PRODUCTION

An integrated approach of sustainable procurement and procurement postponement for the multi-product, assemble-to-order (ATO) production system

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Abstract

Postponement strategy is mainly used to handle the perceived variety and actual variety of product in the most cost effective way. However, postponement strategy has never been used by researchers in procurement to reduce cost and to enhance overall flexibility of the process. This paper gives a new concept of postponement, called procurement postponement, which is considered to be effective for the multi-product, assemble-to-order (ATO) system. A two-stage integrated approach of sustainable procurement and postponement method is proposed for the multi-product ATO production system to deal demand uncertainty, green house gas (GHG) emission, reliability of supply, level of disassembly and social issues of supplier selection with intuitionsitic fuzzy analytic hierarchy (IF-AHP) and multi-objective genetic algorithm (MOGA). Case study of an Indian company is discussed to use the proposed method by cost-emission-decision matrix.

Keywords

Intuitionsitic fuzzy set. AHP. MOGA. Cost-emission-decision matrix. Postponement strategy.

1. Introduction

Traditional supply chain deals with man, money and material (3M) and the green supply chain deals with man, money, material and environment (3Me). Finally, sustainable supply chain deals with man, money, material, environment and society (3MeS). Hence, the sustainable procurement process (SPP) should include the coordination of social, environmental and economic dimensions (the triple bottom line), see e.g Matos & Hall (2007). Sustainable procurement process (SPP) should also include recycling of disposed product to improve sustainability of supply chain (Geyer & Jackson, 2004).

Good practices yield better result and inspire other. Unilever launched "Unilever Sustainable Living Plan" to achieve hundred percent sourcing of agricultural raw material sustainably by 2020. As part of its Sustainable Living Plan, Unilever promotes the use of tomatoes raised sustainably in Knor soups. In 2010, Tesco developed Tesco Knowledge Hub to share knowledge with suppliers and agricultural producers to develop sustainable supply chain to reduce the energy costs, waste and environmental impacts of the products Tesco buys to achieve thirty percent reduction of carbon emissions from the company's supply chain by 2020, compared to 2006-07 levels. In 2014, Ceres conducted the research to measure to what extent more than 600 of the largest, publicly traded U.S. companies are integrating sustainability into their business systems and decision-making to develop the supplier self-assessment questionnaire (SAQ) to form the foundation of sustainable of supply chain. Today companies are keen to know the process of augmenting the sustainable procurement. Thus, it is true that only companies that make sustainability a goal will achieve competitive advantage (Nidumolu et al., 2009).

In this paper an attempt has been made to integrate the concept of sustainable procurement with an

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innovative postponement strategy. The complexity of production process can be avoided by manufacturing a base product or core product as per aggregate demand and then auxiliary parts/components can be manufactured and assembled after the receipt of customer demand. This approach can reduce cost, lead time and also the complexity of logistics and inventory. Thus, 'procure when required' or 'procurement postponement' could be an effective strategy of any manufacturing company that assembles products. In this paper an integrated approach of procurement postponement and sustainable procurement process is discussed in light of a case study of an Indian company. This paper is organized as follows. Section 2 discusses about literature review. Section 3 describes methodology. Section 4 depicts the mathematical model for two-stage supplier selection for ATO. Section 5 provides the case study of an Indian company. Section 6 and 7 discusses about results and conclusions.

2. Literature review

Sustainability can be achieved by changing the objectives from the economy driven towards economy, environment and society driven (Frota Neto et al., 2009). This triple bottom line approach is also the cornerstone of sustainable procurement process. Material intensity, energy intensity, water consumption, toxic emissions and pollutant emissions are five basic sustainability indicators (Schwarz et al., 2002). The sustainable procurement process basically improves above five metrics. Literature on the sustainable procurement process is very limited. Only few journal articles have been found which considered environmental and social aspects – separately or together (Amindoust et al., 2012). With this limited journal articles an attempt has been made to answer few interesting questions: Is supplier selection, one of the key elements essential to supply chain success? What are the key dimensions to measure supplier performance? How to improve sustainable procurement process with postponement strategy?

Suppliers have been acknowledged as the best intangible assets of any business organization (Muralidharan et al., 2002). Tracey & Tan (2001) mentioned that one of the key elements essential to supply chain success is an effective purchasing function. H Shin et al. (2000) proposed that the buyer performance can be enhanced with the improvement of supplier performance. Smith et al. (1995) considered that the good relationship between buyer and supplier is based upon exchanging information and sharing benefits with each other. However, Spekman (1988) showed that communication between supplier and buyer is always limited as buyer always focuses on

the price of products and ignores the importance of preserving the long term relationship with suppliers. Van Hoek (1999) proposed three approaches for green supply chain management: (1) reactive approach, (2) proactive approach, and (3) value-seeking approach. Noci (1997) divided corporative green strategies into (1) reactive strategy, and (2) proactive strategy and integrated these green issues to supplier selection. Hsu & Hu (2009) measured supplier performance with five dimensions: (1) Procurement management, (2) R&D management, (3) process management, (4) incoming quality control, (5) management of the system. Noci (1997) suggested that a firm practicing green supply chain should evaluate suppliers with four factors: (1) green competencies, (2) green images, (3) current environmental efficiency, and (4) net life cycle cost. Handfield et al. (2002) proposed an environmental conscious purchasing decision to trade-off between environmental dimensions using the analytic hierarchy process (AHP). Wu et al. (2007) proposed the integrated approach of AHP and fuzzy logic to select green suppliers. Lee et al. (2009) used both environmental and non-environmental criteria, namely, quality, technology capability, pollution control, environmental management, the green product, and green competencies, for selecting green supplier in high-tech industry. Bai & Sarkis (2010) integrated economic, environmental, and social issues into the supplier selection model. Particularly they emphasized more the social dimension in their model. On the other hand, postponement is a concept which brings the efficiency of the lean concept and the responsiveness of the agile concept together (Van Hoek, 1999). The major reason of using postponement strategy is that one extremely high demand may be offset by another extremely low demand after aggregation (Cheng, pp 3). Apart from reducing demand variability, postponement is also used to tackle process and supply uncertainties. There are four forms of postponement strategies, namely pull postponement, logistics postponement, form postponement (Lee, 1998) and price postponement (Van Mieghem & Dada, 1999). The former three strategies are also referred to as production postponement (Van Mieghem & Dada, 1999). Bowersox & Closs (1996) stated three different postponement strategies- time postponement, place postponement and form postponement. A detail classification of postponement strategy is given in Table 1.

The concept of postponement germinates from the Just-in-Time (JIT) principle; as both focus on to have the right product in the right place at the right time (Cheng & Podolsky, 1996; Heskett, 1976). Postponement makes forecasting easier at a generic level than at the level of finished forms because demand

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Table 1. Classification of postponement strategy.

Sl.No.	Type	Definition	Application
1	Pull postponement	It is also known as process postponement (Brown et al., 2000),which refers to moving the decoupling point earlier in the supply chain such that fewer steps will be performed under forecast results (Lee, 1998).	1. ABC Bicycle Company, India. 2. Benetton, an apparel manufacturer, postpones its colour dyeing process until orders are received (Lee & Tang, 1998).
2	Logistics postponement	Logistics postponement involves the re-designing of some of the processes in the supply chain so that some customization can be performed downstream closer to customers (Lee, 1998). Packaging postponement and labelling postponement (Twede et al., 2000) or branding postponement (Ackerman, 1997) can be subsets of logistics postponement when the packaging, labelling or branding processes are moved closer to customers.	1. Hewlett-Packard produces generic printers at its factory and distributes them to the local distribution centres, where power plugs with appropriate voltage and user manuals in the right language are packed. Since generic printers are lighter, more units could be shipped. 2. All products in IKEA retail stores are kept in semi-finished forms (flat packs) and are assembled after home delivery by customers or deliverymen. In this way, truckload capacities can be utilized and configurations can easily be made at customer locations.
3	Form postponement	Form postponement, also called product postponement (Brown et al., 2000), gives fundamental change of the product structure by using standardized components and processes to achieve high customization (Lee, 1998; Brown et al., 2000).	1. Brown et al. (2000) applied the form postponement in a semiconductor company (Xilinx), where it re-designs the IC so that it could be re-configured by software easily and quickly for customized features and functions.
4	Price postponement	Van Mieghem & Dada (1999) defined price postponement from economic and marketing perspectives. They described the price postponement as a strategy aimed at deferring the pricing decision until customer demand is known. Selling price is negotiated with customers after they place their orders.	1. In July 2002, Bank of China (BOC) in Hong Kong applied a price postponement strategy for its initial public offering.
5	Time postponement	Customer order triggers the forward movement of goods.	1.Dell usually assembles computer after the orders are placed by customers
6	Place postponement	Keep the goods in the central location of the supply chain until the customer orders are arrived.	Hindustan Unilever Limited, India's largest consumer product company, addresses three major market segments: modern trade segment (organized retail sector), general trade segment and rural markets. The modern trade segments, consists of large urban market, are usually serviced by a HUL warehouse that supplies to the cluster of retail locations.

Source: Elaborated by the author.

variability is reduced by aggregation (Christopher, 2000; Ernst & Kamrad, 2000). Postponement strategy always tries to address various ways to reduce the complexity of supply chain with effective product family architecture (PFA). Its modular characteristic not only reduces the cost of assembly (Chiou et al., 2002) but also enables outsource capability and speeds up new product development (Brown et al., 2000; Ernst & Kamrad, 2000). The more outsourcing opportunities a company can pursue with the increase of the degree of modularity. However, extensive literature review has not found any journal article which integrates postponement strategy with the sustainable supplier selection process.

3. Methodology

The proposed method is suitable for the assembled product where product variety is achieved by adding auxiliary parts/components to the main product

or base product or core product as per demand of customer. To tackle uncertainty of demand a two-stage method is considered. The base product is assumed to be manufactured by deterministic demand and auxiliary parts/component is manufactured as per stochastic demand. Stage 1 is required to select suppliers for base product and stage 2 is required to select suppliers for auxiliary parts/components. In both stages analytic hierarchy process (AHP) is used with intuitionistic fuzzy set (IFS) to select and evaluate suppliers and multi-objective genetic algorithm (MOGA) is used to allocate order to selected suppliers for deterministic and/ stochastic demand. AHP is one of the most cited multi-criteria decision analysis (MCDA) tool (Mukherjee, 2014a) and the fuzzy version of integrated AHP is mostly used for supplier selection to deal with uncertainties of the supplier selection process (Mukherjee, 2014b). Intuitionistic Fuzzy Set (IFS) is a generalized fuzzy set and is more suitable in selecting suppliers as it includes the degree

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of hesitation to measure uncertainty associated with each decision. Further, Shannon's Entropy is included in the proposed method to measure the discord or conflict in selecting suppliers.

3.1. Intuitionistic fuzzy set (IFS)

In 1986, Atanassov proposed a generalized concept of fuzzy set popularly known as the intuitionistic fuzzy set (IFS). If X be a universe of discourse, then IFS A can be defined as A= $\{(x,\mu_A(x),v_A(x))|x \in X\}$ where $\mu_A(x)$, $v_A(x)$ denote membership and non-membership functions of A and satisfy $0 \le \mu_A(x)+v_A(x) \le 1 \;\; \forall x \in X$. For every IFS A in X, the degree of hesitation can be defined as $\varpi_A(x)=1- \mu_A(x)-v_A(x)$ which express whether x belongs to A or not. If A = $\{(x,\mu_A(x),v_A(x))|x \in X\}$ and B= $\{(x,\mu_B(x),v_B(x))|x \in X\}$ then the normalized hamming distance between A and B can be represented as

$$l(A,B) \;=\frac{1}{2n}\sum_{i=1}^{n}\begin{bmatrix}|\mu_A(x)-\mu_B(x)|+\\|v_A(x)-v_B(x)|+\\|\pi_A(x)-\pi_B(x)|\end{bmatrix}\frac{1}{2}$$

(Szmidt & Kacprzyk, 2000). To rank three IFS, their normalized hamming distance from the ideal solution M (1,0,0) should be calculated. Lowest distance from M will give better solution.

3.2. Shannon's entropy

Shannon's entropy is a classical measure of discord in probability theory. Let p= <p_x | $x \in X$> a probability defined on X. Then Shannon's entropy is defined as $S(p) \;= \; -\sum_{x \in X} p_x \log_2 p_x$

In AHP, priority p_i is the probability that i^{th} criterion is preferred by decision maker (Sanchez & Soyer, 1998).

3.3. IF-AHP algorithm

1. Prepare intuitionistic fuzzy pairwise comparison matrix for each criterion and alternative.

2. Calculate the score (S_i) of all intuitionsitic fuzzy number with any of the given formula.

$$S_I(X_{ij}) = \mu_{ij} - v_{ij} \text{ where } S_I(X_{ij}) \in [-1,1] \tag{1}$$

$$S_{II}(X_{ij}) = \mu_{ij} - v_{ij}.\varpi_{ij} \text{ Where } S_{II}(X_{ij}) \in [-1,1] \tag{2}$$

$$S_{III}(X_{ij}) = \mu_{ij} - (v_{ij}+\varpi_{ij})/2 \text{ Where } S_{III}(X_{ij}) \in [-0.5,1] \tag{3}$$

$$S_{IV}(X_{ij}) = (\mu_{ij}+v_{ij})/2 - \varpi_{ij} \text{ Where } S_{IV}(X_{ij}) \in [-1,0.5] \tag{4}$$

$$S_V(X_{ij}) = \gamma . \mu_{ij} -(1- \gamma). v_{ij} \text{ where } \gamma \in [0,1] \text{ and } S_V(X_{ij}) \in [-1,1] \tag{5}$$

$S_I(X_{ij})$ is useful for the simple decision making problem and $S_{II}(X_{ij})$, $S_{III}(X_{ij})$, $S_{IV}(X_{ij})$ are useful for the complex decision making problem (Chen, 2011).

3. Calculate the normalized score matrix with the given formula

$$\overline{s_{ij}} =\frac{s_{ij} - \min_{j}\{s_{ij}\}}{\max_{j}\{s_{ij}\} - \min_{j}\{s_{ij}\}} \tag{6}$$

4. Normalize each row of $\overline{S}$ with the given formula

$$\dot{\overline{s}} =\frac{\overline{s_{ij}}}{\sum_{j=1}^{n}\overline{s_{ij}}} \;\; \forall \; i =1,2,3....m \; and \; j=1,2,3...n \tag{7}$$

5. Calculate entropy w.r.t i^{th} attribute with the given formula

$$E_i \;= \; -\frac{1}{\ln n}\sum_{j=1}^{n} \dot{\overline{s_{ij}}} \ln \dot{\overline{s_{ij}}} \tag{8}$$

6. Calculate entropy weight w_i with the given formula

$$w_i =\frac{1-E_i}{\sum_{i=1}^{m}(1-E_i)} \tag{9}$$

7. Calculate normalized entropy weight to rank criteria or alternative with the given formula

$$\overline{w_i} =\frac{W_i}{\sum_{i=1}^{m}W_i} \tag{10}$$

4. Sourcing strategy for sustainable ATO: a mathematical approach

Due to price competition, many companies are manufacturing in low-cost countries and selecting such a location by considering manufacturing costs, corporate tax rate, export incentives, the presence of key suppliers or duty-free imports, infrastructure, the political situation and skilled labour. In ATO base product are expected to be manufactured at low-cost countries/locations and final configurations as well packaging are expected to be made at the distribution point near to the customer.

4.1. Stage-1: selection of supplier for the base product

In this proposed model, shown in Figure 1, we assumed that the base product is manufactured at the manufacturing site and stored at the centralized

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warehouse in generic form. Once order is arrived, base product is shipped with the bill of material (BOM), shown in Figure 2, to retailer's site where auxiliary part/module is prepared and assembled. In closed loop supply chain, shown in Figure 1, used products are collected from the collection site and sent to the disassemble site where products are disassembled completely or partly. After processing, disassembled parts/sub-assembly is sent to the manufacturer site where they are reused as new parts/sub-assembly. Disassembly cost varies with level of disassembly. Hence, up to a certain level product should be disassembled (Mukherjee et al., 2011).

In the proposed AHP model, shown in Figure 3, flexibility encompasses volume flexibility, routing flexibility, material handling flexibility, machine flexibility, operation flexibility, expansion flexibility,

process flexibility. Proposed AHP model encompasses three main criteria to select suppliers for the base product through the sustainable procurement process.

4.2. Deterministic order allocation model for the base product

The following assumptions are considered to prepare objective functions for supplier selection.

Assumptions

1. Multiple items are purchased from selected suppliers.

2. Quantity discounts are not taken into consideration.

3. No shortage of item is allowed for any supplier.

4. Demand of base product for the planned horizon is constant and known with certainty.
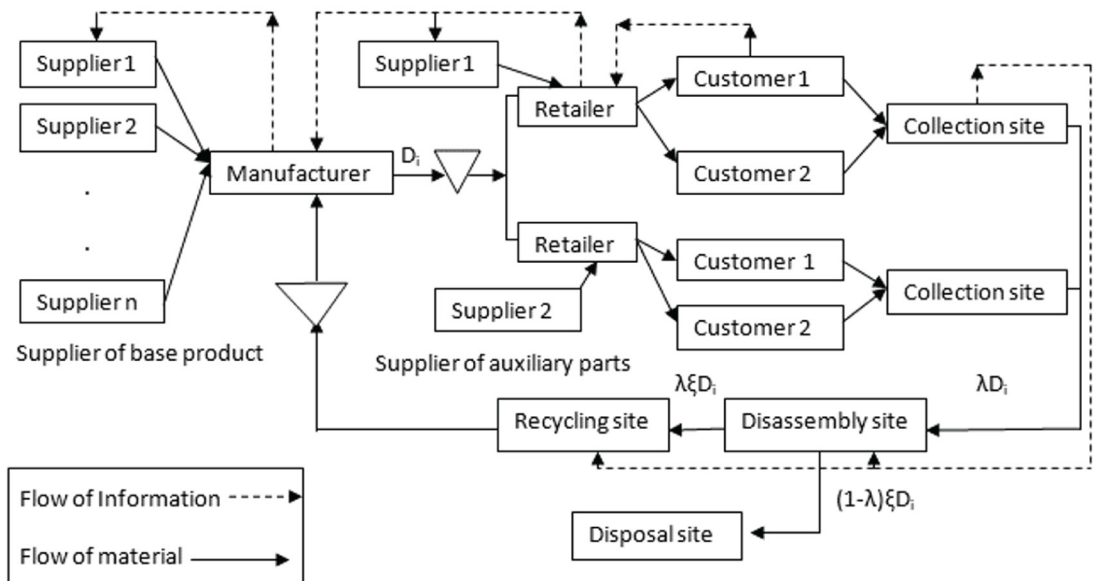

Figure 1. The proposed 2-stage supply chain model for sustainable ATO. Source: Elaborated by the author.
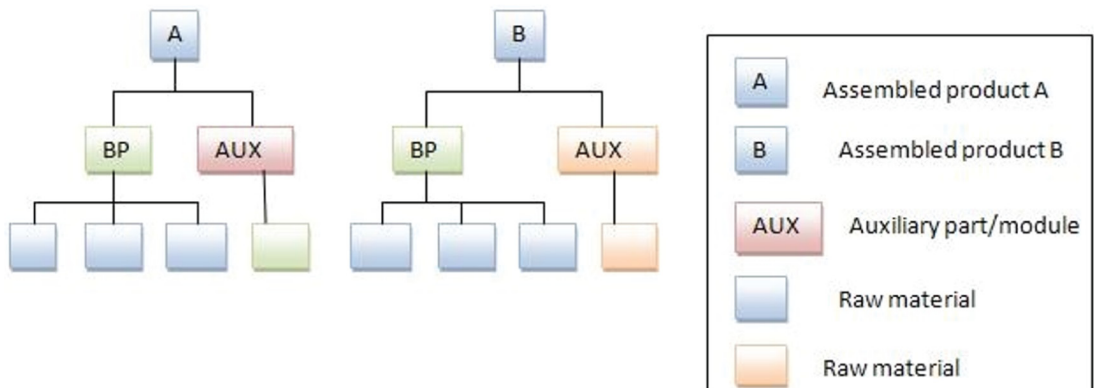

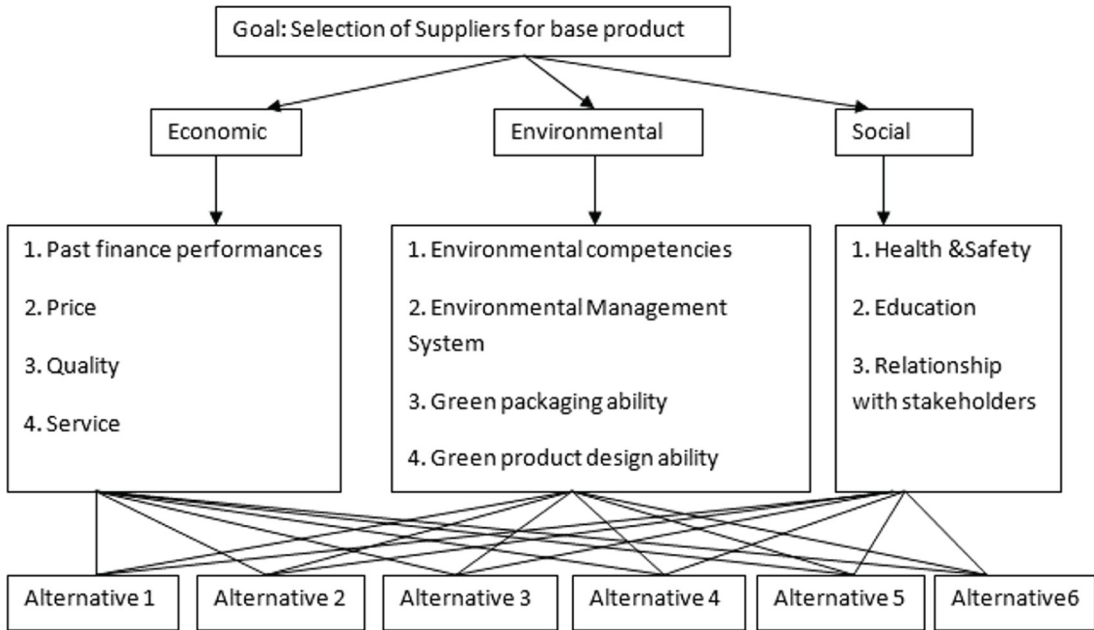Figure 2. The bill of material. Source: Elaborated by the author.

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Figure 3. The AHP model of supplier selection for the base product. Source: Elaborated by the author.

C_{ij} = the purchase cost of product j from i^{th} supplier.

TC_{ij} = the transportation cost of product j from i^{th} supplier.

CC_i = the overall performance index of ith supplier.

C_{Oij} = the ordering cost of jth product from i^{th} supplier.

α_i = the reliability of ith supplier.

X_{ij} = the order quantity of product j to i^{th} supplier.

LD_{ij} = the percentage late delivery of product j from i^{th} supplier.

V_{ij} = the capacity of ith supplier for j^{th} product.

D_j = the demand for j^{th} product

H_j = the handling cost per ton of product j.

B = Total allocated budget for all products.

λ_j = percentage of jth product disposed at disposal site

ξ_j = Level of disassembly of jth product at disassembly site

β_i = GHG emission factor per weight unit distance due to the use of transportation mode.

d_i = the distance of ith supplier from the manufacturing/ retailing site

alpha = probability value of chance constraint

i= 1,2,3......... n of suppliers

j=1,2,3....... m no of products

The total cost of purchase (TCP) consists of purchase, transportation, order/setup, and holding cost. Min TCP:

$$\sum_{i=1}^{n}\sum_{j=1}^{m}C_{ij}X_{ij} + \sum_{i=1}^{n}\sum_{j=1}^{m}TC_{ij}X_{ij} + \sum_{j=1}^{m}H_j\sum_{i=1}^{n}X_i + \sum_{i=1}^{n}\sum_{j=1}^{m}C_{Oij}X_{ij} \quad (11)$$

In the second objective function total value of reliable purchase (TVRP) is considered instead of total value of purchase (TVP) proposed by Ghodsypour & O'Brien (1998). The reliability of supply, α_i, of each supplier is obtained from supplier's reliability measurement data sheet, Table 2, to form TVRP equation.

Maximize TVRP: $\sum_{i=1}^{n}\sum_{j=1}^{m}\alpha_i CC_i X_{ij}$ (12)

Minimize number of late deliveries: $\sum_{i=1}^{n}\sum_{j=1}^{m}LD_{ij}X_{ij}$ (13)

Minimize GHG emission for inbound logistics:

$$\sum_{i=1}^{n}\beta_i d_i \sum_{j=1}^{m}X_{ij} \quad (14)$$

Subject to

Capacity constraint: $\sum_{j=1}^{m}\sum_{i=1}^{n}X_{ij} \leq \sum_{j=1}^{m}\sum_{i=1}^{n}V_{ij}$ for

i=1,2,3.........n and j=1,2,3....m (15)

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Demand constraint: $\sum_{j=1}^{m}\sum_{i=1}^{n}X_{ij} = \sum_{j=1}^{m}D_j - \sum_{j=1}^{m}(1-\lambda_j)\xi_j D_j$ (16)

Cost constraint: $\sum_{j=1}^{m}\sum_{i=1}^{n}C_{ij}X_{ij} \leq B$ (17)

Non-negativity constraint: $X_{ij} \geq 0$ for i=1,2,3........n and j=1,2,3...m.   (18)

4.3. Stage-II: supplier selection for auxiliary parts

Higher priority is given to flexibility and technical capability of suppliers to tackle high volatile demand at retailer's site. In this regard, an AHP model of supplier selection for auxiliary parts/sub-assembly is prepared, shown in Figure 4, to augment sustainable procurement process at retailer's site.

4.4. Mathematical model for stochastic demand

A multi-objective stochastic model is considered at retailers' site to deal with uncertainty in demand. It is assumed that suppliers are very close to the retailer's site. Therefore, transportation cost as well GHG emission through transportation is very negligible.

Min TCP: $\sum_{i=1}^{n}\sum_{j=1}^{m}C_{ij}X_{ij} + \sum_{j=1}^{m}H_j\sum_{i=1}^{n}X_i + \sum_{i=1}^{n}\sum_{j=1}^{m}C_{Oij}X_{ij}$ (19)

Maximize TVRP: $\sum_{i=1}^{n}\sum_{j=1}^{m}\alpha_i CC_i X_{ij}$ (20)

Minimize number of late deliveries: $\sum_{i=1}^{n}\sum_{j=1}^{m}LD_{ij}X_{ij}$ (21)

Subject to

Demand constraint: $\Pr\left[\sum_{i=1}^{n}x_{ij} \geq D_j\right] \geq alpha$ (22)

Table 2. Supplier data sheet.

Name	Cost (INR)		Ordering Cost (INR/tonne)		Capacity (Tonne)		% late delivery	Distance (Km)	Mode of Transport
	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B			
Supp. 1	100	150	2000	3000	1000	2000	0.2	190	1. By HGV 2. 100 Km by rail and 90 Km by HGV
Supp. 2	102	149	2000	3000	1000	1500	0.15	200	1. By Large container
Supp. 3	101	150	2000	3000	1000	1500	0.2	180	1. By HGV
Supp. 4	100	151	2000	3000	1000	1500	0.15	200	1.160 Km by rail and 40 Km by HGV. 2. By HGV
Supp. 5	103	152	2000	3000	1000	1500	0.1	240	1.200 Km by rail and 40 Km by HGV.
Supp. 6	102	150	2000	3000	1000	2000	0.2	240	1. By HGV 2.200 Km by rail and 40 Km by HGV.

Source: Elaborated by the author.
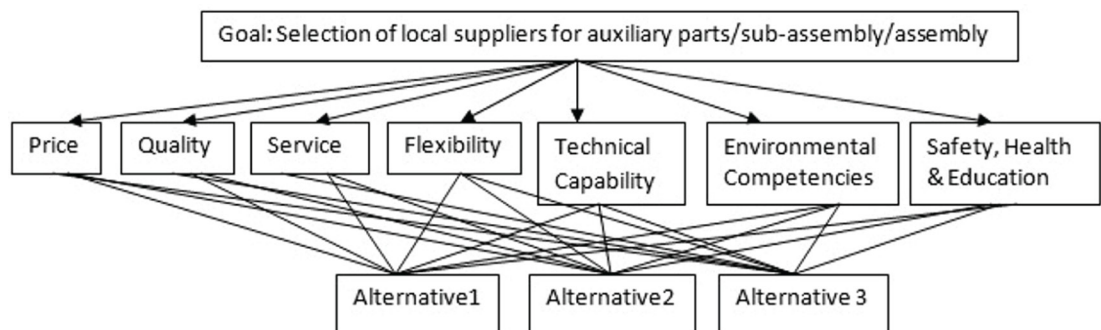

Figure 4. The AHP model of supplier selection for the auxiliary parts/sub-assembly. Source: Elaborated by the author.

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Above chance constrained can be converted to a deterministic constraint as follows (Guan et al., 2007)

$$\sum_{i=1}^{n}\sum_{j=1}^{m}X_{ij} \geq \mu_j + \Phi^{-1}(alpha)\sigma_j \qquad (23)$$

Where,

$$\Phi(X) = \frac{1}{\sqrt{2\pi}\sigma}\int_{-\infty}^{X}e^{-\frac{(X-\mu)^2}{2\sigma^2}}dX = alpha, \ \Phi^{-1}(alpha) \ = \ X \quad (24)$$

Capacity constraint: $\sum_{j=1}^{m}\sum_{i=1}^{n}X_{ij} \leq \sum_{j=1}^{m}\sum_{i=1}^{n}V_{ij}$ (25)

Cost constraint: $\sum_{j=1}^{m}\sum_{i=1}^{n}C_{ij}X_{ij} \leq B$ (26)

Non-negativity constraint: $X_{ij} \geq 0$ for i=1,2,3........n and j=1,2,3...m. (27)

5. Case study

An Indian Company is manufacturing/assembling product A and B as per the bill of material shown in Figure 2. The company is 40 km away from the railway station and well connected with other cities by road. Considering fluctuation of market demand of product A and B, company is seeking effective procurement strategy for their ATO production system. The company has assembling unit in Punjab and retailers in different parts of India. Base product is manufactured as per the forecast and stored at the central warehouse shown in Figure 1. After receiving the customer order, the base product is brought to retailer shops in 15 to 20 days. Auxiliary parts/components/sub-assemblies are manufactured or assembled at the retailer site. It is assumed that material handling

cost is 10% of procurement cost from each supplier. The aggregate demand for raw material to produce base product in the planning horizon is 4,900 tones. Senior members of different departments such as Finance, Marketing, Design and Manufacturing are asked to form a team of decision makers to select the right supplier for the company. Initially, a supply base is formed based on their industrial certifications such as ISO, TUV etc, material test data and ability to supply within the lead time. Based on the above information supplier's data sheet, is prepared, and shown in Table 2. Distance and mode of transfer mentioned in Table 2 is used further to calculate cost of emission for inbound transport.

Linguistic terms, shown in Table 3, are used to prepare supplier's reliability measurement data sheet, shown in Table 4. Arithmetic mean of each IFN, shown in Table 4, is used to calculate reliability of each supplier, shown in Figure 5.

The normal hamming distance of each supplier is measured from ideal IFN (1.0;0.0;0.0). Complement of the normal hamming distance is considered as the overall reliability of each supplier. Cost-Emission-Decision Matrix is prepared with Table 5 and Table 6, shown in Table 7. Cost coefficient and emission coefficient from Cost-Emission-Decision Matrix is used to prepare transportation cost and GHG emission objective function, mentioned in Equation 11 and Equation 14, respectively. Local supplier performance matrix is prepared further with Table 3 and Table 8, shown in Table 9. Supplier's data sheet for auxiliary product and demand of products at retailer's site, shown in Table 10 and Table 11, are prepared to select and to distribute order to the selected suppliers at retailer's site as per stochastic demand.

Table 3. Linguistic terms.

Linguistics terms	IFNs	Linguistics terms	IFNs	Linguistics terms	IFNs
Excellent	[1.00;0.00;0.00]	Good	[0.7;0.2;0.1]	Bad	[0.4;0.5;0.1]
Very good	[0.85;0.05;0.1]	Moderate	[0.5;0.5;0.00]	Very bad	[0.25;0.6;0.15]
				Extremely bad	[0.0;0.9;0.1]

Source: Elaborated by the author.

Table 4. Supplier's Reliability measurement data sheet.

Name	Technical Qualification of workers	Supplier's Quality System	Past supply of similar raw material
Supplier1	Good	Good	Good
Supplier2	Moderate	Good	Good
Supplier3	Bad	Moderate	Bad
Supplier4	Moderate	Good	Good
Supplier5	Excellent	Excellent	Excellent
Supplier6	Good	Excellent	Very good

Source: Elaborated by the author.

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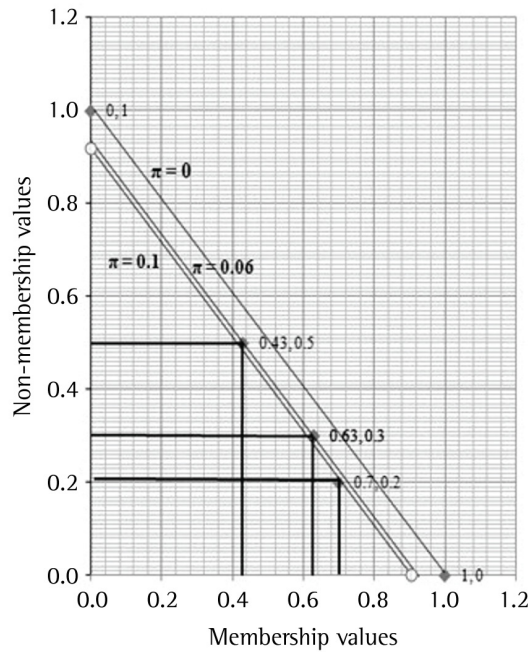
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Figure 5. IFN values for supplier's reliability factors. Source: Elaborated by the author.

Table 5. Freight transmission emission factor (Department of Energy and Climate Change, 2009).

Mode	Road LGV	HGV	Rail	Small tanker	Large container
g/tonne-km	400.1	118.6	28.3	20	13

Source: Elaborated by the author.

Table 6. Inbound logistics cost (Freight Operations Information System, 2012).

Mode	Transportation Charges (INR/tone-Km)	Mode	Distance (Km)		Approx. Transportation Charges (INR/tonne-Km)
			From	To	
By road	200	By rail Train load LR4 Wagon load 120	1	100	120
			101	125	142
			126	150	165
			151	175	185
			176	200	207

Source: Elaborated by the author.

Table 7. Cost-Emission-Decision Matrix per unit tonne of transport.

Name	Mode of transport	Cost (INR)	Emission (g)	Decision
Supplier 1	Option1: By HGV	38000	22534	Option 2 is preferred for low cost and low emission.
	Option 2: 100 Km by rail and 90 Km by HGV	30000	13504	
Supplier 2	Option 1: By Large container	40000	2600	Option 1 is selected.
	Option 2: None	---------	---------	
Supplier 3	Option 1: By HGV	36000	21348	Option 1 is selected.
	Option 2: None	----------	---------	
Supplier 4	Option 1: 160 Km by rail and 40 Km by HGV.	37600	9272	Option 1 is preferred for low cost and low emission
	Option 2: By HGV	40000	23720	
Supplier 5	Option 1: 200 Km by rail and 40 Km by HGV.	49400	10404	Option 1 is selected.
	Option2: None	-------	---------	
Supplier 6	Option 1:By HGV	48000	23720	Option 2 gives 1.03 times higher cost and 2.28 times lower emission than option 1. Assuming equal priority to cost and emission. Hence, option 2 is preferred.
	Option 2: 200 Km by rail and 40 Km by HGV.	49400	10400	

Source: Elaborated by the author.

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Table 8. Linguistic terms.

Linguistic Terms	IFNs
Very Costly	[1.00;0.00;0.00]
Costly	[0.75;0.15;0.1]
Cheap	[0.6;0.3;0.1]
Very Cheap	[0.5;0.3;0.2]

Source: Elaborated by the author.

Table 9. Local Supplier Performance Matrix.

Name	Price	Quality	Service	Flexibility	Technical Capability
Supplier 1	Very Costly	Very good	Good	Very Good	Excellent
Supplier 2	Cheap	Good	Moderate	Good	Moderate
Supplier 3	Cheap	Good	Moderate	Moderate	Moderate

Source: Elaborated by the author.

Table 10. Supplier's data sheet for auxiliary product.

Name	Cost (INR)		Ordering Cost (INR/piece)		Capacity (piece)		% late delivery	Reliability	IFS priority value
	Prod A	Prod B	Prod A	Prod B	Prod A	Prod B			
Supplier 1	200	350	200	300	1000	2000	0.2	0.65	0.091825
Supplier 2	202	349	200	300	1000	1500	0.15	0.68	0.232825
Supplier 3	201	350	200	300	1000	1500	0.2	0.69	0.6751

Source: Elaborated by the author.

Table 11. Demand of products at retailer's site.

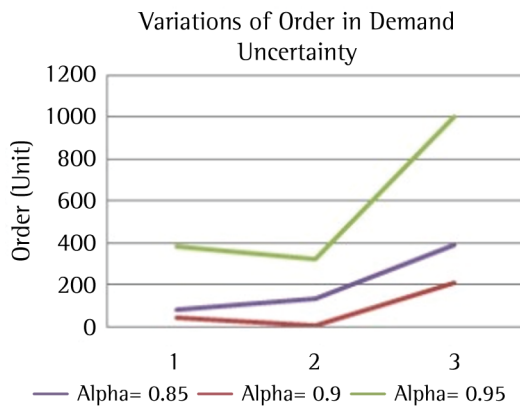| Product Type	μ_j (unit)	σ_j (unit)	α	$\Phi^{-1}(\alpha)$
Product A	2500	1000	0.85	1.0364
Product B	2400	1200	0.85	1.034

Source: Elaborated by the author.

Figure 6. Order allocation at different value of alpha. Source: Elaborated by the author.

6. Results

Intel core i5 PC with 3 GB RAM is used to solve the model. Microsoft Excel is used for IF-AHP and Matlab R 2009a is used for MOGA. Uncertainty in demand at retailer's site changes the amount of order in considerable amount for supplier 3, shown in Figure 6. For different values of alpha, highest order is allocated to supplier 3 as supplier 3 has highest reliability and IFS priority value.

7. Conclusion

In this paper, a new concept and an innovative method is proposed to initiate sustainable procurement process (SPP) by integrating the concept of sustainable supply chain and postponement strategy. The proposed method has several advantages, including but not limited to:

(1) The proposed model is very simple and easy to apply.

(2) It can be used for single item as well as multiple item of the assembly-to-order production system for stochastic and/ deterministic demand.

(3) It considers reliability of supply to reduce inbound risk.

(4) The proposed model also gives better supply chain visibility as it integrates far downstream customers with manufacturer through active co-operation of retailers. However, manufacturer should take appropriate strategy to share limited information with its retailers to maintain better security.

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In addition to the above this innovative method can reduce logistic lead time, chances of over stock or under stock and the complexity of inventory. This proposed method is suitable for manufacturing industries which particularly assembled different components to develop complex products.

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