J Biochem Tech (2018) Special Issue (2): 124-130
ISSN: 0974-2328

Providing a Model for Evaluating Information Sharing Capabilities of Supply Chain Partners using Fuzzy Inference System in Dairy Factories Case Study: Chaharmahal & Bakhtiari Province

N. Sharifikheyrabadi*, R. Rafar

Received: 17 Junuary 2018 / Received in revised form: 12 July 2018, Accepted: 16 July 2018, Published online: 05 September 2018

Abstract

Today, all organizations are somehow exposed to developments in information technology and effects of the application of ICT in all areas of supply chain relationships is clear .In this paper a model for evaluating information-sharing capabilities of supply chain partners with case study dairy factories in Chaharmahal & Bakhtiari Province By using fuzzy inference system is presented. In this model for Fuzzy Inference System input two factors that affect the ability of information shairing one is desire to cooperate and another technological infrastructure is considered .This inputs give ambiguous values that convert to correct values with using fuzzy membership functions. And the output is the ability to share information which is expressed as a fuzzy and convert to correct values with using fuzzy membership functions. The inference rules are 28 and obtained from experts. It is noted that this system is implemented in MATLAB fuzzy Editor.This model has been implemented on three companies from manufacturing supply chain partners is common.

Keywords: Fuzzy Inference System, Supply Chain Management, Information Shairing, Case Study.

Introduction

In the current competitive world, organizations need to work hard for their growth and stability and implement the right strategy to progress and maintain their survival. The occurred changes in customers' demand, the market atmosphere, and technological innovations have made companies to face with growing competition. In such a market, appraising and paying attention to supply chain partners in order to create a powerful chain can be one of the key factors in line with maintaining the survival in this competition, and since information flow can play an important role in accelerating the chain operations, it has been considered as one the significant parameters of the partners' evaluation to continue cooperation.

The information flow between partners increases the possibility of sharing information in the chain, the possibility of transfer and use of information. Consequently, in the field of evaluating the information capabilities of the chain partners, paying attention to the partners' capability and ability to share information will be effective.

The main aim of this research is to provide a supply chain partners evaluation model based on their information sharing capabilities, and its specific objective is to transfer the managers' intuitive and ambiguous judgments of supply chain in line with evaluating this ability in partners into exact and definite amounts by means of fuzzy inference systems and its applied aim is to use the model presented in Chaharmahal and Bakhtiari province dairy factories in the upstream and downstream supply chain.

In the current research, the researcher tries to weigh the supply chain partners' information sharing capability by means of a fuzzy inference system technique in the target society.

In this research, a model has been used for responding and evaluating the following hypotheses in the conceptual model:

1. Collectivism has a more positive effect on willingness to cooperate and individualism has a negative effect on willingness to cooperate.

N. Sharifikheyrabadi*
Graduated from Information Technology Management Department of Islamic Azad University, Tehran, Iran.

R. Rafar
Islamic Azad University, Science & Research Branch, Tehran, Iran.

***Email:** neda.sharifi@gmail.com

2. Appropriate hardware capability has a positive effect on technological infrastructure.
3. Better software capability has a positive effect on technological infrastructure.
4. The proper network infrastructure has a positive impact on technological infrastructure.
5. The presence of a proper data management in organizations has a positive effect on technological infrastructure.
6. A capable specialist force in the organization has a positive effect on technological infrastructure.
7. The appropriate technological infrastructure has a positive effect on information sharing capabilities.
8. The cooperation desire in the organization has a positive effect on information sharing capabilities.

Research Background

Dickson (1966) by means of a research entitled " An analysis of vendor selection systems and decision" that he conducted on purchasing agents, considered 23 factors for the supplier selection process, which were price, delivery, quality, service, geographic location and financial strength, communication systems, attitudes and operational control systems, etc.

Lehmann and O'Shaughnessy (1974) investigated and analyzed these purchasing agents for different classifications of products. Fisher and Raman (1997) emphasized the role of products in supply chain design.

Ellram (1987) introduced the issues that should be explained when launching a link between partners in the supply chain, and these factors are categorized as financial issues, organizational culture, and strategy and technology.

Handfield and Nichols (1999) and Chopra and Meindl (2001), in a research entitled "Supply Chain Management: Strategy Planning, and Operation", emphasized mainly on criteria such as technology infrastructures and cooperation potential, supply resource strategies and sharing information potential.

Premkumar (2000) provided an integrated vision of supply chain management and inter-organization systems and indicated that all organizations in the supply chain benefit from sharing information by reducing the uncertainty of demand and supply.

Huang et al. (2003) by reviewing the effects of information sharing on supply chain dynamics concluded that the related information can be useful for all partners in the supply chain.

Anand and Mendelson (1997) inspected the relationships between coordinate inter-organizational structures and information sharing, and implement it in a company that was facing demand uncertainty in several markets. In this analytical study, some mathematical methods were used to understand the behavior of the established models and the effect of information sharing on supply chain performance.

Li et al. (2006) in a probabilistic and statistical method concluded that real demand information sharing among supply chain members would reduce the demand inconsistency.

Yu et al. (2001) scrutinized the benefits of supply chain collaboration and contributions via information sharing and concluded that by increasing the level of information sharing both vendors and developers can achieve improved performance.

In addition, Chen (1998), Cachon and Fisher (2000), Lee et al. (2000), Gavirneni et al. (1999), used random and capacitive models for evaluating chain performance with emphasis on the benefits of sharing the information. In these studies, researchers investigated a variety of information such as capacity, inventory levels, demand, and cost. Recently, researchers have tried to simulate fuzzy logic-based decision-making methods to appraise the supply chain partners' information sharing capacity.

Perçin Selçuk (2011), in a research entitled "Use of fuzzy AHP for evaluating the benefits of information-sharing decisions in a supply chain," talks about the importance of sharing information in the supply chain, even the type of more important information will be determined by means of the Fuzzy AHP method and analytic hierarchy process.

Moinzadeh (2002) studied the information sharing benefits in a supply chain and indicated that how the supplier benefits from vendor information and inventory level.

Karbassian et al. (2011), in a study, investigated the application of the model for rating the selection criteria of agile suppliers and ranking of suppliers by TOPSIS and fuzzy hierarchical analysis methods. In this research, at first, the criteria of suppliers' agility assessment were investigated. Then, by means of the interpretive structural model method, the leveling and categorizing these factors were discussed. The results of this method illustrated that the delivery speed is at the first level of the output of this model and also has a

very good advancement power. Likewise, the delay time criterion has these characteristics. Then, by the fuzzy hierarchy analysis method, the weight of the criteria of suppliers' agility assessing was determined and it was introduced as the TOPSIS model input. Lastly, by the fuzzy TOPSIS method, six suppliers were ranked.

Ali Mohammadi et al. (2011) conducted a study entitled "Investigating the Influence of Information Technology on Electricity Issues and Supply Chain Performance of Dairy Companies in Fars Province". In this research, in a collection of information technology tools, supply chain communication system, electronic information exchange, e-mail, barcode and radio frequency identification, in line with the capabilities of the supply chain of four dimensions of information exchange, coordination, integration of activities, reactivity of the supply chain and with regard to performance of the supply chain, two performance criteria including marketing and sales performance, and financial performance are investigated. The results designate that using information technology tools affected the supply chain capabilities based on the research process model, and the supply chain performance is affected.

Method

With regard to the fact that the aim of this study is to provide a model for assessing the information sharing capabilities of supply chain partners by means of the fuzzy inference system in dairy factories; therefore, the present study is applied in terms of objective and in terms of the method it is a modeling survey. In the current research, documents, articles, theses and various books have been used and also the field method and the questionnaire and interview have been used, and with regard to the aim of this research it is necessary to use expert advice in the field of technology and industry and supply chain to determine the weight of the evaluation indices. Thus, in terms of data collection, the current research is considered as a descriptive (non-experimental) field study research. The research method is a survey that one of its most important advantages is the results generalizing.

In this research, the research method is to evaluate the supply chain partner's information sharing capability. Consistent with the conducted studies, this capability is related to the two variables of the willingness to cooperate and the technological infrastructure. After determining the indicators of each dimension, it is important to note that each indicator does not have similar value, because by means of consulting with the experts' of technology, industry and the value chain, the researcher extracted each indicator by interviewing and adjusting a questionnaire from the abovementioned individuals. It is necessary to mention that the questionnaire was also prepared with the people's recommendations who are expert in this field. After determining the indexes and rating and categorizing the scores with MATLAB software, the researcher designed a system for evaluating this feature and this system or model will work as follows. The questions must be organized to determine the fuzzy value of each indicator that has prepared according to the expert opinion, also, the fuzzy state of each indicator is determined by the questions asked by the system and the experts' opinion and expressed in the fuzzy state. It should be noted here that the first set of inferential model rules will be defined, that according to the received responses, it will indicate that how much the fuzzy value of each index is.

After extracting the fuzzy values of each index, by the triangular defuzzification function, the values are converted to definitive values, and the weight factor is also considered in line with determining the final value of this index. As the system inference rules have been prepared in a fuzzy state, the values of the indexes will be fuzzy to be matched in the rules.

Lastly, by means of the inference rules and the results obtained from the index questions, the system declares the result in the fuzzy state. Finally, the validity of the model response will be compared with the evaluation of chain managers for different partners and the model performance will be recognized. It should be noted that Mamdani fuzzy inference system has been used in this system.

Findings

To obtain the value of the evaluation indicators from the partners, at first after collecting questionnaire from the partners, the score of each questionnaire is calculated and the average scores are considered as the amount of that indicator for that partner organization or company. After obtaining the index value, according to the categorization the researcher has to determine that in which category this index should be placed and by of the 7 Gaussian membership functions for the 7 terms of this linguistic variable, we obtain the membership of that index in that category. Then, by the second questionnaire that is completed by the IT expert of the organization or the company, the second indicator score is calculated and the classification of the organization is determined in the second index and in line with the four Gaussian membership functions for the terms of this linguistic variable, membership is determined in the index categorization, then by means of the inference rules derived from the third questionnaire it is determined that what is place of the organization information sharing capability in the categorization.

In order to obtain the exact value of data sharing capability in each partner, a fuzzy inference system model is designed by Mamdani Inference, and it is the system that receives its inputs from the seven Gaussian functions considered for the linguistic variables terms

"willingness to cooperate" and the four Gaussian functions considered for the linguistic variables terms "technology infrastructure status" and has 28 extracted inference rules from the third questionnaire based on the opinions of IT experts and the support and business managers of the partners, and its output is 5 triangular functions for “information sharing capability” and the defuzzification method is the center of gravity. Then in this system, based on the system input values, which is a numerical value derived from the questionnaires, after applying the Mamdani method and defuzzification the answer the inference system returns the numerical value of this capability.

It should be mentioned that the classification for the consequences of these rules is based on the lowest score and the highest score in each category in 30 questionnaires collected by experts in the form of the third questionnaire.

In order to implement this model, five steps have been considered and the MATLAB software and its fuzzy editor were used. These five steps are as follows:

The first step – making the inputs fuzzy:

The first step in the fuzzy inference system is to receive inputs and determine their membership degree to each of the fuzzy sets via membership functions.

In this model, there are two variables called "willingness to cooperate" and "technological infrastructure." The amount of the first input, by means of the average of the Hofstede questionnaires collected from the member of the supply chain member, is determined with the number determined by the Cochran formula with the specified number of society. The second output is the technological infrastructure with the following indicators of "software capability", "hardware capability", "network infrastructure", "capable specialist force" and "data management", which is collected based on the standard questionnaire from information technology expert of the supply chain partner and it's given to a system designed to collect inputs.

Linguistic terms for the linguistic variable of the willingness to cooperate are defined as follows:

- ✓ Very weak with the title of **Very_Weak** of Gaussian type with a standard deviation of approximately 0.17 and centrality of 1.5
- ✓ Weak with the title of **Weak** of Gaussian type with a standard deviation of approximately 0.17 and centrality of 2
- ✓ Fairly balanced with the title of **Fairy_Balanced** of Gaussian type with a standard deviation of approximately 0.17 and centrality of 2.5
- ✓ Balanced with the title of **Balanced** of Gaussian type with a standard deviation of approximately 0.17 and centrality of 3
- ✓ Good with the title of **Good** of Gaussian type with a standard deviation of approximately 0.17 and centrality of 3.5
- ✓ Fairly excellent with the title of **Fairy_Excellent** of Gaussian type with a standard deviation of approximately 0.17 and centrality of 4
- ✓ Excellent with the title of **Excellent** of Gaussian type with a standard deviation of 0.17 and a centrality of 4.5

For the second system input that was the technology infrastructure, the following terms were also defined:

- ✓ Very weak with the title of **Very_Weak** of Gaussian type with a standard deviation of 9,527 and centrality of 35
- ✓ Weak with the title of **Weak** of Gaussian type with a standard deviation of approximately 4.078 and a centrality of 72.5
- ✓ Middle with the title of **Middle** of Gaussian type with a standard deviation of approximately 9,527 and centrality of 115
- ✓ Good with the title of **Good** of Gaussian type with a standard deviation of 9.527 and centrality of 175

Step Two - Applying Fuzzy Operators:

After making the inputs fuzzy, the degree of accuracy of each constituent of the hypothesis is determined. If the hypothesis part has multiple sections, fuzzy operators will be used to combine the degree of accuracy of the sections and generate a number as the degree of accuracy of the hypothesis. The resulting number of this process is applied to the output function.

In the MATLAB fuzzy toolbox, there are two methods for the implementation of AND; minimum and multiplication. Also, the two methods for implementing OR are maximum and probable OR.

Since both indicators affect the partners’ information sharing capability, in this model, the AND and Min operators are used to combine the degree of accuracy of the sections. Of course, the other reason is using the Mamdani method in this inference that uses AND and Min operators in line with the combination of inputs and determining the degree of accuracy.

Step 3 - Applying the implication method:

Before defining the implication applying method, the researcher must first explain the method of defining the rules extracted from the questionnaire completed by the experts and the output required of this inference system in the fuzzy editor.

In this section, the output variable the supply chain partners "information sharing capabilities" is defined by means of the following terms:

- ✓ Very weak with the title of **Very_Weak** of the triangular type with the first, center and end points of 0, 5, 10
- ✓ Weak with the title **Weak** of the triangular type with the first, center and end points of 10, 20, 30
- ✓ Middle with the title of the triangular type with of triangular type with the first, center and end points of 30, 42.5, 55
- ✓ Fairly good with the title of Fairly_ Good with of triangular type with the first, center and end points of 50, 62.5, 75
- ✓ Good with the title of Good with of triangular type with the first, center and end points of 75, 87.5, 100

Then, the inference rules of the inference system were defined in this editor. These rules with regard to the input and output variables and the values they could have, and taking into account all the states, in the form of the 28 extraction rules were extracted from a questionnaire provided to the experts. These rules were defined with the same weight and by means of logical AND in the connection of the antecedents in the system. And this is while, in applying the implication method, according to the weight given to each rule, there is a number between 0 and 1 specifies the effect of that rule on implication. As it was mentioned above, in this model, the weight of all these rules is in accordance with expert opinion is considered as 1.

After assigning the suitable values to the weights of each of the rules, the implication method will be implemented; the result section of a fuzzy set is determined by the membership function. As noted above, the output section in our model is defined with the triangular membership function on the output variable terms. This section is changed by a function, and the number derived from the hypothesis. The output of the implication process is a number and its output is a fuzzy set. The implication process is implemented based on each rule. There were two methods for the implication process in the MATLAB toolbox that in this model, based on the Mamdani model, we used the minimum method for the AND inputs and this minimum cuts the output and creates a fuzzy set.

Step Four: Aggregation of outputs:

Since in a fuzzy inference system, decisions are made based on an evaluation of all rules, the rules must be combined in some way. Aggregation is a process in which the fuzzy sets that provide the output of rules each are combined in the form of a fuzzy set. The aggregation operation is accomplished only once for each output variable before the start of the defuzzification phase. The list of the cut output functions via the process of implication forms the input of the aggregation process. The output of the aggregation process is a fuzzy set for each output variable.

Since the aggregation process is moveable, so the order of the performed rules is not important. In the fuzzy editor of the MATLAB software, three methods were considered for aggregation:

- Maximum
- Probable OR (Probor)
- Calculate the sum (Sum)

That according to the Mamdani model, the maximum method was used for the inference system of the proposed model.

Stage Five - Defuzzification:

The input of the defuzzification process is a fuzzy set (the result of the aggregation operation) and its output is a number. The fuzzy logic during the middle stages helps to evaluate the rules, but the anticipated output for each variable is commonly a number. That is a while; the result of fuzzy sets aggregation contains a range of output values, and need defuzzification, in order to generate an output value.

Perhaps the most popular defuzzification method is to calculate the center of mass. This method calculates the center of the area below the curve. Mostly, there are five methods in the defuzzification set of fuzzy sets:

- Center of mass
- Bisection
- Maximum middle (average of maximal values from output sets)
- The biggest maximum
- The smallest maximum

Where in the fuzzy inference system, the proposed model, and also based on the use of the Mamdani method in the inference, the center of mass defuzzification method was used.

Due to the fact that the statistical society of this research is the partners of the supply chain of dairy companies of Falat-e Koohrang, Shimbar and PakPay of the Chaharmahal and Bakhtiari province, and since three companies of Salem Poodran, Tetrapak and Carton Plast with the number of personnel 40, 70, and 53 are of the supply chain partners of the all three above mentioned companies, to evaluate the model, these three companies were selected and by means of distributing the first questionnaire (willingness to cooperate) among 36, 59 and 47 people, respectively, in these companies and completing the second questionnaire (technology infrastructure) by IT experts of this company, with the cooperation of their commercial and administrative managers, the proposed model will be implemented and the following results were obtained:

- Salem Poodran Company with a willingness to cooperate index of 3.87 and technology infrastructure index of 129 has the information sharing capabilities of 62.6.
- The second company was Carton Plast with a willingness to cooperate index of 3.46 and technology infrastructure index of 143 has an information sharing capability of 67.8.
- The third company, TetraPak, with a willingness to cooperate index of 4.01 and technology infrastructure index of 169, has an information sharing capability of 86.8.

Conclusion and Recommendations

The results of the model implementation of different companies exhibited that when the amount of technology infrastructure indicator and willingness to cooperate is high; the information sharing capacity is also greater. On the other hand, we know that these results are obtained from the inference rules implementing that are derived from experts' ideas who emphasized the impact of the two issues on information sharing. So it can be indicated that the results obtained from the inference in the form of this model also confirm this hypothesis.

In the meantime, with regard to the questionnaires and the considered Likert scale, if the responses are more "I agree" and "I totally agree", the response score will be high and as a result, the index will be high and its effect will be more on the sharing capability. So this explanation confirms the correctness of the stated hypotheses. It can be indicated that the assumptions of "collectivism have a more positive effect on willingness to cooperate and "individualism" has a negative effect on the willingness to cooperate", "the appropriate hardware capability has a positive effect on the technological infrastructure," "better software capability has a positive effect on the technological infrastructure," "the appropriate network infrastructure has a positive impact on technological infrastructure," "the presence of appropriate data management in the organization has a positive effect on technological infrastructure ", " a capable specialist force in the organization has a positive effect on technological infrastructure" , "the proper technological infrastructure has a positive effect on the information sharing capability " and "willingness to cooperate in the organization has a positive effect on the information sharing capability" are correct.

This model, in fact, by receiving the obtained fuzzy values from two indicators of the willingness to cooperate and technology infrastructure, and including the inference rules obtained from experts' opinion and performing defuzzification operations on the fuzzy result of the inference, not only approves the effect of these two indicators that are mentioned in detail in the hypotheses, but also expresses the amount of this effect with an integer.

Meanwhile, the current research presents a model for other research hypotheses implementation that have discussed exclusively about the effect of the key factors on the information sharing capability, that by means completing and applying other factors and indicators in this inference system, one can implement other studies in this field and designate the effect of indicators as integer.

Also, the following recommendations will be made for future research:

- Try to identify more effective indicators to make more accurate current indicators and inference rules and to obtain more accurate results.
- Investigate other effective factors in collectivism or infrastructure of information technology and implement them in questionnaires to obtain a more accurate score for these indicators.
- Use other inference techniques such as Sugeno and compare the results with current research. This study, due to the fact that the Mamdani inference is more common, used this method.

The following limitations are also considered in this research:

- In the current research, the researcher relied on the respondents' responses and it was not possible to observe their real behavior in real conditions.
- Due to the using questionnaires with items that have more than one answer in this research, there is a possibility that the order of the responses has influenced the choice of options.

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