

Analysis of Sustainable Procurement in SMEs in Developing Countries

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Abstract- The purpose of the paper is to integrate supply base consolidation, rationalization, and buyer's perspective about its suppliers to reveal more insight to implement sustainable procurement in small and medium enterprises (SMEs) in developing countries like India. In this paper an attempt has been made to integrate Constrained Optimization of Frobenius Norm by Genetic Algorithm (COFGA) with traditional spend, and value risk analysis to consolidate and rationalize supply base w.r.t fifteen triple bottom line indicators (TBL). This paper shows that spend analysis is justified in crisp domain and becomes myopic in limited data environment. Spend analysis becomes more ineffective to deal imprecise and vague qualitative data. Integrated approach of multiple criteria decision analysis, spend analysis, and value risk analysis, thus, an alternative approach to give better insight to sustainable procurement in fuzzy environment. Finally, a case study is discussed to use proposed method.

Keywords- Sustainable supplier selection; small and medium enterprises (SMEs); genetic algorithm(GA); spend analysis; triple bottom line (TBL); multiple criteria decision analysis; value risk analysis

1. Introduction

Sustainable procurement (SP) aligns objective of the procurement with the principles of sustainable development to generate additional revenues from low-cost eco-friendly products (Walker and Brammer, 2009; Nidumoluet al., 2009). Companies can have strategically competitive position with judicious selection of suppliers as performance of suppliers can enhance buyer performance (Shin et al., 2000; Tracey & Tan, 2001; Chen et al., 2006). Corporate legitimacy and reputations can also be enhanced by integrating environmental aspects with the existing supplier selection process and because of that several authors are continuously addressing such supplier selection issues (Noci, 1997; Van Hoek, 1999; Handfield et al., 2002; Humphreys et al., 2003; Lee et al., 2009). Sustainable development and sustainability is usually considered as an integrated approach of economic, environmental and social development, a triple-bottom-line approach (Gauthier, 2005). However, most of the executives of companies in UK and US still feel that sustainability comes at the cost of the business objective. SP is highly influenced by education, religious belief, cast, creed, gender equality, poverty, prolong work hours, child labor, feminist labor, relationship of supplier-buyer dyad, product, and geographic location. Brundtland Commission Report, the originator of the concept of sustainability, clearly highlights that companies in developing countries bring economic fortune at the cost of environment (Hutchins and Sutherland, 2008). Moreover, the social dimension of the sustainability is still at infancy and mainly concerned with legislative issues or human health and safety (Hutchins and Sutherland, 2008). To date very limited researchers have been identified the aspects of sustainable procurement process for small medium enterprises (SMEs) in developing countries. This paper addresses such issues in light of SMEs of India. By addressing this void, the significance of this study is clearly justified.

1.1 Research questions

Based on the identified literature gaps, the following research questions underpin the study:

1. What is the existing nature of sustainable procurement (SP) practices for SMEs in developing countries?
2. What limitations SMEs usually face to implement sustainable procurement practices in developing countries?
3. Which market-winning criteria should be used to select and evaluate suppliers for SMEs of India to augment sustainable procurement practices?
4. How to rationalize and consolidate supply base with the integrated approach of spend analysis, multiple criteria decision analysis, and value risk analysis?

2. Literature Review

2.1 Drivers and barriers of sustainable procurement (SP) practices for SMEs

Environment, diversity, philanthropy, human rights, and safety are the five common aspects of sustainable procurement practices (Carter and Jennings, 2004). Seven factors usually decide the fate of sustainable procurement practices are 'Leadership', 'Policy and Programs', 'Organizational Strategy', 'Organizational Culture', 'Capacity Building', 'Supply-side' and 'Finance' (McMurray et al., 2013). Attitudes of owners, degree of religious belief or religiosity, entrepreneurial orientations, geographic and psychic distance do influence the success of procurement practices (Arthur-Aidoo et al., 2016; Said et al., 2014; Mohd et al., 2014; Ojala, 2015). External stimuli, namely, Government, customer and stakeholder triggers pressure on focal company and focal company passes pressure on to suppliers to augment sustainability (Seuring and Müller, 2008). A healthy relation between Government, customer, and stakeholder are highly appreciated to implement sustainable procurement process. Such healthy relation is almost missing in developing country like India. Inertia of customer and

stakeholder, lack of co-ordination between Government and customer, limited buying power and lack of awareness of the customer, and extreme religious belief are some of the predominant factors to oppose sustainable procurement process in developing countries like India. Different sustainability indicators are proposed by researchers (Tsuda and Takaoka, 2006; Labuschagne and Brent, 2006; Labuschagne et al., 2005; UNSD,2001) but the selection of such indicators is still an open issue. A differential input-output model has been proposed to study the effect of changes in economic activity on social indicators (Hutchins and Sutherland, 2006; Norris, 2006). Financial constraints, on the other hand, received high priority as one of the barriers to limit the use of sustainable procurement practices in the developed countries (Preuss, 2007; Walker and Brammer, 2009). Researcher shows that green or sustainable practices is still feasible for Small and Medium Enterprises (SME) (Tomomi, 2010; Moore and Manring, 2009; Lee and Klassen, 2008; Lee, 2008) but cost of greening, effective buyer-supplier dyadic relationship, lack of collaboration and trust to bring innovation, lack of JIT capabilities and willingness to take risk for new ventures are some of the barriers to adopt SP.

2.2 SMEs in India

United Nations Industrial Development Organization (UNIDO) made significant achievements in promoting CSR for SMEs in global supply chain context through responsible entrepreneurs achievement program (REAP) to enhance productivity with better work environment, less absenteeism of workers, less rate of accidents, less consumption of energy resources and less amount of waste. UNIDO report confirms that SMEs usually prefers to use CSR approaches without publicizing their CSR engagement. Such “Silent CSR” approach is the outcome of the philanthropic attitude of so many SMEs. UNIDO signed strategic partnership with METRO Group, one of the world largest retailers, to build capacity of suppliers of SMEs in the targeted market of METRO Group in developing countries to start the era of “supermarketization”. India, Russia, Egypt etc are some of countries which received due consideration from UNIDO for capacity building of SMEs to integrate them into a profitable and sustainable supply chain. Since 1975, a steady increase in number of small scale industries (SSI) units, later known as SMEs, has been observed with marked jump during post-liberalization period due to effective implementation of new economic policy in 1991 by Government of India. Today India has around 30 millions of micro, small and medium enterprises (MSME) units which creating employment of about 70 million people and contributing about 45 percent of manufacturing output and about 40 percent of export, directly and indirectly. They have been facing severe problem in implementing sustainable procurement process due to lack of awareness, financial restrictions, lack of availability of standard data and presence of strict norms for culture of socializations because of the differences between casts, creed and religion. Govt. of India has been mandated all Scheduled Commercial Bank (SCBs) not to accept collateral security to issue loan up to Rs. 10 lakh for SMEs and launched ‘Udyamimitra’ portal as universal loan portal to improve accessibility of credit up to Rs. 2 crore exclusively for SMEs. Digital Movement of India further helps SMEs to blend ecommerce and mcommerce to make a 25.8 billion USD market by 2020. However, majority of the SMEs in India have not shown exemplary growth yet due to direct effect of Goods and Services Tax (GST), draconian demonetization etc.

3. Research Methodology

Both the deductive approach and inductive method is used to select and analyze research papers from peer –reviewed scientific journals in English to identify concept, trend, opportunities, issues, limitations and challenges of the existing research to propose a mathematical model for sustainable procurement process (SP) in fuzzy environment to find answers of the above stated questions.

3.1 Data Collection

Both primary and secondary sources, namely, telephonic interviews, emails, site visit etc should be collected data in structured, semi-structured, and unstructured format. Structured questionnaire are designed based on literature review of previous research and discussions with industrial practitioners. Fuzzy linguistic variables were used to compare suppliers w.r.t 15 triple bottom line (TBL) indicators.

3.2 Data Cleansing

Proper data cleansing enhance quality of data analysis. It is the art of data analysis. Presence of abnormal data, missing data etc produces erroneous result. Outlier detection, data imputation, plot of heat map etc were used with open source ‘R’ programming language to prepare data for further calculation.

3.3 Product Segmentation

Kraljic matrix (1983) usually considered as starting point for procurement analysis. However, its limitation is an open issue. Today different companies are developing their own 2D metrics to position their product, process, and sourcing. Value risk matrix is one of them. It creates four quadrants – leveraged, strategic, focused and routine, shown in fig 1. Each quadrant represents specific type of product.

3.4 Stage I : Spend Analysis – Supply Base Consolidation

Japanese words *seiri*(sort), *seiton* (set in order), *seiso* (shine), *seiketsu* (standardize) and *shitsuke*(sustain),popularly known as 5S's, are the corner stone of lean concept (Bullington, 2003). Supply base rationalization is the process of elicitation of lean concept. Often supply base consolidation or rationalization is used as misnomer. In practice they are different. Supply base reduction is popularly known as supply base consolidation. Supply base rationalization, on the other hand, is the reduction of supply base with right suppliers. It is the replacement of good suppliers with better suppliers. Usually spend analysis, 20/80 rule, improve/else method, Triage method etc are used to rationalize supply base (Muthoni, 2014). Such approaches are limited crisp domain. Multiple criteria decision analysis, on the other hand, is one of the most cited approaches to tackle qualitative criteria. Even their fuzzification is quite easy. Initially tail spend and cumulative spend analysis are used to remove suppliers if their cumulative contribution is less than twenty percent.

3.5 Stage II : Supplier Segmentation – Supply Base Consolidation

Value risk matrix basically segments supply base. Leveraged or high value –low risk supply segment is most suitable for SMEs. Annexure –I shows twenty questions that were used to evaluate supply risk and value of each supplier from buyer’s perspective. Decision Makers (DMs) i.e. senior members of the focal company were asked to rate each supplier in 0-5 scale. 5 refers high risk or high value. A good supplier should contribute low risk and high value to the organization. If a supplier’s total risk score is 50 out of 85 and total value score is 8 out of 15 then total risk score out of 100 would be 58.82 and total value score would be 53.33. Refer table 1. Graphical presentations of value risk matrix, shown in fig 1.

Table 1 Value risk matrix

DM#1	Sourcing Risk	Risk to organization’s mission and goal	Risky past performance	Contract risk	Legal risk	Environmental and social risk	Value	Total risk score out of 85	Scale the risk score to 100	Total value score out of 15	Scale the risk score to 100
Supplier name	Score out of 25	Score out of 5	Score out of 15	Score out of 25	Score out of 5	Score out of 10	Score out of 15				



Fig 1 Value Risk Analysis

3.6 Stage III : TBL Indicator Selection

To determine the sustainable supplier selection indicators or triple bottom line (TBL) indicators for SMEs, 10 journal articles have been identified to combine work of all researchers as shown in table 2. Majority of the researchers propose different names for similar or almost similar indicators because of absence of effective taxonomy.

Table 2 TBL indicators for supplier selection

Criteria sub-criteria	Chiuo et al. (2008)	Yang and Wu(2008)	Lee et al.(2008)	Amindoust et al. (2012)	Govindan et al. (2012)	Mani et al. (2014)	Jauhar et al.(2014)	Sarkis and Dhavale	Mukherjee (2016)	Singh et al.(2016)
Economic										
Cost	✓	✓	✓	✓	✓		✓	✓	✓	✓
Quality	✓	✓	✓	✓	✓		✓	✓	✓	✓
Delivery	✓			✓	✓		✓	✓		
Service	✓	✓	✓	✓			✓		✓	
Technology capability		✓	✓	✓	✓					
Flexibility				✓						✓
Responsiveness										✓
Production facilities and capabilities				✓						
Financial position						✓			✓	
Environmental										
Green design	✓			✓	✓					
Eco-labeling	✓									
Environmental management system	✓	✓	✓	✓	✓				✓	✓
Environmental competencies	✓			✓					✓	✓
Green image	✓		✓							
Pollution control			✓	✓	✓	✓	✓	✓		✓
Green product				✓					✓	✓
Green packaging									✓	✓
Resource consumption					✓					✓
Supplier's energy efficiency										
Penalties related to environmental violations								✓		
Social										
The interests and rights of employee				✓						✓
Education									✓	✓
The rights of stake holders				✓	✓				✓	✓
Work safety and labor health				✓	✓	✓			✓	✓
Respect for the policy				✓	✓				✓	✓
Right to information				✓	✓				✓	✓
Local communities influence				✓	✓				✓	✓
Employment practices				✓	✓				✓	✓
Underage labor				✓	✓				✓	✓
Long working hours				✓	✓				✓	✓
Feminist labor issues				✓	✓				✓	✓
Human rights issues				✓	✓				✓	✓
Philanthropic contributions						✓			✓	✓
Employee turnover rate								✓		

3.7 Stage III: Constrained Optimization of Frobenius Norm by Genetic Algorithm (COFGA) – Supply Base Consolidation and Rationalization

COFGA is a non-linear constrained optimization to find priority in fuzzy environment. Commercial solver such as IBM ILOG Cplex, Gurobi etc can also be used instead of genetic algorithm (GA). COFGA calculates range instead of point value. It means decision maker can expect to have upper and lower limit of priority instead of single priority. It helps to tackle biasness in decision. COFGA generates upper and limit of consistency for each pair wise comparison w.r.t a predetermined fuzzy alpha-cut value. By adjusting fuzzy alpha-cut value, thus, range of priority/consistency could be reduced or increased to tackle uncertainty.

3.7.1 Constrained Optimization of Frobenius Norm by Genetic Algorithm (COFGA) : A new FHAP

Following steps of COFGA that can be used to derive priorities of alternatives in fuzzy environment are described.

Step1: Determine set of criteria and prepare the hierarchical structure of the problem with goal, criteria and alternatives. In this step, a set of criteria $\{c_1, c_2, \dots, c_n\}$ and a set of alternatives $\{A_1, A_2, \dots, A_n\}$ are identified. A goal is also set by decision makers to prepare hierarchical structure of the problem like classical analytic hierarchy process (AHP).

Step2: Determine fuzzy linguistic numbers and convert each fuzzy pairwise comparison matrix to series of interval numbers by fuzzy-alpha cut method.

In this step, fuzzy linguistic members are determined initially to prepare fuzzy pairwise comparison matrices. To overcome the limitations of reciprocal axiom for FAHP, only $n(n-1)/2$ terms are compared with fuzzy numbers to form an incomplete fuzzy judgment matrix, \tilde{A} .

$$\tilde{A} = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ - & \tilde{a}_{21} & \dots & \tilde{a}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ - & - & - & \tilde{a}_{nn} \end{bmatrix} \dots \dots \dots (1)$$

Where ‘-’ refers missing element in fuzzy judgment and $\tilde{a}_{ij} = (r_1, \dots, r_m) \forall i = 1, 2, \dots, m$ and $j = 1, 2, \dots, m$ with $m=3$ for triangular fuzzy number and $m=4$ for trapezoidal fuzzy number.

$$A = (a_{ij})_{n \times n} = \begin{bmatrix} 1 & [l_{12}, u_{12}] & \dots & [l_{1n}, u_{1n}] \\ - & 1 & \dots & [l_{2n}, u_{2n}] \\ \vdots & \vdots & \vdots & \vdots \\ - & - & \dots & 1 \end{bmatrix} \dots \dots \dots (2)$$

Where $l_{ij} = a_{ij} + (b_{ij} - a_{ij})\alpha$ and $u_{ij} = c_{ij} - (c_{ij} - b_{ij})\alpha \forall i, j \dots \dots \dots (3)$
 At $\alpha = 1$ fuzzy number becomes a crisp value.

Step 3: Split above interval comparison matrix into two incomplete nonnegative crisp matrices as $A = [A_L, A_U]$, where

$$A_L = \begin{bmatrix} 1 & l_{12} & \dots & l_{1n} \\ L_{21} & 1 & \dots & l_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ L_{n1} & L_{n2} & \dots & 1 \end{bmatrix} \quad \text{and} \quad A_U = \begin{bmatrix} 1 & u_{12} & \dots & u_{1n} \\ M_{21} & 1 & \dots & u_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ M_{n1} & M_{n2} & \dots & 1 \end{bmatrix} \dots \dots \dots (4)$$

Where L_{ij} and M_{ij} are the missing values for lower limit matrix A_L and A_U

Step 4: Determine the principal eigenvalue of upper and lower matrix through optimization.

Let $\lambda = [\lambda_l, \lambda_u]$ be the principal eigenvalue of A , which is an interval number. Both A_L and A_U can be represented in the given form

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ L_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ L_{n1} & L_{n2} & \dots & 1 \end{bmatrix} \dots \dots \dots (5)$$

Where $L_{ij} > 0 \forall i = 1, 2, \dots, n$ and $j = 1, 2, \dots, n$

Purpose of this step is to find a positive matrix Y in the form

$$Y = \begin{bmatrix} 1 & w_1/w_2 & \dots & w_1/w_n \\ w_2/w_1 & 1 & \dots & w_2/w_n \\ \vdots & \vdots & \vdots & \vdots \\ w_n/w_1 & w_n/w_2 & \dots & 1 \end{bmatrix} \dots \dots \dots (6)$$

which minimizes the Frobenius norm

$$\|A - Y\|_F^2 = (a_{12} - w_1/w_2)^2 + (a_{13} - w_1/w_3)^2 + (L_{21} - w_2/w_1)^2 + (a_{23} - w_2/w_3)^2 + (L_{31} - w_3/w_1)^2 + (L_{32} - w_3/w_2)^2 + \dots \dots + (L_{n(n-1)} - w_n/w_{n-1})^2 \dots \dots \dots (7)$$

Subject to

$$\sum_{i=1}^n w_i = 1 \dots \dots \dots (8)$$

$$w_1, w_2, w_3, \dots, w_n > 0 \dots \dots \dots (9)$$

$$L_{ij} > 0 \text{ and } M_{ij} > 0 \dots \dots \dots (10)$$

Above constrained non-linear optimization problem is solved in this paper with genetic algorithm. However, an extra constraint is highly justified to check consistency of priority.

Step 5: Determine aggregate interval of priority of M -number of decision makers.

In group decision making more than one decision makers participate and to bring consensus aggregation of priorities are required. If $W_{ijLK} = (w_{1jLK}, w_{2jLK}, \dots, w_{njLK})^T$ and $W_{ijUK} = (w_{1jUK}, w_{2jUK}, \dots, w_{njUK})^T$ are the set of priorities given by K number of decision makers for i th criteria and j th alternatives then aggregate priorities can be calculated as follows:

$$W_{ijL} = \min \{w_{ijLK} \mid K \in M\} \dots \dots \dots (11)$$

$$W_{ijU} = \max \{w_{ijUK} \mid K \in M\} \dots \dots \dots (12)$$

Step 6: Determine weighted priority or global weight of each alternative with respect to each criterion as follows:

$$W_i = \sum_{j=1}^m P_j W_{ij} \forall i = 1, 2, 3, \dots, m \text{ and } j = 1, 2, 3, \dots, n \dots \dots \dots (13)$$

Where

$P_i = [P_{iL}, P_{iU}]$ is the priority interval of each criteria.

$W_{ij} = [W_{ijL}, W_{ijU}]$ is the priority of j^{th} alternative w.r.t i^{th} criteria.

3.7.2 Modified concept of consistency ratio

In this section, a new consistency ratio is proposed for COFGA. Saaty, the originator of classical AHP, proposed consistency ratio (C.R) which is the ratio of consistency index (C.I) and random index (RI) and defined as follows:

$$C.I = \frac{\lambda_{max} - n}{n - 1} \text{ and } C.R = \frac{C.I}{R.I} < 0.1 \dots\dots\dots(14)$$

C.R, proposed by Saaty, can be simplified as follows:

$$C.R = \frac{\lambda_{max} - n}{RI(n-1)} < 0.1 \Rightarrow \lambda_{max} \leq 0.1.RI(n-1) + n \dots\dots\dots(15)$$

In this regard, limit of principle eigenvalue is calculated for different values of random index, shown in table 3.

Table 3 Limit of principal eigenvalue

Size, n	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Random Index	0	0	0.52	0.89	1.12	1.3	1.41	1.46	1.49	1.52	1.54	1.6	1.58	
Principal eigenvalue is less than equal to	1	2	3.104	4.267	5.44	6.63	7.8	8.98	10.1	11.34	12.5	13.69	14.9	16.0

To have better reliability of result, Eq.15 is used as an extra constraint to modify non-linear optimization problem stated in step 4 as follows:

$$\|A - Y\|_F^2 = (a_{12} - w_1/w_2)^2 + (a_{13} - w_1/w_3)^2 + (L_{21} - w_2/w_1)^2 + (a_{23} - w_2/w_3)^2 + (L_{31} - w_3/w_1)^2 + (L_{32} - w_3/w_2)^2 + \dots\dots + (L_{n(n-1)} - w_n/w_{n-1})^2 \dots\dots\dots(16)$$

Subject to

$$\sum_{i=1}^n w_i = 1 \dots\dots\dots(17)$$

$$w_1, w_2, w_3, \dots, w_n > 0 \dots\dots\dots(18)$$

$$L_{ij} > 0 \text{ and } M_{ij} > 0 \dots\dots\dots(19)$$

$$\lambda_{max} \leq 0.1.RI(n-1) + n \dots\dots\dots(20)$$

Where, λ_{max} is the principle eigenvalue of A of order n. For a 3x3 matrix, $\lambda_{max} = 1 + X + X^{-1}$ where $X = \left(\frac{a_{12}c_{23}}{a_{13}}\right)^{\frac{1}{3}}$ (Saaty, 2004). For higher order (>3), Leverrier's Algorithm is used to form characteristics equation which is used as an extra constraint along with Eq.20 as every principle eigenvalue of a matrix also satisfies its characteristic equation. The proposed approach is implemented with MATLAB R2009a, and open source R programming language. Reader can refer MATLAB GA Toolbox manual for genetic algorithm. In this sec., a three stage supply base consolidation and rationalization approaches is discussed, shown in fig 2.



Fig 2 Proposed approach

Aim of supply base rationalization is to determine optimum number of suppliers the buyer wants to deal with to optimize overall system efficiency and total cost and it begins with elimination of marginal and small-purchase volume suppliers (Monczka et al., 2009; Cousins ,1999). Supply consolidation was also substantiated by the sourcing triangle of Capgemini. Proposed approach, thus, well justified.

3 Case study

A SME in India is willing to implement sustainable procurement process but fails to understand expected return on investment. Company has 25 suppliers and wants to identify its key suppliers for one of its products. Suppliers of the company is using labor intensive manufacturing process with traditional lathe, milling, drilling and shaping machines and also using fossil fuel for their furnaces. Suppliers of the company prefer to employ contractual labors and have tradition to continue its daily work beyond 8 hrs with minimum wages. It has been confirmed that some of the suppliers are also employing women and underage as labors. Primary and secondary sources are used to collect data in semi-structure and unstructured format.

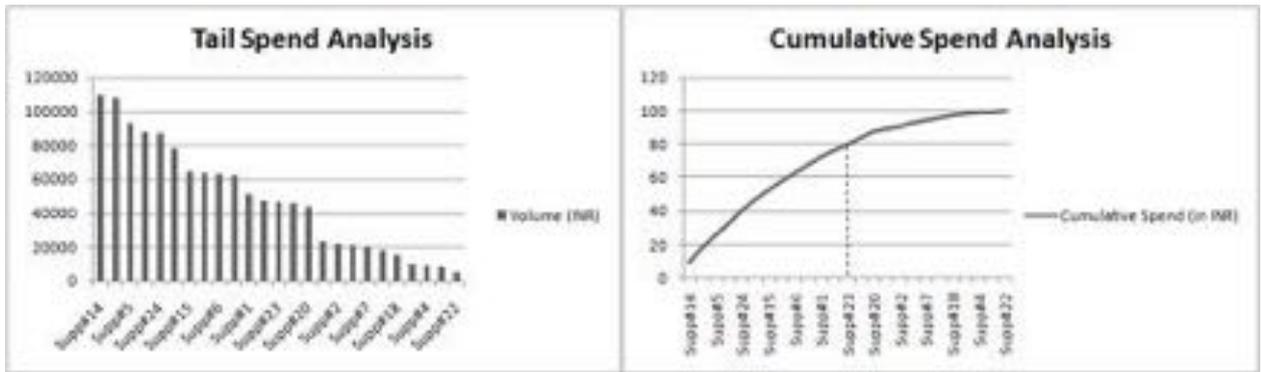


Fig.3 Tail spend analysis and cumulative spend analysis

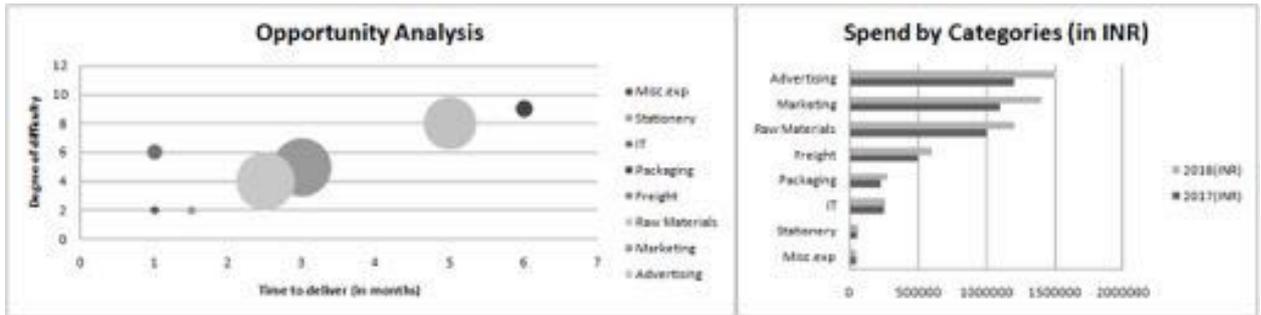


Fig.4 Opportunity analysis

Tail spend analysis, shown in fig.3, confirms pruning of supplier 21,2,9,7,8,18,11,4,25,and 22 as their cumulative contribution is less than twenty percent. Advertising, marketing, and raw material are the top three spend category. Series of interactions reveal that company can reduce significant spend by re-letting and negotiating the contract, shown in fig 4. Such addressable spend are the hidden treasure of procurement analytics. In stage I, spend analysis removed ten suppliers. In stage II, remaining 15 suppliers are filtered through value risk matrix, 6 out of 15 suppliers are removed, shown in fig 5. Suppliers belong to high value and high risk are not considered because company policy.

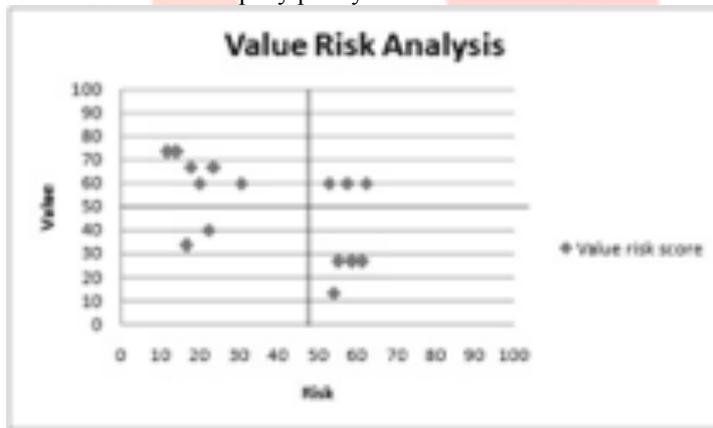


Fig.5 Value risk analysis

In stage III, remaining 9 suppliers are further evaluated by COFGA w.r.t the TBL indicators, shown in fig 6.

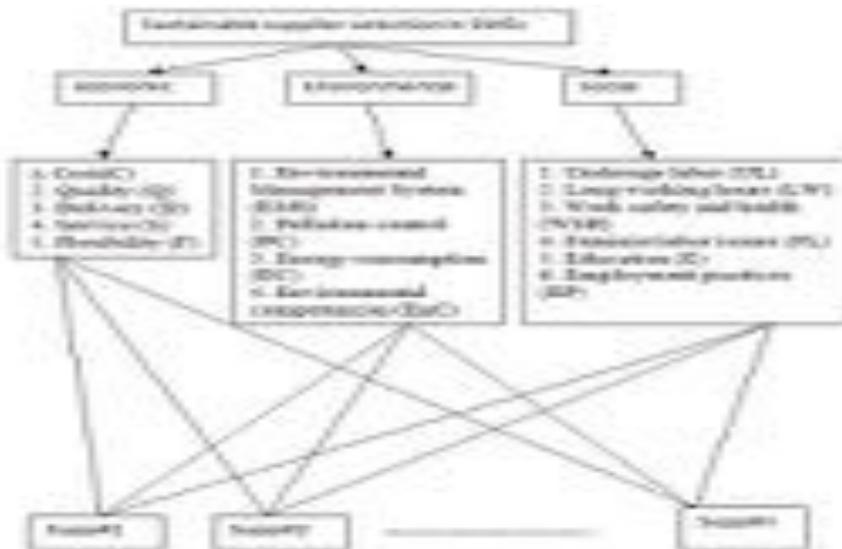


Fig.6 Generic form of sustainable supplier selection in SMEs here

Total 15 TBL indicators are considered to rationalize supply base with COFGA. An 8 point fuzzy comparison scale is developed, shown in table 4. Table 5 shows fuzzy pairwise comparison matrices for economic, environmental and social criteria. Table 6 shows result obtained from COFGA.

Table 4 Linguistic terms for criteria/sub criteria

Linguistic term	Triangular Numbers	Fuzzy
Very weakly preferred (VWP)	(0,0.15,0.3)	
Weakly preferred (WP)	(0.2,0.3,0.4)	
Fairly preferred (FP)	(0.3,0.4,0.5)	
Equally preferred (EP)	(0.5,0.5,0.5)	
Strongly preferred (SP)	(0.5,0.6,0.7)	
Very strongly preferred (VSP)	(0.6,0.7,0.8)	
Extremely preferred (Exp)	(0.7,0.8,0.9)	
Absolutely preferred (AP)	(0.9,0.95,1)	

Table 5 Fuzzy pairwise comparison

Economic Criteria	C	Q	D	S	F	Env. Criteria	EMS	PC	E	En	Social Criteria	UL	LW	WSH	FL	E	EP
C	EP	FP	FP	FP	SP	EMS	EP	EP	EP	EP	UL	EP	SP	FP	FP	FP	SP
Q	--	EP	FP	FP	EP	PC	--	EP	EP	FP	LW	---	EP	FP	WP	FP	FP
D	---	---	EP	EP	SP	EC	---	---	EP	FP	WSH	---	---	EP	FP	EP	FP
S	---	---	---	EP	SP	EnC	---	---	---	EP	FL	---	---	---	EP	EP	SP
F	---	---	---	---	EP						E	---	---	---	---	EP	SP
	-	-	-	-							EP	---	---	---	---	---	EP

Table 6 Priorities of TBL indicators

Eco. Crit.	Priority	Lower Limit	Upper Limit	Avg. Priority	Range of Principal Value and Consistency	Env. Crit.	Priority	Lower Limit	Upper Limit	Avg. Priority	Principal Value and Consistency	Eigen and Social Crit.	Priority	Lower Limit	Upper Limit	Avg. Priority	Principal Value and Consistency
C	0.0944	0.1333	0.1139	5.1602-5.3697	EMS	0.138	0.1476	0.1528	4.1057-4.2015	UL	0.0813	0.112	0.0966	6.1911-6.4460			
Q	0.1181	0.1448	0.1315	Avg=5.26495<-5.448	PC	0.1653	0.2022	0.1837	Avg=4.1536<-4.267	LW	0.0722	0.1104	0.0913	Avg=6.32<-6.63			
D	0.2441	0.2011	0.2226	Consistent	EC	0.2319	0.2932	0.2626	Consistent	WSH	0.1328	0.1392	0.1360	Consistent			
S	0.2895	0.2610	0.2572		EnC	0.4448	0.3571	0.4010		FL	0.2482	0.1867	0.2175				
F	0.2540	0.2596	0.2568							E	0.2308	0.2276	0.2292				
										EP	0.2348	0.2241	0.2294				

Computational time = 91.167227 secs. Computational time = 68.648142 secs. Computational time = 83.723919 secs.

Table 7 Priorities w.r.t economic criterion

	Cost(0.1139)			Quality(0.1315)			Delivery(0.2226)			Service(0.2572)			Flexibility(0.2568)			Weighted
	Lower	Upper	Avg	Lower	Upper	Avg	Lower	Upper	Avg	Lower	Upper	Avg	Lower	Upper	Avg	
Supp#14	0.0396	0.0787	0.05915	0.1157	0.1169	0.1163	0.1034	0.1555	0.12945	0.1202	0.1259	0.12305	0.098	0.1686	0.1333	0.116726
Supp#10	0.0405	0.0693	0.0549	0.1401	0.1522	0.14615	0.081	0.0964	0.0887	0.0903	0.1175	0.1039	0.0786	0.1388	0.1087	0.099854
Supp#5	0.0962	0.1365	0.11635	0.1494	0.1596	0.1545	0.0933	0.0947	0.094	0.1083	0.1312	0.11975	0.0782	0.1058	0.092	0.108919
Supp#16	0.1327	0.1749	0.1538	0.105	0.1193	0.11215	0.1105	0.1254	0.11795	0.1148	0.1226	0.1187	0.0999	0.1205	0.1102	0.11735
Supp#6	0.1362	0.1433	0.13975	0.1185	0.1225	0.1205	0.1141	0.1669	0.1405	0.1247	0.1662	0.14545	0.0893	0.1845	0.1369	0.135604
Supp#13	0.1419	0.1429	0.1424	0.1091	0.197	0.15305	0.0995	0.1285	0.114	0.127	0.1459	0.13645	0.1098	0.1305	0.12015	0.127671
Supp#24	0.139	0.2086	0.1738	0.0813	0.1016	0.09145	0.037	0.1122	0.0746	0.049	0.1174	0.0832	0.1001	0.272	0.18605	0.117604
Supp#12	0.1587	0.161	0.15985	0.0929	0.1189	0.1059	0.1733	0.3083	0.2408	0.1473	0.1959	0.1716	0.1053	0.12	0.11265	0.158799

Table 8 Priorities w.r.t environmental criterion

	EMS(0.1528)			PC(0.1837)			EC(0.2626)			EnC(0.401)			Weighted
	Lower	Upper	Avg	Lower	Upper	Avg	Lower	Upper	Avg	Lower	Upper	Avg	
Supp#14	0.098	0.1686	0.1333	0.0834	0.1309	0.10715	0.0909	0.1116	0.10125	0.0898	0.1396	0.1147	0.11263465
Supp#10	0.0786	0.1388	0.1087	0.1153	0.2039	0.1596	0.0998	0.1203	0.11005	0.0885	0.1445	0.1165	0.12154351
Supp#5	0.0782	0.1058	0.092	0.0835	0.1152	0.09935	0.0991	0.0995	0.0993	0.0983	0.1723	0.1353	0.11263968
Supp#16	0.0999	0.1205	0.1102	0.11	0.1207	0.11535	0.1264	0.1301	0.12825	0.0824	0.0862	0.0843	0.10551111
Supp#6	0.0893	0.1845	0.1369	0.1246	0.1408	0.1327	0.1136	0.1247	0.11915	0.1388	0.1814	0.1601	0.1407842
Supp#13	0.1098	0.1305	0.12015	0.1454	0.1651	0.15525	0.1402	0.1924	0.1663	0.1192	0.1259	0.12255	0.13969128
Supp#24	0.1001	0.272	0.18605	0.1105	0.1106	0.11055	0.1196	0.134	0.1268	0.1226	0.1298	0.1262	0.13264036
Supp#12	0.1053	0.12	0.11265	0.1083	0.1319	0.1201	0.1433	0.1545	0.1489	0.1298	0.1508	0.1403	0.13463673

Table 9 Priorities w.r.t social criterion

	UL (0.0966)			LW (0.0913)			WSH (0.136)			FL (0.2175)			E (0.2292)			EP (0.2294)			Weighted
	Lower	Upper	Avg	Lower	Upper	Avg	Lower	Upper	Avg										
Supp#14	0.0157	0.0592	0.03745	0.0143	0.0584	0.03635	0.0815	0.0878	0.08465	0.0179	0.0601	0.039	0.0773	0.1181	0.0977	0.2145	0.1002	0.15735	0.08542
Supp#10	0.016	0.0867	0.05135	0.0147	0.0754	0.04505	0.0937	0.1423	0.118	0.016	0.1433	0.07965	0.0894	0.1099	0.09965	0.0828	0.1304	0.1066	0.089739
Supp#5	0.1355	0.0799	0.1077	0.0155	0.0956	0.05555	0.0954	0.1083	0.10185	0.017	0.0822	0.0496	0.1324	0.114	0.1232	0.0661	0.0991	0.0826	0.087301
Supp#16	0.3061	0.0909	0.1985	0.2506	0.1105	0.18055	0.2174	0.2314	0.2244	0.2167	0.0881	0.1524	0.071	0.0958	0.0834	0.0882	0.0799	0.08405	0.137721
Supp#6	0.1241	0.1472	0.13565	0.1451	0.1792	0.16215	0.0881	0.0846	0.08635	0.1089	0.1252	0.11705	0.0769	0.1113	0.0941	0.1224	0.1082	0.1153	0.113128
Supp#13	0.2108	0.1684	0.1896	0.2071	0.1355	0.1713	0.1372	0.1081	0.12265	0.2149	0.0958	0.15535	0.125	0.1727	0.14885	0.1578	0.0819	0.11985	0.146034
Supp#24	0.1013	0.1799	0.1406	0.1878	0.1244	0.1561	0.1268	0.116	0.1214	0.2406	0.1612	0.2009	0.1744	0.1681	0.17125	0.1081	0.2945	0.2013	0.173469
Supp#12	0.0905	0.1879	0.1392	0.1649	0.2209	0.1929	0.1598	0.1215	0.14065	0.168	0.2441	0.20605	0.2536	0.1102	0.1819	0.1601	0.1059	0.133	0.167204

Table 10 Ranking of suppliers

Supplier Name	Cost	Env	Social	Priority	Normalized Priority	Rank
Supp#12	0.158799	0.134637	0.167204	0.46064	0.23234	1
Supp#24	0.117604	0.13264	0.173469	0.423713	0.213715	2
Supp#13	0.127671	0.139691	0.146034	0.413396	0.208511	3
Supp#6	0.135604	0.140784	0.113128	0.389516	0.196466	4
Supp#16	0.11735	0.105511	0.137721	0.360582	0.181873	5
Supp#14	0.116726	0.112635	0.08542	0.314781	0.158771	6
Supp#10	0.099854	0.121544	0.089739	0.311137	0.156933	7
Supp#5	0.108919	0.11264	0.087301	0.30886	0.155784	8

Spend analysis shows supplier 14, 24, and 5 as some of the top contributors. Table 10 shows a complete different ranking of suppliers after integrating value risk analysis and COFGA, the buyer’s perspective. Table 7,8, and 9 give further insight to each supplier w.r.t different criterion. Proposed approach shows that company is basically focusing on leveraged and routine suppliers prior to move on for strategic suppliers. Company started with 25 suppliers and finally realized importance of only 8 suppliers (supplier 12, and 24 from routine and remaining 6 from leveraged supply).

4 Conclusions

Spend analysis is justified in crisp domain. Presence of imprecise and vague data restricts the direct use of spend analysis. Spend analysis become myopic in presence of limited data. Further insight about potential suppliers can be revealed from buyer’s perspective. Multiple criteria decision analysis can outperform other methods as it can generate huge amount of quality data through brain storming group discussions. It assures that multiple criteria decision analysis as the complementary

approach to spend analysis. Value risk matrix segments supply base. Multiple criteria decision analysis, on the other hand, cluster suppliers on the basis of rank or priorities. Multiple criteria decision analysis, thus, cross verifies the result of value risk matrix. It ranks supplier and thereby consolidate and rationalize supply base. Proposed approach combines spend analysis, multiple criteria decision analysis, and value risk matrix to reduce transaction cost of procurement. In the proposed approach, triangular fuzzy numbers (TFNs) are used as they are easy to calculate and give stable result w.r.t different defuzzification approaches. Integrated use of COFGA, spend analysis, and value risk analysis, thus, justified for SMEs.

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Annexure –I **Risk Questions**

A. Sourcing risk

- Q1. What level of confidence do the stakeholders have about the services of supplier?
- Q2. Are the parts/components/assemblies/raw materials critical to the organization?
- Q3. Do the specifications of goods/services conform to organization's expectation?
- Q4. Does the price offered by the supplier vary with demand and market condition?
- Q5. Would there be any significant impact on organization's core performance if the supplier fails to supply?

B. Risk to organization's mission and goal

- Q6. Does the supplier match organization's mission and goal?

C. Risky past performance

- Q7. What is the attitude of supplier to risk?
- Q8. Is the supplier prone to collusion?
- Q9. Is the supplier fraud?

D. Contract risk

- Q10. What would be the expected financial loss to the organization if the supplier fails to supply?
- Q11. What is the legal or regulatory risk to the organization if the supplier fails to supply?
- Q12. What is the reputational risk to the organization if the supplier fails to supply?
- Q13. Is the contract critical to the organization's core performance?
- Q14. Do the stakeholders recommend the supplier?

E. Legal risk

- Q15. Is the supplier facing any litigation or disputes with other businesses?

F. Environmental and social risk

- Q16. Is the supplier employing any underage labor?
- Q17. Is the supplier using any hazardous technology and/ raw material?

Value Questions

- Q18. Is the purchase of the parts/assemblies/goods conform to the sustainable procurement norms of the Govt. and/organization?
- Q19. What is the total cost of ownership (TCO) for the goods/services?
- Q20. What is the total cost of ownership for the goods/services purchased under the contracts?