Research on Selection of Cooperation Partners in Supply Chain of Agricultural Products Based on *IL–WGA*

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***Abstract*—This thesis proposes the index system for the selection and evaluation of cooperation partners in the supply chain of agricultural products, and based *on IL—WGA* operators, the selection and evaluation is made so that the decision making process of selecting cooperation partners in the supply chain of agricultural products is verified for its scientific nature. In practical operations, many instant factors need to be considered with the changes of environment and the development of science and technology, and meanwhile, companies from different industries and with different backgrounds need to make suitable adjustments to the system and methods for selecting a partner.**

***Index Terms*—Supply chain of agricultural products, Selection of cooperation partners, Intuition- istic language set, *IL—WGA* operators**

I. INTRODUCTION

As a new management idea and operation mode for companies, supply chain management has caught more and more attention both at home and abroad in recent years, in which it is the key and core point to establish a strategic cooperative partnership. The supply chain of agricultural products is a network in the processes of production and circulation, which is formed by all the node enterprises providing agricultural products and related services for consumers. The participating enterprises in this chain are producers of agricultural products, logistic centers (wholesale markets), various kinds of logistic companies, retailers and consumers. According to the barrel theory, the whole operation performance of a supply chain is mainly dependent on the weakest segment in the chain. Therefore, every company in this chain should attach great importance to the selection of cooperation partners, so as to choose a partner that is capable and willing to cooperate with, thus reaching the goal of optimizing the supply chain. Since the 21st century, the supply chain management of agricultural products has caught more and more attention from the academic circle, government and agricultural enterprises and become a hot topic of study. Ahumada thinks that it is necessary to integrate the supply chain based on the fact that the agricultural supply chain of food between and among countries turns to be more complicated in the market with international competition [1]. Jack G.A.J investigated the situation of pollution of fresh agricultural products and points out that government should play an important role in the backtracking in the supply chain of agricultural products [2]. Jiao et al. presented a harvest-scheduling model for a region in Australia with multiple independent sugar cane fields. The paper presents an LP model for determining the amount of crops to harvest along the season with the objective of increasing the amount of sugar obtained. The model also restricts the harvest decisions to assure fairness to the farmers in the region. Ekman presented an example of strategic planning applied to technology selection. The paper describes an SP model for selecting the best mix of equipment and tillage schedule for an individual farm with the purpose of maximizing revenue. The model uses discrete probability distributions to represent the available working days. The distributions are used to determine the optimal amount of equipment required to meet tillage schedule. The results presented indicate that deterministic models underestimate the capacity requirements for unfavorable-weather years. The main contribution of this work is the selection of machinery investment with uncertain constraints (time available for tillage) given by the stochastic nature of the weather.

Schilizzi and Kingwell investigated the impact of price and yield uncertainty in cropping decisions for a farm in Western Australia. The objective is to maximize the expected utility function of the farmers. The model includes decision variables such as crop rotation, crop selection, and land allocation. These decisions take into consideration constraints related to the soil type, crop rotation, available crops, expected yield, the farmer’s risk attitudes and the weather patterns. Of particular importance is the effect of the weather on production, which is modeled through a set of discrete weather conditions with a corresponding probability of occurrence. The models presented include the use of farmer’s specific utility functions and the modeling of weather uncertainty.Tan and Fong present an LP model to select the best crop mix for a perennial crop plantation. The objective is to maximize the revenue and to consider risky outcomes by penalizing negative returns. One of the main considerations in evaluating perennial crops is the determination of the multiple periods in which the model has to be evaluated, and the corresponding uncertainty in

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the prices of the crops. The researchers use the net present value of the mean absolute deviation to evaluate the alternative crops. An efficient frontier is developed with the different potential plans from which the decision makers can select according to their level of risk. The main contribution of this paper is the development of a methodology for making long term decisions under uncertainty.

Leng Zhijie and Tang Huanwen establish the four-dimension network model for the supply chain of primary agricultural products, which is just applicable to the circulation of primary agricultural products like grains [3]. Yi Famin thinks that the integration of the supply chain of agricultural products is to effectively control and coordinate logistics, decision flow and cash flow based on IT and to make the resources and information shared among enterprises through process optimization and system integration, so as to optimize the resources as a whole [4].

Generally speaking, current researches on the supply chain of agricultural products are mainly focusing on its contents, categories and safety of products, etc. while there are few of the researches that target for the selection of cooperation partners in the supply chain[5-7]. Under the concept of supply chain, the selection of cooperation partners is a strategic activity, in which selecting a suitable partner is to establish a stable cooperative relationship and integrate the resources of the partners with the production and business activities of the enterprises, so that a win-win result can be realized and the total competitiveness of the supply chain of agricultural products can also be improved. Therefore, it is significant in both theory and practice to design an evaluation index system for the selection of cooperation partners in the supply chain of agricultural products and select the scientific evaluation methods.

II. DETERMINATION OF THE INDEX SYSTEM OF THE EVALUATION OF COOPERATION PARTNERS IN THE SUPPLY CHAIN OF AGRICULTURAL PRODUCTS

The agricultural production is a co-functioning process of natural reproduction and economic reproduction, which causes such particularities of the supply chain of agricultural products quite different from that of manufacturing industry as the biological nature of the product itself, high degree of difficulty in logistics control and management, complexity of the participants, limitation of time-based competition and importance of quality safety [8][9]. All these particularities make the supply chain of agricultural products be a supply chain of environmental conservation friendly and with quality safety, harmony and health [10]. Therefore, it is required that when doing researches on the selection of cooperation partners in the supply chain, it is necessary to consider the special features of the subjects and make in-depth observations that are different from the supply chain of manufacturing industry, on the design of the index system as well as the selection of evaluation methods.

Currently, there are a lot of influencing factors of the selection of cooperation partners in the supply chain, such as product quality, cost, environment, weather, credit, product safety, delivery time, after-sale service, etc[11-14]. It is obvious here that the selection of cooperation partners is a problem of multi-criteria evaluation, in which the candidates are evaluated by a comprehensive index based on the quantitative and qualitative analysis on each of the criteria, so as to pick out the most suitable cooperation partner. This thesis, by considering the features of the supply chain of agricultural products, takes five key indices as the evaluation basis, namely, delivery time, product quality, cost (internal cost and coupling cost), product capability and green degree and gives a scientific judgment to the selection of cooperation partners in the supply chain of agricultural products.

III. THE SELECTION METHOD OF COOPERATION PARTNERS IN THE SUPPLY CHAIN OF AGRICULTURAL PRODUCTS BASED ON *IL—WGA*

In order to conduct empirical research, an index system of maneuverability is needed to be established based on the model described above and considering the characteristics of supply chain system and the key factors (order parameters) which exert impact on supply chain synergy and data's availability.

For the decision-making of selecting cooperation partners, suppose there are m candidates $B=\{b_1,b_2,\cdots,b_m\}$, l criteria $C=\{c_1,c_2,\cdots,c_l\}$, the corresponding weight vector is $W=\{\omega_1,\omega_2,\cdots,\omega_l\}$ and $\omega_j\in[0,1]$, $\omega_1+\omega_2+\cdots+\omega_l=1$. The value of plan b_i under the criterion c_j is the intuitionistic language number $b_{ij}=<h_{\theta(b_{ij})},(\mu(b_{ij}),\nu(b_{ij}))>$. Here $\mu(b_{ij})$ and $\nu(b_{ij})$ indicate the separate degrees of affiliating and non-affiliating with the language evaluation value $h_{\theta(b_{ij})}$ for plan b_i under the criterion c_j, and $0\le\mu(a_{ij})\le1$, $0\le\nu(a_{ij})\le1$, $u(a_{ij})+\nu(a_{ij})\le1$, which forms a decision making matrix, i.e. $D=(b_{ij})_{m\times l}$. Then the order of the cooperation partners is determined.

Definition1[15]: Suppose $\mathrm{A}=\{<x,[h_{\theta(x)},(\mu_A(x),\nu_A(x))]>x|\in X\}$ is an intuitionistic language set, then the triad

$$<h_{\theta(x)},(\mu_A(x),\nu_A(x))> \quad (1)$$

is regarded as the intuitionistic language number, and A can also be taken as the set of intuitionistic language number, and so it can also be illustrated as $\mathrm{A}=\{<h_{\theta(x)},(\mu_A(x),\nu_A(x))>x|\in X\}$. Here

$\pi_A(x) = 1 - u_A(x) - v_A(x)$ indicates the hesitation degree, i.e. the fuzzy index of the intuitionistic language number.

Compared with the definition of intuitionistic fuzzy numbers, the language evaluation value $h_{\theta(x)}$ is added to the intuitionistic language number, so that the degrees of affiliation and non-affiliation correspond to a specific language evaluation value "excellent" or "good", which helps reflect the information of the decision maker in a more accurate way. Suppose there is an intuitionistic language number $a = < h_4, (0.5, 0.3) >$, the decision maker thinks that the degree of affiliation to h_4 (good) is 0.5 for the evaluated subject while its non-affiliation degree to h_4 (good) is 0.3, and the hesitation degree is 0.2 for the problem of whether the evaluated subject falls into the category of h_4 (good).

If the decision-maker is risk neutral, then the method based on intuitionistic language aggregation operators is illustrated as follows:

Step 1: Standardizing the decision making information

For decision making problems with multi-criteria, the commonly used criterion types are benefit criteria and cost criteria. In this case, no changes are made under benefit criteria while changes should be made for the language evaluation value $h_{\theta(b_{ij})}$ under cost criteria by adopting language inverse operators, which is shown as follows:

$$h'_{\theta(b_{ij})} = neg(h_{\theta(b_{ij})}) = h_{2t-\theta(b_{ij})} \quad (2)$$

For the sake of convenience, the value of plan b_i under criterion c_j is, after the above changes, still recorded as: $b_{ij} = < h_{\theta(b_{ij})}, (\mu(b_{ij}), \nu(b_{ij})) >$.

Step 2: Calculating the comprehensive criteria values for each of the candidates

The criteria of the candidate b_i is aggregated based on Formula (3) and (4), with the result of the intuitionistic language number z_i.

Definition 2 [16]: Suppose $a_j \ (j = 1, \cdots, n)$ is a group of intuitionistic language numbers, and $IL-WGA: \Omega^n \to \Omega$. If

$$IL-WGA(a_1, a_2, \cdots, a_n) = \prod_{j=1}^{n} a_j^{\omega_j} \quad (3)$$

Here, Ω is the set of all the intuitionistic language numbers, $\omega = (\omega_1, \omega_2, \cdots, \omega_n)^T$ is the weight vector of $a_j (j = 1, \cdots, n)$, $\omega_j \in [0,1]$, $\sum_{j=1}^{n} \omega_j = 1$, then $IL-WGA$ is regarded as the weighted arithmetic average operator of the intuitionistic language numbers. Especially, if $\omega = (\frac{1}{n}, \frac{1}{n}, \cdots, \frac{1}{n})^T$,then $IL-WGA$ is the arithmetic average operator of the intuitionistic language numbers（$IL-GA$）.

Proposition1: Suppose $a_j = < h_{\theta(a_j)}, (u(a_j), v(a_j)) >$ is the intuitionistic language number, then the result after aggregation is still an intuitionistic language number, and

$$IL-WGA(a_1, a_2, \cdots, a_n) = < \prod_{j=1}^{n} h_{\theta(a_j)^{\omega_j}}, (\prod_{j=1}^{n} u(a_j)^{\omega_j}, 1 - \prod_{j=1}^{n} (1 - v(a_j))^{\omega_j}) > \quad (4)$$

Here, $\omega = (\omega_1, \omega_2, \cdots, \omega_n)^T$ is the weight vector of $a_j (j = 1, \cdots, n)$, $\omega_j \in [0,1]$, $\sum_{j=1}^{n} \omega_j = 1$.

Verification: The conclusion that the aggregated result is still an intuitionistic language number can be achieved directly from the definition. Next Formula (4) is verified by mathematical induction:

(1) When $n = 2$, because

$$a_1^{\omega_1} = < h_{\theta(a_1)^{\omega_1}}, (\mu(a_1)^{\omega_1}, 1 - (1 - v(a_1))^{\omega_1}) >, a_2^{\omega_2} = < h_{\theta(a_2)^{\omega_2}}, (\mu(a_2)^{\omega_2}, (1 - v(a_2))^{\omega_2}) >$$

$$IL-WGA(a_1, a_2) = a_1^{\omega_1} \cdot a_2^{\omega_2}$$

$$= < h_{\theta(a_1)^{\omega_1}} h_{\theta(a_2)^{\omega_2}}, (u(a_1)^{\omega_1} \cdot u(a_2)^{\omega_2}, 1 - (1 - v(a_1))^{\omega_1} + 1 - (1 - v(a_2))^{\omega_2}$$

$$- (1 - (1 - v(a_1))^{\omega_1})(1 - (1 - v(a_2))^{\omega_2}) >$$

$$= < h_{\theta(a_1)^{\omega_1}} h_{\theta(a_2)^{\omega_2}}, (u(a_1)^{\omega_1} \cdot u(a_2)^{\omega_2}, 1 - (1 - v(a_1))^{\omega_1} (1 - v(a_2))^{\omega_2}) >$$

Then it is obvious that formula (4) is verified when $n = 2$.

(2) When $n=k$, suppose formula (4) could be verified, i.e.

$$IL-WGA(a_1,a_2,\cdots,a_k)$$
$$=<\prod_{j=1}^{k} h_{\theta(a_j)^{\omega_j}},(\prod_{j=1}^{k} u(a_j)^{\omega_j},1-\prod_{j=1}^{k}(1-v(a_j))^{\omega_j})>$$

then when $n=k+1$, there comes to the following result according to the operation rules:

$$IL-WGA(a_1,a_2,\cdots,a_k,a_{k+1})$$
$$=<h_{\theta(a_{k+1})^{\omega_{k+1}}}\prod_{j=1}^{k} h_{\theta(a_j)^{\omega_j}},(u(a_{k+1})^{\omega_{k+1}}\prod_{j=1}^{k} u(a_j)^{\omega_j},1-\prod_{j=1}^{k}(1-v(a_j))^{\omega_j}+1-(1-v(a_{k+1}))^{\omega_{k+1}}$$
$$-(1-\prod_{j=1}^{k}(1-v(a_j))^{\omega_j})(1-(1-v(a_{k+1}))^{\omega_{k+1}}))>$$
$$=<\prod_{j=1}^{k+1} h_{\theta(a_j)^{\omega_j}},(\prod_{j=1}^{k+1} u(a_j)^{\omega_j},1-\prod_{j=1}^{k}(1-v(a_j))^{\omega_j}+1-(1-v(a_{k+1}))^{\omega_{k+1}}-1+(1-v(a_{k+1}))^{\omega_{k+1}}$$
$$+\prod_{j=1}^{k}(1-v(a_j))^{\omega_j}-\prod_{j=1}^{k+1}(1-v(a_j))^{\omega_j}$$
$$=<\prod_{j=1}^{k+1} h_{\theta(a_j)^{\omega_j}},(\prod_{j=1}^{k+1} u(a_j)^{\omega_j},1-\prod_{j=1}^{k+1}(1-v(a_j))^{\omega_j})$$

In conclusion, formula (4) is verifiably true.

Definition3[16]: Suppose $a=<h_{\theta(a)},(u(a),v(a))>$ is an intuitionistic language number and the reliability interval for the language value $h_{\theta(a)}$ is $[u(a),1-v(a)]$ according to the definition, with the medium expected value being

$$E(a)=h_{\theta(a)}\cdot(\mu(a)+1-\nu(a))/2 \qquad (5)$$

Definition4[16]: Suppose $a=<h_{\theta(a)},(u(a),v(a))>$ is an intuitionistic language number, then

$$S(a)=I(E(a))(\mu(a)-\nu(a)) \qquad (6)$$

This is the score function of a, in which $I(h_x)=x$ is Subscript function and $E(a)$ is the medium expected value of the intuitionistic language number.

Definition5[16]: Suppose $a=<h_{\theta(a)},(u(a),v(a))>$ is an intuitionistic language number, then

$$H(a)=I(E(a))(\mu(a)+\nu(a)) \qquad (7)$$

This is the precise function of a, in which $I(h_x)=x$ is Subscript function and $E(a)$ is the medium expected value of the intuitionistic language number.

Step 4: Ordering the candidates according to Definition 6.

Definition 6: Suppose a_1 and a_2 are two intuitionistic language numbers, then

(1) If $S(a_1)>S(a_2)$, then $a_1>a_2$;

(2) If $S(a_1)=S(a_2)$, and $H(a_1)=H(a_2)$, then $a_1=a_2$;

(3) If $S(a_1)=S(a_2)$, and $H(a_1)>H(a_2)$, then $a_1>a_2$.

IV. Empirical analysis

Now evaluation and decision making is executed on the five candidates of cooperation partners. As defined previously, the five key indices are applied here, namely, delivery time, product quality, cost (internal cost and coupling cost), production capability and green degree, which are recorded as $C=\{c_1,c_2,\cdots,c_l\}$. The value of every candidate under each of the criteria given by the decision maker is shown in Table 1, and the criteria weight vector is $W=(0.15,0.20,0.30,0.25,0.10)$. Then the candidates are ordered.

Table 1 Criteria value of candidates

	c_1	c_2	c_3	c_4	c_5
b_1	$<h_3,(0.6,0.4)>$	$<h_2,(0.6,0.3)>$	$<h_5,(0.7,0.2)>$	$<h_5,(0.8,0.2)>$	$<h_4,(0.7,0.3)>$
b_2	$<h_4,(0.9,0.1)>$	$<h_5,(0.9,0.1)>$	$<h_3,(0.6,0.3)>$	$<h_5,(0.8,0.2)>$	$<h_3,(0.9,0.1)>$
b_3	$<h_3,(0.8,0.2)>$	$<h_4,(0.9,0.1)>$	$<h_2,(0.6,0.4)>$	$<h_6,(0.9,0)>$	$<h_3,(0.7,0.3)>$
b_4	$<h_6,(0.7,0.1)>$	$<h_2,(0.8,0.2)>$	$<h_3,(0.6,0.2)>$	$<h_2,(0.7,0.2)>$	$<h_3,(0.6,0.4)>$
b_5	$<h_4,(1,0)>$	$<h_3,(0.8,0.1)>$	$<h_4,(0.8,0.2)>$	$<h_4,(0.7,0.2)>$	$<h_5,(0.7,0.3)>$

Step 1: Standardized processing

The criterion of cost is cost-oriented type, and according to formula (2), conversions are made as follows:

$$h'_{\theta(b_{13})} = neg(h_{\theta(b_{13})}) = h_{2t-\theta(b_{13})} = h_1,$$

Similarly,

$$h'_{\theta(b_{23})} = h_3, \quad h'_{\theta(b_{33})} = h_4, \quad h'_{\theta(b_{43})} = h_3, \quad h'_{\theta(b_{53})} = h_2$$

For the sake of convenience, after the treatment, the value of b_i under criterion c_3 is still recorded as: $b_{i3} = < h_{\theta(b_{i3})}, (\mu(b_{i3}), \nu(b_{i3})) >$.

Step 2: Aggregating the criteria values of the candidates through weighted arithmetic average operators

The criteria values of b_i are aggregated according to Formula (3) and (4), hence z_i, the comprehensive intuitionistic trapezoidal fuzzy value of b_i:

$$z_1 = < h_{2.33}, (0.69, 0.26) >,$$
$$z_2 = < h_{3.94}, (0.77, 0.19) >,$$
$$z_3 = < h_{4.12}, (0.76, 0.22) >,$$
$$z_4 = < h_{2.77}, (0.68, 0.21) >,$$
$$z_5 = < h_{3.14}, (0.79, 0.16) >.$$

Step 3: Calculating the score function value of z_i

The score function value of z_i is figured out according to formula (5) and (6):

$$S(z_1) = 0.791, \quad S(z_2) = 1.494, \quad S(z_3) = 1.554, \quad S(z_4) = 0.896, \quad S(z_5) = 1.203.$$

Step 4: Ordering the candidates

The order of the candidates is gained, i.e. $b_3 \succ b_2 \succ b_5 \succ b_4 \succ b_1$, with b_3 being the best partner.

V. Conclusion

The agricultural production is a co-functioning process of natural reproduction and economic reproduction, which causes the particularities of the supply chain of agricultural products that is quite different from that of manufacturing industry[17]. Therefore, it is required that when doing researches on the selection of cooperation partners in the supply chain, it is necessary to consider the special features of the subject and make in- depth observations that are different from the supply chain of manufacturing industry, on the design of the index system as well as the selection of evaluation methods[18][19].In this thesis, an evaluation index system is established for the selection of cooperation partners in the supply chain of agricultural products and the $IL-WGA$ operators are adopted to evaluate and select the partners, so that the decision making process turns to be more scientific. In practical operations, many instant factors need to be considered with the changes of environment and the development of science and technology, and meanwhile, companies from different industries and with different backgrounds need to make suitable adjustments to the system and methods for selecting a partner.

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