Implementing Fuzzy Rank Function Model for a New Supply Chain Risk Management

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Abstract

Effective management of risks is essential for reducing the vulnerability of the supply chain. Supply risk management is the most basic concept of the supply-chain risk management; therefore, this study examines this subject by developing a mathematical model consisting of a set of equations to quantify typical risk such as delayed delivery, substandard quality, natural disasters, and financial risk of the supplier. This model designed to select and allocate orders to suppliers to minimize the supply risk imposed by the mentioned risk factors. A fuzzy order function is used to turn this crisp model into a fuzzy supply chain risk assessment model. The defuzzified solutions of the fuzzy model show significant improvements over the result of crisp model. Uncertainty in supply chain and intense competitiveness between organizations and managers create different challenges. New management approaches are used to strengthen and improve the effectiveness of organizations. The results show that the fuzzy model yields better results compared to the deterministic model. Moreover, it shows that the ability of the model for activities risk control is improved. The work presented addresses the same challenging problems that others have tried to address but the methodology presented in this paper is more efficient in terms of execution performance and accuracy.

Keywords

Risk Management; Supply Chain; Fuzzy; Rank Function

1. Introduction

Due to the increased uncertainty in the supply chain and related factors such as politics, fluctuations in demand, technological change, financial instability and natural disasters to reduce vulnerability and increase the sustainability of their supply chain, organizations have to spend resources to predict demand, supply and internal uncertainty. These uncertainties and risk factors led to the introduction of risk management in the field of supply chain (Vanany et al., 2009). The presence of risk as well as failure in the supply chain can have significant impacts on short-term performance and long-term negative impacts on the financial performance of the organization. Therefore, supply chain risk management is essential to reduce the failures due to various risks such as uncertain economic cycles, uncertain customer demand and unpredictable natural and human disasters, etc. (Tang, 2006; Aven, 2011). Risk management involves identification, assessment and ranking of different risks. One of the pillars of risk management is the risk assessment aimed to measure risks based on various factors such as the impact and probability of occurrence; the higher accuracy in the results of this stage, guarantees elevated confidence level of the risk management process (Choudhry & Iqbal, 2013; Goh, 2013). Ranking risks is the key factor for this process; because ranking determines the superiority of a risk over others and thus the decision maker can plan about the allocation of resources to deal with the risk (PMI, 2004). Risk means the probability of incurring losses. This definition includes two main aspects of risk: (1) the amount of loss must be feasible; (2) there must be uncertainty about the loss (Wu et al., 2015; Rohaninejad et al., 2013). In general, risk management is the risk assessment process and then planning strategies for risk management (Hochrainer-Stigler et al., 2015) Overall, the strategies used include risk transfer to other sectors, avoiding the risk, reducing the negative impacts of the risk and acceptance of a part or all of the consequences of a particular risk (Lin et al., 2015). In the meantime, the traditional risk management focuses on risks preventing legal and physical causes (e.g. natural disasters or fires, accidents, deaths and lawsuits). On the other hand, financial risk management focuses on risks that can handle financial and business tools (Svobod et al., 2015). Aside from the two mentioned risks, the intangible risk management focuses on the risks related to the human capital, such as knowledge risk, communication risk and operational processes risk (Khan et al., 2015). Regardless of the type of risk management, all big companies have risk management teams and small groups. Companies use risk management in an informal way in the absence of a formal type of risk management (Lehtiranta, 2011; Dawson et al., 2015). However, the objective of organizations is to implement the ideal risk management, which involves a prioritization process by which risks with the highest level of losses and the highest probability of occurrence are first assessed and then the risks with lower probability of occurrence and lower level of loss (Adam et al., 2015). Ezzabadi et al. (2015) also performed a successful analysis about Implementing Fuzzy Logic and AHP into the EFQM model for performance improvement.

In practice, this process may be very difficult and often creates a balance between the risks with high probability of occurrence and low level of loss and the risks with low probability of occurrence and high level of loss (Yeo & Ren, 2009; Veltman & Cphrm, 2015). As a result, risk management can be regarded as a series of processes, methods, and tools for risk management in organizational activities (Lehtiranta et al., 2010). The risk management model is in fact a set of tasks that form a series of continuous activities throughout the life cycle of a mission, and include risk identification, analysis, planning, follow-up, and control (Ethridge et al., 2011). Nowadays, applications of risk assessment techniques in different industries are growing (Baloi & Price, 2003). More than 70 varieties of qualitative and quantitative risk assessment methods exist in the world (When & Evers, 2015). These methods are often used to identify, control and reduce the impact of hazards (Hadrich & Johnson, 2015). Most of the existing risk assessment methods target hazard assessment which be used to make decisions to reduce the risk consequences (Zhao et al., 2013). Industries can take advantage of the above-mentioned methods depending on their needs. These methods encompass different advantages and disadvantages compared to each other (Serpell et al., 2015). In general, the type of method used in the risk assessment and its depth of assessment can partly reveal the ability of the existing safety system and therefore the role of safety management in the industry (Huerga et al., 2015; Li et al., 2015). Usually acceptable level of risk for any organization or individual is different and depends on the financial and economic resources, technological constraints of experienced human factors, discretion and decision of the management and underlying risks such as hidden risks (Giannakis & Papadopoulos, 2015; Guadix et al., 2015). In addition to the manufacturing sector, in the service sector, such as hospital research on diabetic patients, it was concluded that electronic reminder system for enabling smarter planning by means of classified information, leads to better risk management (Adjei et al., 2015). In the green chain, the results of the American Agriculture Ministry showed that the impacts of five risk management tools to improve the return on investment, to determine the successful grain and dairy markets and to develop organizational success of this ministry, have been substantial and constructive (Hadrich & Johnson, 2015).

Garg and Singh (2014) used ε-FDPSO method which was used for the first time for grid scheduling. The metric, fuzzy dominance which quantified the relative fitness of solutions in multi-objective domain was used for generating the Pareto optimal solutions. For performance of their work, they compared it with other acknowledged meta-heuristics like non-dominated sort genetic algorithm and multi-objective particle swarm optimization. They found that the results of their work delivered a better convergence and uniform spacing among the solutions keeping the computation overhead limited. Zhang et al. (2011) proposed a novel multi target bearings tracking algorithm that combined the fuzzy clustering data association technique together with a Gaussian particle filter (GPF). They also used simulation for their results which showed the effectiveness of the algorithm. Adabi et al. (2014) investigated Bi-level fuzzy based advanced reservation of Cloud workflow applications on distributed Grid resources. For obtaining their goal, they implemented a new bi-level advanced reservation strategy, which was based upon the idea of first performing global scheduling and then conducting local scheduling. Rezaee et al. (2014) presented the Fuzzy Inference Cloud Service (FICS) and introduced a discipline for formal modeling of the FICS. The FICS does the services of Fuzzy inference to the consumers. They presented four different formal verification tests. The tests were evaluated and concluded that their model of FICS was verified to ensure that it passed all these four tests. Cocaña-Fernández et al. (2015) compared two kinds of evolutionary learning algorithms. For the first case, they tuned some of the numerical parameters. For the other case, they used genetic fuzzy system. Validation of results showed that adopting the new learning system was promising. The results of the past studies show that most articles and studies have discussed topics of supply chain risk management concepts, presenting field studies, and deterministic case models. However, subjects such as the use of fuzzy modeling and simulation approaches are scarce. Nowadays, the demand for implementing Fuzzy inference method is increasing in the domain of complex and critical systems (Rezaee et al., 2014).

The present study has taken a step towards fuzzy modeling approaches and simulation of the risk management development in the supply chain by implementing a fuzzy solution to a deterministic mathematical model. The proposed mathematical model presents definition of the rank function, fuzzy solution of the proposed model, and numerical example to solve the model. In this paper, first the order function is defined, and then the procedure of conversion is described, and in the end the results are compared with the results of (Mehrali-Dehnavi & Aqaei, 2013). Contribution of this study for presenting Fuzzy Rank Function is to improve the output of the mathematical model aimed at reducing the risk.

2. Methodology

This study contains a modeling study and does not include a statistical analysis; thus in accordance with the methodology here, no questionnaire is used and for the analysis of all desired data documents and quantitative data available are studied.

2.1. Supply Risk Management model

After reviewing the conditions of the existing suppliers and the application of multi-criteria decision-making techniques and considering important supply-associated criteria, a list of potential suppliers can obtained out of the existing suppliers and by considering risk factors such as delayed delivery, quality problems, natural disasters, financial problems and economic stability of suppliers. Subsequently the ordering of risk factors for each product of the suppliers can be determined to minimize the total supply risk of the organization. The model proposed by Ravindran et al (2010) and Yang (2007) used as the basis to present the model and the risk factors mentioned above were added to it. The notations are presented below in table 1 followed by the model.

Table1. Models parameters, nomenclature and decision variables.

Nomenclature	**Description**
i	Number of required products
k	Number of potential suppliers
Decision variables	**Description**
x_{ik}	Amount of purchased product of type *I* from supplier *k*
z_{ik}	Binary variable showing if the product *i* is purchased from supplier *k*
z_k	Binary variable showing if the supplier *k* is selected
Parameters	**Description**
P_{ik}	The purchase cost of a single product from the supplier
FC_k	Fixed cost of ordering to the supplier *k*
D_{ik}	Distribution function of delay in delivery for product *I* from supplier *k*
Q_{ik}	Function of number of defective products of type *I* purchased from supplier *k*
$VaRD_{ik}$	Risk of delay in delivery from supplier *k* for product *i*
$VaRQ_{ik}$	Defective risk of defective products of type *i* purchased from supplier *k*
$VaRND_k$	Risk of natural disaster for supplier *k*
$CFaR_k$	Financial risk of supplier *k* (risk of lack of *liquidity*)
CaP_{ik}	Capacity of supplier *k* to produce the product *i*
DE_{ik}	Demand for product *i*
$N\min$	Maximum number of selected suppliers
$N\max$	Minimum number of selected suppliers

General model of supply risk minimization would be as follows:

$$Z_1 = \min \sum_i \sum_k P_{ik}.x_{ik} + \sum_i FC_k.z_k \qquad (1)$$

$$Z_2 = \min \sum_i \sum_k D_{ik}.x_{ik} \tag{2}$$

$$Z_3 = \min \sum_i \sum_k Q_{ik}.x_{ik} \tag{3}$$

$$Z_4 = \min \sum_i \sum_k VaRD_{ik}.x_{ik} \tag{4}$$

$$Z_5 = \min \sum_i \sum_k VaRQ_{ik}.x_{ik} \tag{5}$$

$$Z_6 = \min \sum_i \sum_k VaRND_{ik}.x_{ik} \tag{6}$$

$$Z_7 = \min \sum_i \sum_k CFaR_{ik}.x_{ik} \tag{7}$$

Subject to:

$$z_{ik} \le x_{ik} \le z_{ik}.Cap_{ik} \qquad \forall i,k \tag{8}$$

$$\sum_k x_{ik} \ge DE_i \qquad \forall i \tag{9}$$

$$z_k \le \sum_k z_{ik} \le mz_k \qquad \forall k \tag{10}$$

$$N\min \le \sum_k z_k \le N\max \tag{11}$$

$$x_{ik} \ge 0 \ , \qquad z_k, z_{ik} \in \{0,1\} \tag{12}$$

The first objective function minimizes the total cost of products, which includes two components of variable cost and fixed cost of communication with the supplier. The second and third objective functions minimize the number of parts with delayed delivery and the number of defective parts, respectively, for which it assumed that their values follow a certain distribution function. The fourth, fifth, sixth and seventh objective functions are to minimize the risk of delays in delivery, quality (defective parts), natural disasters and supplier financial risk, respectively.
First constraint (equation 8) applies capacity constraint of any supplier for different products if the desired supplier selected. Equation 10 means that the total amount of product purchased from different suppliers should cover the demand of the product. The third constraint (equation 10) indicates that the supplier *k* selected if one of its products purchased. The fourth constraint points to the minimum and maximum number of suppliers that should be selected. The last equations show the non-negativity constraint and definition of binary variables. So, these following steps had been taken in this research work:

- The study of literature and selection of appropriate fuzzification method.
- Fuzzification and defuzzification of the model by defining ranking function
- Coding of defuzzy model in GAMZ software
- Numerical study
- Extracting the results and comparing them with the results of the base article
- Presenting the result of comparison of the two models in the form of discussion and conclusion

2.2. Rank fuzzy function

Real-world problems usually have a very complex structure that is due to presence of uncertainty in their constituting concepts and definitions. The accurate expression, solution and analysis of a problem however require complete and precise information regarding its aspects. But what if this information is not available? The fuzzy logic allows the crisp value of a variable to be replaced with an upper limit, a lower limit and an average estimate and thereby provides an approach for solution of problems in the absence complete or accurate information. Considering the inaccurate and uncertain nature of the data involved with real world problems, the present work uses the upper limit, lower limit and average estimate of variables to shift the model from a crisp framework to a fuzzy environment, and then modifies the resulting model to obtain a model that is more suited for generation of rational results.

The left and right developed matrices of $a = \{a_j\}$ are first shown by $n = \{n_j\}$ and $m = \{m_j\}$. Now $\tilde{a}_j$ defined as follows (Tansel, 2012):

$\tilde{a}_j = (a_j, m_j, n_j)$ j=1, 2, 3 … n (13)

On the other hand, we know that matrices developed above and the two original matrices, all are deterministic. All numbers used in the study are considered trapezoidal fuzzy numbers. We intend to use the definition of rank function, to change fuzzy model into a deterministic model. Rank function, is a mapping which projects fuzzy numbers on real numbers. This mapping is defined as follows (Hatami & Kazemipour, 2014):

$$\forall\ \tilde{a}_j = (a_j, m_j, n_j) \tag{14}$$

$$R : F(R) \rightarrow R$$

$$R(\tilde{a}_j) = \frac{(a_j - m_j) + 2a_j + (a_j + n_j)}{4} \cong \frac{a^l + a^u}{2}$$

It must be first proved that this mapping is a function. The mapping is clearly injective and surjective and it is not necessary to prove that it is a function. Thus, we accept that the defined mapping is a function. In this function, $F(R)$ is a set of fuzzy numbers like $\tilde{a}_j = (a_j, m_j, n_j)$ that by rank function becomes a deterministic number as $R(\tilde{a}_j)$ shown above. For the expressed function we have (Hatami & Kazemipour, 2014):

$$if \quad \tilde{a} \succeq \tilde{b} \quad R(\tilde{a}) \geq R(\tilde{b}) \tag{15}$$

$$if \quad \tilde{a} \succ \tilde{b} \quad R(\tilde{a}) > R(\tilde{b}) \tag{16}$$

$$if \quad \tilde{a} \approx \tilde{b} \quad R(\tilde{a}) = R(\tilde{b}) \tag{17}$$

Now properties of the function including addition, multiplication, and multiplication by a scalar and etc. are proved. To examine the performance of the function R, it is sufficient to demonstrate that the following equations are true (Kumar et al., 2011):

1- $R(\tilde{a}_i \otimes \tilde{a}_j) \overset{?}{=} R(\tilde{a}_i) \otimes R(\tilde{a}_j)$ (18)

2- $R(\tilde{a}_i \oplus \tilde{a}_j) \overset{?}{=} R(\tilde{a}_i) \oplus R(\tilde{a}_j)$ (19)

3- $R(\lambda \tilde{a}_i) \overset{?}{=} \lambda R(\tilde{a}_i)$ (20)

4- $R(\frac{\tilde{a}_i}{\tilde{a}_j}) \overset{?}{=} R(\tilde{a}_i) \times \frac{1}{R(\tilde{a}_j)}$ (21)

To prove the equations, we need to define the equations of addition, multiplication, division and inversion of a fuzzy number. To define them on fuzzy numbers of $F(R)$ and using the proof of equations for $F(R)$, we establish the equation 4 for function R. Thus, four fuzzy equations are defined for $\tilde{a}_i, \tilde{a}_j \in F(R)$ as follows (Farhadini, 2014):

$$\tilde{a}_i + \tilde{a}_j = (a_i, m_i, n_i) + (a_j, m_j, n_j) = (a_i + a_j, m_i + m_j, n_i + n_j) \tag{22}$$

$$\tilde{a}_i \times \tilde{a}_j = (a_i, m_i, n_i) \times (a_j, m_j, n_j) = (a_i \times a_j, m_i \times m_j, n_i \times n_j) \tag{23}$$

$$\tilde{a}_i - \tilde{a}_j = (a_i, m_i, n_i) - (a_j, m_j, n_j) = (a_i - n_j, m_i - m_j, n_i - a_j) \tag{24}$$

$$\tilde{a}_i \div \tilde{a}_j = (a_i, m_i, n_i) \div (a_j, m_j, n_j) = (a_i \div n_j, m_i \div m_j, n_i \div a_j) \tag{25}$$

$$(\tilde{a}_i)^{-1} = ((a_i, m_i, n_i))^{-1} = (\frac{1}{n_i}, \frac{1}{m_i}, \frac{1}{a_i}) \tag{26}$$

Now to prove 4 equations above, it is sufficient to make use of fuzzy equations mentioned above. So we have:

$$\begin{aligned} & R(\tilde{a}_i \otimes \tilde{a}_j) = R((a_i, m_i, n_i) \times (a_j, m_j, n_j)) = R(a_i \times a_j, m_i \times m_j, n_i \times n_j) = \\ & \frac{((a_i \times a_j) - (m_i \times m_j)) + 2(a_i \times a_j) + ((a_i \times a_j) + (n_i \times n_j))}{4} = \\ & \frac{a^l{}_i a^l{}_j + a^l{}_i a^u{}_j + a^u{}_i a^l{}_j + a^u{}_i a^u{}_j}{4} = \frac{(\frac{a^l{}_i + a^u{}_i}{2}) \times (\frac{a^l{}_j + a^u{}_j}{2})}{2} = \\ & \frac{(a_i - m_i) + 2a_i + (a_i + n_i)}{4} \times \frac{(a_j - m_j) + 2a_j + (a_j + n_j)}{4} = R(\tilde{a}_i) \otimes R(\tilde{a}_j) \end{aligned} \tag{27}$$

2.3. Fuzzy solution of the proposed model

To solve the proposed model by Ravindran et al. (2010) and Yang (2007), we define the fuzzy model of the study. Then, using trapezoidal fuzzy numbers, rank function is used for the defuzzification of the fuzzy model, and finally we solve the case study again by the new form of the model. Because the model can be summarized, first the proposed model is further summarized. We have:

$$\tilde{Z}_1 \approx \min \sum_i \sum_k \tilde{P}_{ik}.x_{ik} + \sum_i \tilde{F}\tilde{C}_k.z_k \tag{28}$$

$$\tilde{Z}_2 \approx \min \sum_i \sum_k (\tilde{Q}_{ik} + \tilde{D}_{ik}).x_{ik} \tag{29}$$

$$\tilde{Z}_3 \approx \min \sum_i \sum_k (\tilde{V}aR\tilde{D}_{ik} + \tilde{V}aR\tilde{Q}_{ik}).x_{ik} \tag{30}$$

$$\tilde{Z}_4 \approx \min \sum_i \sum_k (\tilde{V}aRN\tilde{D}_{ik} + \tilde{C}Fa\tilde{R}_{ik}).x_{ik} \tag{31}$$

Subject to:

$$z_{ik} \preceq x_{ik} \preceq z_{ik}.\tilde{C}ap_{ik} \qquad \forall i,k \tag{32}$$

$$\sum_k x_{ik} \succeq \tilde{D}E_i \qquad \forall i \tag{33}$$

$$z_k \preceq \sum_k z_{ik} \preceq \tilde{m} z_k \qquad \forall k \tag{34}$$

$$\tilde{N}\min \preceq \sum_k z_k \preceq \tilde{N}\max \tag{35}$$

$$x_{ik} \succeq \tilde{0} \ , \qquad z_k, z_{ik} \in \{\tilde{0}, \tilde{1}\} \tag{36}$$

Now, ranking function is used for defuzzification of the model. We have:

$$R(\tilde{Z}_1) = R(\min \sum_i \sum_k \tilde{P}_{ik}.x_{ik} + \sum_i \tilde{F}\tilde{C}_k.z_k) = \min(R(\sum_i \sum_k \tilde{P}_{ik}.x_{ik} + \sum_i \tilde{F}\tilde{C}_k.z_k)) =$$

$$= \min \sum_i \sum_k R(\tilde{P}_{ik}.x_{ik}) + \sum_i R(\tilde{F}\tilde{C}_k.z_k)) = \min \sum_i \sum_k R(\tilde{P}_{ik}).R(x_{ik}) + \sum_i R(\tilde{F}\tilde{C}_k).R(z_k)) =$$

And when all variables of the problem are real numbers, the rank function has identity effect on them and thus they will remaine unchanged. So we have:

$$R(\tilde{Z}_1) = Z_1' = \min \sum_i \sum_k R(\tilde{P}_{ik}).x_{ik} + \sum_i R(\tilde{F}\tilde{C}_k).z_k \tag{37}$$

Similarly, for equations 30 to 37, defuzzy equations are obtained as follows, respectively:

$$R(\tilde{Z}_2) = Z_2' = \min \sum_i \sum_k (R(\tilde{Q}_{ik}) + R(\tilde{D}_{ik})).x_{ik} \tag{38}$$

$$R(\tilde{Z}_3) = Z_3' = \min \sum_i \sum_k (R(\tilde{V}aR\tilde{D}_{ik}) + R(\tilde{V}aR\tilde{Q}_{ik})).x_{ik} \tag{39}$$

$$R(\tilde{Z}_4) = Z_4' = \min \sum_i \sum_k (R(\tilde{V}aRN\tilde{D}_{ik}) + R(\tilde{C}Fa\tilde{R}_{ik})).x_{ik} \tag{40}$$

Subject to:

$$z_{ik} \le x_{ik} \le z_{ik}.R(\tilde{C}ap_{ik}) \qquad \forall i,k \tag{41}$$

$$\sum_k x_{ik} \ge R(\tilde{D}E_i) \qquad \forall i \tag{42}$$

$$z_k \le \sum_k z_{ik} \le R(\tilde{m}).z_k \qquad \forall k \tag{43}$$

$$R(\tilde{N}\min) \le \sum_k z_k \le R(\tilde{N}\max) \tag{44}$$

$$x_{ik} \ge R(\tilde{0}) \ , \qquad z_k, z_{ik} \in \{R(\tilde{0}), R(\tilde{1})\} \tag{45}$$

Where, R is the same rank function with the equation given in (14). $\tilde{0} = (-1,0,1)$ and $\tilde{1} = (0,1,2)$ are also defined. Now that the presented fuzzy model became defuzzy, using a real numerical example, we validate the model.

3. Numerical example

To validate the model, the numerical example data of Mehrali-Dehnavi and Aqaei (2013) is used. Table 2 illustrates information about the functions of cost, delay in delivery and defective parts.

Table 2. Information about the functions of cost, delay in delivery and defective parts.

Suppliers	Defective parts distribution Function		Delay distribution function (day)		Cost distribution function ($)	
	Product2	**Product1**	**Product2**	**Product1**	**Product2**	**Product1**
Supplier1	Exp(0.9)	Exp(1.5)	N(5,0.3)	N(8,0.4)	N(6,1)	N(14,1)
Supplier2	Exp(0.93)	Exp(1)	N(6,0.2)	N(6,1)	N(6.8,0.5)	N(13.8,2)
Supplier3	Exp(0.9)	Exp(2.5)	N(6,1)	N(7,0.5)	N(6.9,0.7)	N(13,0.5)
Supplier4	Exp(0.95)	Exp(2)	N(5,0.7)	N(6,0.4)	N(6,1)	N(14.2,1.5)
Supplier5	Exp(0.9)	Exp(1.2)	N(6,0.8)	N(8,0.5)	N(6.5,0.8)	N(13,2)
Supplier6	Exp(1.4)	Exp(1.6)	N(5,0.3)	N(9,1)	N(6.9,1.2)	N(13.8,1)
Supplier7	Exp(0.95)	Exp(1.7)	N(4,0.1)	N(8,0.3)	N(7,0.6)	N(13.5,0.5)
Supplier8	Exp(0.91)	Exp(1.1)	N(7,0.2)	N(6,0.3)	N(7,2)	N(13.2,1.5)

Fixed cost of communication with defuzzy supplier and defuzzy production capacity of each supplier for each product are presented in Table 3:

Table 3. Information related to the fixed cost and defuzzy production cost

Suppliers	Fix cost of relationship with costumer	Production capacity	
		Product1	**Product2**
Supplier1	650	950	9500
Supplier2	650	1900	9500
Supplier3	1900	2450	19500
Supplier4	950	950	19500
Supplier5	950	950	9500
Supplier6	650	500	14500
Supplier7	1900	1450	14500
Supplier8	650	950	9500

With required information within specified periods, including the information on the frequency of delays in deliveries and quality problems that confront the company with risk and also the frequency of natural disasters that have disrupted the activities of supplier and created risks for the company, and according to the desired confidence level of the company, the corresponding risk is set. Furthermore, based on the cash flow at risk and in accordance with the desired confidence level, the financial risk of defuzzy supplier can be determined. Defuzzy risks at the confidence level of 95% are presented in Tables 4 to 7.

Table 4. The defuzzy risk of "delay in delivery" at 95% confidence level.

Supplier	1	2	3	4	5	6	7	8
Product 1	123629	114306	145342	132706	125824	165342	137571	165671
Product 2	134517	123851	187184	134216	143795	145237	148673	123061

Table 5. The defuzzy risk of "quality" at 95% confidence level.

Supplier	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Product 1	165168	137381	167168	205373	178895	179770	210895	190387
Product 2	144311	153415	128684	136695	148211	133562	156682	141606

Table 6. The defuzzy risk of "natural disasters" at 95% confidence level.

Supplier	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Product 1	198983	178516	187406	205383	178895	179770	210895	190387
Product 2	209784	198496	188406	212686	189240	190215	199812	202715

Table 7. The defuzzy supplier financial risk at 95% confidence level.

Supplier	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Cash risk	4246500	4054327	4063090	3970542	3808945	4082920	4401094	4050437

To solve the model the problem data first need to be normalized (Mehrali-Dehnavi & Aqaei, 2013). To do this, the greatest data of each group is selected by the corresponding numbers are divided and then they are multiplied by 1000 for all numbers range from 0 to 1000. The proposed model also includes several objective functions by assigning weights to which we can transform the model into the one with single objective function (coefficient 0.2 for the first two objectives and coefficient 0.1 for the second two objective functions taken into account). On the other hand, because the objective functions defined in Equations 1 to 7 can be transformed into a smaller number of objective functions, and also because these are cost functions, they are transformed into 4 objective functions described in equation 29 to 32.
The results of the first round of running the model by Gomez software are as follows:

- Selection of the first and second suppliers for the first product and the order quantities are 1900 and 950, respectively.
- Selection of the fourth and seventh suppliers for the second product and the order are 19,500 and 14,500, respectively.

The results of 8 ranks of running the model are as Table 8:

Table 8. The results of the final defuzzy model

Step	**Product 1**	**Order amount**	**Product 2**	**Order amount**
1	2,8	1900,950	4,7	19500,14500
2	1,5	950,950	4,6	19500,14500
3	1,5	950,950	4,6,1	19500,14500,9500
4	2,8	1900,950	1,3,6	9500,19500,14500
5	2,8	1900,950	4,7	19500,14500
6	2,8	1900,950	4,7	19500,14500
7	2,8	1900,950	4,7	19500,14500
8	2,8	1900,950	4,7	19500,14500

The results obtained in the table above, along with all information in the tables of risks and fixed costs and production capacity were analyzed. For product 1, steps 1, 4, 5, 6, 7 and 8 which includes only suppliers 2 and 8 and the order of size 1900 and 950 units have been selected. In steps 2 and 3 for the product 1, suppliers 1 and 5 with the order of 950 and 950 were selected. For the steps 4 to 8, model leads to selection of suppliers 2 and 8 for product 1, with the order of 1900 and 950 units. Similarly, for product type 2, first suppliers 4 and 7 with the order of 19500 and 14500 units were selected. Then in the second stage, suppliers 4 and 6 with the same order were selected. Then in the third step, the supplier 1 was also selected and added to 4 and 6 to be the next selection in the third step of processing. In addition, as shown in Table 7, in steps 5 through 8, suppliers 4 and 7 with the order of 19500 and 14500 were confirmed as the optimal choice.
As shown in Table 8, step 5 onwards for both products has resulted in achieving the optimized state. The notable points in these results are the orders for both products and the risk estimates given in Tables 4 to 7. The obtained values for the variables in the defuzzy model are far superior to the values obtained from the model presented in the reference (Mehrali-Dehnavi & Aqaei, 2013). This means that the respective model presents better results after defuzzification by rank function and trapezoidal fuzzy numbers. Therefore, the proposed fuzzy model compared to the general model presented in the base article Mehrali-Dehnavi and Aqaei (2013) is improved.

4. Conclusions

As the world of business and industry faces with numerous changes such as globalization, outsourcing and the creation of strategic alliances, risk management in commercial and non-profit organizations activities is of increasing importance. Furthermore, risk management is one of the issues addressed in the implementation and development of supply chain management that due to extensive outsourcing, the globalization of markets, increased dependence on suppliers, and creating competitive advantage and emergence of information technology, has resulted

in the control and coordination of the supply chain. This study was performed aiming at transformation of a definitive risk management model to a fuzzy risk management model and defuzzification of the model by rank function. Model defined by Ravindran et al. (2010) described in equations 1 to 12 was first presented, and then its fuzzy model was defined. After defining the obtained wholly fuzzy model, using the definition of the rank function described in equation 14, the model was defuzzificated. The main objective of this study was to compare the results of the general model presented in the literature with those of the fuzzy model developed here. By solving the model in Gomez software using the source data Mehrali-Dehnavi and Aqaei (2013), it was found that the results obtained from fuzzy model solved in this study were much improved compared to the results obtained in Mehrali-Dehnavi and Aqaei (2013). Defuzzy model is also capable of higher integration than the similar model defined by Ravindran et al. (2010) and the model developed by Yang (2007).
In general, risk management is associated with reduction of uncertainty and improvement of current efficiency, thus the content of this study involves the improvement of two concepts "efficiency' and "accuracy". In this study, a mathematical model provided in the literature was examined and then redefined and optimized for improved efficiency, resulting in a model with significant structural differences with its predecessor. In this model, the first objective function minimizes the overall cost of purchase consisting of two components, variable cost and fixed cost of association with the supplier, and the second and third objective functions minimize respectively the number of parts with delayed delivery and the number of parts with defects. Thus, the overall objective of this mathematical model is to reduce the cost or the number of delayed parts. Hence, it is clear that the most important factor in this model is the efficiency. In addition, the model has been optimized with fuzzy-order function technique, the most notable characteristic of which is the increased accuracy reflected in better quality and optimality of results. So, using an accuracy and optimality oriented technique along with an efficient model results in accurate outputs and improved efficiency through the following:

- Providing realistic production capacity proportional to demand: Defuzzification technique allows the model to provide optimal capacity and address excess or low production (this enhances the accuracy and improves overall efficiency by balancing the production with demand).
- Optimization of "delay in delivery": It is obvious that the shorter is the delay in the delivery, the higher is the efficiency. Therefore, providing the real delay in product delivery leads to improved accuracy.
- Optimization of purchase cost: Optimizing the cost by estimating the real capacity reduces the excess financial burden and thus improves the efficiency of the company, thereby serving both efficiency and accuracy objectives.
- Moderation of cost of association with suppliers: Estimating the realistic number of suppliers and defining the type of association with the selected suppliers eliminates additional costs arising from, for example, rework, replacement of suppliers, and forming relationships with new ones. This increases the efficiency and allows the number of suppliers and type of extent of associations to be estimated with greater accuracy.
- The risk of delay in delivery, substandard quality, and natural disasters and the financial risk suppliers: The goal of this study is reduce the risks, or actually increase the certainty (accuracy) of model outputs and its efficiency.
- The size of order: The model provides orders suitable for production capacity, and also determines the cost of these orders and delay penalties. Thus, it enables the user to achieve optimal production level and costs according to the size of orders. This also serves the efficiency in performance and accuracy in outputs of the model.
- The work presented addresses the same challenging problems that others have tried to address but the methodology presented in this paper is more efficient in terms of execution performance and accuracy.

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