BUYER-SUPPLIER RELATIONSHIP SELECTION FOR A SUSTAINABLE SUPPLY CHAIN: A CASE OF THE INDIAN AUTOMOBILE INDUSTRY

Divesh Kumar
Malaviya National Institute of Technology Jaipur
India
diveshcms@gmail.com

ABSTRACT

The primary objective of this study is to propose an analytical approach to evaluate dimensions of the buyer-supplier relationships alternative selection in the context of a sustainable supply chain considering benefits, opportunities, costs, and risks of a relationship type. The study uses a Fuzzy Analytic Hierarchy Process (FAHP) approach to develop a model that explores benefits, costs, opportunities, and risks of a buyer-supplier relationship in a sustainable supply chain. A case study of the Indian automobile sector is used to determine the appropriate form of the buyer-supplier relationship. This study found that a problem solving relationship is the most preferred form of relationship. Long term relationships and joint development ranked 2 and 3, respectively. A sensitivity analysis showed that if the weights of benefits, opportunities, costs and risks are changed the preference for alternatives selection also changes. The most important implication of the study is in providing supply chain managers with a model for development of buyer-supplier relationships with their supply chain partners based on the considerations of benefits, opportunities, costs and risks involved in developing such a relationship in a sustainable supply chain. The novelty of the present study rests in the incorporation of sustainability specific criteria for selection of the relationship between two parties in a supply chain context considering benefits, opportunities, costs, and risks of a relationship type. This is the first such model that incorporates considerations of BOCR in a sustainable supply chain.

Keywords: sustainable supply chain; Analytical Hierarchy Process; fuzzy logic; buyer-supplier relationship

1. Introduction

Relationships with supply chain partners are developed with the intention of providing assistance for technology development, resource sharing, information dissemination, and developing capacity and capability of supply chain partners (Kam & Lai, 2018; Kumar & Rahman, 2016). Buyer-supplier relationships have undergone significant changes during the last decade due to increased focus on sustainability (Kumar et al., 2017; Pagell, & Shevchenko, 2014). The focus of the research has shifted from company specific sustainability to buyer-supplier collaborative relationships for managing supply chain sustainability (Dekker et al., 2019; Gimenez & Tachizawa, 2012). Few studies have

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

indicated the negative impact of supplier activities on environmental and social sustainability, making it difficult for any firm to claim their products are sustainable without considering their supply chain (Kumar & Garg, 2017; Carter & Rogers, 2008; Mahler, 2008). This has led to the emergence of 'supplier’s attitude towards sustainability' as one of the most important criteria in industrial purchase and order allocation (Kumar et al., 2017). In order to achieve sustainability objectives, firms always look for an appropriate partner to be able to attract a considerable investment of time and resources (Hammerschmidt et al., 2018). Lee (2009) has highlighted the need for a comprehensive model for buyer-supplier relationship selection. This puts forth a strong case for developing a buyer-supplier relationship model based on the benefits, opportunities, costs and risks (BOCR) of a relationship alternative.

There is, however, a paucity of studies in the extant literature that consider BOCR in buyer-supplier relationships. Only one model based on Fuzzy AHP proposed by Lee (2009) includes BOCR to study the buyer-supplier relationship for an electronics company manufacturing LCDs. However, this two-step model does not consider sustainability dimensions. Lee (2009) further suggested that more complicated alternatives should be selected in order to study supplier specific relationship types based on the BOCR. The current study aims to extend the work of Lee (2009) by including the sustainability dimensions in the buyer-supplier relationship. A two-stage model is proposed to study the four selection criteria – benefit, opportunity, cost, and risk of a relationship in the supply chain as suggested by the Lee (2009).

The present study builds upon the proposition that buyer-supplier relationships are based on an analysis of benefit, cost and expected return on the relationship in terms of opportunities and risks. Most of the BOCR analysis in the extant literature has been done using statistical techniques such as the Analytical Hierarchy Process (AHP) and the Analytical Network Process (ANP) (Wijnmalen, 2007; Ming-Chien et al., 2015; Hernandez et al., 2016*)*. The present study employs fuzzy logic with the AHP technique for developing a buyer-supplier relationship model for a sustainable supply chain. The use of fuzzy logic with AHP has been advised by many authors in order to remove any vagueness in the responses (Kumar & Garg, 2017; Lee, 2009; Chang, 1996).

The remainder of the paper has been organized as follows: section 2 discusses the literature on buyer-supplier relationships, followed by a computational procedure in section 3; section 4 will discuss a case study of the Indian automobile supply chain and section 5 discusses the conclusions and direction of future research.

2. Buyer-supplier relationship in a sustainable supply chain

Buyer-supplier relationships are influenced by the level of inter-organizational dependency (Dekker et al., 2019). A few authors argue that close cooperation with supply chain partners would result in better performance of sustainable supply chains (Im et al., 2019; Seuring & Muller, 2008). However, relationships between all supply chain partners may not be based on the same considerations. The relationships between supply chain partners may be based on varied levels of economic, technological and behavioral considerations (Stranieri et al., 2019; Hadjikhani & LaPlaca, 2013). Further, developing long-term relationships might not guarantee the expected return with respect to the

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

investment (Vishnu et al., 2019). Firms are required to optimize their available resources among the supply chain partners for developing relationships. The extant literature on relationship marketing in the industrial environment emphasizes that a relationship should be developed with consideration of the costs and risks involved.

The contemporary approach to marketing is witnessing a shift from the traditional product-based transactional approach to a resource-based relational approach (Zhou et al., 2018; Grönroos, 1996). The relationship approach is based on allocation of resources towards developing relationships with suppliers on the basis of the expected return from the relationship (Hong et al., 2018). Further, the quality and nature of the buyer-supplier relationship is influenced by inter-organizational dependency and their joint abilities to achieve a common objective (Aharonovitz et al., 2018).

2.1 Dimensions of a sustainable supply chain

Carter & Roger (2008) defined sustainable supply chain management as "*The strategic achievement and integration of an organization's social, environmental, and economic goals through the systemic coordination of key inter-organizational business processes to improve the long-term economic performance of the individual company and its value network*." Similarly Seuring & Muller (2008) defined management of a sustainable supply chain as "*the management of material, information and capital flow as well as cooperation among companies along the supply chain while taking goals from three dimensions of sustainable development, i.e. economic, environmental, and social, into account which is derived from customer and stakeholder requirements*."

Elkington (1994) defined the three dimensions of sustainability as environmental, social and economic. Thus, sustainability should be assessed by the activities of the supplier on the environmental standards, social development for the employees and society, and the economic production of the product. The criteria for supplier selection can be developed based on evaluation by experts and from support of extant literature for specific problems. (Kumar et al., 2017; Mangla et al., 2018). Rejection percentage on a quality basis (Walker *et al.*, 2008; Matos & Hall, 2007), percentage of late delivery items (Zsidisin & Hendrick, 1998; Daugherty, 2011) and cost of the sourcing item (Zutshi & Sohal, 2004; Holt & Ghobadian, 2009) are some of the economic and operational criteria used for identifying acceptability of suppliers. Social sustainability criteria listed in the topical literature include child labor (Joplin et al., 2007; Muller et al., 2009), working conditions (Pommel, 2010; Carter & Rogers 2008), rights of employees (Rocha et al., 2007; Calibers, 2008; Ni et al., 2010) and poverty reduction (Blitzer et al., 2008; Ni et al., 2010). Various environmental sustainability criteria identified in the literature includes packaging improvements (Souflas & Pappies, 2006; Hall, 2000), energy efficiency (Wu & Patel, 2011; Nakano & Hirao, 2011), pollution and emission minimization (Florida, 1996; Calibers, 2008), waste minimization (Matos & Hall, 2007; Bitzer et al., 2008), reverse logistics (Ni et al., 2010, Carter & Jenning, 2002), green purchasing (Bitzer et al., 2008; Ni et al., 2010), green designing (Holt & Ghobadian, 2009; Bai & Sarkis, 2010), using renewable energy (Smith, 2007; Zhu et al., 2007) and disposal (Vachon & Klassen, 2006; Olorunniwo & Li, 2010). Kumar and Garg (2017) prioritized several dimensions of a sustainable chain in the context of the Indian automobile industry. Kumar et al. (2017) also used dimensions of sustainability for optimizing the order among the suppliers.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

2.2 Evidences of buyer-supplier relationship in a sustainable supply chain

There are many studies that have shown evidence that a relationship based supply chain is necessary for the adoption of a particular practice across the supply chain; like ISO adoption, new technology and sustainability adoption (Kumar et al., 2017; Kumar & Rahman, 2016). The literature has used many keywords for supply chain relationships, like collaboration, coordination, integration, and cooperation. However, the exact form of the relationship is not clear with these keywords. For example, collaboration is important for product designing, forecasting, planning and increasing sustainability performance (Attaran & Attaran, 2007; Vermeulen & Seuring, 2009). Collaboration is also vital for creating awareness about sustainability across the supply chain (Dangol et al., 2015; Zhu & Sarkis, 2004). Kumar & Rahman (2016) used supplier performance, supplier selection and suppliers' performance review to define the construct of the buyer-supplier relationship. Zsidisin & Hendrick (1998) argued that collaboration with suppliers to provide equipment, material, parts and services is essential for extending environmental sustainability across the supply chain. The authors have found various situations in which the word ‘collaboration’ fits. Hence, a single keyword cannot define the nature of a buyer-supplier relationship. It is situational and based on the need of the relationship and areas for improvement.

In order to understand the buyer-supplier relationship, a detailed analysis needs to be done. The type of relationship depends upon the capabilities, capacity and commitment of the supplier. Besides this, some buyer firms do not want to indulge in any relationship and use their buying power to create pressure on the suppliers (Ford, 1980). The channel literature first discussed supply chain relationships that vary from arm's length to vertical integration (Golicic et al., 2003; Contractor & Lorange 1988). Relationships were further categorized by many authors based on the scope and magnitude of the relationship. Supply chain relationships can be termed as partnerships, alliances, joint ventures, network organizations, franchisees, license agreements, contractual relationships, service agreements, and administered relationships (Golicic et al., 2003). Cannon & Perreautt (1999) argued in favor of characterizing buyer-seller relationships based on a variety of different ways and listed eight types of buyer-seller relationships as basic buying and selling, bare bones, contractual transaction, customer supply, cooperative systems, collaborative, mutually adaptive, and customer is king. Hansen (2006) explained four types of relationships in terms of exchange as transactional, collaboration, co-production and co-creation. Rinehart et al. (2002), based on empirical data, defined seven types of buyer-supplier relationships based on three dimensions of trust, interaction frequency and commitment. They labeled these seven types of relationships as non-strategic transactions, administered relationships, contractual relationships, specialty contract relationships, partnerships, joint ventures, and strategic alliances.

The nature and extent of the relationship with a supplier can be determined by the expected performance of the relationship (Zhu & Sarkis, 20008). For example, if a supplier is the most sustainable among all available suppliers of a particular input material but lacks in the capacity, the buyer firm can work on developing the capacity of that supplier. Firms in the buyer-seller relationship should consider strengthening each other in order to improve the sustainability performance of the relationship. Hence, developing a relationship is specific to the capacity, capability and current performance of the supplier.

2.3 Benefits, costs, risks and opportunities of buyer-supplier relationship

Sustainability of the supply chain is fast becoming a mandatory criterion in relationships between supply chain partners. Firms are adopting sustainability practices due to external pressure, while others see it as an opportunity for growth and the associated benefits. Firms may also be reluctant towards sustainability because of the costs involved in overhauling the process or due to the perception of low economic returns and performance (Nakano & Hirao, 2011; Ageron et al., 2011; Cai et al., 2008; Bowen et al., 2001; Simpson & Power, 2005; Keatinga et al., 2008, Fortes, 2009). The buyer-supplier relationship always depends on the trade-off between costs, risks and benefits, opportunities involved. In the literature on supply chain sustainability, the authors have quoted many benefits, costs, risks and opportunities with respect to relationship development for sustainability adoption in the supply chain (Kumar & Rahman, 2015) (See Table 1).

Table 1
BOCR of buyer-supplier relationship in sustainable supply chain

Criteria		Sub criteria	Definition	Source
BENEFITS				
Financial (B1)	1.1	Reduce Distribution cost	Buyer/supplier will have less cost on the distribution due to the relationship	Ytterhus, 1999; Tsoulfas & Pappis, 2006; Green *et al.*, 1998; Eltayeb, 2011; Zhu *et al.*, 2008; Peters *et al.*, 2011
	1.2	Low cost on information	Better information exchange and sharing	Darnll *et al.*, 2008; Tsoulfas & Pappis, 2006; Eltayeb, 2011; Zhu *et al.*, 2008; Peters *et al.*, 2011
	1.3	Reduce inventory	A good relationship may help in reducing the inventories of buyer / supplier	Hong *et al.*, 2009; Closs *et al.*, 2010; Ageron et al., 2011; Zhu *et al.*, 2008; Attaran &Attaran, 2007
Operational (B2)	2.1	Improve Internal process	Improving process by providing feedback on supplier's operations.	Hong *et al.*, 2009; Tsoulfas & Pappis, 2006; Zhu et al., 2008;
	2.2	Resource optimization	Understanding each other's operations and optimization	Hong *et al.*, 2009; Brito *et al.*, 2008; Tsoulfas &Pappis, 2006
	2.3	On time delivery	Real time supply of items due to relationship	Eltayeb, 2011; Daugherty, 2011; Zhu et al., 2008; Brito et al., 2008
Sustainability adoption (B3)	3.1	Improved quality on sustainability standards	Improving product quality on sustainability dimensions.	Zhu & Sarkis, 2008; Ytterhus, 1999; Eltayeba *et al.*, 2011; Bitzer et al., 2008; Ageron *et al.*, 2011
	3.2	Reduced pressure from various agencies	Less pressure from various stakeholders.	Matos & Hall, 2007; Ageron *et al.*, 2011; Cai et al., 2008; Muller *et al.*, 2009; Zhu & Sarkis, 2010
	3.3	Sustainable supply chain	Incorporation of sustainability across supply chain	Zutshi & Sohal, 2004; Klassen &Vachon, 2003; Nakano & Hirao, 2011; Seuring & Muller, 2008; Smith, 2007
OPPORTUNITIES				
Marketing advantage (O1)	4.1	Improve corporate Image/ Reputation	Improved reputation due to better sustainability performance.	Simpson *et al.*, 2007; Matos & Hall, 2007; Rocha et al., 2007; Vermeulen & Ras, 2006; Muller et al., 2009
	4.2	Premium Pricing	Pricing the product for better sustainability performance	Ytterhus, 1999; Eltayeba et al., 2011; Ageron et al., 2011
	4.3	Product Differentiation	Product differentiation due to sustainability adoption.	Kogg, 2003
	4.4	New Market	Targeting new customers	Holt & Ghobadian, 2009; Clemens & Douglus, 2006;

			having positive attitude towards sustainable products.	Bitzer *et al.*, 2008; Markley & Devis, 2007
Technical capabilities (O2)	5.1	Sharing technology and knowledge	Sharing new and advanced technology with buyers and suppliers.	Rao, 2002; Rocha *et al.*, 2007; Muller *et al.*, 2009; Vachon, 2007; Kogg, 2003; Hong *et al.*, 2009; Koplin *et al.*, 2007
	5.2	Educating each other's employee	Providing education to buyers and suppliers' employees on sustainability issues.	Clemens & Douglus, 2006; Lee, 2008; Ytterhus, 1999; Seuring& Muller, 2008; Zhu *et al.*, 2007; Ciliberti, 2008
	5.3	Developing technical standards	Developing better sustainability enables standards	Rao & Holt, 2005; Klassen &Vachon, 2003; Bai & Sarkis, 2010; Zhu *et al*, 2007
Mutual growth (O3)	6.1	Capacity building and development	Developing the capacity of buyer/ supplier considering length of relationship	Klassen & Vachon, 2003; Wu & Pagell, 2011; Lee, 2008; Ageron *et al.*, 2011; Markley & Davis, 2007
	6.2	Sharing resources and information	Sharing the resources with each other to better utilization.	Bommel, 2010; Wu & Pagell, 2011; Klassen &Vachon, 2003; Nakano & Hirao, 2011; Smith, 2007; Lee, 2008
	6.3	Jointly setting goals	Buyer and suppliers jointly setting up economic, social and environmental goals.	Vachon & Klassen, 2008; Olorunniwo & Li, 2010; Matos & Hall, 2007
COSTS				
Cost of relationship (C1)	7.1	Financial investment for developing relationship	Financial investments required from the supply chain partners.	Linton *et al.*, 2007; Ageron *et al.*, 2011; Cai *et al.*, 2008; Muller *et al.*, 2009; Bowen *et al.*, 2001
	7.2	Time required to develop relationship	Time investment required from the supply chain partners.	Peters *et al.*, 2011; Handfield, 2005; Bitzer *et al.*, 2008; Zsidisin & Hendrick, 1998; Carter & Jenning, 2002
	7.3	Responsibility sharing	Sharing of responsibilities among supply chain partners.	Zutshi & Sohal, 2004; Rocha *et al.*, 2007; Ni *et al.*, 2010; Ageron *et al.*, 2011; Cai *et al.*, 2008; Daugherty, 2011
Impact of relationship (C2)	8.1	Perception of relationship success	Buyers and suppliers are not sure of the success of the relationship	Nakano & Hirao, 2011; Ageron *et al.*, 2011; Cai *et al.*, 2008; Bowen *et al.*, 2001; Simpson & Power, 2005; Fortes, 2009
	8.2	No improvement in sustainability performance	There is no improvement in sustainability performance.	Ageron *et al.*, 2011; Cai *et al.*, 2008; Bowen *et al.*, 2001; Simpson & Power, 2005; Keatinga *et al.*, 2008; Fortes, 2009

	8.3	Poor partner commitment towards sustainability	Partners are not ready to share the cost of the relationship.	Diabata & Givindanb, 2011; Rao & Holt, 2005; Zutshi & Sohal, 2004; Lee, 2008; Vachon, 2007; Ageron *et al*, 2011
Cost of adoption (C3)	9.1	Technological changes	Investment required by supply chain partners for technological changes	Wu & Pagell, 2011; Klassen &Vachon, 2003; Lee, 2008; Bitzer *et al.*, 2008; Zhu & Sarkis, 2004
	9.2	Process change	Investment required by supply chain partners for process change.	Olorunniwo & Li, 2010; Rocha *et al.*, 2007; Cai *et al.*, 2008; Attaran & Attaran, 2007
	9.3	Infrastructure development	Investment required by supply chain partners for infrastructure development	Bowen et al., 2001; Simpson & Power, 2005; Markley & Devis, 2007
RISKS				
Management (R1)	10.1	Lack of trust	Lack of trust between parties	Bitzer *et al.*, 2008; Senge & Prokesch, 2010; Diabat & Govindan, 2011; Rao & Holt, 2005
	10.2	Problem in sharing risk	No party is ready to share the risk involved	Hall, 2000; Olorunniwo & Li, 2010, Simpson & Power, 2005
	10.3	Lack of integration	Parties are integrating their operational process with respect to others	Asif *et al*, 2008; Seuring & Muller, 2008; Vachon, 2007
Market (R3)	11.1	Dependency on few suppliers	Dependency on a few available sustainable suppliers	Handfield, 2005; Matos & Hall, 2007; Rocha *et al.*, 2007
	11.2	Bargaining power of supplier	Few suppliers have better bargaining power	Bitzer *et al.*, 2008; Senge & Prokesch, 2010; Diabat & Govindan, 2011; Rao & Holt, 2005
	11.3	Competition in future	Buyer or supplier may do forward or backward integration and create competition	Bitzer *et al.*, 2008; Senge & Prokesch, 2010; Diabat & Govindan, 2011; Rao & Holt, 2005
Investment (R4)	12.1	Huge investment required for developing relationship	Buyer/supplier need to investment in developing relationship	Linton *et al.*, 2007; Ageron *et al.*, 2011; Cai *et al.*, 2008; Muller *et al.*, 2009; Bowen *et al.*, 2001
	12.2	Unavailability of required technology with partners	Existing buyer/supplier are not having required technology	Zutshi & Sohal, 2004; Lee, 2008; Hall, 2000; Bai & Sarkis, 2010; Bitzer *et al.*, 2008; Vermeulen & Ras, 2006
	12.3	Breaking partnership in between	Fear of buyer/supplier breaking relationship	Diabat & Govindan, 2011; Rao & Holt, 2005

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Table 1 presents the several criteria and sub-criteria under the benefits, opportunities, costs, and risks. The benefits of the relationship include financial, operational and sustainability adoption. The opportunities include marketing advantage, technical capability development, and mutual growth possibilities. The costs include cost of relationship, impact of relationship, and cost of adoption of sustainability practices. The risks of a relationship include management of relationship, market risk, and investment risk.

3. Computational procedure

3.1 Fuzzy AHP

Fuzzy set theory helps analyze the vagueness and fuzziness of uncertain environments (Zadeh, 1965). In AHP, the crisp value is taken for the pairwise comparison, but it is not appropriate for making real life decisions where responses are supposed to be uncertain (Shaw et al., 2012). To solve this problem, decision models should incorporate a fuzzy theory to deal with uncertainty (Lee, 2009; Yu, 2002).

Fuzzy AHP is often used in research for decision-making with various proposed methods for calculating fuzziness (Chang, 1996; Kumar et al., 2017). There are advantages and disadvantages for each method. Considering the simplicity of calculations and advantages of one method over another, Chang (1996) used the extent analysis method for Fuzzy AHP. This approach deals with the uncertainty of decision making and is more robust in nature (Chan & Kumar, 2007). Wang et al. (2008) published one article "On the extent analysis method for fuzzy AHP and its applications" in the *European Journal of Operation Research*. In this article the author commented on the feasibility of usage of the extent analysis method in obtaining crisp numbers from fuzzy triangular numbers. Though many previous studies have used the extent analysis method due to its simplicity in computation and supported the methodology, the researchers must make an adequate decision before opting for any method.

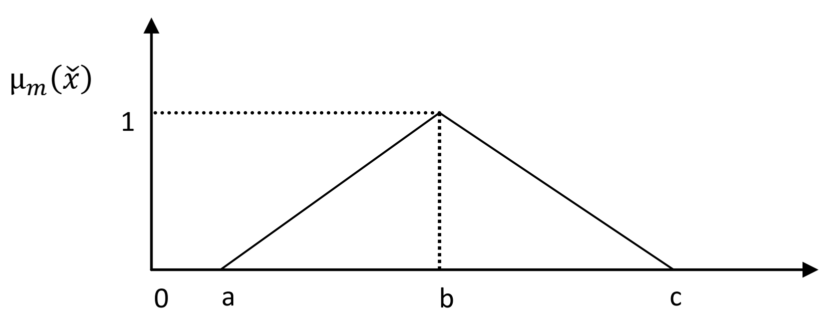

Figure 1a Triangular fuzzy number

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

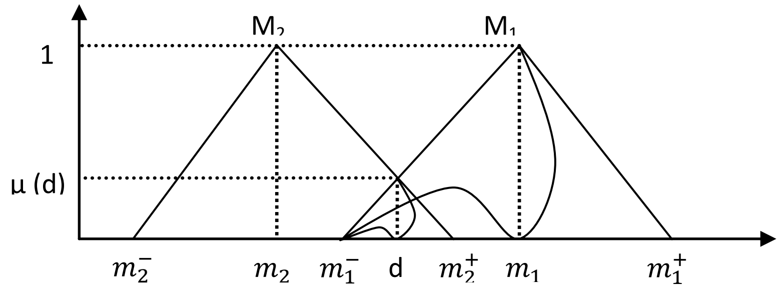

Figure 1b Two triangular fuzzy numbers M_1 and M_2 (Lee, 2009).

The triangular fuzzy number M can be represented by (a, b, c), and the membership function for fuzzy number is shown in Figure 1a (Cheng, 1999; Lee et al., 2005).

$$\mu_m(x) = \begin{cases} \frac{x-a}{b-a} & (a \le x \le b) \\ \frac{c-x}{x-b} & (b \le x \le c) \\ 0 & otherwise \end{cases} \qquad (1)$$

with $-\infty < a \le b \le c \le \infty$.

The strongest grade of membership is the parameter b that is, f_M (b) = 1, while a and c are the lower and upper bounds. Two triangular fuzzy numbers M_1 (m_1^-, m_1, m_1^+) and $M_2(m_2^-, m_2, m_2^+)$ are shown in Figure 1 (b).

When, $m_1^- \ge m_2^-,\ \ m_1 \ge m_2, m_1^+ \ge m_2^+)$ (2)

The degree of possibility is represented in Equation (3):

$V(M_1 \ \ge M_2) = 1$ (3)

Otherwise, the ordinate of the highest intersection point is calculated as (Chang, 1996; Zhu, et al., 1999; Lee, 2009; Shaw et al, 2012).

$$V(M_2 \ge M_1) = hgt(M_1 \cap M_2) = \mu(d) = \frac{m_1^- - m_2^+}{(m_2 - m_2^+) - (m_1 - m_1^-)} \qquad (4)$$

Equations (5) to (11) can be used for the calculation of the fuzzy synthetic extent value (Chang, 1996; Zhu et al., 1999; Lee, 2009).

$$\text{Fi} = \sum_{j=i}^{m} M_{gi}^{j} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right)^{-1}, \qquad i = 1,2, \ldots \ldots . . n \qquad (5)$$

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

$$\sum_{j=i}^{m} M_{gi}^{j} = \left(\sum_{j=i}^{m} M_{ij}^{-}, \sum_{j=i}^{m} M_{ij}, \sum_{j=i}^{m} M_{ij}^{+} \right) \qquad i = 1,2, \dots \dots . . n \tag{6}$$

$$\left(\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right)^{-1} = \left[\frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}^{+}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}}, \frac{1}{\sum_{i=1}^{n} \sum_{j=1}^{m} M_{ij}^{-}} \right] \tag{7}$$

A convex fuzzy number can be defined as,
$V (F \geq F_1, F_2 \dots F_K) = \min V (F \geq F_i)$, $i = 1, 2, \dots\dots k$ (8)

$d (F_i) = \min V (F \geq F_k) = W_i'$ $k = 1, 2, \dots\dots, n$ and $k \neq i$ (9)

Based on the above procedure, the weights, W_i' of the factors are
$W' = (W_1', W_2', \dots\dots, W_n')^{T}$ (10)

After normalization, the priority weights are as follows
$W' = (W_1, W_2, \dots\dots, W_n)^{T}$ (11)

3.3 BOCR addition methods

In order to deal with the benefits, opportunities, costs and risks, a pair wise comparison has been done to know which option is more beneficial and more opportunistic in nature. The same approach has been done for costs and risks by asking which option is costlier and riskier in nature. The weights calculated from the pair-wise comparison can be added as proposed by Saaty (2003):

(1) Additive

$$Relative\ priority\ for\ alternatives\ = bB + oO + c(1/C) + r(1/R)$$

(2) Probabilistic additive

$$Relative\ priority\ for\ alternatives = bB + oO + c(1 - C)normalized + r(1 - R)normalized$$

(3) Subtractive

$$Relative\ priority\ for\ alternatives\ = bB + oO - cC - rR$$

(4) Multiplicative priority powers

$$Relative\ priority\ for\ alternatives = BbOo[(1/C)normalized]c[(1/R)normalized]r$$

(5) Multiplicative

$$Relative\ priority\ for\ alternatives\ = BO/CR$$

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Where B, O, C and R represent the synthesized results and b, o, c and r are normalized weights of B, O, C and R, respectively.

3.4 Methodology and algorithm

A systematic fuzzy AHP model for evaluating the forms of buyer–supplier relationship is proposed in this section. The steps are summarized as follows:

Step 1: Identify the experts and clearly state the problem to them. Collaboration is not always a good option, and there are various types of relationships based on the degree of collaboration and expected outcomes of the relationship. An identification of relationship type in the industry under consideration is also required.

Step 2: Decompose the problem hierarchically. Develop two hierarchies based on the literature and expert opinions.

Step 3: A nine-point scale questionnaire is developed for pairwise comparison by the experts (Table 2). Experts are included from the supply chain and operation management department of the company (Lee, 2009).

Table 2
Nine point scale (Lee, 2009)

Fuzzy Number	**Membership Function**
$\tilde{1}$	(1,1,2)
$\tilde{x}$	(x-1, x, x+1) for x= 2,3,4,5,6,7,8
$\tilde{9}$	(8,9,9)
$1/\breve{1}$	(2^{-1}, 1^{-1}, 1^{-1})
$1/\breve{x}$	($(x+1)^{-1}$, x^{-1}, $(x-1)^{-1}$) for x= 2,3,4,5,6,7,8
$1/\breve{9}$	(9^{-1}, 8^{-1}, 8^{-1})

Step 4: Combine experts' opinions on the importance weight for each strategic criterion. For a number of S experts, the synthetic set representing the relative importance level between strategic criteria p and q can be generated by geometric average as (Lee, 2009):

$$h^{-} = \left(\prod_{t=1}^{s} l_t\right)^{\frac{1}{s}}, \qquad \forall t = 1, 2 \ldots s.$$

$$h = \left(\prod_{t=1}^{s} m_t\right)^{\frac{1}{s}}, \qquad \forall t = 1, 2 \ldots s.$$

$$h^{+} = \left(\prod_{t=1}^{s} n_t\right)^{\frac{1}{s}}, \qquad \forall t = 1, 2 \ldots s.$$

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

and (l_t, m_t, u_t) is the lower, middle and upper limit of fuzzy response from expert *t*.

Step 5: Calculate the relative weights, b, o, c and r, for the four merits B, O, C and R (stage 1).

Step 6: Fuzzy extent analysis method developed by Chang (1996) is used to obtaining the crisp relative priority of criteria.

Step 7: Stage 2 calculations. Calculate the fuzzy ranking of alternatives under each merit (B, O, C and R) by following step 6.

Step 8: Obtain the performances of each alternative under each qualitative criterion by following step 6.

Step 9: Identify the ranking of each alternative under benefits, opportunities, cost and risk.

Step 10: Synthesize and establish the fuzzy ranking of alternatives under each merit (B, O, C and R) by following the five combination ways as discussed in section 3.3.

4. Application of the model on an Indian automobile supply chain supplier

The effectiveness of the model is discussed by a case study on a multinational automobile company (ABC), at the corporate office based in Noida (India). The company has four manufacturing units, one research center and five sales offices across India. The company is mainly domestic demand oriented and partially export oriented. The company produces electrical, thermal, electronic, as well as power train products for both two wheelers and four wheelers. The company procures products from various suppliers in both semi-finished and finished forms. This study has been done for a plastic mold parts supplier. In this case, the company is sourcing material from four different suppliers.

The ABC Company has decided to improve its sustainability performance and wants to convey this to its suppliers. ABC has decided to develop a relationship with its suppliers based on the company performance of several strategic sustainability criteria. These criteria have been selected by six experts and the type of relationship that can be made with the plastic mold parts supplier are as follows: one time relationship, foundation relationship, problem solving relationship, long term relationship and joint development.

Profiles of experts involved in decision making are as follows:

1. Production manager - 16 years of experience
2. Procurement manager - 13 years of experience
3. Quality manager (Supplier) - 9 years of experience
4. Professor working on sustainable supply chain management: 25 years of experience.
5. General manager (Supplier) - 21 years of experience
6. Production Manager (Supplier) - 17 years of experience

Experts from the automobile supply chain finalized the following relationship alternatives for the case study. The types of relationships in the industry under consideration and their definition are as follows:

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

1. **One time relationship (**Carter & Rogers 2008; Seuring & Muller, 2008, Vachon, 2007**)**. Relationship depends upon the current transaction only.
2. **Foundation relationship (**Monczkaet et al., 1998; Wu & Pagell, 2011; Klassen & Vachon, 2003**).** A relationship intended to develop basic trust and commitment between the supplier-buyer. In terms of sustainability, it is related to the basic support extended to each other for developing a sustainable product.
3. **Problem solving relationship (**Smith, 2007; Lee, 2008; Bai & Sarkis, 2010; Vachon, 2007; Bitzer et al., 2008, Ageron et al., 2011; Elkington, 1994**).** This relationship is intended to know and solve the supplier's problems. This type of relationship is problem specific and help is provided to the supplier for handling problems of sustainability adoption.
4. **Long term trust based relationship (**Monczkaet et al., 1998; Sahay, 2003; Walker et al., 2008; Lee, 2008; Seuring & Muller, 2008; Bai & Sarkis, 2010; Zsidisin & Hendrick, 1998**).** In this type of relationship, the buyer and supplier enter into long-term business objectives. Trust between the buyer and supplier is very important to attract long-term investments in the relationship.
5. **Mutual development and growth (**Klassen & Vachon, 2003; Wu & Pagell, 2011; Lee, 2008; Ageron et al., 2011; Markley & Devis, 2007**).** A relationship focused on setting joints goals and developing a program for sustainability adoption. It also concentrates on mutually developing the capacity and capability of each other.

Due to the increase in sustainability practices across the industry, the ABC Company is looking to incorporate sustainability related criteria in the procurement processes. The company found that having excellent relationship management makes a supplier more sustainable and loyal. The relationship between the two parties depends on the capability and capacity of the individual suppliers. Management has invited experts from the marketing, production, quality, and research departments for the buyer-supplier relationship selection.

4.1 Two-stage model

In this study, the problem of the best form of relationship selection is divided into two phases as shown in Figures 2 and 3. In phase 1, the hierarchal model is to achieve a sustainable supply chain while maintaining the best form of relationship. The criteria for the best form of relationship in a sustainable supply chain are at level 2 and each criterion can be considered as sub-goals that firms want to achieve by developing a buyer-supplier relationship in terms of sustainability. The sub-criteria selected for this research are: energy usage, pollution emission, waste reduction, employee and society welfare, late delivery, rejection on quality, cost of the product and demand (Kumar et al., 2017). The four merits, benefits (B), opportunities (O), costs (C), and risks (R), for the evaluation of buyer-supplier relationships are at level 3. The main objective behind developing phase one is to calculate the relative weights (b, o, c & r) of benefits, opportunities, costs, and risks (Saaty, 2005). It is obvious that in the real world priorities for all the merits are not equal and hence these should be calculated. However, it is not easy for experts to determine the priorities of these four merits by doing pairwise comparisons. For example, asking a question like, "what is the relative importance of benefits compared with opportunities in achieving the goal of the best form of buyer–supplier relationship?" is very complex and hard to answer. Therefore, as suggested by Saaty (2005), a control hierarchy can be used to determine the relative weights b, o, c, & r, for the four merits B, O, C, and R. For example, questions can be reframed in the control hierarchy (Phase 1) as

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

"what level of 'benefit' do you associate with strategic criterion 'pollution emission'. Experts then respond on the level of benefit of that strategic criterion.

In phase 2 of this study, the objective is to identify and select the best form of relationship in a supply chain. BOCR are considered here to achieve the goal and there are criteria and sub-criteria (Table 1). The weights calculated from Phase 1 are used as input and used to calculate the overall priority weight of each relationship type alternatives.

The following two-stage model has been developed to solve the relationship selection problem. This case study has been done with respect to the particular supplier. In the first stage, the benefits, costs, opportunities, and risks have been compared with respect to the sustainability criteria finalized for the relationship selection. In the second stage, all the relationship alternatives have been compared with respect to the benefits, opportunities, costs, and risks of the relationship.

Stage 1 Calculate the weight of benefits by comparing the sustainability indicators and demand of the product. In our case, eight criteria have been considered for deciding the buyer-supplier relationship. This includes energy use, emission, waste, employee and society, cost of sourcing, quality of input product, on time delivery and product demand. Figure 2 illustrates the comparison hierarchy of stage 1.

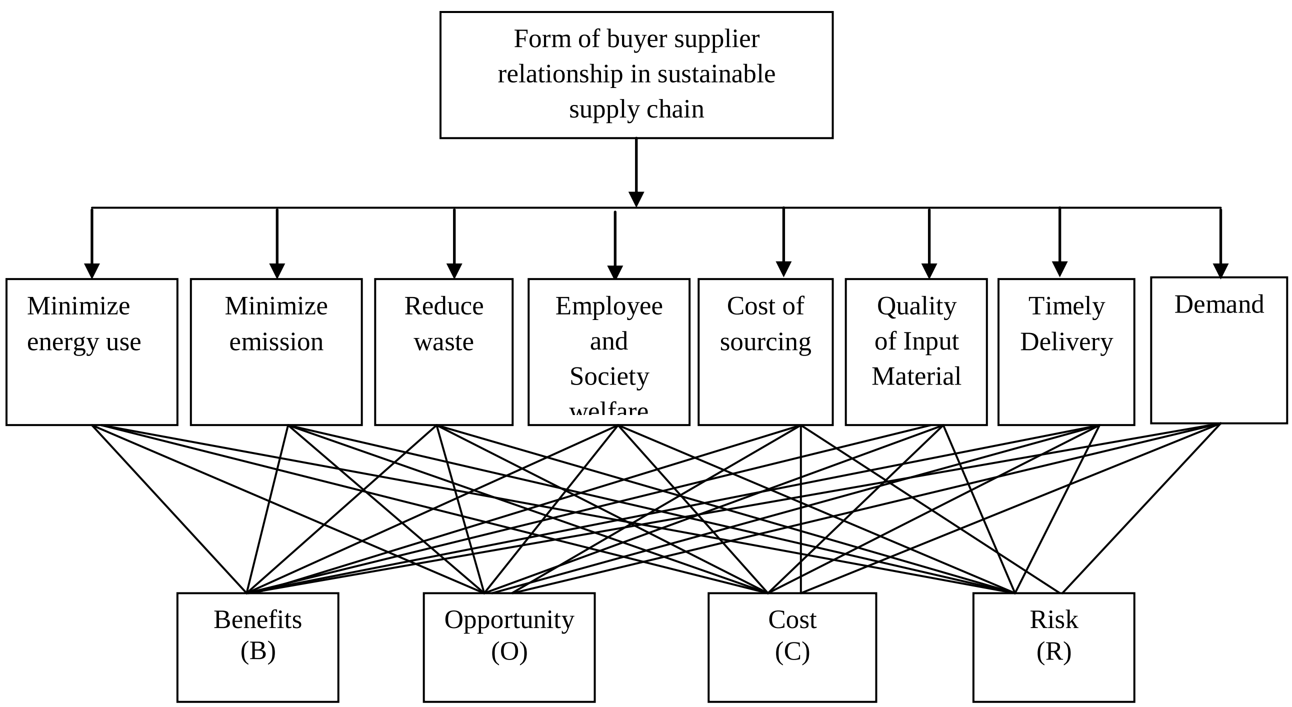

Figure 2 Control hierarchy (Stage 1)

Stage 2 All the relationship alternatives are compared with respect to the benefits, costs, risks, and opportunities of the buyer-supplier relationship.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

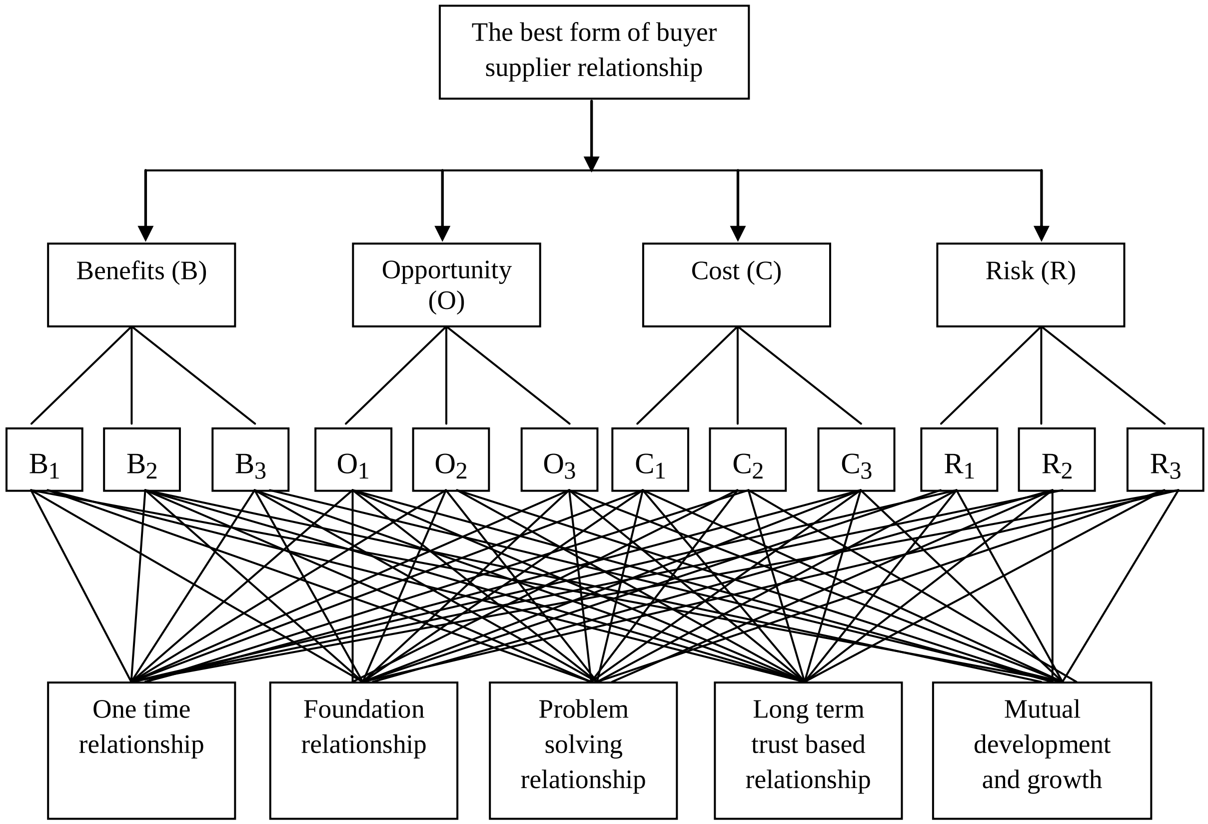

Figure 3 Stage 2

Figure 3 illustrates a comparison hierarchy for selecting the best form of buyer-supplier relationship with respect to the benefits, opportunities, costs, and risks of the relationship. The criteria for the model are benefits, opportunities, costs and risks. Each criterion has several sub-criteria (Table 1). There are five buyer-supplier relationship alternatives: one time relationship, foundation relationship, problem-solving relationship, long-term trust based relationship and mutual development and growth. A pairwise comparison has been done for each level of the model in order to prioritize the final alternatives.

5. Findings and discussion

The sustainability criteria have been compared to the relationship selection. Experts were asked to compare the criteria to determine the final weight for deciding the best form of the buyer-supplier relationship. The response from the experts was added using Lee's (2009) formula discussed in the computation procedure. The final cumulative response of the experts is shown in Table 3. A response matrix has been calculated using Chang's fuzzy method (1996). Similar steps were used for the calculation of all possible metrics in stage 1 and stage 2 of our model.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Table 3
Comparison of selection criteria

	Ordering Cost	Rejection on Quality	Late Delivery	Social welfare	Emission	Energy use per product	Demand	Waste Generation
Ordering Cost	1.00,1.00,1.00	1.51,1.82,2.94	0.48,0.66,0.93	1.59,2.08,3.17	1.59,2.08,2.83	1.62,1.91,3.05	1.59,2.08,3.17	1.35,1.82,2.62
Rejection on Quality	0.34,0.55,0.66	1.00,1.00,1.00	1.00,1.44,2.00	1.59,2.08,3.17	1.59,2.08,3.17	1.51,1.82,2.94	1.26,1.44,2.24	2.14,2.85,3.96
Late Delivery	1.07,1.52,2.08	0.50,0.69,1.00	1.00,1.00,1.00	1.41,1.73,2.52	1.51,2.18,2.94	1.91,2.62,3.70	1.59,2.08,3.17	1.51,2.04,3.14
Social welfare	0.31,0.48,0.63	0.31,0.48,0.63	0.40,0.58,0.71	1.00,1.00,1.00	1.00,1.12,2.14	0.46,0.56,0.87	0.92,1.07,1.73	0.41,0.45,0.78
Emission	0.35,0.48,0.63	0.31,0.48,0.63	0.34,0.46,0.66	0.47,0.89,1.00	1.00,1.00,1.00	1.26,1.44,2.52	1.41,1.73,2.83	1.00,1.00,1.41
Energy use / product	0.33,0.52,0.62	0.34,0.55,0.66	0.27,0.38,0.52	1.15,1.78,2.15	0.40,0.69,0.79	1.00,1.00,1.00	1.26,1.44,2.52	1.12,1.20,1.59
Demand	0.31,0.48,0.63	0.45,0.69,0.79	0.31,0.48,0.63	0.58,0.93,1.09	0.35,0.58,0.71	0.40,0.69,0.79	1.00,1.00,1.00	0.89,0.89,1.78
Waste generation / product	0.38,0.55,0.74	0.25,0.35,0.47	0.32,0.49,0.66	1.29,2.24,2.42	0.71,1.00,1.00	0.63,0.83,0.89	0.56,1.12,1.12	1.00,1.00,1.00

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = (1,1,1) + \ (1.51,1.82,2.94) + \cdots + (1,1,1) = (57.94, 74.71, 103.15)$$

$$\left(\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right)^{-1} = \left(\frac{1}{103.15},\frac{1}{74.71},\frac{1}{57.94}\right) = (0.0097, 0.0134, 0.0173)$$

$\sum_{j=1}^{m} M_{g1}^{j} = (1,1,1) + (1.51, 1.82, 2.94) + \cdots + (1.59,2.08,3.17)$ = (10.72, 13.44, 19.71)

$$\sum_{j=1}^{m} M_{g2}^{j} = (10.43,13.27,19.15), \sum_{j=1}^{m} M_{g3}^{j} = (10.51,13.87,19.55), \sum_{j=1}^{m} M_{g4}^{j} = (4.82,5.74,8.48)$$

$$\sum_{j=1}^{m} M_{g5}^{j} = \ (6.15,7.48,10.68), \sum_{j=1}^{m} M_{g6}^{j} = \ (5.87,7.57,9.86), \sum_{j=1}^{m} M_{g7}^{j} = \ (4.30,5.757.43),$$

$$\sum_{j=1}^{m} M_{g8}^{j} = \ (5.14,7.59,8.30)$$

$$F_1 = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{\mathrm{i}=1}^{\mathrm{n}}\sum_{\mathrm{j}=1}^{\mathrm{m}} \mathrm{M}_{\mathrm{gi}}^{\mathrm{j}}\right]^{-1} = (10.72, 13.44, 19.71) \otimes \ (0.0097, 0.0134, 0.0173)$$
$$= (0.10, 0.18, 0.34)$$

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

$F_2 = (10.43, 13.27, 19.15) \otimes (0.0097, 0.0134, 0.0173) = (0.10, 0.18, 0.33)$
$F_3 = (10.51, 13.87, 19.55) \otimes (0.0097, 0.0134, 0.0173) = (0.10, 0.19, 0.34)$
$F_4 = (4.82, 5.74, 8.48) \otimes (0.0097, 0.0134, 0.0173) = (0.05, 0.08, 0.15)$
$F_5 = (6.15, 7.48, 10.68) \otimes (0.0097, 0.0134, 0.0173) = (0.06, 0.10, 0.18)$
$F_6 = (5.87, 7.57, 9.86) \otimes (0.0097, 0.0134, 0.0173) = (0.06, 0.10, 0.17)$
$F_7 = (4.30, 5.757.43) \otimes (0.0097, 0.0134, 0.0173) = (0.04, 0.08, 0.13)$
$F_8 = (5.14, 7.59, 8.30) \otimes (0.0097, 0.0134, 0.0173) = (0.05, 0.10, 0.14)$
$V(F_1 \geq F_2) = 1$, $V(F_1 \geq F_3) = 1$, $V(F_1 \geq F_4) = 1$, $V(F_1 \geq F_5) = 1$,
$V(F_1 \geq F_6) = 1$, $V(F_1 \geq F_7) = 1$, $V(F_1 \geq F_8) = 1$

Similarly,
$V(F_2 \geq F_1\ F_3\ F_4\ F_5\ F_6\ F_7\ F_8) = (1, 1, 1, 1, 1, 1, 1)$
$V(F_3 \geq F_1\ F_2\ F_4\ F_5\ F_6\ F_7\ F_8) = (1, 1, 1, 1, 1, 1, 1)$
$V(F_4 \geq F_1\ F_2\ F_3\ F_5\ F_6\ F_7\ F_8) = (0.375, 0.444, 0.444, 1, 1, 1, 0.857)$
$V(F_5 \geq F_1\ F_2\ F_3\ F_4\ F_6\ F_7\ F_8) = (0.143, 0.25, 0.25, 0.80, 1, 0.833, 0.667)$
$V(F_6 \geq F_1\ F_2\ F_3\ F_4\ F_5\ F_7\ F_8) = (0.286, 0.375, 0.375, 1, 1, 1, 0.833)$
$V(F_7 \geq F_1\ F_2\ F_3\ F_4\ F_5\ F_6\ F_8) = (0.143, 0.25, 0.25, 0.80, 1, 0.833, 0.667)$
$V(F_8 \geq F_1\ F_2\ F_3\ F_4\ F_5\ F_6\ F_7) = (0.429, 0.50, 0.50, 1, 1, 1, 1)$

The weight vectors are calculated as follows:
$d(f_1) = \text{Min } V(F_1 \geq F_2\ F_3\ F_4\ F_5\ F_6\ F_7\ F_8) = \text{Min } (1, 1, 1, 1, 1, 1, 1) = 1$
$d(f_2) = \text{Min } V(F_2 \geq F_1\ F_3\ F_4\ F_5\ F_6\ F_7\ F_8) = \text{Min } (1, 1, 1, 1, 1, 1, 1) = 1$
$d(f_3) = \text{Min } V(F_3 \geq F_1\ F_2\ F_4\ F_5\ F_6\ F_7\ F_8) = \text{Min } (1, 1, 1, 1, 1, 1, 1) = 1$
$d(f_4) = \text{Min } V(F_4 \geq F_1\ F_2\ F_3\ F_5\ F_6\ F_7\ F_8) = \text{Min } (0.375, 0.444, 0.444, 1, 1, 1, 0.857) = 0.375$
$d(f_5) = \text{Min } V(F_5 \geq F_1\ F_2\ F_3\ F_4\ F_6\ F_7\ F_8) = \text{Min } (0.143, 0.25, 0.25, 0.80, 1, 0.833, 0.667) = 0.143$
$d(f_6) = \text{Min } V(F_6 \geq F_1\ F_2\ F_3\ F_4\ F_5\ F_7\ F_8) = \text{Min } (0.286, 0.375, 0.375, 1, 1, 1, 0.833) = 0.286$
$d(f_7) = \text{Min } V(F_7 \geq F_1\ F_2\ F_3\ F_4\ F_5\ F_6\ F_8) = \text{Min } (0.143, 0.25, 0.25, 0.80, 1, 0.833, 0.667) = 0.143$
$d(f_8) = \text{Min } V(F_8 \geq F_1\ F_2\ F_3\ F_4\ F_5\ F_6\ F_7) = \text{Min } (0.429, 0.50, 0.50, 1, 1, 1, 1) = 0.429$
$W' = (d(f_1)\ d(f_2)\ d(f_3)\ d(f_4)\ d(f_5)\ d(f_6)\ d(f_7)\ d(f_8))^T$
$= (1, 1, 1, 0.375, 0.143, 0.286, 0.143, 0.429)^T$
$= (0.229, 0.229, 0.229, 0.086, 0.033, 0.065, 0.033, 0.098)$

The normalized priorities of the sustainability criteria for the relationship selection are 0.229, 0.229, 0.229, 0.086, 0.033, 0.065, 0.033, and 0.98 (Figure 2). The final priorities of the benefits, costs, opportunities and risks can be calculated by following the same procedure. The final priority weights for the stage 1 of the model are shown in Table 4. The final normalized weights have been calculated by multiplying the weights of sustainability criteria and BOCR weight of the control criteria.

For example, the weight of benefit is calculated by:

0.229*0.415+0.229*0.401+0.229*0.374+0.033*0.543+0.065*0.396+0.033*0.364+0.098*0.524 = 0.426

The weights of opportunity, cost and risk are 0.260, 0.226 and 0.088 respectively.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Table 4
BOCR Rating

	Ordering Cost	Rejection on Quality	Late Delivery	Social welfare	Emission	Energy	Demand	Waste	Normalized weight
	0.229	0.229	0.229	0.086	0.033	0.065	0.033	0.098	
Benefits	0.415	0.401	0.374	0.554	0.543	0.396	0.364	0.524	0.426
Opportunities	0.333	0.209	0.291	0.197	0.215	0.244	0.297	0.200	0.260
Costs	0.149	0.289	0.200	0.212	0.229	0.349	0.191	0.257	0.226
Risks	0.103	0.101	0.135	0.037	0.013	0.010	0.148	0.019	0.088

These priorities are obtained by comparing the BOCR with respect to the strategic criteria. The strategic criteria were selected from the literature and expert opinions (Figure 3).

In stage 2, the relative weight of the criteria and sub-criteria are listed in Table 5. The most important control criterion under the benefit category is financial benefits, which have a priority of 0.411. It means a firm keen on developing a relationship with the supplier for developing a more sustainable supply chain should look for the financial benefits. In the sub-criteria under benefits, reducing distribution costs is preferred, having a priority of 0.2198. Other major benefits in the sub-criteria are low cost of information (0.1465), improved internal process (0.1278) and reduced pressure from the external agencies (0.1277). The improvement of quality on sustainability standards also makes a significant contribution in the benefits sub-criteria (0.1192). Under the opportunity merit, improved corporate image (0.1698) under marketing advantage and sharing technology and knowledge (0.1516) under technical capabilities are the most important criteria. This implies the buyer-supplier relationship in a sustainable supply chain is developed for improving the buyer’s and supplier’s image, and companies look for sharing technology and knowledge about increasing sustainable practices. Under the cost merit, all the control costs of a relationship (0.352), impact of relationship (0.343) and the cost of adoption (0.304) have nearly equal priority. This is because each type of relationship has a different cost of developing the relationship. The type of relationship is also dependent upon the type of adoption the supplier needs in terms of sustainability and impact of the relationship in developing sustainability performance. Under the opportunity merit, the most important sub-criteria are financial investment for the relationship (0.1598), cost of infrastructure development (0.1373), time required for developing a relationship (0.1299) and perception of the relationship success (0.1209). Under risk merit, management of the relationship is the most important control criteria having a priority of 0.815. All the important sub-criteria that come under the relationship management control criteria are lack of trust (0.2485), lack of integration (0.2685) and problem in sharing loss (0.2980). This means that a firm worries the most about the capability of managing the relationship.

The relative importance of relationship alternatives is shown in Table 6. Under the benefits merit, long-term relationship and joint development performed well with a priority of 0.319 and 0.309, respectively. Problem solving relationship is also at 0.306. In the opportunity merit, joint development is the best option with a priority of 0.332. Long-

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

term relationship is at 0.323. However, under the cost merit, foundation relationship becomes the best with a weight of 0.626 and one-time relationship is in second place with a weight of 0.272. Under the merit of risk, one-time relationship has a high priority (0.747) followed by the foundation relationship (0.150).

Consistency check of the metrics

All the comparison metrics were checked for the consistency. Some authors only verify the consistency for crisp matrices whose elements are the middle significant values of the triangular fuzzy numbers from the corresponding fuzzy pair-wise comparison matrix (Tesfamariam & Sadiq, 2006, Pan, 2008, Vahidnia et al., 2009). The above matrix (Table 3) was transformed into a crisp matrix by considering only the middle value of the triangular fuzzy number. The following values were found: CR= 0.040970119, RI (for n=8) = 1.41, CI=0.029056822, as CI is less than 0.1, the above matrix is considered consistent. A similar approach was used for each comparison matrix. There are other methods to check the consistency of a fuzzy matrix such as Zheng et al. (2012), but in this approach, the crisp matrix obtained is not reciprocal, hence its check of consistency is questionable.

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Table 5
Relative priorities of control criteria and sub- criteria

Merits	Control Criteria	Sub Criteria	Normalized priority	Integrated priority
Benefits (0.426)	Financial (B1) (0.411)	Reduce Distribution cost	0.516	0.2198
		Low cost of information	0.344	0.1465
		Reduce inventory cost	0.140	0.0596
	Operational (B2) (0.326)	Improve Internal process	0.392	0.1278
		Resource optimization	0.301	0.0981
		On time delivery	0.307	0.1001
	Sustainability adoption (B3) (0.263)	Improved quality on sustainability standards	0.453	0.1192
		Reduced pressure from various agencies	0.485	0.1277
		Sustainable supply chain	0.061	0.0161
Opportunities (0.260)	Marketing advantage (O1) (0.454)	Improve corporate Image/ Reputation	0.374	0.1698
		Premium Pricing	0.291	0.1321
		Product Differentiation	0.200	0.0908
		New Market	0.135	0.0613
	Technical capabilities (O2) (0.369)	Sharing technology and knowledge	0.411	0.1516
		Educating each other’s employee	0.326	0.1202
		Developing technical standards	0.263	0.0972
	Mutual growth (O3) (0.177)	Capacity building and development	0.600	0.1063
		Sharing resources and information	0.257	0.0457
		Jointly setting goals	0.141	0.0250
Costs (0.226)	Cost of relationship (C1) (0.352)	Financial investment for relationship	0.454	0.1598
		Time required to develop relationship	0.369	0.1299
		Responsibility sharing	0.177	0.0623
	Impact of relationship (C2) (0.343)	Perception of relationship success	0.352	0.1209
		No improvement in sustainability performance	0.343	0.1178
		Poor partner commitment	0.304	0.1043
	Cost of adoption (C3) (0.304)	Technological changes	0.244	0.0742
		Process change	0.304	0.0925
		Infrastructure development	0.452	0.1373
Risks (0.088)	Management (R1) (0.815)	Lack of trust	0.305	0.2485
		Problem in sharing risk	0.329	0.2685
		Lack of integration	0.366	0.2980
	Market (R2) (0.162)	Dependency on few suppliers	0.815	0.1320
		Bargaining power of supplier	0.163	0.0264
		competition in future	0.022	0.0036

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Investment (R3) (0.022)	Huge investment for relationship	0.233	0.0051
	Unavailability of required technology with partners	0.145	0.0032
	Breaking partnership in between	0.623	0.0137

Table 6
Priorities of alternatives under the four merits

	Merits			
	Benefits (0.426)		Opportunities (0.260)	
Alternatives	Relative	Normalized	Relative	Normalized
One time relationship	0.150	0.048	0.151	0.050
Foundation relationship	0.059	0.019	0.090	0.030
Problem solving relationship	0.958	0.306	0.800	0.266
Long term relationship	1.000	0.319	0.973	0.323
Joint development	0.968	0.309	1.000	0.332

	Merits							
	Cost (0.226)				Risk (0.088)			
Alternatives	Relative	Normalized	Reciprocal	Normalized	Relative	Normalized	Reciprocal	Normalized
One time relationship	0.073	0.032	31.10	0.272	0.035	0.013	75.28	0.747
Foundation relationship	0.032	0.014	71.45	0.626	0.173	0.066	15.12	0.150
Problem solving relationship	0.351	0.156	06.41	0.056	0.560	0.214	04.67	0.046
Long term relationship	0.800	0.355	02.81	0.024	0.852	0.325	03.07	0.030
Joint development	1.000	0.443	02.25	0.019	1.000	0.382	02.62	0.026

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

Table 7
Final synthesis of priorities of alternatives

	Synthesis methods									
	Additive		Probabilistic additive		Subtractive		Multiplicative priority powers		Multiplicative	
Alternatives	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank
One time relationship	0.094985	V	0.3391992	IV	0.024971	IV	0.043697	IV	0.000991	V
Foundation relationship	0.157577	IV	0.3209759	V	0.006748	V	0.041111	V	0.002649	IV
Problem solving relationship	0.205222	III	0.4593121	I	0.145084	I	0.170002	I	0.111408	I
Long term relationship	0.234654	II	0.4251118	II	0.110884	II	0.162888	II	0.094357	II
Joint development	0.235069	I	0.3980857	III	0.083857	III	0.158281	III	0.088181	III

Table 8
Sensitivity analysis

Merit	Benefits (0.426)				Opportunities (0.260)			
Change in merit with synthesis method	b decreases		b increases		o decreases		o increases	
	b best alternatives		b best alternatives		o best alternatives		o best alternatives	
Additive	No Change	MDG	0.467	LTR, MDG	0.213	LTR, MDG	No Change	MDG
Probabilistic additive	No Change	PSR	No Change	PSR	No Change	PSR	0.858	LTR, PSR
Subtractive	No Change	PSR	No Change	PSR	No Change	PSR	0.858	LTR, PSR
Multiplicative priority powers	No Change	PSR	No Change	PSR	No Change	PSR	0.479	LTR, PSR
Multiplicative	No Change	PSR	No Change	PSR	No Change	PSR	No Change	PSR
Merit	Cost (0.226)				Risk (0.088)			
Change in merit with synthesis method	c decreases		c increases		r decreases		r increases	
	c best alternatives		c best alternatives		r best alternatives		r best alternatives	
Additive	No Change	MDG	0.354	LTR (0.311), FR	No Change	PSR	No Change	MDG
Probabilistic additive	0.053	LTR, PSR	No Change	PSR	No Change	PSR	0.688	FR
Subtractive	No Change	PSR	No Change	PSR	No Change	PSR	No Change	PSR
Multiplicative priority powers	0.173	LTR, PSR	0.815	FR	No Change	PSR	0.151	MDG
Multiplicative	No Change	PSR	No Change	PSR	No Change	PSR	No Change	PSR

The final alternative priority is calculated by using five different combination methods shown in Table 7. Under all the combination methods, the problem solving relationship ranks first, except in the additive method, while joint development scores first in the additive method and ranks third in the remaining methods. Long-term relationship scores second under all methods of combination. Under the additive method, long-term relationship ranks second and joint development ranks first with scores of 0.235069 and 0.234653, respectively (insignificant difference of only 0.000415). Similarly, the problem solving relationship ranks third, foundation relationship ranks fourth and one-time relationship ranks fifth with the scores of 0.205222, 0.157577 and 0.094985, respectively. Under the probabilistic additive method and the subtractive and multiplicative priority powers method, the ranking of all the alternatives is the same. The problem solving relationship ranked first, followed by long-term relationship and joint development which ranked second and third. One-time relationship ranked fourth in all the synthesis methods of combining priorities. In the multiplicative synthesis method, one-time relationship ranked fifth and foundation relationship is at rank four with priorities (0.000991) and (0.002649), respectively.

The reason for the good performance of the alternative “problem solving relationship” is the moderate performance of all the merits. Other relationship types ranked second and third are more beneficial and have more opportunity, but have more risks and costs.

A sensitivity analysis was performed to check the change in the priority level of the alternatives. The sensitivity analysis was done by changing the value of one merit while keeping the others constant. Table 8 shows the change in the priority level of the alternatives with the change in the priorities of benefits, opportunities, costs and risks. The sensitivity analysis was performed by changing the value of one strategic factor and keeping the value of the other constant. When b decreases from 0.426, mutual development and growth remain the most preferred alternative in the additive method. Figure 4 shows the sensitivity analysis in the additive method with respect to the change in the value of b. In all the other methods of combination, the problem-solving relationship is the most preferred. Similarly, when opportunity is decreased to 0.213, long-term relationship is the most preferred.

A special case is seen with the cost factor. When the cost priority is increased by more than 0.226, the most preferred alternatives at 0.311 are LTR and MDG and when it is increases further, after 0.354 the foundation relationship is the most suitable alternative in terms of cost. Similarly, all the variances can be seen in Table 8. In this study, the problem-solving relationship was preferred, since it is focused on a specific problem related to sustainability adoption. It has been found to be moderate on the benefits and opportunities; it also has moderate values on risk and cost compared to the other alternatives.

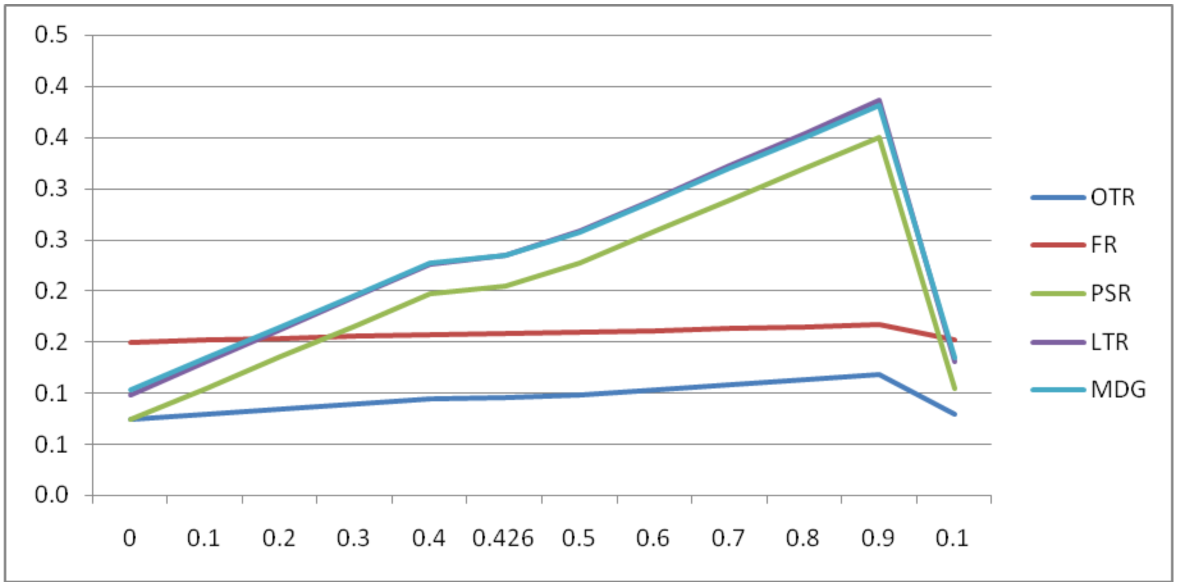

Figure 4 Sensitivity analysis with respect to the change in the value of b in additive method

6. Managerial implications and conclusions

The primary aim of this study was to evaluate the forms of buyer-supplier relationships for developing a more sustainable supply chain model using AHP based on benefits, opportunities, costs and risks (BOCR). In contrast to most supplier selection models available in the extant literature, the proposed model takes into consideration the benefits, costs, opportunities and risks related to development of buyer-supplier relationships in a sustainable supply chain. Firms can apply the learning from this study while choosing an appropriate relationship type with supply chain partners in their supply chains. It is to be noted, that this study has also integrated learning from fuzzy theory in the development of a sustainable buyer-supplier relationship model to address the issues of ambiguity and vagueness faced by managers while making supply chain decisions. Managers can use the identified criteria and criteria of BOCR for developing relationships with their supply chain partners. For example, managers can understand the benefits of a relationship type in term of sustainability adoption, finance and operations. Similarly, managers can compare the relationship type in terms of opportunity of a relationship type considering the marketing advantage, technical capability and mutual growth. At the same time, managers can incorporate several criteria related to cost and risk of a relationship type. For example, cost of developing a relationship (financial investment, time required, and responsibility sharing) with respect to a supplier provides better decision making possibilities to managers.

This model also provides information on the most profitable relationship alternative with respect to changes in the priority of benefits, opportunities, costs and risks that are manifested in buyer-supplier relationships in addition to the sustainability indicators for deciding the best form of the buyer-supplier relationship (Stage 1). This study provides the supply chain managers with the freedom to include customized sustainability

ISSN 1936-6744
https://doi.org/10.13033/ijahp.v11i2.605

indicators based on the industry and specific problems under consideration. In addition to this, the supply chain managers can use this model as a framework to evaluate their current supply chain relationships. A sensitivity analysis based on the model may provide these managers with the knowledge to decide relationship alternatives with the changing priorities of BOCR. This study has also considered five types of addition methods to incorporate all possible decision realities related to the selection of the best form of relationship. The proposed model can further be modified with respect to other industries to cater to their specific needs from their supply chains considering the benefits, opportunities, costs, and risks of developing such buyer-supplier relationships. Another contribution of this study includes the identification of several criteria and sub-criteria under benefits, opportunities, costs and risks of relationship type in the context of a sustainable supply chain. This study provides an opportunity in future research to analyze the benefits, opportunities, costs and risks of existing relationship types in industries using empirical study on larger sample.

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