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An Improved AHP for Analysis of the Impact Factors about Customer Return Rate in Agriculture E-commerce

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Abstract: In agriculture E-Commerce, returning customers are the greatest profile providers. In this study, we analysis the impact factors about customer return rate by using an improved Analytic Hierarchy Process (AHP) which integrates four calculation methods of AHP factor weights. Four AHP computation methods are proposed, which are Geometric Average (GA), Arithmetic Average (AA), Eigenvector Method (EM) and Least Squares (LS). Only one of the four computation methods is used in computing weight vector in most studys previously. But the different computation methods can induce some deviations in analyzing customer return rate. In this study, four computation methods are used to compute weight vectors of the impact factors about customer return rate in agriculture e-commerce. The influence factors of customer return rate is analyzed, after integrating four methods.

Key words: Agriculture e-commerce, customer return rate, AHP, improved AHP

INTRODUCTION

With the development of e-commerce technology and internet technology, agriculture e-commerce is developing with an irreversible tender. Since, agriculture e-commerce profitability is provided by returning customers, it is helpful and critical to analyze the impact factors about returning customer.

The former researchers have performed plenty of ways to analyze them: Study on Cultivation Strategy of Customer Loyalty (Duffy, 1998); Study on Cultivation Strategy of Customer Loyalty Based on Internet Marketing (Zhen, 2012); Rank B2C e-commerce websites in e-alliance based on AHP and fuzzy TOPSIS (Yu *et al*., 2011); Comparing the effects of usability on customer conversion and retention at E-commerce websites (Kuan *et al*., 2005). The first two studys only proposed the factors impacting returning consumers without proposing the accurate weight of each factor. The last two studys presented with only one way to compute factor weights. There are many articles is similar (Zhanga *et al*., 2012; Amiri, 2010; Chen and Wang, 2010). In this study, we propose an improved AHP to analyze the impact factors, which is a method of integrated 4 kinds of weights computing means.

The remainder of this structured as follows: Section 2 describes the problem definition, common symbols definition and brief introduction of analytic hierarchy process. In section 3, we describe the improved method in detail. The improved AHP algorithm will be evaluated in section 4. In section 5, drawback and future work will be proposed.

PRELIMINARIES

Influencing factors analyzing: Customer return rate means the number of an enterprise customer who purchases again. It reflects the ability of maintaining corporate customers and the fidelity of customers to an enterprise. Since eighty percent of business profits created by returning customers, it is critical to improve the returning customers.

There are considerable studys analyzing e-commerce customer retention factors previously: Study on Cultivation Strategy of Customer Loyalty (Duffy, 1998); Study on Cultivation Strategy of Customer Loyalty (Zhen, 2012); Rank B2C e-commerce websites in e-alliance based on AHP and fuzzy TOPSIS (Yu *et al*., 2011); Comparing the effects of usability on customer conversion and retention at E-commerce websites (Kuan *et al*., 2005). By analyzing previous research, combined with the characteristics of agriculture e-commerce, we present ultimate impact factors about customer return rating (Table 1).

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Table 1: Impact factors about customer return rating

Variable	Description of the variables	Variable	Description of the variables
B_1	System quality	H_6	Financial security
B_2	Information quality	H_7	Information security
B_3	Service quality	H_8	Price
C_{11}	Lead time	H_9	Quality
C_{12}	interactivity	H_{10}	Product brand
C_{13}	Security	H_{11}	Product description
C_{21}	Product appeal	H_{12}	Product activity information
C_{22}	Product information	H_{13}	Product evaluation
C_{31}	Customer service	H_{14}	Shop description
C_{32}	Logistics	H_{15}	Consulting service
H_1	Connection speed	H_{16}	After-sale service
H_2	Response speed	H_{17}	Self-service
H_3	Purchase process	H_{18}	Logistics query
H_4	Interface design	H_{19}	Type of payment
H_5	Ease of navigation	H_{20}	Timeliness

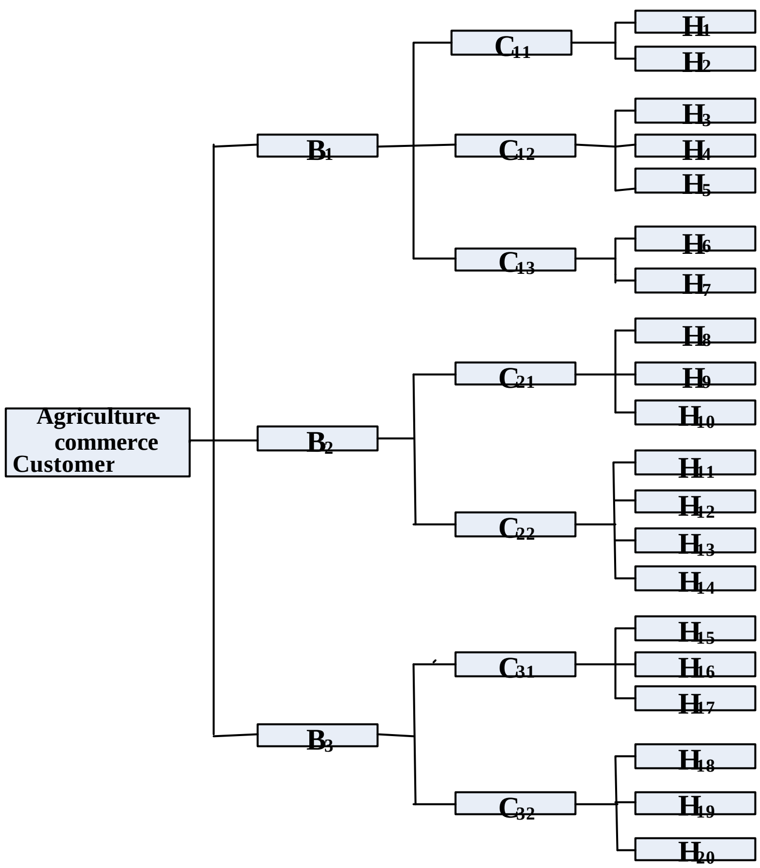

Fig. 1: Heirarchical model of e-commerce customer returntion

Constructing decision tree: In this part, a hierarchical structure about this problem is established by analyzing the previous researching and customer behavior. The problem is to analyze the impact of agricultural e-commerce customer retention factors. It is classified into 4 major levels shown in Fig. 1. The first level of this hierarchy is the goal of the analyzing: Agriculture e-commerce customer return. Level 2 propose 3 major aspects influencing customer retention factors, including system quality (Palmer, 2002; Ranganathan and Ganapathy, 2002) and information quality (Negash *et al*., 2003) and service quality (Lin and Lu, 2000). Level 3 each aspect divides into 2 or 3 smaller factors. Level 4, the ultimate factors associated with agriculture e-commerce customer return are contained (Ghodsypour and O'Brien, 1998). The construction of decision tree is described in Fig. 1.

Analytic hierarchy process: Analytic Hierarchy Process developed by Saaty (1980), is popularly applied

Table 2: Value of RI

Dimension	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.46

in solving decision making and analyzed the weight of factors. AHP is a powerful and critical tool for handling quantitative and qualitative multi-criteria factors in decision marking problems. AHP has been used in multi-criteria decision making problems: Assessment of E-Commerce security using AHP and evidential reasoning (Zhanga *et al*., 2012); Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods (Amiri, 2010); The critical factors of success for information service industry in developing international market: Using Analytic Hierarchy Process (AHP) approach (Chen and Wang, 2010), A decision support system for supplier selection using an integrated analytic hierarchy process and linear programming(Ghodsypour and O'Brien, 1998).

The first step of AHP is to establish a hierarchical structure of the problem. A hierarchy has at least three levels: overall goal of the problem at the top, multiple criteria that define alternatives in the middle and decision alternatives at the bottom. The second step is to construct pairwise comparison judgment matrix according to Table 2. The third step is to calculate the eigenvector of the matrix and to test consistency by using CR (equation 1). Then, it is the time to compute each level element combined weights. The last step is to detect total consistency by applying CR:

$$CR = \frac{CI}{RI}, \quad CI = \frac{\lambda_{max} - n}{n-1} \quad (1)$$

where, λ_{max} is the maximum eigenvector of the pairwise comparison judgment matrix $A_{n\times n}$. RI is the random consistency index. The value of RI varies according to the dimension of matrix listed in Table 2.

IMPROVED AHP METHOD FOR ANALYSIS OF THE IMPACT FACTORS ABOUT CUSTOMER RETURN RATE

Various methods of calculating matrix weight: After establishing pairwise comparison matrixes, the maximum eigenvalue of the matrix should be computed. There are four methods to calculate the weight of matrix: Geometric Average (GA), Arithmetic Average (AA), Eigenvector Method (EM) and Least Squares (LS). Supposing the eigenvector of n×n pairwise comparison judgment matrix can be defined as $w = (W_1 \ldots W_i \ldots W_n)^T$.

Geometric Average is one of the simple and common methods to calculate elements relative weight. It is formulated as follow:

$$W_i = \frac{(\Pi_{j=1}^{n} a_{ij})^{\frac{1}{n}}}{\Sigma_{i=1}^{n} (\Pi_{j=1}^{n} a_{ij})^{\frac{1}{n}}} \quad (2)$$

Because each column in matrix A approximately reflects the form of weight distribution, we can use the average of all column vectors to estimate weight vector. Arithmetic Average (AA) is delimited as shown bellows:

$$W_i = \frac{1}{n}\sum_{j=1}^{n} \frac{a_{ij}}{\Sigma_{k=1}^{n} a_{kj}} \quad (3)$$

Eigenvector of n×n pairwise comparison judgment matrix can be defined as $W = (W_1 \ldots W_i \ldots W_n)^T$ (presented before), which is calculated as follow with eigenvector method:

$$AW = \lambda_{max} W \quad (4)$$

where, λ_{max} is the maximum eigenvector in the W of the matrix $A_{n\times n}$ .The value of λ_{max} is unique. The weight of each criterion will be calculated by normalizing any of the rows or columns of matrix.

The least square define the weight vector in fitting method by minimizing the residual sum of squares. The solution of the model is as bellow:

$$\text{Min } Z = \sum_{i=1}^{n}\sum_{j=1}^{n} (a_{ij} w_j + w_i)^2, \quad \sum_{i=1}^{n} w_i = 1 \quad (5)$$

st.
$w_l > 0$, $1 = 1, 2, 3, \ldots, n$
where, the first formula is the objective function, the second and the third are the constraint functions. We can choose Lagrange multiplier method to calculate by using matlab.

Fusion algorithm: Since, the four methods of weight calculation have some limitations and singularity, we will consider the four methods comprehensively and propose a reasonable proposal. First of all, element weights in each matrix are calculated by applying the four methods (previously mentioned). The values are shown as bellows:

$$\begin{pmatrix} w_{11}\ w_{21} \ldots w_{1j} \ldots w_{1n} \\ w_{12}\ w_{22} \ldots w_{2j} \ldots w_{2n} \\ w_{13}\ w_{23} \ldots w_{3j} \ldots w_{3n} \\ w_{14}\ w_{24} \ldots w_{4j} \ldots w_{4n} \end{pmatrix} \quad (6)$$

where, w_{1j} is the weight vector calculated by the method of Geometric Average (GA) and w_{2j} is the weight vector calculated by the method of Arithmetic Average AA) and w_{3j} is the weight vector that calculated by the method of Eigenvector Method (EM) and w_{4j} is the weight vector calculated by the method of Least Squares (LS).

After calculating the elements weights in different matrixes with various methods, each element is sorted in descending according to the size of the weight. R_j is used to present the composite sequence of element j in similar level, which is delimited as follows:

$$R_j = \frac{R_{1j} + R_{2j} + R_{3j} + R_{4j}}{4} \quad (7)$$

where, R_{1j} is the sequence of element j with the method of GA . R_{2j} is the sequence of element j according to the method of GA. R_{3j} is the sequence of element j according to the method of EM. R_{4j} is the sequence of element j according to the method of LS.

Secondly, we can choose one of the results (w_{1j} or w_{2j} or w_{3j} or w_4) to determine the weight of element j, which is described by w_1. It is proposed as follows:

$$w_j = \text{Max}\,(w_{1j}, w_{2j}, w_{3j}, w_{4j}) \quad (8)$$

where, $R_j < n/2$ or $R_j = n/2$

$$w_i = \text{Min}\,(w_{1j}, w_{2j}, w_{3j}, w_{4j}) \quad (9)$$

where, $R_j > n/2$ .Where n is the number of elements in the level which include element j. with previous processing, the sum of element weight values may over one. In order to overcome this problem, w_j should be normalized by using the shown method as follows:

$$\overline{w_j} = \frac{w_j}{\Sigma_{i=1}^{4} w_i} \quad (10)$$

$\bar{w}_j$ where $\bar{w}_j$, is the finalized weight of element j. Each pairwise comparison matrix has an ultimate weight vector. When each matrix weight vector is determined, we can get the final weights of level 4 elements.

CALCULATION

Constructing pairwise comparison matrix: Once the hierarchical structure is established (Fig. 1), the inputs of relative importance between variables given by expert groups are need to construct pairwise comparison matrix. Presuming the one-dimensional matrix ($M_1 \ldots M_{11}$ $(\ldots M)_j n$) are n decision elements. The pairwise comparison matrix judgment matrix $A_{n\times n}$ = $[a_{ij}]$ is delimited as bellows:

$$\alpha i{\bullet}j = \frac{1}{\alpha j{\bullet}i} \quad (11)$$

where $a_{i\times j}$ is scale of the relative importance of decision element M_I over M_j.

The weights of various matrixes are calculated previously. Since the method of EM is used in computing matrix weight in AHP, we choose the EM weight and fusion weight to compare. Next we should get the order weight about the lowest level over the target (depicted Table 3). In EM weight, the most important factor is quality, but the most critical factor is product description in fusion weight. Which method is better should be discussed in next section.

Table 3: Order weight about the lowest level

Factor level	EM weight	fusion weight
Connection speed	0.0114059	0.003080018
Response speed	0.0057021	0.007272983
Purchase process	0.0100662	0.013488132
Interface design	0.0263789	0.048378351
Easy of navigation	0.0057611	0.006950517
Financial security	0.0780644	0.00609609
Information security	0.0260215	0.03653391
Price	0.0858007	0.033032615
Quality	0.2248446	0.118479226
Brand	0.0491061	0.017021909
Product description	0.0417788	0.090736305
Activity information	0.0247652	0.038921099
Product description	0.0982333	0.246938058
Shop description	0.0150713	0.021370788
Consulting	0.1392188	0.031344942
After-self service	0.0531259	0.00873913
Self-service	0.0304054	0.004503327
Logistic query	0.0191788	0.058786772
Type of payment	0.007774	0.021109795
Timeliness	0.0472973	0.187316

EVALUATION

In reality, we often only need one or several important factors, rather than the weight of all the factors. Improving those important factors can get a promising sequel. In this study, since we get different results by using various methods, we will verify the superiority of fusion algorithm with experiment in this section. The three most important factors are selected to ameliorate. In EM weight, we choose product quality, consulting and description. In fusion weight, we choose product description, quality and timeliness. First, the company invested a sum of money in accordance with EM-weight. The investing founds of each factor is decided with the relative

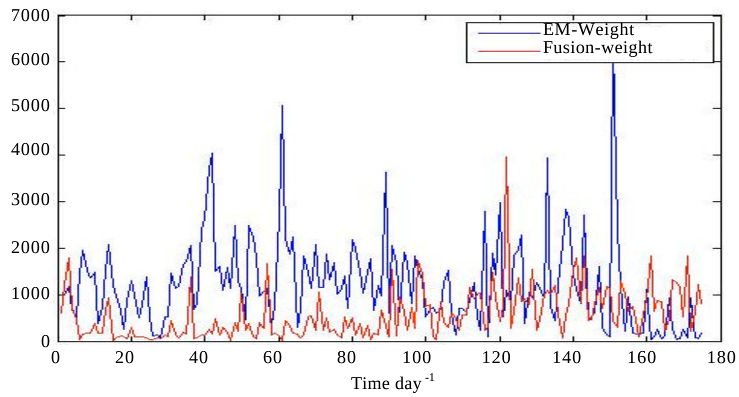

Fig. 2: EM-weight and FUSION-weight Revenue Comparison

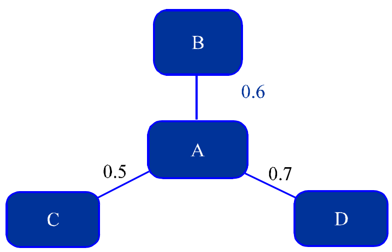

Fig. 3: Elements relationship in e-commerce customer returning

weight of three elements (quality, product description and consulting). 176 days after, the company invested a sum of money in accordance with FUSION-weight. The investing founds of each factor also is decided with the relative weight of three elements (quality, product description and timeliness). The results of two methods are depicted as follow (Fig. 2): The horizontal axis represents the number of days and the vertical axis represents the value created by the returning customers.

The results of experiment illustrate that the fusion algorithm in AHP presented in this study can improve the returning customers than the normal method EM-weight. Our fusion algorithm is an effective and useful way to improve returning customer in agriculture e-commerce.

DRAWBACK AND FUTURE WORK

In this study, there is a previous surmise that elements are mutually independent. In other word, there is no correlation between each element. But some elements have some relevance in reality. We take the following example to illustrate this problem (Fig. 3). Supposing the weight of element A is 0.1 and the others are, respectively 0.3. We assume that in order to improve customer returning we should choose an adaptive element from the elements set (A, B, C, D) to improve. If we suppose that the elements are independent, the best choice is not A. But if each element is associated, the best choice is A. The reason is that if A is improved, other elements are improved in some extent. We also can consider the element relationships by using the combination of Graph Theory.

What we proposed previously is limited in the area of agricultural electronic commerce. It also can be extended to the range of e-commerce, even wilder filed.

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