Fuzzy AHP and FCM-driven Hybrid Group Decision Support Mechanism

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Abstract

In this research, we propose a hybrid group decision support mechanism (H-GDSM) based on Fuzzy AHP (Analytic Hierarchy Process) and FCM (Fuzzy Cognitive Map). The AHP elicits a corresponding priority vector interpreting the preferred information among the decision makers. Corresponding vector was composed of the pairwise comparison values of a set of objects. Since pairwise comparison values are the judgments obtained from an appropriate semantic scale. However, AHP couldn't represent the causal relationship among information, which were used by decision makers. In contrast to AHP, FCM could represent the causal relationship among variables or information. Therefore, FCMs were successfully developed and used in several ill-structured domains, such as strategic decision-making, policy making, and simulations. Nonetheless, many researchers used subjective and voluntary inputs to simulate the FCM. As a result of subjective inputs, it couldn't avoid the rebukes of businessman. To overcome these limitations, we incorporated the Fuzzy membership functions, AHP and FCM into a H-GDSM. In contrast to current AHP methods and FCMs, the H-GDSM method developed herein could concurrently tackle the pairwise comparison involving causal relationships under a group decision-making environment. The strengths and contributions of our mechanism were 1) handling of qualitative knowledge and causal relationships, 2) extraction of objective input value to simulate the FCM, 3) multi-phase group decision support based on H-GDSM. To validate our proposed mechanism, we developed a simple prototype system to support negotiation-based decisions in electronic commerce (EC).

1 Introduction

Considerable progress has been made in area of group decision and negotiation support systems (GDNSS) reflecting a strong interdisciplinary approach in supporting multiplayer decision/negotiation processes (Bui et al., 1990). In this point, we focused on the negotiation based-decision support mechanism in EC. Especially, during the decision-making between buyer and seller, it is crucial to negotiate on multiple attributes of a deal such as price, quantity, quality, delivery, relative preference, and terms of payment. Where, we could think about the negotiation was a form of decision-making with two or more actively involved agents who could not made decisions independently, and therefore must make concessions to achieve a compromise. Therefore, negotiations for an enormous volume of transaction on the Internet became a fundamental mechanism to automating the transaction in EC (Bichler, 2000; Honert, 1998). Furthermore, the flexibility and adaptability of negotiation mechanism may be used as a plausible source of motivation and framework for the design of intelligent and autonomous EC. Recently, many researchers and practitioners have proposed a wide variety of computer-assisted negotiation frameworks (Bichler, 2000; Conry et al., 1991; Darling & Mumpower, 1992; Delaney et al., 1997; Ehtamo et al., 1999; Foroughi et al., 1995; Guttman & Maes, 1998; Jarke et al., 1987; Kersten & Noronha, 1999; Krovi et al., 1999; Oliver, 1996; Rangaswamy & Shell, 1997). However, these researches could consider only the quantitative conditions such as price, quantity or delivery. Especially, relative preference or trust for counterpart may be a qualitative conditions used in negotiations process. However, there were few studies tackling the issue of considering qualitative conditions and changes of contractor's preference explicitly.

In this study, we focused on multi-attribute negotiation mechanism including *qualitative conditions*. Which could enables automated negotiation on multiple attributes. During the negotiation, AHP deals with the traders' relative preference and satisfaction for offer and counteroffer. In addition, fuzzy membership functions manipulate the user's cognition for each condition and uncertainty occurred on the negotiation process. Therefore, H-GDSM mechanism could adapt and change the conditions for a deal dynamically. To validate the quality of our proposed negotiation mechanism, we developed a prototype negotiation support system H-GDSM. Then, we simulated that system with the hypothetical data for *healthcare products purchase*. The results of implementation showed that the H-GDSM mechanism could reflect both qualitative and quantitative efficiently.

2 Research Background

2.1 Fuzzy Membership Functions

Zadeh (1965) proposed the concept of graded membership in fuzzy sets. Generally, the fuzzy logic provides an inference structure that enables approximated human reasoning capabilities (Gupta, 1991; Pal & Mitra, 1992; Simpson, 1992; Zadeh, 1965; Zimmermann, 1991). This notion of graded membership was introduced in order to provide a mathematical precision to information arising from our cognitive process. Traditional fuzzy membership values computed by fuzzy membership functions were divided into three categories, such as *numeric value, linguistic value, and hybrid (combination of numeric and linguistic) value*. In this study, the theory of fuzzy sets provides a mechanism for representing linguistic constructs such as 'low', 'medium', and 'high'. Then, each linguistic construct was induced by the bell-shaped numeric fuzzy membership function π (Mitra & Pal, 1994). The fuzzy membership function π, lying in the range [0, 1], with F_j was defined as follows.

$$\pi(F_j;c,\lambda)=\begin{cases} 2\left(1-\frac{|F_j-c|}{\lambda}\right)^2, & \text{for } \frac{\lambda}{2}\le|F_j-c|\le\lambda \\ 1-2\left(\frac{|F_j-c|}{\lambda}\right)^2, & \text{for } 0\le|F_j-c|\le\frac{\lambda}{2} \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

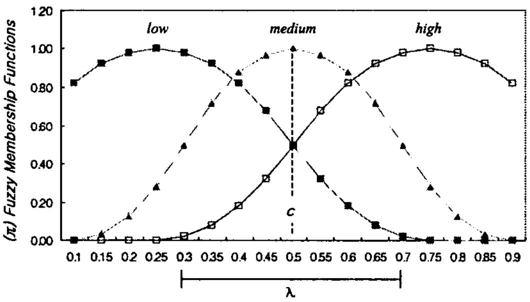


Figure 1. Fuzzy Membership Functions

Where, $\lambda > 0$ is the radius of the π-function with c as the central point at which $\pi(c;\ c,\ \lambda)=1$. Figure 1 shows the π-function representing three fuzzy linguistic values (*low, medium, and high*) (Eq. (1)).

2.2 AHP (Analytic Hierarchy Process)

AHP mechanism proposed by Satty (1994, 1980, 1977) was known as an effective tool to support the multi-attribute decision-making. Its versatility in dealing with qualitative factors, multiple objectives, and decision makers has resulted in an impressive array of applications such as energy planning, conflict resolution, banking, architecture, and etc. (Neuhold, 2000; Vargas, 1990; Zahedi, 1986). It was a compositional approach where a multi-attribute problem was first structured into a hierarchy of interrelated elements, and then a pairwise comparison of elements in terms of their dominance was elicited. The weights were given by the eigenvector associated with the highest eigen value of the reciprocal ration matrix of pairwise comparisons. A detail description of the AHP algorithm was given into four steps as follows.

Step 1: Pairwise comparison matrix A

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1m} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2m} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mm} \end{bmatrix} \qquad (2)$$

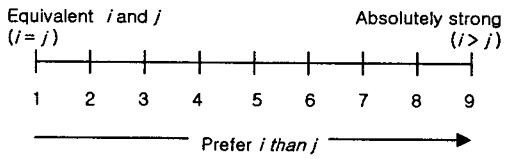
Where, a_i, i =1, 2, ...m, means the alternative or location requirement. Then, a_{ij} indicates how much more important the ith alternative is than the jth alternative for constructing the column vector of importance weighting of alternatives (location requirements). For all i and j, it is necessary that $a_{ii} = 1$ and $a_{ij} = 1/a_{ji}$. The possible assessment value of a_{ij} with the corresponding interpretation is shown in Table 1.

Table 1. Representation of relative importance

(a) Linguistic representation and numeric value of relative importance

Value of a_{ij}		
Linguistic representation	Numeric value	Interpretation
Equivalent	1	Objective i and j are of equal importance
A little strong	3	Objective i is weakly more important than objective j
Strong	5	Objective i is strongly more important than objective j
Very strong	7	Objective i is very strongly more important than objective j
Absolutely strong	9	Objective i is absolutely more important than objective j
-	2, 4, 6, 8	Intermediate values

(b) Graphical representation of relative importance



The linguistic representation and numeric value were transformed into Table 1(b).

Step 2: Generalization of pairwise comparison matrix A

In this step, each entry in column i of A was divided by the sum of the entries in column i. This yields a new matrix A_w, in which the sum of the entries in each column is 1.

$$A_w = \begin{bmatrix} \frac{a_{11}}{\sum_{i=1}^{m} a_{i1}} & \frac{a_{12}}{\sum_{i=1}^{m} a_{i2}} & \frac{a_{13}}{\sum_{i=1}^{m} a_{i3}} & \cdots & \frac{a_{1m}}{\sum_{i=1}^{m} a_{im}} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ \frac{a_{m1}}{\sum_{i=1}^{m} a_{i1}} & \frac{a_{m2}}{\sum_{i=1}^{m} a_{i2}} & \frac{a_{m3}}{\sum_{i=1}^{m} a_{i3}} & \cdots & \frac{a_{mm}}{\sum_{i=1}^{m} a_{im}} \end{bmatrix} \qquad (3)$$

Step 3: Average vector C

Compute c_i as the average of the entries in row i of A_w to yield column vector C.

$$C=\begin{bmatrix} c_1 \\ \vdots \\ \vdots \\ c_m \end{bmatrix}=\begin{bmatrix} \dfrac{\dfrac{a_{11}}{\sum_{i=1}^{m} a_{i1}}+\dfrac{a_{12}}{\sum_{i=1}^{m} a_{i2}}+\dfrac{a_{13}}{\sum_{i=1}^{m} a_{i3}}+\ldots+\dfrac{a_{1m}}{\sum_{i=1}^{m} a_{im}}}{m} \\ \vdots \\ \vdots \\ \dfrac{\dfrac{a_{m1}}{\sum_{i=1}^{m} a_{i1}}+\dfrac{a_{m2}}{\sum_{i=1}^{m} a_{i2}}+\dfrac{a_{m3}}{\sum_{i=1}^{m} a_{i3}}+\ldots+\dfrac{a_{mm}}{\sum_{i=1}^{m} a_{im}}}{m} \end{bmatrix} \quad (4)$$

Where, c_i represents the relative degree of importance for the ith alternative in the column vector of importance weighting of alternatives. In addition, c_i represents the evaluating score that the ith candidate alternative is assessed for a particular alternative criterion for making the optimal decision.

Step 4: Consistency check for *A* and *C*

To check for consistency in a pairwise comparison matrix, the substeps are required as follows:

(i) $$A\cdot C=\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1m} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2m} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & a_{m3} & \cdots & a_{mm} \end{bmatrix}\begin{bmatrix} c_1 \\ c_2 \\ \vdots \\ c_m \end{bmatrix}=\begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_m \end{bmatrix} \quad (5)$$

(ii) $$\delta=\frac{1}{m}\sum_{i=1}^{m}\frac{i\text{th entry in } A\cdot C}{i\text{th entry in } C}=\frac{1}{m}\sum_{i=1}^{m}\frac{x_i}{c_i} \quad (6)$$

(iii) Consistency index (CI) $$CI=\frac{\delta-m}{m-1},\quad CR=\frac{CI}{RI} \quad (7)$$

Note) Consistency Ratio (CR), Random Index (RI), Average Random Consistency Index = m-1

(iv) Compare CI to the random index (RI) for the appropriate value of m to determine if the degree of consistency is satisfactory. If CI is sufficiently small, the decision maker's comparisons are probably consistent enough to give useful estimates of the weights for the objective function. If $CI/RI < 0.10$, the degree of consistency is satisfactory, but if $CI/RI > 0.10$, serious inconsistencies may exist, and the AHP may not yield meaningful results. The reference values of the RI for different numbers of m are shown below (Chuang, 2001).

m	2	3	4	5	6	7	8	9	10
RI	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.51

At this point, we should focus on the comparison matrix A. Generally, most of researchers compose AHP comparison matrix A according to user's individual and flexible preference. In the flexible negotiation environment, however, most of agents may change their offers according to the counter offers. Therefore, there was need for the dynamic comparison and construction mechanism to build the comparison matrix A. We combined fuzzy membership functions with AHP to pursue the preference of agent dynamically. As a result, we could get the fuzzy comparison matrix A.

2.3 Fuzzy Cognitive Map (FCM)

Cognitive map firstly introduced by Tolman (1948) has originally been used for representing knowledge in political and social sciences, representing the cause-effect relationships, which are perceived to exist among the elements of a given environment.

The concern of cognitive map is to see whether the state of one element is perceived to have an influence on the state of the other. For instance, in Figure 2, if market position of a firm improves, then the stock price would increase. In turn, this increase of stock price would consecutively result in the improvement of credit. From these descriptions about interpreting the cognitive map operation, it can be easily observed that positive causal links (denoted as + in cognitive map) should be regarded as excitatory relationships while negative causal links (denoted as in cognitive map) as inhibitory relationships between nodes (Zhang et al., 1989). Therefore, cognitive map can represent expert's beliefs and cognition about ill-structured social relationships (Huff, 1990).

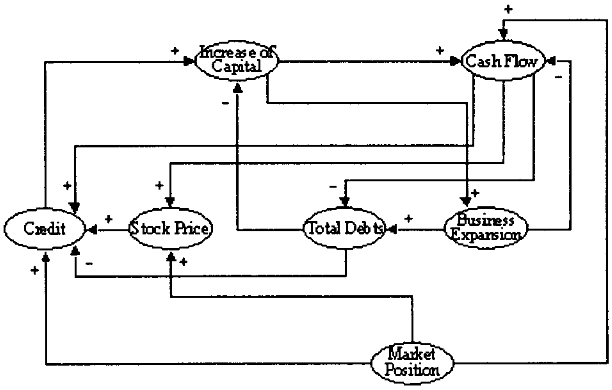


Figure 2 Cognitive map for analyzing firms credit

Usually, cognitive map has a causality value + and for the causal links. However, the causality value can be fuzzified into a real value between 1 and 1 (Kosko, 1986a; Lee et al., 1992). Axelrod (1976) claimed that the simple cognitive map with causality value + and is sufficient for replicating human cognition because decision-makers typically do not use a more complicated set of relationships. However, FCM which is a fuzzified version of the cognitive map, enables causal links to have a fuzzy value in [-1, 1]. Therefore, FCM is more general than cognitive map, including cognitive map as a special version of FCM with causal links having +1 and 1. In this sense, we will use a term FCM instead of cognitive map. FCM is fuzzy signed directed graphs with feedback, and they model the world as a collection of concepts (or factors) and causal relations between concepts (Kosko, 1986a). In usual, a concept is depicted as a node in FCM, and a causal relationship between two concepts is represented as an edge. Therefore an edge value between concept i (C_i) and concept j (C_j), e_{ij}, indicates a causality value between the two concepts. To clearly understand the FCM's logic, let us define a concept as *causality*. The causality value e_{ij} take values in the interval [-1,1]. $e_{ij}=0$ indicates no causality. $e_{ij}>0$ indicates causal increase or positive causality: a concept C_j increases as C_i increases, and C_j decreases as C_i decreases. $e_{ij}<0$ indicates causal decrease or negative causality: C_j decreases as C_i increases, and C_j increases as C_i decreases.

Over the last ten years, a variety of FCMs have been used for representing knowledge and artificial inference in engineering applications. In addition, a few modifications have been proposed: Silva (1995) proposed new forms of combined matrices for FCM; Hagiwara (1992) extended FCM by permitting nonlinear and time delay on the arcs; Schneider et al. (1995) presented a method for automatically constructing FCM. More recently, Liu and Satur (1999) have carried extensive research on FCM, investigated inference properties of FCM, proposed contextual FCMs (CFCMs) based on the object-oriented paradigm for decision support, and applied CFCMs to geographic information systems.

Lee & Kim (1997) has applied successfully FCMs to infer rich implications from the stock market analysis results. Lee & Kim (1998) also suggested a new concept of fuzzy causal relationships found in FCMs, and applied it to analyze and predict the stock market trends. The inference power of FCMs was uniquely adopted to analyze the competition between two companies which are assumed to use differential games mechanism to set up their own strategic planning (Lee & Kwon, 1998). FCM has been integrated with case-based reasoning technique to build organizational memory in the field of knowledge management (Noh et al., 2000).

3 Methodology

Our proposed negotiation mechanism was composed of six phases as shown in Figure 2. The first phase of negotiation mechanism was started with the *initial offers for a deal* of agent (buyer/seller).

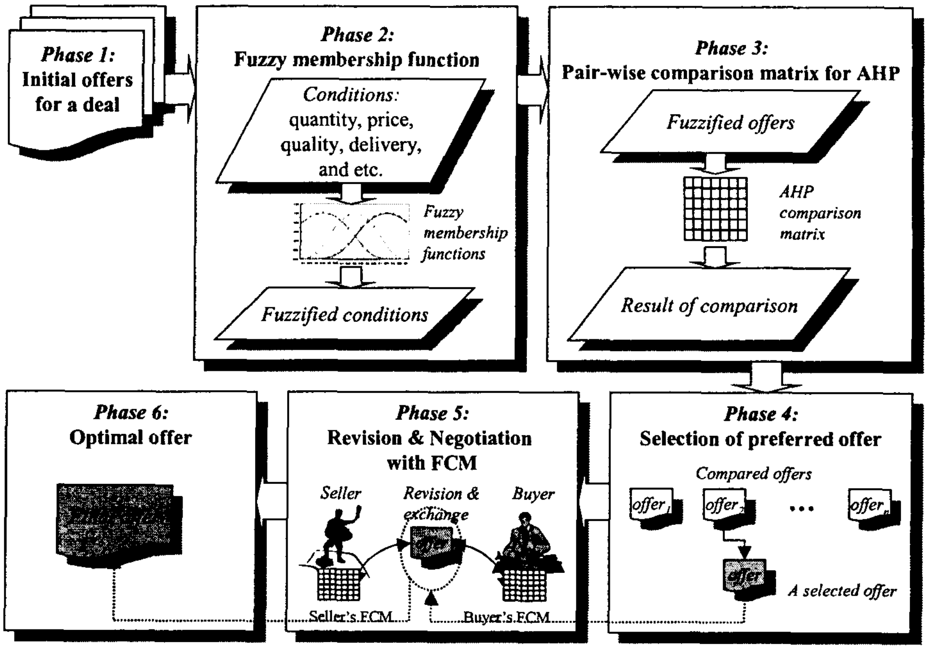


Figure 2. H-GDSM mechanism

In the first phase, each negotiation agent offers their negotiation conditions reflecting their relative preference for a deal. Where, a deal was composed of quantitative conditions such as quantity, price, quality, and delivery. However, the fuzzy value for these conditions will changed by fuzzy membership functions reflecting qualitative conditions such as relative preference.

After the initial offers of agent, we used *fuzzy membership functions* to construct support the construction of fuzzy pairwise comparison matrix A. Using this fuzzy membership function, we transformed buyer/seller's relative preference into fuzzy membership values. During the transformation process, we adopted Mitra and Pal (1994)'s bell-shaped fuzzy membership functions.

The third phase of our proposed negotiation mechanism was *construction of pairwise comparison matrix A*. in this phase, we used AHP comparison matrix to compute the relative importance about each alternative (deal). As a result, each agent's offers were fully compared. Fourth phase of our mechanism is '*selection of preferred offer*' of negotiation agent. According the result of comparison in phase 3, preferred offers were selected by buyers (or sellers). However, this is the first step of dynamic negotiation process.

The fifth phase of our mechanism is '*revision and negotiation with FCM*'. In this phase, each agent revise their 'initial offer and continue to negotiate with their counter part. To this purpose, we used '*FCM*' methodology to revise the initial offers.

Final sixth phase of our proposed mechanism is to suggest the '*optimal offer*'. In this phase, buyer and seller could get a satisfactory offer.

4 Implementation

To validate the effectiveness of our proposed negotiation support mechanism, we used health care product purchase data. In this case, buyers and sellers exchange and revise their offers using H-GDSM.

4.1 *Phase 1*: Initial offers

Detailed conditions for negotiation were composed of quantity, price, quality, and delivery time. At the first phase, three sellers suggested their initial offers to buyer.

Table 2. 1st (initial) offers of sellers

	Offer1 (Seller1)	Offer2 (Seller2)	Offer3 (Seller3)
Quantity (Boxes)	1,300	1,100	1,200
Price (US$)	110,000	108,000	105,000
Quality (Grade)	1	3	4
Delivery (Days)	12	11	9

At this point, we may assume that the buyer could change his offers with his own trade conditions as follows:

- Quantity = 500~1,500 Boxes
- Price = 85,000~110,000 US$
- Quality = 1~8 Grade
- Delivery = 1~15 Days

4.2 *Phase 2*: Fuzzy membership functions

The initial offers shown in Table 2 were transformed into fuzzy membership values by using the fuzzy membership functions (Table 3). In this phase, we adopted bell-shaped fuzzy membership functions to transform the value of each condition (Mitra & Pal., 1994). However, users (buyer/seller) could set the limit of each factor used in fuzzy membership functions. Which are the range of data, center value, radius, and others. Figure 3 shows the graphical representation of fuzzy membership functions for each condition.

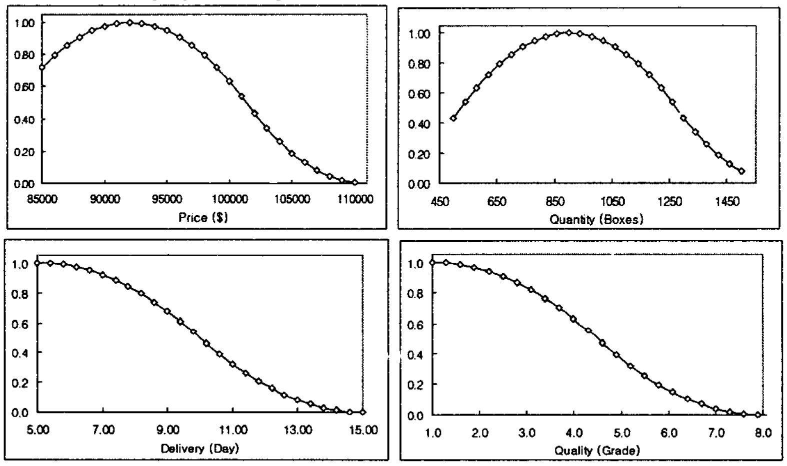


Figure 3. Fuzzy membership functions for each negotiation conditions

4.3 *Phase 3*: Pairwise comparison matrix for AHP

In the case of traditional AHP-based reasoning, backward tracking for the change of variable was impossible. To overcome this limitation, we used fuzzy AHP-based 'goal-seeking' methodology. There is a need for computation of relative importance among variables (negotiation conditions: quantity, price, quality, and delivery).

Table 3. Fuzzy membership value for each offers shown in Table 2

	Offer1	Offer2	Offer3
Quantity (Boxes)	0.44	0.86	0.68
Price (US$)	0.00	0.04	0.19
Quality (Grade)	1.00	0.84	0.63
Delivery (Days)	0.18	0.32	0.68
Averaged satisfaction	**0.40**	**0.51**	**0.55**

First, we should decide which condition is most important than other conditions. Table 4(a) shows the paired comparisons among variables (negotiation conditions). Then Table 4(b) shows the normalized comparison matrix.

Table 4. Pairwise comparison matrix for negotiation offers

(a) Initial comparison matrix

	Quantity	Price	Quality	Delivery
Quantity	1	5	3	2
Price	1/5	1	1/2	1/2
Quality	1/3	2	1	2
Delivery	1/2	2	1/2	1

(b) Normalized comparison matrix

	Quantity	Price	Quality	Delivery	Averaged score (weight)
Quantity	0.49	0.50	0.60	0.36	**0.49***
Price	0.09	0.10	0.10	0.09	0.09
Quality	0.16	0.20	0.20	0.36	0.23
Delivery	0.25	0.20	0.10	0.18	0.18

Where, consistency value of AHP is 0.01 (CR=0.01). This result means that the comparison matrix shown in Table 4 could make a meaningful decision in the future decision making or negotiation. To get a meaningful relative comparison matrix about all condition, in the next phase, we showed the computation example about all offers using 'price' condition only. As a result, the third offer was selected as the most preferred offer (average score = 0.53). However, that was not the final decision.

Table 5. Pairwise comparison matrix for price

(a) Initial comparison matrix for price and offers

	Offer1	Offer2	Offer3
Offer1	1	0.76	0.40
Offer2	1.32	1	0.46
Offer3	2.48	2.16	1

(b) Generalized comparison matrix for price

	Offer1	Offer2	Offer3	Averaged score
Offer1	0.21	0.19	0.22	0.21
Offer2	0.27	0.26	0.25	0.26
Offer3	0.52	0.55	0.54	**0.53***

4.4 *Phase 4*: Selection of preferred offer

In contrast with the results shown in Table 5, we computed relative importance about all offers with all negotiation condition. As a result, we could decide that the offer 2 was the most important (preferred) offer (total score = 0.4411) (Table 6). Where offer 3 was ranked at the second order. It was a difference result with which shown in Table 5.

Table 6. Comparison matrix for all negotiation conditions

(a) Comparison matrix for all conditions

	Quantity	Price	Quality	Delivery
Offer1	0.1106	0.2060	0.4264	0.1195
Offer2	0.5674	0.2593	0.3720	0.2869
Offer3	0.3221	0.5346	0.2016	0.5936

(b) Comparative score (weight) for offers

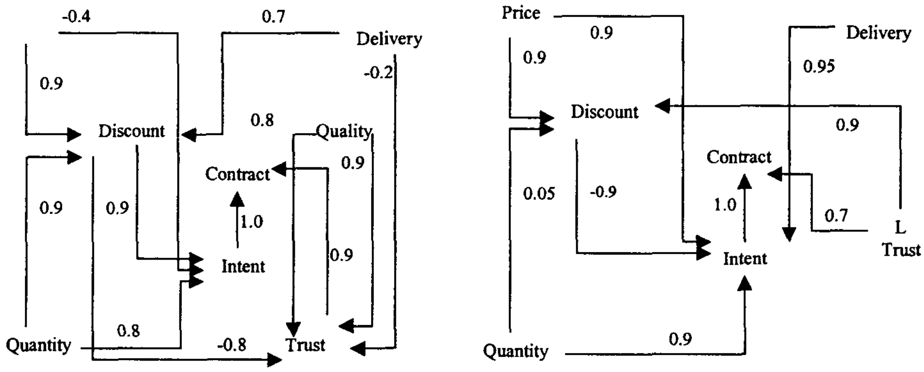
	Total score
Offer1	0.1947
Offer2	**0.4411***
Offer3	0.3642

Therefore, the buyer may select the seller 2 as a best trader. Then, next negotiation process will be executed between buyer and seller 2 except other sellers.

4.5 *Phase 5*: Revision & Negotiation with FCM

In this phase, we could assume that the buyer may want to improve the satisfaction level (value) from 0.51 to 0.7~0.9. How could we improve the satisfaction level efficiently? And, how could they (buyer/seller) change the each negotiation condition?

To get an optimal offer, we used *FCMs (buyer and seller)*. The causal relationship among quantitative conditions and qualitative conditions was shown in Figure 3.



(a) FCM for buyer **(b) FCM for seller**

Figure 3 Buyer and seller's FCM

In addition, the fuzzy value of each condition related with fuzzy membership functions and real value directly. Therefore, the fuzzy values were transformed into real value such as quantity, price, quality, and other values. Table 8 shows the results of computation (real value transformed) to improve buyer's satisfaction level from 0.51 to 0.9.

Table 8. Buyer's new offer after 1st negotiation

	Before revision (Seller)	After revision (Buyer)
	Offer	Revised offer
Quantity (Boxes)	1,100	1,100
Price ($)	108,000 $	98,730 $
Quality (Grade)	3 Grade	1 Grade
Delivery (Days)	11 Days	5 Days
Averaged satisfaction	**0.63**	**0.50**

4.6 *Phase 6*: Optimal offer

As shown in Figure 2, revision and negotiation process will continue to find an optimal solution or consensus between buyer and seller. Table 9 shows the final consensus between buyer and seller and summarized the final offers of them.

Table 9. Buyer & Seller's final offer

Final offer (Buyer/Seller)	
Conditions	Values
Quantity (Boxes)	1,210 Boxes
Price ($)	97,900 $
Quality (Grade)	1 Grade
Delivery (Days)	9 Days
Satisfaction (Buyer/Seller)	**0.76 / 0.72**

5 Conclusions

Buyer and seller in EC commonly used their own prices, margins, and other trade terms through negotiations. These negotiation conditions have significant impact on channel members' profit streams over the duration of the business relationship. In this case, traditional researchers used equilibrium function such as Nash's cooperative formulation. This kind of negotiation mechanism was a key normative benchmark for testing models of two person negotiations. Nonetheless, it has a critical limitation for representing a real-world bargaining behavior (Srivastava et al., 2000).

In this study, we assumed that the negotiations occur in an incomplete and asymmetric information environment such that the seller is uncertain about the buyer's reservation price, whereas the buyer knows it precisely because of the threat of potential competitive entry. Both parties have identical opportunity costs of delay in reaching agreement (Srivastava et al., 2000). In addition, we considered a situation where a buyer and exclusive, independent sellers are negotiating with the price, quantity, quality, and delivery for a new product. As a result, we proposed fuzzy AHP and FCM-based negotiation mechanism to support the agents in multiple and dynamical negotiation environment.

Our proposed mechanism has three important contributions. First, most of former researchers used simple query to compute the relative importance in AHP. However, this simple query was very static and changed by the minute. Therefore, we proposed the fuzzy AHP and FCM-based computation mechanism. It was flexible and could prevent the user's error during the computation of relative importance. Second, traditional negotiation support mechanisms were based on quantitative conditions. However, our proposed H-GDSM mechanism could support the quantitative and qualitative conditions used in negotiation simultaneously. Third, our H-GDSM mechanism could suggest an optimal solution and trace the change of negotiation conditions using fuzzy AHP and FCM. This facility could help the agent to change the conditions safety and efficiently.

Nonetheless, further research topics still remains. First, the number of qualitative negotiation conditions should be increased. Second, the basic technology of fuzzy membership function and AHP should be improved with other artificial intelligence techniques. Third, there are need to expand our laboratory experiment to real real-world negotiation case. Fourth, distributed processing and intelligent agent mechanisms could enhance the reality of negotiation.

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