = 1, 2… n, m denotes the number of sub-indicators of U_i.

- $V = \{v_1, v_2, \ldots, v_m\}$

  It is remarks set. The remarks are always fuzzy concept, such as “good, normal and bad”; they are often expressed with some interval value, For example, we can use interval value (45, 55) express the risk lever “risk in general”. Some remarks can be described using one-dimensional normal clouds such as “very high” and “very low”, it correspond to the range of satisfaction are upper limit or lower limit. Some remarks have bilateral constraint such as “higher”, it correspond to the range of risk is both upper limit and lower limit.
  For the remark of bilateral constraint [C_{min}, C_{max}], when we establish the cloud model of the remarks set, expectations can be used to be as the median value of constraint conditions, cloud which main function area is the bilateral constraints can be used to approximate the regional remarks; cloud parameter computation formula is as follows:

$$\begin{cases} E_x = (X_{\max} + X_{\min})/2 \\ E_n = (X_{\max} - X_{\min})/6 \\ H_e = k \end{cases} \quad (4)$$

  where, k is a constant, it can be adjusted specifically according to its fuzzy remarks.
  The unilateral constraints' remarks, for example C_{min} and C_{max}, we can determine the expected value of the default boundary parameters firstly, such as remarks “very high”, its expectations (value of risk) is 100%, then calculate cloud parameters using formula (4) and describe it with a half rise and a half drop cloud.

- $W = \{w_1, w_2, \ldots, w_n\}$

  It is weight set, $w_i \geq 0$ and $w_1 + w_2 \ldots + w_n = 1$

Calculate: Since the risk evaluation of cold logistics chain is a multi-level comprehensive evaluation, according to the general calculation steps of the multi-level evaluation, we should evaluate from the bottom (second layer) firstly, when the second layer is completed, the results can be used to calculate the results of the most high-level (first level). In risk evaluation of cold logistics chain based on cloud model, the method of calculation in the process will use the

Cloud Generation and the computing formula of Virtual Cloud which described above.

RESULTS

After working out the final cloud of the purpose indicator by calculating with formula of the Virtual Cloud, we can get the result of the evaluation by calculating the degree of similarity between the cloud of the purpose indicator and remark cloud.

The algorithm for degree of similarity is as follows:

- $E_{n0} = NORM(E_{n0}, H_{e0}^2)$

  Generating the random number E'_{n0} that the expectation is E_{n0} and the variance is H_{e0}^2. where, E_{n0} and H_{e0}^2 are belonging to the cloud of purpose indicator U_0

- $x_i = NORM(E_{x_0}, E_{n_0}^{'2})$

  Generating the normal random number x_i that the expectation is E_{x0} and the variance is E'^2_{n0}, where, E_{x0} and E'^2_{n0} are belonging to the cloud of purpose indicator U_0

- $E'_{ni} = NORM(E_{n_i}, H_{e_i}^2)$

  Generating the random number E'_{nj} that the expectation is E_{nj} and the variance is H_{ej}^2. Where, E_{nj} and H_{ej}^2 are belonging to remarks cloud

- $\mu_i = \exp[-(x_i - E_{x_j})^2 / 2E_{n_j}^{'2}]$

  Generating the cloud droplets (x_i, μ_i)
- Repeat the steps above until generate cloud droplets which number is n

- $SIM(j) = \frac{1}{n}\sum_{i=1}^{n} \mu_i$

  where, j is an element of remarks set

Using the same method to work out the degree of Similarity (SIM) for all remark clouds and then comparing the value, the remark cloud that the maximum value of these similarities corresponds is the most similar cloud compared with the cloud of purpose indicator and the remark that the remark cloud corresponds is the final result of evaluation.

Table 2: Remarks cloud and the corresponding interval

Remarks	The corresponding interval	Cloud
Security	(0, 30)	(0, 10, 0.5)
Less risk	(30, 45)	(37.5, 2.5, 0.2)
Risk in general	(45, 55)	(50, 1.6, 0.2)
Higher risk	(55, 70)	(62.5, 2.5, 0.3)
High risk	(70, 100)	(100, 10, 0.5)

Table 3: The weight of each indicator

I indicators	Weight	II indicators	Weight
ω_1	0.20	ω_{11}	0.4
		ω_{12}	0.3
		ω_{13}	0.3
ω_2	0.15	ω_{21}	0.3
		ω_{22}	0.3
		ω_{23}	0.4
ω_3	0.25	ω_{31}	0.6
		ω_{32}	0.4
ω_4	0.15	ω_{41}	0.5
		ω_{42}	0.5
ω_5	0.15	ω_{51}	0.4
		ω_{52}	0.6
ω_6	0.10	ω_{61}	0.2
		ω_{62}	0.2
		ω_{63}	0.3
		ω_{64}	0.3

APPLICATION EXAMPLE

In this study, we take the cold chain logistics industry in China as the research object. And then we use the theories introduced above as a research method to make a comprehensive evaluation of risk about the cold logistics chain.

According to Table 1, the sets of indicators as follows:

$$U = \{U_0, U_1, U_2, U_3, U_4, U_5, U_6\}$$
$$U_1 = \{u_{11}, u_{12}, u_{13}\}, U_2 = \{u_{21}, u_{22}, u_{23}\},$$
$$U_3 = \{u_{31}, u_{32}\}, U_4 = \{u_{41}, u_{42}\},$$
$$U_5 = \{u_{51}, u_{52}\}, U_6 = \{u_{61}, u_{62}, u_{63}, u_{64}\}$$

- **The remarks set:** V= {security, less risk, risk in general, higher risk, high risk}. In the 100 point system, the Corresponding to interval value is V' and V' = {(0, 30), (30, 45), (45, 55), (55, 70), (70, 100)}. By calculating the formula (4), the remarks cloud can be given in Table 2.
  We can draw the graph of remark clouds by MATLAB and the graph shown as Fig. 1.
- **The weight set:** Limited to the length and the focus of this article, the weight of each indicator given directly by the relevant experts. The weight is shown in Table 3.

In this study, we invited 10 experts to estimate the risk the cold logistics chain. Each expert evaluates the

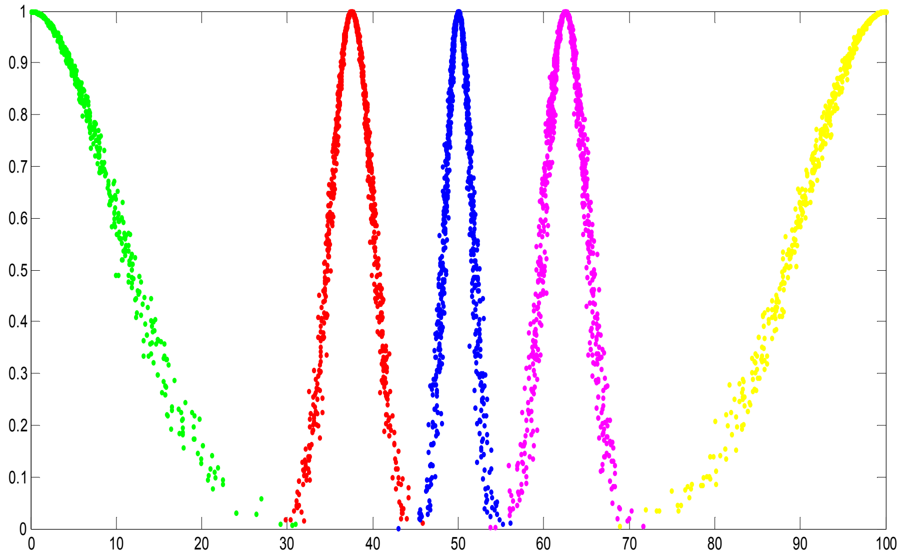

Fig. 1: The graph of remark clouds

Table 4: The scores of each indicator given by experts

	u_{11}	u_{12}	u_{13}	u_{21}	u_{22}	u_{23}	u_{31}	u_{32}	u_{41}	u_{42}	u_{51}	u_{52}	u_{61}	u_{62}	u_{63}	u_{64}
Expert 1	70	50	40	60	70	80	85	40	65	60	75	70	40	50	75	80
Expert 2	65	55	30	65	75	75	80	43	60	65	78	75	45	55	70	75
Expert 3	73	53	37	62	73	75	81	45	67	62	73	71	50	53	75	80
Expert 4	65	59	42	67	71	74	90	49	63	66	80	67	39	57	79	86
Expert 5	72	63	35	64	71	75	86	45	69	68	86	66	43	56	73	84
Expert 6	70	57	42	73	69	69	88	54	64	70	83	72	42	63	85	79
Expert 7	75	65	35	71	65	68	75	46	65	65	75	70	50	60	80	75
Expert 8	75	55	38	60	75	75	88	40	70	65	75	75	45	45	65	75
Expert 9	75	60	40	65	70	80	85	35	65	68	70	70	40	50	65	80
Expert 10	75	45	40	60	75	80	90	45	68	60	75	68	45	55	70	85

Table 5: The cloud of each II indicator

II indicators	Remarks cloud (E_x, E_n, H_e)
u_{11}	(71.8, 4.3, 0.5)
u_{12}	(56.2, 5.8, 1.6)
u_{13}	(56.2, 5.8, 1.6)
u_{21}	(65.2, 3.9, 1.8)
u_{22}	(71.4, 3.1, 0.8)
u_{23}	(75.1, 3.7, 2.0)
u_{31}	(84.8, 4.6, 1.4)
u_{32}	(44.2, 4.7, 2.2)
u_{41}	(65.6, 2.9, 0.7)
u_{42}	(64.9, 3.2, 1.1)
u_{51}	(77.0, 4.7, 0.7)
u_{52}	(70.4, 2.9, 1.0)
u_{61}	(43.9, 3.9, 0.3)
u_{62}	(54.4, 4.9, 1.7)
u_{63}	(73.7, 6.4, 1.1)
u_{64}	(79.9, 3.9, 1.3)

risk by giving a score. And the scores of each indicator are shown in Table 4.

Calculating these scores with Backward Cloud Generator (CG^{-1}) defined in the formula (1), we can get the cloud of each II indicator showing in Table 5.

Table 6: The cloud of each I indicator

I indicators	Remarks cloud (E_x, E_n, H_e)
U_1	(62.4, 5.1, 1.1)
U_2	(71.0, 3.6, 1.6)
U_3	(68.6, 4.6, 1.6)
U_4	(65.3, 3.1, 0.9)
U_5	(73.0, 3.5, 0.9)
U_6	(65.7, 4.9, 1.1)

We regard each cloud in Table 5 as a basic cloud. Considering the independence of I indicators, we choose the formula (2) to calculate the cloud of each I indicator. The cloud of each I indicator are shown in Table 6.

In order to get a synthesized cloud which can express the risk of cold logistics chain, we have to carry out a new calculation with the clouds in Table 6. Taking the synthesized of purpose indicator into account, we choose the Eq. (3) as a basic formula. The cloud of the purpose indicator shown as follows:

$$U_0 \ (67.2, 25.1, 1.3)$$

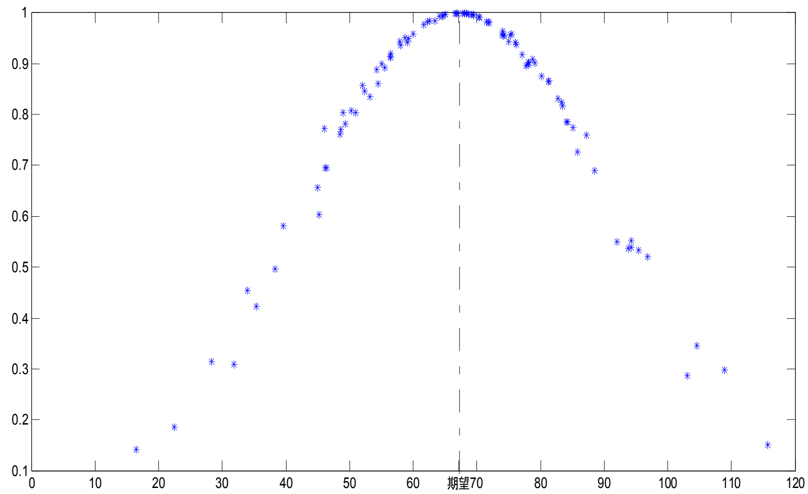

Fig. 2: The distribution of cloud droplets and theirs' membership

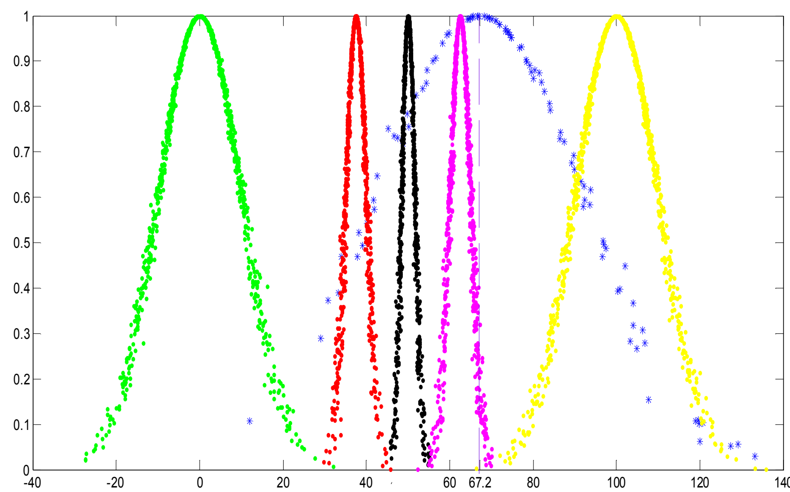

Fig. 3: The distributions of cloud droplets of remark clouds and the purpose cloud

Using the Forward Normal Cloud Generator, we can restore the cloud of the purpose indicator into cloud droplets. In this paper, we do normal random simulation for 100 times by MATLAB. The result of the distribution of cloud droplets and theirs membership is shown as Fig. 2.

Comparing with the remark clouds, the distribution of cloud droplets and theirs' membership are shown as Fig. 3.

From Fig. 2 and 3, we can see that most of cloud droplets fall into the range of "higher risk" and "high risk". The E_x of the cloud of purpose indicator is just in the range of "higher risk", hereby, we initially determine the result could be "higher risk". But, the result may different if we calculate the degree of similarity. In this example, calculate the degree of similarity by the algorithm of degree of similarity which introduce in the preceding paragraphs, the result is shown as Table7.

From Table 7, we can know that the value of "high risk" is maximum for degree of similarity. Therefore, the result of evaluation can be further identified as "high risk". We can verify this conclusion by statistical methods. In Fig. 2, we get the numbers of droplets which fall into the five remark intervals and shown as Table 8. It is consistent with the results of similarity. Therefore, we eventually found that the risk level of the cold logistics chain is "high risk". Comparing with the real situation of cold logistics chain industry in China, it's consistent with the national conditions.

Table 7: The degree of similarity between cloud of the purpose indicator and remark cloud

Remarks	Cloud	The degree of similarity comparing with U_0
Security	(0, 10, 0.5)	0.0183
Less risk	(37.5, 2.5, 0.2)	0.0537
Risk in general	(50, 1.6, 0.2)	0.0523
Higher risk	(62.5, 2.5, 0.3)	0.0872
High risk	(100, 10, 0.5)	0.1883

Table 8: The numbers of droplets which fall into the remark intervals

The remarks and their corresponding interval	The numbers of droplets
Security (0, 30)	3
Less risk (30, 45)	5
Risk in general (45, 55)	16
Higher risk (55, 70)	33
High risk (70, 100)	39

Furthermore, from the number features of the cloud (U_0) of the purpose indicator, we can see more information. In this paper, the value of entropy (E_n) is larger; it shows poor consistency of experts on risk of indicators.

CONCLUSION

It is proved that the cloud model is feasible in comprehensive assessment of risk of the cold logistics chain. The model also applies to all comprehensive evaluation with two or more sub-indicators. Comparing to the results of model in fuzzy comprehensive evaluation, the results based on cloud model can provide more information.

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