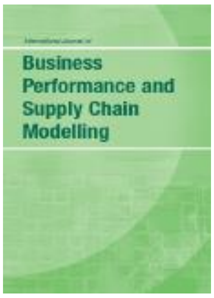

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SRM index development and validation in Indian automobile sector

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Abstract: The research paper proposes a reliable and valid supplier relationship management (SRM) index as a strategic tool specifically catering to Indian automobile sector. A standard methodology of scale development was followed to develop SRM scale and a case-based method was used to develop the index. SRM in Indian automobile sector emerged out to be a multi-dimensional construct comprising of trust, service quality, R&D and technological capability, flexibility, market orientation and support services. The literature in the area of SRM majorly deals with specific aspects of supply chain management like supplier selection, development and collaboration as well as purchasing strategy. But there is paucity of research pertaining to industry specific SRM index development and validation so as to get a holistic view. The strategic implications as well as marketing practitioners point of view is also discussed at the end for efficient and effective SRM practices by using SRM index.

Keywords: SRM scale; SRM index; Indian automobile sector; exploratory factor analysis; confirmatory factor analysis; India.

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1 Introduction

Aggressive globalisation, deregulation, more informed and demanding customers, shrinking product life cycle, steep price erosion and complex technicality of product components due to innovations are some of the factors which are enforcing the manufacturing industry to shift their focus from transactional orientation to relationship orientation (Cousins and Spekman, 2003; Moller and Torronen, 2000). This situation clearly demands a better and well thought of implementation of relationship practices with the customers as well as suppliers and a parallel focus towards the core competencies so as to sustain and grow in the current competitive scenario. Managing relationships between manufacturers and their suppliers is typically called supplier relationship management (SRM). Until 1990s, manufacturers have no interest in establishing and maintaining the relationship with their suppliers. Initially the manufacturers were self cantered and focused primarily on cost and quality on contract basis with a major goal of profit maximisation. But due to challenging and competitive era prevailing now a day's manufactures are slowly recognising that suppliers can make long-term contributions and have started developing the relationship with suppliers to get competitive advantage (Kerns, 2000; Fretty, 2001). Manufacturers now have started giving considerations to much wider range of criteria for maintaining relationships including supplier's competencies, overall service, financial stability and organisational culture (O'Toole and Donaldson, 2002). These aspects are most likely to offer competitive advantage to a manufacturer, few of which can be achieved through SRM.

The SRM process helps to build the structure for relationships with suppliers and to develop and maintain them. Close relationships (Jeong, 2003; Chopra and Sodhi, 2004) are developed with a small set of key suppliers based on the value that they offer to the organisation over a period of time. Supplier characteristics are used by a few researchers for maintaining supplier relationship (Lang et al., 2002; Trent, 2005; Azmawani, 2008), whereas many supplier aspects have been evaluated in the literature dealing with the supplier selection and evaluation process (Cakravastia et al., 2002; Murthy et al., 2004; Amid et al., 2009). SRM can be broadly grouped into three categories (Jeong, 2003; Wang and Che, 2007):

1 supplier selection

2 supplier performance evaluation

3 relationship building/maintaining (closer manufacture-supplier relationships).

The main focus of supplier relationship management is on maximising the value of a manufacturer's supply base and parallely providing an holistic and integrated set of management tools focused on the ongoing relationships with the manufacturer and his suppliers. The aim of supplier relationship management strategies should not be about negotiating price reductions, which alienate suppliers, but rather focus on creating closer collaboration with key suppliers (Martin and Grbac, 2003). Through appropriate SRM, both manufacturer and supplier can leverage their advantages to deliver value through their supply chain as well as serve as an enhancer for overall stakeholder relationship management.

To get a better understanding about the SRM, it is necessary to know about the different characteristics and types of relationships existing between suppliers and manufacturers which are prevailing in the existing scenario. In literature, various researchers describe the manufacturer-supplier relationship in various ways. Broadly these relationships are characterised in four ways (Trent, 2005).

a counterproductive (or antagonistic relationships)

b competitive relationships (or distributive or adversarial relationships)

c cooperative relationship (or integrative relationships)

d collaborative relationship (or integrative or creative relationships).

Based on a review of definitions of SRM by the various researchers proposed so far and in authors understanding it can be defined as a set of processes including supplier selection, supplier performance evaluation and relationship building/ maintaining which helps the manufacturer to develop a long term mutually beneficial relationship with its supplier base with an ultimate goal of improving the quality of product and reduction in price of product, delivery time and inventory level.

2 Literature review

As it is evident from the literature that customer relationship management is of utmost importance but other side of the value chain, i.e., supplier cannot be ignored because both are the part of the same value chain (Rother and Shook, 1999). SRM is the business process comprising of strategic, tactical and operational processes that enables in structuring the relationships development and maintenance with suppliers. SRM has now become as a crucial process of any manufacturing organisations because of intense competition, risk and sustainability aspects, the need to innovate new products and their timely release in the market place and in achieving cost efficiency to get competitive advantage over industry rivals by maintaining close tie ups with selected supplier base.

Although a plenty of studies have already proved that customer is the focal point for the business organisations while recent studies have extended the scope to include aspects of the supply chain (Reichart and Holweg, 2007) because of their crucial role in the organisations value chain. Ziropli and Caputo (2002) have investigated the set of factors that are quite essential for the establishment of effective supplier relationships including contractual agreements on long term basis for reducing uncertainty and supporting investments and parallel use of financial monitoring techniques such as target costing through proper information sharing. Based on the characteristics and the goals of developing a relationship, it can be categorised into two major types: adversarial and collaborative (Humphreys et al., 2001; Bunduchi, 2005; Szwejczewski et al., 2005). The first type of relationship is called as adversarial or contractual or arms-length characterised by short term orientation with a main focus on purchasing cost reduction through bargaining (Humphreys et al., 2001; Emiliani, 2003; Szwejczewski et al., 2005). The second type of relationship has been called as collaborative or closed type characterised by long term orientation with a main focus on getting competitive advantage and overall performance improvement through closed tie ups with key supplier base, currently used by many of the automobile manufacturers such as Toyota and Honda and Nissan (Humphreys et al., 2001; Benko and McFarlan, 2003; Szwejczewski et al., 2005). Bensaou (1999) has proposed four types of relationships as shown below.

Figure 1 Types of relationship

Buyer's specific investments	Low	High
High	**Captive buyer** • Technically complex products with mature, stable technology and few innovations • Supplier proprietary technology and unique skills • Frequent and regular mutual visits • Strong effort by buyer for cooperation • Lack of mutual trust, tense climate	**Strategic partnership** • High level of customization required • Technically complex part or integrated subsystem based on new technology • Strong supplier proprietary technology • Extensive joint action and cooperation • Frequent and "rich media" information exchange • Mutual trust
Low	**Market exchange** • Highly standardized and simple products with mature technology and little innovation • No supplier proprietary technology • Limited information exchange • No systematic joint effort and cooperation	**Captive supplier** • Technically complex products based on new technology • Strong supplier proprietary technology • Little exchange of information • High mutual trust, but limited direct joint action and cooperation

Supplier's Specific Investments

Source: Bensaou (1999)

Figure 2 Model of relationship strategies

Supplier's Commitment to Manufacture

Commodity's Importance to Manufacturer		**High**	**Low**
	High	Family	Business partner
	Low	Friendly	Transactional

Source: Svensson (2004)

From the literature, it is clear that relationship is a dynamic process (Jap and Ganesan, 2000; Jap, 2001) and evolve through a lifecycle which consists of five stages namely awareness, exploration, expansion, commitment and dissolution (Dwyer et al., 1987) which were again redefined as awareness, exploration, build-up, maturity and decline/deterioration (Jap and Ganesan, 2000). Although different research studies have explored the different stages of relationship evolution in a different manner but most of the studies agree on a move towards closer relationship between suppliers and manufacturers from market exchange to a partnership relationship type (Boon-itt and Paul, 2006). Some of the research studies (Boon-itt and Paul, 2006; Golicic and Mentzer, 2006) have explored the relationship evolution through the development of supply chain integration. Integration of manufacturing system plays a crucial role under a high level of environmental uncertainty and can be done through collaboration across suppliers, customers (externally) and functional departments (internally) to arrive at mutually acceptable outcomes (Frohlich and Westbrook, 2001; Rosenzweig et al., 2003; Pagell and Krause, 2004; Liao and Tu, 2008).

A fair amount of literature has explored the concept of supply chain integration in different research areas such as information processing (Lee et al., 1997, 2003; Zhao et al., 2007), inventory planning and logistics (Disney and Towill, 2002; Romano et al., 2009; Danese and Romano, 2011), or partnership/relationships (Carter et al., 2000; Fynes et al., 2005). As per the recent study done by Soni and Kodali (2013) in which the authors have done a review of 57 supply chain management frameworks clearly shows the inconsistencies among the frameworks proposed so far and also suggested to propose 'unified theory of SCM' with a distinct set of constructs. Organisational performance can be improved through integration of operations with suppliers (Frohlich and Westbrook, 2001; Rosenzweig et al., 2003; Fabbe-Costes and Jahre, 2008; Singh and Power, 2009; Flynn et al., 2010) through co-creating value for the end customer which ultimately enhance mutual profitability (Lusch and Vargo, 2006; Enz and Lambert, 2012). Van Echtelt and Wynstra (2000) have proposed the framework for SRM, and classified the identified factors in two major categories namely driving and enabling factors. Driving factors are those which drive the need for purchasing involvement, e.g., size of the organisation, competitive pressures from market, market volatility, dependence for research and development. Enabling factors are those factors which help in enabling the involvement of purchasing, e.g., organisational culture compatibility, information sharing, internal teams of the organisation concerned with purchasing, social climate and trust. Some of the authors have explored the different factors based on which the relationship is developed such as matured understanding, trust, coordination, collaboration, commitment, communication, flexibility, dependence, transparency, faith, relationship strength, closeness and physical proximity and have also explored the relationships from manufacturer perspective, supplier perspective as well as dyadic perspective (Larson and Kulchitsky, 2000; Martin and Grbac, 2003; Burt et al., 2004; Benton and Maloni, 2005; Narasimhan and Nair, 2005).

2.1 SRM for Indian automobile sector

Over the years, Indian automobile industry in itself is growing at an increasing rate. This industry contributes to the total growth of Indian economy by contributing about 7% in the gross domestic product (GDP) of the country and also provides employment to approximately 19 million people directly and indirectly. The Indian automotive Industry is growing at a rapid pace and accounts for more than 20% of the GDP (Times of India, April, 2012). The growth process along with the entry of multinational enterprises has led to a transformation of the supplier base and relationships with supplier in India (Saripalle, 2006). The consideration for automobile industry in Indian context is raised due to the fact that the country like India is experiencing huge number of road accidents. There are various reasons behind road accidents like, violation of traffic rules by driver, less attentive driver, defective or low quality parts of the vehicle, etc. This study is an initiative to respond one of the reasons behind road accidents, i.e., defective or low quality parts of the vehicle. The idea is, if a manufacturer is able to build and maintain good relationship with their suppliers then one can expect to receive defect-free and good quality raw material as well as timely delivery of the raw material.

Kulkarni and Ramdasi (2004) surveyed 56 manufacturing industries in India and found that the manufacturing firms are not too keen on information sharing with the suppliers at the early stage of planning, cut throat competition, billing to payment cycle, quality of raw material, demand uncertainty are some of the reasons for that and is not good for long term orientation perspective. The availability of alternate suppliers sometimes acts as a major external influencer in business relationships (Walter et al., 2003). Demirtas and Ustun (2009) have identified two major problems faced by manufacturing organisations during supplier selection in single sourcing and multiple sourcing scenarios and suggested the cooperative negotiations with the key supplier base as a major strategy to deal with such kind of problems. Saripalle (2006) discussed the shift in relationship focus from arms-length to a long-term orientation in Indian automobile sector. The author has explored three cases of quasi multinational and found that the changes in supplier relations are must to attain core competence and flexibility. The main challenge lies in converting the different business ideologies of the collaborating organisations into mutual profit and risk sharing relationships. Information technology is identified as one of the important factor in fostering manufacture-supplier relationships dyad and many of the organisations are not yet information technology savvy. Table 1 briefly enumerates the select list of studies of SRM based on relevance and gap identification for the present study.

Table 1 Select list of studies (1994–2012)

S. no.	*Author*	*About the study*
1	De Toni et al. (1994)	The authors have analysed the components and critical aspects of service in the modern supply transaction through a case study and revealed import ant operational and organisational effects of buyer-supplier interactions in the area of service provision.
2	Kim and Michell (1999)	The authors have conducted the study in Japanese automaker industry and found that the major Japanese automakers have far more diversity than commonality in their supplier policies, and suggests that a comparison of major Japanese companies individually, not collectively might be a future area of research into buyer-supplier relationships.
3	Ypatia et al. (2006)	The authors have focused on dyadic buyer-supplier relationship as part of supply chain management and related the implementation of supplier management practices to intra-firm implementation of quality management practices. The study revealed a positive correlation between supplier management practices and quality management practices.
4	Ndubisi et al. (2007)	The authors have examined the impact of the relationship marketing underpinnings, namely: Competence; communication; commitment and conflict handling on the one hand and customer loyalty on the other, as well as the mediation effects of trust and relationship quality.

Table 1 Select list of studies (1994–2012) (continued)

S. no.	*Author*	*About the study*
5	Field and Meile (2008)	The authors have empirically tested the relationship between supplier relations and satisfaction with overall supplier performance in services context at a process level of analysis.
6	Squire et al. (2009)	The authors have examined the relationships between supply chain collaboration, supplier capabilities and buyer responsiveness.
7	Emiliani (2010)	The authors have reviewed and analysed the key recommendations of early practitioners of purchasing management by focusing on different policies and practices for obtaining lower unit prices affect buyer-seller relationships.
8	Park et al. (2010)	The authors have suggested a framework for integrative Supplier Relationship Management system by analysing comprehensive approaches to overall Supplier Relationship Management functions.
9	Govindan et al. (2010)	The authors have identified and rank different criteria used for the supplier development using interpretative structural modelling (ISM).
10	Frodell (2011)	The authors have identified different criteria for achieving efficient contractor-supplier relations in the construction industry for large contractors.
11	Jiang et al. (2011)	The authors have provided empirical evidence about the effects of trust and dependence in business relationships in UK construction industry.
12	Danese and Romano (2011)	The authors have analysed the impact of customer integration on efficiency, and the moderating role of supplier integration.
13	Boon-itt and Wong (2011)	The authors have tested the moderating effects of technological and demand uncertainties on the relationship between customer delivery performance and supply chain integration.
14	Song et al. (2012)	The authors have examined the creation of relationship value and its consequences on the existing buyer-supplier relationship as well as buyer's performance. In the study the construct of business relationship function is used to analyse why the business relationship is valuable and to investigate the links between business relationship function, relationship quality and buyer's performance. In addition to this the authors have investigated whether the availability of alternative suppliers changes the influence of business relationship function on relationship quality.
15	Lambert and Schwieterman (2012)	The authors have proposed a framework that managers can use to implement a cross-functional, cross-firm, supplier relationship management process in business-to-business relationships.

As identified from the literature there is plenty of studies that have been done in countries mainly the USA and Japan, relatively little research have been carried out in developing countries like India (Humphrey and Schmitz, 1998; Calabrese, 2000; Carr and Leong, 2000; Dyer and Chu, 2000; Perez and Sanchez, 2000; Gonzales-Benito and Dale, 2001; Zirpoli and Caputo, 2002; Sanchez and Perez, 2003 ; Peterson et al., 2005; Sanders and Premus, 2005; Gyau et al., 2011; Lambert and Schwieterman, 2012; Meena and Sarmah, 2012; Naude et al., 2013; Kumar and Banerjee, 2014). The literature in the area of SRM majorly deals with specific aspects of supply chain management such as supplier selection, development and collaboration as well as purchasing strategy but there is a lack of holistic view about these aspects specifically in terms of an index (Park et al., 2010). Based on these observations from literature this study caters to development and validation of SRM index in Indian automobile sector. That will serve as a guide for planning and implementing SRM practices in an effective and efficient manner.

3 Methodology

For this study, authors have initially developed 98 scale items derived from 171 research papers for identifying SRM constructs in manufacturing sector and 50 general relationship marketing scale items were taken from Agariya and Singh (2011) and those scale items were taken which are having the minimum of five citations; after this a total of 78 scale items retained initially this was followed by depth interviews with the automobile manufacturers all across India.

3.1 Depth interview

Depth interview was conducted with top officials of 15 automobile manufacturers (turnover and reputation in the industry was taken as a bas is for selection) all across India. The duration of depth interview varied anywhere between 15 to 30 minutes. A list containing 78 dimensions extracted from the literature review is given to interviewee along with a brief description of each dimension. Based on the results of the depth interview the questionnaire is modified.

3.2 Key findings of depth interview

The authors provided a list of 78 dimensions obtained to the interviewees. They were asked to list down the ones they feel relevant to their respective organisation. They were also told to include the dimensions other than the 78 dimensions provided to them in the list. After getting their responses the list was pruned to 46 based on modal values (10). Findings of depth interview shows, all of the respondents were aware of SRM practices. The major issues identified were related to information sharing, technological infrastructure, lack of trust, price, quality, personalisation, support and services and image in the market place.

3.3 Questionnaire survey

The modified questionnaire is based on these 46 dimensions followed by a pilot survey of the questionnaire to assess the content validity. Content validity can be evaluated by a panel of persons, sometimes experts, who judge whether a scale logically appears to accurately reflect what it purports to measure. From the result of the pilot survey 14 dimensions are removed as a result, the revised questionnaire contained 32 dimensions (survey items). The revised questionnaire structure comprises of:

- Section 1: Demographic information of the respondents.
- Section 2: Items measuring the respondent's perceptions on specific characteristics of services and overall quality of the supplier and relationship specific dimensions.

The respondents were requested to select the response that best indicates their experiences or perceptions on each statement, using a five-point Likert-type scale (from 1 = strongly disagree to 5 = strongly agree).

3.4 Key findings of questionnaire survey

Responses to the revised questionnaire were received through online as well as offline from the respondents all across India. The respondents of this study were the top official and middle level managers and engineers of different automobile manufacturing organisations all across India and were selected randomly. A total of 346 responses were received. Furthermore the reliability analysis, sampling adequacy analysis and exploratory factor analysis was carried out with the first half of the data (sample size: 173) to identify the major constructs, subsequently confirmatory factor analysis was carried out with the second half of the data (sample size: 173) to confirm the factor structure as well as to provide evidence of scale reliability, dimensionality and validity and finally to validate the results. SPSS-15 and AMOS-7 software were used for carrying out statistical analysis mentioned above. The demographic profile of the respondents is given in Table 2.

Table 2 Demographic profile of the respondents (field survey)

S. no.	*Demographic criteria*		*%*
1	Gender	Male	91.33%
		Female	8.67%
2	Age	Between 18–30 years	33.53%
		Between 30–45 years	31.79%
		Above 45 years	34.68%
3	Designation	Production manager	11.85%
		Production engineer	12.43%
		Purchasing in-charge/manager	20.52%
		Marketing Manager	23.41%
		Chief marketing manager	6.65%
4	Association with the organisation	Less than 1 year	16.18%
		Between 1–3 years	39.02%
		More than 3 years	44.80%

4 Analysis of results

The reliability of the data is checked by calculating Cronbach-α value which is found 0.950 for the total dataset. The calculated value is in the quite acceptable range (>0.7) (Nunnally, 1978). Further to this Kaiser Mayer Oklin statistics is calculated for checking the sampling adequacy, the calculated value is 0.921 (>0.5) which is found quite suitable for carrying out exploratory factor analysis. Exploratory factor analysis was carried out and based on the rotated component matrix a total of six factors were extracted along with 28 indicators contributing towards 64.78% of the variance. Based on these factors the authors have proposed the SRM models. The extracted factors a long with their indicators are shown in Table 3. In the first model (Figure 3) SRM is represented as a unidimensional construct and all the extracted dimensions from the factor analysis are leading to SRM. This model is verified through confirmatory factor analysis by using the second half of the data (sample size: 173). This model is discarded because of poor fit based on the calculated absolute measures, incremental fit measures and parsimonious fit measures. The calculated statistics of these measures is shown in Table 4. In the second model (Figure 4) SRM is represented as a multi-dimensional construct explained by the six factors extracted through exploratory factor analysis. This measurement model is verified through confirmatory factor analysis by using the second half of the data (sample size: 173). This model is accepted because of much improved level of fit as compared to model-1 based on the calculated absolute measures, incremental fit measures and parsimonious fit measures. A total of eight indicators namely TRUS1, TRUS5, SEQ3, FLE2, RTC3, RTC4, SUS2, MAO1of the unidimensional construct (Figure 3) were eliminated in this model (Figure 4) because of poor loadings (< 0.5). The comparative calculated statistics of these measures are shown in Table 4. The measurement model indicated an acceptable model fit of the data ($\chi 2$ = 1018.78, df = 155, $p < .05$; $\chi 2/df$ = 1.75; GFI = 0.89; AGFI = 0.85; CFI = 0.93; TLI = 0.92; PCFI = 0.76 and RMSEA = 0.06) (Anderson and Gerbing, 1988). In addition to this all the indicators loaded significantly on the corresponding latent constructs. The values of the fit indices indicate a reasonable fit of the measurement model with the sample data (Byrne, 2001).

Table 5 clearly indicates that the composite reliability of all the constructs is more than 0.6, which is fairly acceptable and is one of the criteria to assess reliability of the proposed constructs (Carmines and Zeller, 1988). Construct validity is established in this study by establishing the content validity, convergent validity and discriminant validity. Content validity is verified through existing literature and expert's interaction in the area of SRM. Convergent validity is assessed by examining the average variance extracted (AVE) and factor loadings (Fornell and Larcker, 1981).

All the indicators have shown significant loadings onto their respective latent constructs with values varying in between 0.62 to 0.83. In addition, the AVE for each construct is greater than or equal to 0.50, which further supports the convergent validity of the constructs. As suggested by Fornell and Larcker (1981) the discriminant validity can be assessed by comparing the AVE with the corresponding inter-construct squared correlation estimates. AVE values were found more than the square of the inter-construct correlations. Thus, the measurement model reflects good construct validity and desirable psychometric properties (Agariya and Singh, 2012, Agariya et al., 2012). In the third model (Figure 5) the structural SRM model is validated by using structural equation modelling. The calculated statistics of absolute measures, incremental fit measures and parsimonious fit measures is shown in Table 6. The structural model indicated an acceptable model fit of the data ($\chi 2$ = 292.58, df = 164, p < .05; $\chi 2$/df = 1.78; GFI = 0.88; AGFI = 0.84; CFI = 0.93; TLI = 0.91; PCFI = 0.79 and RMSEA = 0.06) (Anderson and Gerbing, 1988). In addition to this all the indicators loaded significantly on the corresponding latent constructs. The values of the fit indices indicate a reasonable fit of the structural model with the sample data (Byrne, 2001). In short, the structural model confirms the six-factor structure of SRM.

Table 3 Exploratory factor analysis (rotated component matrix)

	Component					
	TRU	*SEQ*	*FLE*	*RTC*	*SUS*	*MAO*
TRU1: Honesty	.552					
TRU2: Credibility	.697					
TRU3: Price	.645					
TRU4: Information sharing	.737					
TRU5: Bonds	.564					
TRU6: Commitment	.732					
SEQ1: Competence		.670				
SEQ2: Responsiveness		.736				
SEQ3: Assurance		.521				
SEQ 4: Prompt delivery		.758				
SEQ5: Service recovery		.648				
FLE1: Production facilities and capacity			.736			
FLE2: Convenient operating hours			.516			
FLE3: Integrated production planning			.797			
FLE4: Customisation			.840			
FLE5: Cooperation			.584			
RTC1: Updated technological infrastructure				.801		
RTC2: Certifications				.673		
RTC3: Technical skills				.545		
RTC4: Effective information analysis system				.501		
RTC5: Market research				.793		
SUS1: Training					.659	
SUS2: Warranties and claim policies					.580	
SUS3: Capital support					.606	
SUS4: Recognition and reward system					.528	
MAO1: Interdependence						.509
MAO2: Competitor orientation						.748
MAO3: Reputation and position in industry						.717

Notes: TRU: trust, SEQ: service quality, FLE: flexibility, RTC: R&D and technological capability, SUS: support services, MAO: market orientation

Figure 3 Model 1 – SRM as an unidimensional construct

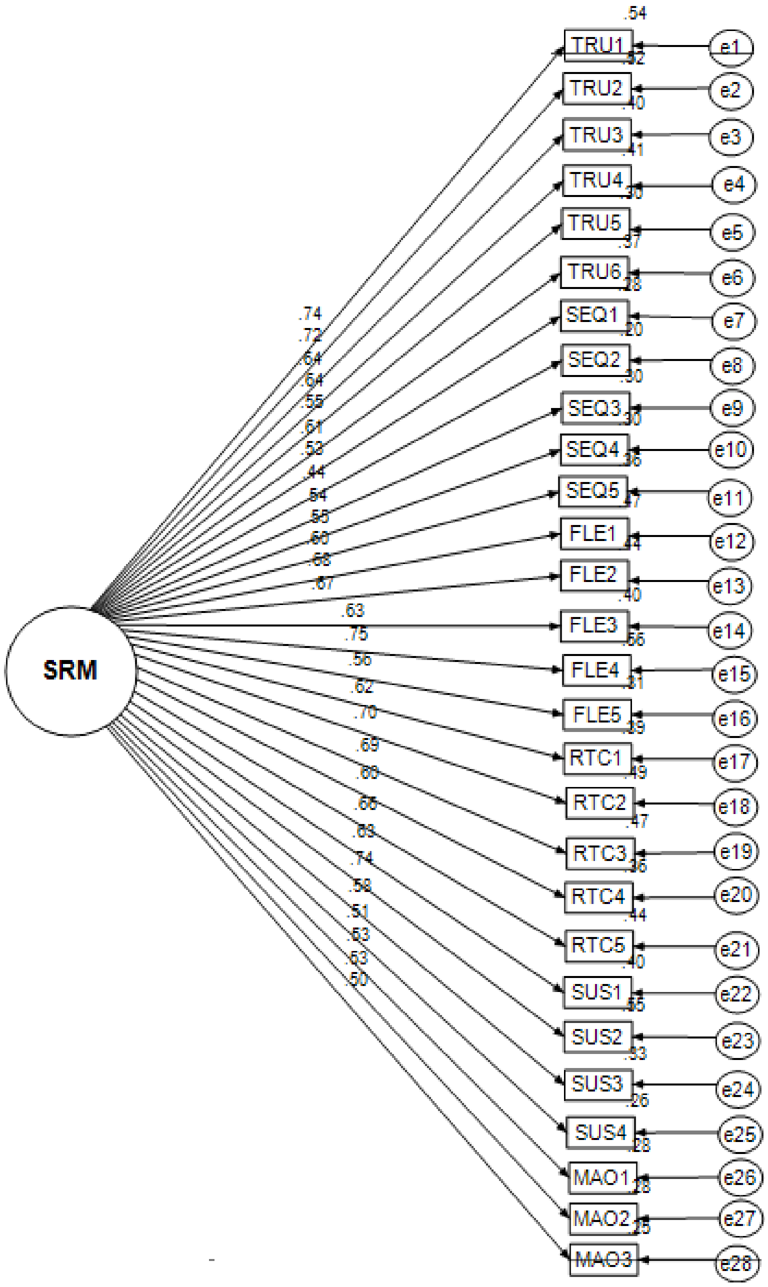

Table 4 Comparison of the calculated statistics for the models 1 and 2

S. no.	*Model fit*		*Absolute measures*			*Incremental fit*		*Parsimonious fit*	*RMSEA*
	χ2	*χ2/df*	*RMR*	*GFI*	*AGFI*	*CFI*	*TLI*	*PCFI*	
Model 1	1,018.78	2.91	0.07	0.63	0.57	0.73	0.71	0.68	0.10
Model 2	270.78	1.75	0.04	0.89	0.85	0.93	0.92	0.76	0.06

Figure 4 Model 2 – measurement model (six-factor model)

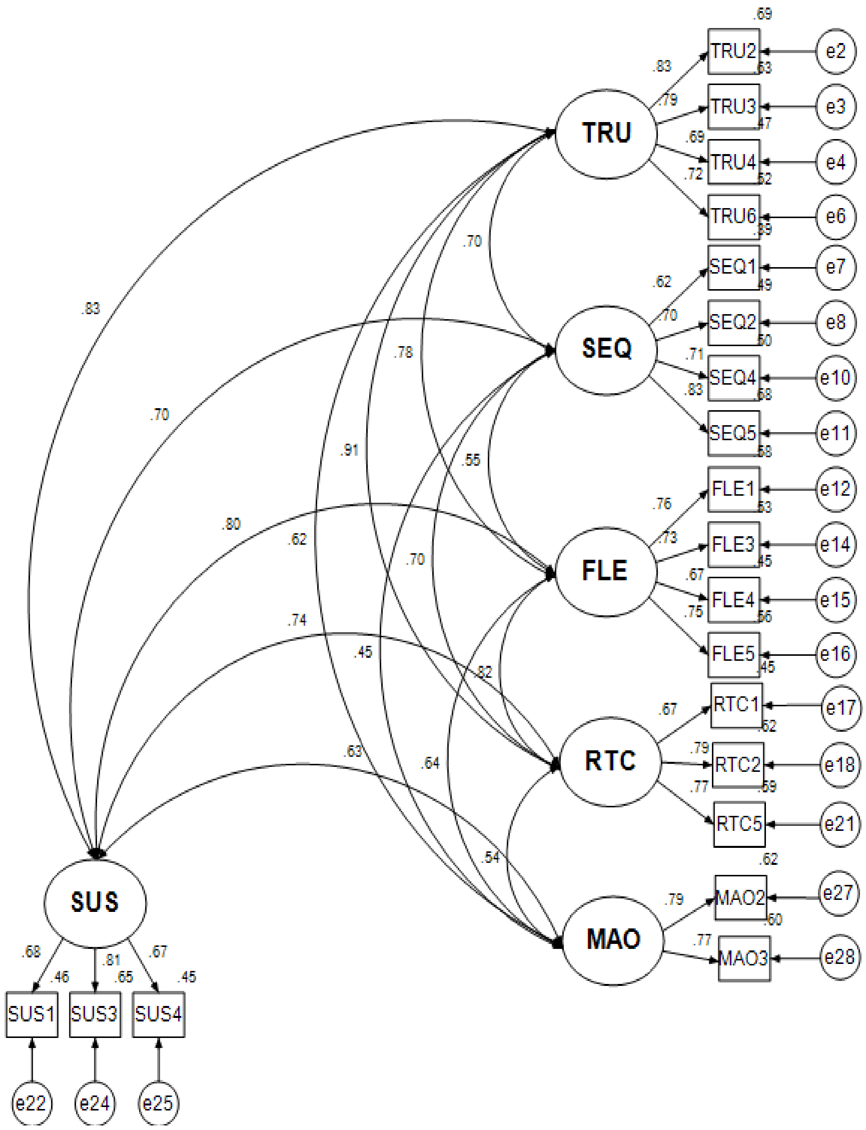

Table 5 Composite reliability of the constructs

Construct	*Composite reliability*
TRU	0.79
SEQ	0.80
FLE	0.79
RTC	0.75
SUS	0.76
MAO	0.67

Figure 5 Model 3 – structural model (six-factor model)

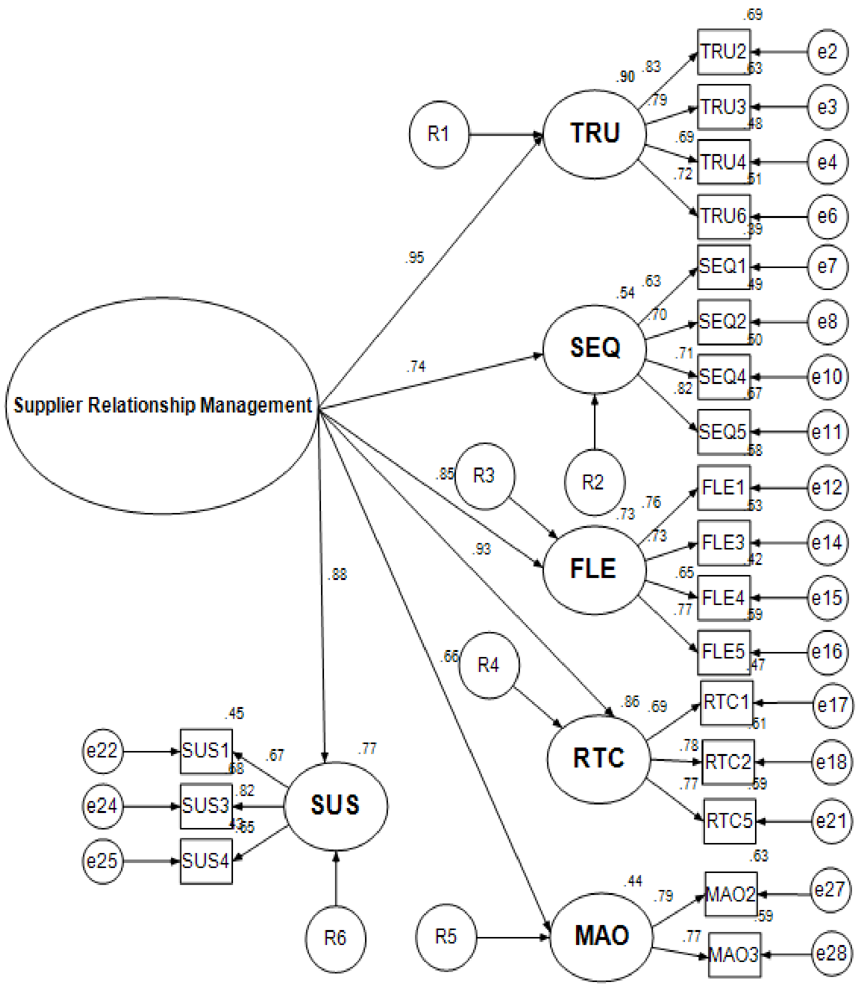

Table 6 Calculated statistics for Model 3

S. no.	*Model fit*		*Absolute measures*			*Incremental fit measures*		*Parsimonious fit measures*	*RMSEA*
	χ2	*χ2/df*	*RMR*	*GFI*	*AGFI*	*CFI*	*TLI*	*PCFI*	
Model 3	292.58	1.78	0.04	0.88	0.84	0.93	0.91	0.79	0.06

5 Inferences and strategic implications

The study verified the long held belief that SRM is a multidimensional construct. The critical factors that explain SRM in Indian automobile sector have been identified as trust, service quality, flexibility, R&D and technological capability, support services and market orientation.

5.1 Trust

Trust plays a crucial role in achieving efficient communication, risk minimisation, economic exchange, foster confidence and other significant benefits leading to manufacturer supplier dyad success. In case of high level of trust the manufacturers tend to satisfy because of the infusion of positive feeling in supplier actions that it will be beneficial for both of them and in turn both the parties are ready for information sharing which lead to satisfaction of both the players on the manufacturer supplier dyad and finally results in long term relationship orientation. This factor comprises of dimensions namely credibility, i.e., it is the belief that the supplier organisation fulfils its promises and obligations which should be there to a greater extent so as to maintain long term relationship continuity; Price, i.e., It consists of the actual cost of the material and the revenue margin of the supplier after including freight charges and discounts; information sharing in both the aspects quality as well as extent of sharing and commitment, i.e., refers to the manufacturers belief that making long term relationship with the supplier base is so important as to warrant maximum efforts from the top management for maintaining it and serve as a cornerstone for relationship continuity and to eliminate the root causes of the problems as and when aroused. All of these have a crucial role to play in developing, maintaining and enhancing the relationships.

5.2 Service quality

This factor comprises of sub dimensions namely competence, i.e., it can be defined as the skills and efficiency of suppliers; responsiveness, i.e., willingness of supplier organisation to help the manufacturers and providing prompt service to them; prompt delivery, i.e., suppliers ability to make proper arrangements for delivery on a very short notice as and when required and service recovery, i.e., supplier organisation response in case of service failure and all of them play a pivotal role in improving the service quality.

5.3 Flexibility

Flexibility denotes an ability to change as and when the situation demands. This factor comprises of dimensions namely production facility and capacity, i.e., the infrastructure facilities and overall capability of suppliers; integrated production planning, i.e., integrated production functions so as to improve the efficiency and performance. It leads to a harmonious atmosphere in which both the parties have a good understanding of the manufacturing system as well as the product quality; customisation, i.e., ability of the supplier to offer tailor made offerings to supplier and cooperation as and when problems arise. Manufacturing organisations can adopt customised relationship marketing strategies based on the crucial role and contribution of the supplier organisations in the value chain. Flexibility may be in terms of mix or volume. Manufacturers get the flexibility in responding to changing customer demands in a proactive manner without a proportionate increase in cost and also no compromise on the quality aspects.

5.4 R&D and technological capability

This factor comprises of subdimensions namely updated technological infrastructure, i.e., latest technology for the efficiency and effectiveness in production; certifications by professional bodies for quality products and efficiency and use of market research so as to make appropriate modifications across different functions and operations according to end customer needs. This factor varies from product to product and industry to industry. Specifically if we talk about the automobile industry complexity and novelty of spare part functions may directly lead to technological uncertainty which ultimately may results into product quality problems and delivery delay.

5.5 Support services

This factor comprises of dimensions namely training and development; capital support and proper recognition and reward system for the supplier base and play a crucial role in enhancing the relationship of manufacturer supplier dyad.

5.6 Market orientation

This factor comprises of competitor orientation, i.e., a close watch on the actions of the competitors and acting proactively; reputation and position in the industry in which core competencies plays a major and crucial role and lead to win-win situation for both the parties. All of the above mentioned factors are the prerequisite for successful SRM and enables the enhancement of the financial, purchasing and overall efficiency of both the concerned parties.

6 SRM index development using the case-based method in Indian automobile sector

This section includes the validation of SRM scale through a case-based method and development of SRM index along with the manufacturers and suppliers weights with the help of questionnaire design and survey conducted.

6.1 SRM index derivation steps

- identification of factors leading to SRM (empirically validated factors along with their indicators)
- 20 indicators
- questionnaire development
- survey
- respondents score
- calculation of weights (manufacturers as well as suppliers perspective)
- development of SRM index (manufacturers as well as suppliers perspective)
- gap analysis.

6.2 Questionnaire design

The questionnaire structure comprises of:

- Section 1: demographic information of the respondents.
- Section 2: 20 items measuring the respondent's perceptions on specific characteristics of Suppliers relationship management.

The respondents were requested to select the response that best indicates their experiences or perceptions on each statement, using a five-point Likert-type scale (from 1 = strongly disagree to 5 = strongly agree).

6.3 Sample selection

For generation of weights for SRM index, the researcher has used non-probability sampling. A judgment sample (Deming, 1960) is selected on the basis of the judgment of the researcher. A total of 63 and 34 responses were received from the production, marketing, purchasing, store managers and top management officials of manufacturing and supplier organisations respectively.

- manufacturing organisations: XYZ
- supplier organisations: PQR

6.3.1 Mathematical model for ranking

SRM index can be evaluated with the help of the following mathematical model:

$$\text{SRM index score} = \left(\text{WA1}*\ \text{SA1}+\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + \text{WA6}*\ \text{SA6}\right)$$

where

WA1-WA5 are the calculated weights for the SRM constructs.

S A1-S A5 are the scores corresponding to the SRM constructs.

Table 7 Demographic profile of the respondents (manufacturing organisations and supplier organisations)

S. no.	*Demographic criteria*		*Manufacturing organisations*	*Supplier organisations*
1	Gender	Male	79.37%	85.29%
		Female	20.63%	14.71%
2	Age	Between 18–30 years	20.63%	35.29%
		Between 30–45 years	47.62%	47.06%
		Above 45 years	31.75%	17.65%
3	Designation	Production manager	15.87%	41.18%
		Production engineer	3.17%	-
		Purchasing in-charge/manager	34.92%	20.59%
		Marketing manager	7.94%	29.41%
		Chief marketing manager	4.76%	-
4	Association with the organisation	Les s than 1 year	23.81%	20.59%
		Between 1–3 years	28.57%	32.35%
		More than 3 years	47.62%	47.06%

7 Data analysis

A sample size of 63 and 34 responses and 20 questions led to a total of 1260 and 680 data points which are actually the preferences of the manufacturing and supplier organisations.

Table 8 Weights calculation

S. no.	*SRM sub-element*	*Manufacturers point of view*			*Suppliers point of view*		
		Average score	*Averag e score (SAi)*	*Weights (WAi)*	*Average score*	*Average score (SAi)*	*Weights (WAi)*
1	TRU2: Credibility	4.87	4.66	0.19	4.81	4.62	0.19
2	TRU3: Price	4.73			4.39		
3	TRU4: Information sharing	4.55			4.59		
4	TRU6: Commitment	4.49			4.71		
5	SEQ1: Competence	3.57	3.63	0.15	3.94	4.22	0.17
6	SEQ2: Responsiveness	3.61			4.63		
7	SEQ4: Prompt delivery	3.83			4.27		
8	SEQ5: Service recovery	3.51			4.06		
9	FLE1: Production facilities and capacity	4.23	4.33	0.18	4.79	4.75	0.19

Table 8 Weights calculation (continued)

S. no.	*SRM sub-element*	*Manufacturers point of view*			*Suppliers point of view*		
		Average score	*Average score (SAi)*	*Weights (WAi)*	*Average score*	*Average score (SAi)*	*Weights (WAi)*
10	FLE3: Integrated production planning	4.89			4.83		
11	FLE4: Customisation	4.17			4.71		
12	FLE5: Cooperation	4.03			4.66		
13	RTC1: Updated technological infrastructure	3.77	3.93	0.16	3.71	3.48	0.14
14	RTC2: Certifications	4.13			3.32		
15	RTC5: Market research	3.89			3.41		
16	SUS1: Training	3.67	3.35	0.14	3.97	3.86	0.16
17	SUS3: Capital support	3.01			3.81		
18	SUS4: Recognition and reward system	3.36			3.79		
19	MAO2: Competitor orientation	4.33	4.26	0.18	3.54	3.63	0.15
20	MAO3: Reputation and position in industry	4.19			3.73		

Table 9 Comparison matrix

		Manufacturers perspective	*Suppliers perspective*
		Weights (WAi)	*Weights (WAi)*
1	Trust	0.19	0.19
2	Service quality	0.15	0.17
3	Flexibility	0.18	0.19
4	R&D and technological	0.16	0.14
5	Support services	0.14	0.16
6	Market orientation	0.18	0.15

The comparison matrices (Table 9) shown above clearly indicate that there exist a gap between the importance given to the factors by manufacturers and suppliers. The weights given by the suppliers should be duly taken care of and the manufacturer should work upon to minimise the gaps as indicated from the table by devising proper SRM strategies so as to get the maximum benefit of SRM implementation and side by side use this index from time to time to get the feedback of the supplier to check the level of effectiveness of the devised and implemented SRM strategies.

8 Conclusions

In present competitive scenario Indian automobile manufacturers are facing the sharp increase in the demand for higher quality products, more variants with innovative features and prompt and reliable delivery. This kind of volatile situations clearly demands proper integration of suppliers and proper information sharing. Implementing right supplier relationship marketing practices give the organisations a closer view of the customers so as to correctly identify the needs of them and according creating and delivering superior value which ultimately help in maintaining effective long term relationships with them. Several studies have mentioned a plenty of benefits that the manufacturing organisations can achieve through proper coordination and implementation of SRM practices and developing and maintaining long-term relationships with their key supplier base (Walter et al., 2001; Moller and Torronen, 2003; Ulaga and Eggert, 2006; Lepak et al., 2007; Lefaix-Durand et al., 2009).

However there is a paucity of research done in context of Indian automobile sector with a focus on developing and validating SRM index. Here lies the contribution of this research work by proposing a holistic view of SRM in form of a valid index specifically catering to Indian automobile sector. These factors should be duly considered by the Indian automobile manufacturers in order to achieve a high degree of customer satisfaction and business performance which are the primary and compulsive goals for any business organisation in the current competitive scenario. Academically this research work bridges the gap in the existing literature by proposing comprehensive index specifically catering to Indian automobile industry. Managerially by implementing the proposed index by Indian automobile manufacturers can enhance their customer acquisition, customer retention and overall profitability. This will ultimately have a positive impact on Indian economy as this sector is growing at a faster pace. Novelty of this work lies in the fact that considering the views of manufacturers as well as suppliers of different automobile companies all across India and proposing a comprehensive model for better implementation of SRM in Indian automobile sector. The different perspectives identified from this research work will serve as a guideline in formulating the segmentation strategies for Indian automobile manufacturers.

9 Limitations and future research lines

The sample sizes itself were relatively small, which is one of the limitations of this study. Large and more diversified samples can be taken for the further enhancement as well as validation of this research work. The applicability, validation and generalisability of the proposed index can be done by replicating this study in SRM aspects of other business segments at a national level.

10 Implications for marketing practitioners

Around the globe various standard methods are employed to rank the companies within an industry and identify the industry leaders from getting responses from all the companies and distributing weights to the criteria on which responses are received. For example Interbrand uses discounted values and Fortune Magazine uses company revenue to rank the companies. The approaches used by these companies to rank the companies is very robust and already in practice. But there is no such measure available in Indian automobile industry that captures the behaviour of the manufacturers as well as the suppliers. The outcome of the research work in terms of SRM index is an innovative tool which forms the cornerstones for the SRM strategies for Indian automobile sector by laying down the importance of the various factors and indicators as being perceived by Indian automobile manufacturers and suppliers.

Supplier's behaviour and preferences can be captured in various geographies that will be of great help and will give the multinational automobile manufacturers the new insights and the areas to work upon and will be result in the fruitful outcomes. The gaps have been identified between the perspectives of automobile manufacturers and suppliers. Proposed SRM index can be used as a strategic tool for capturing the supplier's preferences from time to time and designing and implementing newer marketing strategies for effective SRM. The proposed index will serve as a step by step guideline for the automobile manufacturers to check and measure the effectiveness of their SRM initiatives from time to time. For suppliers of different automobile organisations it can be used as an instrument to give their opinions about the SRM practices. The proposed SRM index can also be used as a tool for differentiation as it takes care of both the perspectives manufacturers as well as suppliers thereby creating a balancing situation between the two and can serve as the foundation for better and effective SRM practices leading to win-win situation for all the stakeholders of the business organisations. The proposed SRM index can serve as a diagnostic tool to identifying the problem areas as well as exploring new business opportunities in a much better way than even before.

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Review of agile supply chain implementation frameworks

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Abstract: The paper aims to identify major models and frameworks to implement agile supply chain (ASC), organises them in a structure so as to spot opportunities for future research, and provides industry practitioners a bird's eye view on how to bring agility in their supply chain. Published literature on this research was selected by searching database 'Business Source Complete' and 'ProQuest'. Among 430 articles, 44 were chosen for further analysis on the basis of evaluation on two broad criteria and then again rated on nine parameters to spot the gaps in current research. The paper suggests focusing on implementation layout, locates opportunities in the area of logistics and pricing, and recommends that more frameworks should target dyad level of impact. This paper reviews a sample of state of the art and classic research, spots gaps in the current work and provides clear guidelines for future research.

Keywords: agile supply chain; ASC; frameworks for agile supply chain; agile supply chain tools; responsive supply chain; implementation of agile supply chain; supply chain frameworks.

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1 Introduction

Today's dynamic business environment is continuously changing because of globalisation, regulatory changes, increasing intensity of competition, increasingly demanding customers, new information technology, and mergers and acquisitions (Wing et al., 2006). The uncertainties and unpredictability in the market are forcing everyone to be as much flexible and responsive as possible. Ramasesh et al. (2001) have categorised these unanticipated changes into three categories – product-market or output-related change, factor-market or input-related change, and transformation-process related change. The first change includes variation in the product demand, emergence of new products and customers, disappearance of old products and customers, etc. The second category includes emergence of a new raw material, loss of availability of old raw material, or newly discovered health or environmental hazards, etc. The final category takes into account emergence of a radically new process technology, imposition of new regulations, etc.

The need for agility is no more a point of debate for any organisation. Responsiveness and customisation have become the new strategic priorities in place of cost and conformance quality, which are now order qualifiers only. The paradigm shift has been from economy of scale to a contradictory complex strategic intent for economy of scale on cost in conjunction with economy of scope in customer fulfilment (Wadhwa et al., 2007). Ayyapan et al. (2010) summarised the need for agility as increased intensity of global competition, shorter product life cycles and reduction in lead time, diversification of demand, and effective utilisation of modern technologies.

Due to the evident urgent need of agility in different organisations, academicians and practitioners are working hard to come up with practical implementable models to introduce ASC. From last two decades, many conceptual, mathematical, and strategic models have been proposed but none has achieved success on field to a significant level. Research focusing on finding the way to approach agility is mostly related to manufacturing and mainly provides only the general guidelines to approach agility without supporting tools and techniques (Baramichai et al., 2007). Due to the apparent gaps in the academic work, there is a pressing need to collate all the relevant work done on ASC models so far, have an exhaustive review, identify the gaps and provide a roadmap for future research. This paper attempts to serve the same purpose for academicians and practitioners in their future endeavours. It brings out the gaps in research done on ASC so far, provides academicians the future direction of research and gives industry practitioners a bird's eye view on how to bring agility in their supply chain.

The paper comprises of seven sections. In the next section, the stepwise research methodology behind the literature survey is discussed. Section 3 provides review of the literature on definition of agility while Section 4 focuses on various definitions and characteristics of ASC. Section 5 presents the list of all the frameworks to implement ASC targeting various aspects of supply chain. The academic work done so far on ASC has been structured on the basis of two classification contexts. First classification context is based on the framework on supply chain drivers proposed by Chopra and Meindl (2001). Second context is based on the level of impact on supply chain (function, firm, dyad, chain or network) (Sachan and Datta, 2005). The section also reviews the frameworks on nine different parameters, brings out gaps in current academic work and proposes the areas which need attention. The final Section 6 concludes the literature review and suggests practical implication of the work done both for academicians and industry practitioners. Hopefully, this work will act as a helpful reference tool to researchers as well as industry practitioners in the field of supply chain management.

2 Research methodology

There are two main objectives of the paper. First, it aims to analyse and synthesise various models and frameworks to introduce agile supply chain (ASC) in an organisation. Second, it develops a detailed agenda to help guide future research in this area. A literature review seems to be a valid approach, as it is a necessary step in structuring a research field and forms an integral part of any research conducted (Easterby-Smith et al., 2002). This helps to identify the conceptual content of the field (Meredith, 1993) and guides towards further theory development (Srivastava, 2007). Research syntheses make invaluable contributions to the literature by examining the relevant theories, resolving conflicts in the literature, and identifying central issues for future research (Halvorsen, 1994).

The step by step methodology followed for the literature survey is shown below:

Step 1 To identify papers for the review, two online electronic journals were searched – 'Business Source Complete' and 'ProQuest' with keywords such as 'agile supply chain' and 'responsive supply chain'. 430 papers were identified in the process.

Step 2 During the study of 430 articles, 44 papers, which offered relevant models for achieving ASC, were selected for further research and analysis. Two broad criteria for evaluating relevance of ASC models were used – business process perspective and epistemological perspective. The 'business process perspective' focuses on the potential of contribution of conceptual models for improving a company's operations or decisions. The 'epistemological perspective' relates to the quality of conceptual models (Wolff and Frank, 2005). Three parameters were used to assess quality of the papers – abstraction, originality and reason. Abstraction ensured that the proposition should be applicable to generic phenomena and not specific cases. Originality ensured differentiation among the various models and Reason brought credibility to them. The papers were assessed thoroughly on these two criteria and selected after rigorous brainstorming.

Step 3 The frameworks selected were categorised on the basis of two different principles – supply chain drivers (Chopra and Meindl, 2001) and supply chain level of impact (Sachan and Datta, 2005). Classification context were selected and defined to provide a structure to the review and classify the material. The two principles have been presented in greater detail in Section 4.

Step 4 The selected papers were assessed further on the basis of nine parameters: addressing business process complexities, value creation for the organisation, coverage of all the affected areas of organisation, simplicity, understandability, flexibility, completeness, integration, and implementability. All the 44 papers were rated on the parameters after detailed study and discussion.

Step 5 As a result of the analysis, the gaps in the currents academic work done on implementation of ASC were located for each of the fields of supply chain area and guidelines for the conduct of future research were formulated.

Being the final objective of the research, the opportunities for further research in all the fields under supply chain area has been located as objectively as possible. This work integrates and takes forward the literature on implementation of ASC in various kinds of firms across sectors.

3 Literature on agility

Seeking solution to respond to the increasing rate of change and uncertainty in the business environment, previously sought in flexibility mainly provided by automation, led to the origination of agile thinking in the 1990s (Nagel and Dove, 1991; Goldman et al., 1995). The term got popular when in 1991, a group of researchers at the Iaccoca Institute, Lehigh University, investigated how the USA could regain its pre-eminence in manufacturing. Their report recommended adoption of an agile manufacturing paradigm. The report's notion of agile manufacturing involves competitive foundations, characteristics, elements, and enabling subsystems of agility. A pioneering work, this report was well received by many academics, practitioners, and government officials (Li et al., 2008). However, some scholars argued that the agility, as used in the Iacocca report was ill-defined, and they advocated more work to refine the concept (Burgess, 1994).

Holsapple and Jin (2007) identified agility as a key element in the science of competitiveness – allowing the firm to ride atop environmental mega-waves such as market dynamism, mass customisation, virtual organisations, continuous learning, pervasive computing, and socio-political diversity, while simultaneously being able to successfully cope with the inevitable environmental storms that often strike with little advance notice. Various definitions of agility have come till now but there is no consensus on any one of them. Following are some of the definitions which gained recognition with time:

- Fliedner and Vokurka (1997) defined agility as "the ability to successfully market low-cost, high quality products with short lead times and in varying volumes that provide enhanced value to customers through customization"

- agility is a business-wide capability that embraces organisational structures, information systems, logistics processes and in particular, mindsets (Pandey et al., 2009)
- agility is the ability of a supply chain to rapidly respond to changes in market conditions and customer demands thereby enabling the attainment of competitive advantage (Gunasekaran, 1999; Christopher and Towill, 2001; Yusuf et al., 2004; Vinodh et al., 2008).

Also, there are different views on components of agility in an organisation:

- Wixom and Watson (2007) mentioned that enterprise agility has two components. The first is being able to sense changes in the environment. The second is being able to respond to these changes. For example, an agile organisation is able to quickly detect when a competitor's new product is gaining market share and to respond by introducing a competing product.
- Speed, quality, flexibility and responsiveness are the key components of agile capabilities necessary to meet the unique needs of customers and markets (Baramichai et al., 2007).
- Zhang and Sharifi (2000) divide the agile capabilities into four major categories: responsiveness; competency; flexibility; and speed.

The general concept of agility has now been extended to supply chain agility with its components: speed and flexibility (Praveen et al., 2008).

4 Agile SCM

A rule of thumb (that varies by industry) is that on average 7% to 9% of sales revenue and fully 15% of the value-add in any given industry is eaten up by SCM (Reynolds, 2001). The objective of a supply chain is to deliver the right product, in the right quantity, in the right condition, to the right place, at the right time and for the right cost. Fisher (1997) proposes that innovative products should be matched with responsive supply chains and functional products should be matched with efficient supply chains. Fisher defines functional products such as groceries or office supplies as staples with long life cycles, and predictable, price sensitive demand and innovative products such as high-tech personal electronics have short life cycles and unpredictable, price insensitive demand. The focus on agility from the supply chain perspective emerged in the year 2001 and was first initiated by VanHoek et al. (2001).

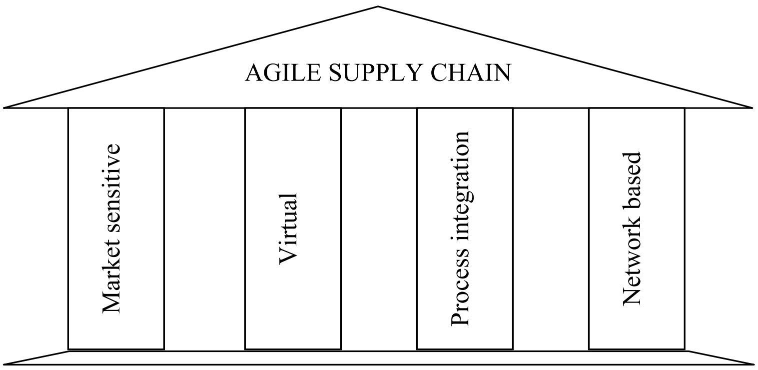
As in the case of agility, ASC has also been explained by many academicians but have failed to agree upon a standard definition. Baramichai et al. (2007) consider that

> "an ASC is an integration of business partners to enable new competencies in order to respond to rapidly changing, continually fragmenting markets. The key enablers of the ASC are the dynamics of structures and relationship configuration, the end-to-end visibility of information, and the event-driven and event-based management. An ASC is a key enabler for an enterprise's agility."

Ismail and Sharifi (2006) define Supply chain agility as the ability of the supply chain as a whole and its members to rapidly align the network and its operations to the dynamic and turbulent requirements of the demand network. Li et al. (2008) define supply chain agility as being the result of integrating a supply chain's alertness to changes (opportunities/ challenges) – both internal and environmental – with the supply chain's capability to use resources in responding (proactively/reactively) to such changes, all in a timely and flexible manner.

Hofman and Cecere (2005) identified speed, ease, predictability and quality as metrics of ASC. The first metric was described as the speed at which you can sense routine and unanticipated demand at consumption and effectively broadcast the signal for an intelligent supply chain response. Next, how easy it is for you to sense the change and move in response to it. The response has to be predictable – it should not be quickly sometimes and sometimes take a long time. Need to look at supplier quality, manufacturing quality, and quality of the order (and product) delivered to the customer. Iskanius (2006) has mentioned virtual enterprise/organisation, outsourcing, collaborative relationships, production planning, product design and service, customer focus, customer and market sensitivity as the characteristics of ASC. Christopher (2000) also identified a number of characteristics a supply chain must have in order to be truly agile as shown in Figure 1. They are market sensitivity (through the capturing and transmission of point of sale data), creating virtual supply chains (based on information rather than inventory), process integration (collaboration among buyers and suppliers, joint product development, etc.) and networks (confederations of partners linked together as opposed to 'stand alone' organisations) (Power et al., 2001).

Figure 1 Characteristics of an agile supply chain

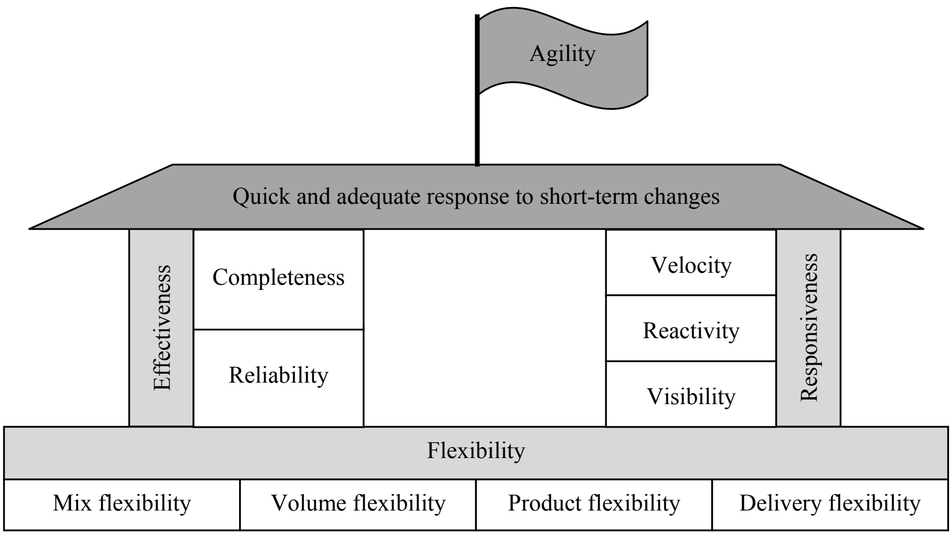


Source: Christopher (2000)

An ASC should be truly collaborative and should be able to provide benefits such as visibility, flexibility, speed, predictability, and scalability (Helo et al., 2006). Charles et al. (2010) developed house of supply chain agility (as shown in Figure 2) which summarises the main components, which enable the supply chain to be agile.

Leslie et al. (2001) proposed production system, market, logistics, supply, organisational, and information system as the six types of flexibility elements needed to represent the change capability in an enterprise supply chain. Pandey and Garg (2009) classified all the variables concerning ASC into 12 key enabler variables which have different level of dependency among each other and have different levels of agility driving power. These enablers include customer satisfaction, quality improvement, cost minimisation, delivery performance, understanding market volatility, JIT approaches, logistics planning and management, use of information and communication technology (ICT) tools, process integration, collaborative planning forecasting and replenishment (CPFR), buyer-supplier trust, and automation. In the next section, models proposed for each of these elements of supply chain have been collated.

Figure 2 House of supply chain agility by



Source: Charles et al. (2010)

5 Models for ASC implementation

The list of academic works, proposing models to implement ASC in an enterprise, is provided in Table 1 (for list of sources refer to the Appendix). To provide a structure to the research done on these papers, the frameworks listed in the table have been categorised on the basis of two different principles – supply chain drivers (Chopra and Meindl, 2001) and supply chain level of impact (Sachan and Datta, 2005). Supply chain drivers have been divided into two sub categories – logistical and cross-functional drivers. logistical drivers include facilities, inventory and transportation while cross-functional drivers include information, sourcing and pricing. Level of impact determines the level at which the frameworks and different models targets to create agility. Function, firm, dyad, chain and network are the five levels at which a model can be implemented.

Table 1 Models and frameworks to implement ASC

Driver	*Area*	*Framework/model*	*Level of impact*
Overall ASC design	Strategy/ design	Achieving agility in supply chain through simultaneous 'design of' and 'design for' supply chain [1]	Network
		Agile supply chain transformation matrix: an integrated tool for creating an agile enterprise [2]	Dyad
		An integrated model for the design of agile supply chains [3]	Firm
		Application of fuzzy QFD for enabling agility in a manufacturing organisation [4]	Firm
		Epilogue: moving forward with agility; entry level and move forward reaching practices [5]	Network
		Supply chain flexibility in an uncertain environment: exploratory findings from five case studies [6]	Firm
		A portfolio approach to supply chain design [7]	Chain
	Evaluating agile application	What is the buzz about moving from 'lean' to 'agile' integrated supply chains? A fuzzy intelligent agent-based approach [8]	Firm
	Mathematical model	Designing an integrated multi-echelon agile supply chain network: a hybrid Taguchi-particle swarm optimisation approach [9]	Network
		A network approach for modelling and design of agile supply chains using a flexibility construct [10]	Firm
		Advanced planning and scheduling with collaboration processes in agile supply and demand networks [11]	Chain
	Conceptual models	A unified model of supply chain agility: the work-design perspective [12]	Chain
		Essays in collaborative supply chains: Information sharing, event management and process verification [13]	Network
		Implementation and management framework for supply chain flexibility [14]	Chain
		Theoretical development and empirical investigation of supply chain agility [15]	Chain
	Organisational relationships	Effective quick response practices in a supply chain partnership: an Australian case study [16]	Chain

Table 1 Models and frameworks to implement ASC (continued)

Driver	*Area*	*Framework/model*	*Level of impact*
Logistical drivers	Continuous improvement	Continuous improvement and learning in the supply chain [17]	Firm
	Logistic services	Service-controlled agile logistics [18]	Function
Facility	Design for MTO and ATO SC networks	Response time reduction and service-level differentiation in supply chain design: models and solution approaches [19]	Firm
	Distribution channel design	An iterative approach for distribution chain design in agile virtual environment [20]	Chain
Inventory	Inventory management	A decision support system for improving performance of inventory management in a supply chain network [21]	Network
		Customer-aligned inventory strategies: agility maxims [22]	Function
		Improving materials management effectiveness: a step towards agile enterprise [23]	Firm
Cross-functional drivers	Organisation design	Foundations of supply chain agility: a work design perspective [24]	Chain
	Organisation culture	Organisational culture and supply chain strategy: a framework for effective information flows [25]	Firm
Information	Knowledge management	A framework for efficient use of electronic communication tools for knowledge transfer for agile offshore development of financial software applications in India [26]	Network
		Virtual teaming in the agile supply chain [27]	Network
		CALS: An enabling strategy for agile management systems [28]	Network
		Strategic decisions in supply-chain intelligence using knowledge: an analytic-network-process framework [29]	Firm
	Information system (IS)	A web-based logistics management system for agile supply demand network design [30]	Chain
		Virtual agent modelling of an agile supply chain infrastructure [31]	Chain
		A framework to develop multi-agent architectures for enterprises [32]	Firm
		A layered software architecture for the management of a manufacturing company [33]	Network
		Enabling the adaptive enterprise: using mobile technology [34]	Firm
		Cloud computing and SaaS; get your head in the cloud [35]	Network

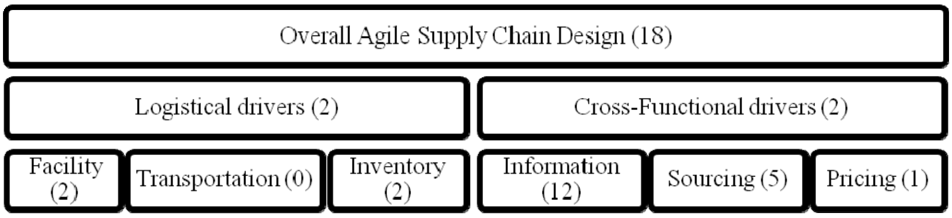
Table 1 Models and frameworks to implement ASC (continued)

Driver	*Area*	*Framework/model*	*Level of impact*
	Evaluating IS	Realising business value of agile IT applications: antecedents in the supply chain network [36]	Firm
	Software solutions	Top tips for enabling your 21st century SC from today's leading SC solutions providers [37]	Firm
Sourcing	Partner selection	A dynamic feedback model for partner selection in agile supply chains [38]	Function
	Collaboration	Quick response movement/strategy [39]	Firm
	Strategy sourcing	Fractal manufacturing partnership: exploring a new form of strategic alliance between OEMs and suppliers [40]	Dyad
	Sourcing tools	Value-based procurement [41]	Function
	Purchasing	The role of purchasing in the agile enterprise [42]	Function
Pricing	Dynamic pricing	Essays on dynamic pricing and operational flexibility in managing capacity and inventory of agile supply chains [43]	Firm
NPD	NPD	Managing global outsourcing to enhance lean innovation [44]	Network

The categorisation on the basis of first principle will identify the areas of supply chain which are relatively less explored. These areas need special attention of the academicians as well as industry practitioners to maximise the potential of supply chain agility. It is well proven fact that improving agility in one area of supply chain does not guarantee improvement in overall supply chain. The analysis will bring out the gaps, if any, in current research done and provide direction for future. Also, the compilation of the work done so far in any particular area will provide an overview for a comprehensive solution and help identify gaps during further research. The analysis done on the basis of level of impact will give an idea whether the models are sufficiently wide in scope.

The analysis on the frameworks has been done by reviewing all the frameworks on nine parameters – addressing business process complexities, value creation for the organisation, coverage of all affected areas, simplicity, understandability, flexibility, completeness, integration and implementability. These parameters have been selected as further breakdown of the evaluating criteria used for first level of papers selection – business process perspective and epistemological perspective, proposed by Wolff and Frank (2005). They ensure an objective review of the parameters and enables scientific process to conduct research on ASC implementation frameworks.

Figure 3 Number of models in each area of supply chain drivers



The areas in supply chain which can be targeted for introducing agility are shown in Table 1. Figure 3 shows the number of models proposed in each area. The gaps and the research opportunities in each area are mentioned below:

- *Overall ASC design* – This section comprises of a large number of models. These models are mostly strategic in nature and provide solutions for improving overall supply chain. The academic work in the area of design and conceptual frameworks are particularly commendable. On the flip side, these models lack the depth to be implemented smoothly. They touch the issues under building ASC comprehensively but do not provide the detail execution plan to make them usable for industry practitioners. The frameworks are good in understandability and flexibility, particularly the implementation and management frameworks by Kumar et al. (2006). However, most of them are conceptual in nature and lack focus on plan for implementability. Frameworks covering strategy and design of ASC implementation covers all areas under SC quite well and promises significant value creation for the organisation. Work done by Vinod and Chinta (2011) and Christopher and Towill (2001) are particularly commendable in this regard. However, there is a clear gap in integration of different areas of supply chain to ensure maximum benefit for the firm. The mathematical models have done a good job in terms integrating different fields of SC but the frameworks lack simplicity and are difficult to implement in an organisation. Finally, the conceptual models presented in this field are simple and flexible but lack the guidelines for implementability for a firm.

  There is a definite need for future academic work to focus more on implementable models, discussion on issues faced while implementation and sustainability of the models. Also, there is an opportunity in the area of integrating various aspects of SC in ASC implementation frameworks which will help a firm achieve its strategic objective in a better fashion. Another limitation in most of the research papers is lack of new idea, tool or concept to introduce agility into the supply chain. Most of the papers bring out the same tools under different categories or portfolios. The papers are good in terms of understandability, covering all the aspects of supply chain and ability to create value for the organisation. Also, all the papers fail to integrate the various tools for different areas of supply chain. All of them propose different methods for each area. The need is to develop a method which will comprehensively introduce agility in all the area of supply chain.

- *Logistical drivers* – Overall there has been little work done in the field of Logistics. This area needs great attention as it has a major and direct impact on supply chain. There is no model to provide comprehensive solution in the area of Transportation. There are specific tools such as RFID and mobile communication softwares but no business model to provide a comprehensive solution. Frameworks focusing on Logistics assure considerable value creation for the organisation and are flexible in terms of practical usage in the field. However, similar to the Strategic frameworks, they lack the depth for the firms to make it implementable. Also, the models cover only certain areas of logistics. There is a clear opportunity to build a comprehensive framework providing end to end agile logistics solution. Case studies discussing implementation of ASC in the firm might also fill the current gap in academic work.
- *Facility* – Models presented under this area seems to address the business process complexities in an enterprise well and has the potential to add considerable value to the organisation. On the flip side, they are mostly mathematical models which lack the simplicity and understandability due to their complex nature. There is an opportunity to build a business model around the mathematical tool and make it more user friendly for organisations. If simplified and made understandable, these models have great potential to be implemented on field and deliver great value to the organisations.
- *Inventory* – The research work done on inventory management has reached a mature stage now where all the aspects of a successful conceptual model have been addressed. The only area of improvement is to go a step further and integrate it with rest of the supply chain. The involvement of business process complexities into inventory management will make the upcoming models more robust and valuable for organisations.
- *Cross-functional drivers* – Frameworks on cross-functional drivers are simple and understandable for the corporate world but there is a need to develop a comprehensive model which includes all aspects of cross-functional integration. Present models target a few aspects only and are very specific in nature. Academic work from other areas such as value chain can prove to be a helpful guideline for future research in this field.
- *Information* – Academic work on Information system and management so far has focused a great deal on creating significant value for the organisation through increased responsiveness. The models has also evolved from the being a technical tool to a comprehensive business solution. However, there is a gap in the research on implementation plan, comprehensive picture of the issues faced and the solution to them. Interestingly, it comes as an opportunity both in the knowledge management and other Information System area for future academic work.
- *Sourcing* – Sourcing in ASC is still an evolving area. There is good amount of work that has been done in this field but there is lack of an innovative breakthrough model that brings a new perspective. Though the models proposed seem to be valuable for the organisation, they seem to lack integration with the rest of the supply chain, and addressing business process complexities on ground. There is significant focus given to building strategic alliance with the vendor partners but there is an opportunity for

a comprehensive model on how to build and sustain profitable relationships with responsive partners.

- *Pricing* – Simplicity and understandability comes out as a major gap on the research done on dynamic pricing. The mathematical tools need to be presented with the business perspective so that its effect and benefits can be made clearer.
- *New product development* – The academic work done in this area is considerably comprehensive and relevant. It promises value and seems to be implementable. The quality of work is satisfactory but there is a definite scope for new models to come up in this area to provide different perspectives to bring agility in this area.

Figure 4 shows the distribution of the number of models by level of impact. It can be easily deduced from the figure that the research is moving in the right direction where most of the models are focusing on inter-organisational level (network and chain). However, an interesting fact noted is that very few models are on the Dyad level. This level in easy to target and the models are relatively more implementable since collaboration between two organisations is comparatively easier than many firms in the supply chain. There can be more models structured at this level. It will help improve success ratio of ASC in various industries and will be an ideal stepping stone for next level of collaboration in a chain or network.

Figure 4 Number of models at different level of impact

Level of impact	Network	Chain	Dyad	Firm	Function
No. of models	11	10	2	16	5

6 Conclusions

There has been significant research in the field of ASC and attempts are being continuously made to develop comprehensive models for its definition, characteristics and implementation in industry. This paper focuses on the frameworks and models to implement ASC in industry. It presents the literature review of research done to implement ASC integrating the whole gamut of different fields in supply chain management. The list of models can be a guide for any industry practitioner or researcher before beginning to work in ASC. Any organisation willing to implement ASC can select models from the list suitable for its unique needs. After selecting the most suitable model(s), firms will find a direction to work and then can pursue it in greater details. From the review of 44 research papers, it is found that depth of research in different categories has been different. Since most of the models are strategic in nature, they provide a good understanding of ‘what is to be achieved’ but there’s still gap in the providing comprehensive solution for ‘how ASC is to be achieved’. Though many empirical studies (case studies, survey-based methods, etc.) have been carried out, they have not covered all the aspects of supply chain. Following are the findings of the analysis of the ASC models:

- Overall there is an urgent need to focus on the implementation layout of the conceptual models proposed in all the areas of supply chain. There is scope of case studies and surveys recording the experiences of different organisations while implementing ASC.
- There is a clear opportunity in the field of logistics to build a comprehensive framework providing end to end agile logistics solution as there has been insufficient contributions in this field considering its relevance in overall supply chain. Also, an implementable solution needs to be developed specifically in the area of transportation.
- Academicians should come up with innovative pricing models to support ASC which also present business perspective of the models. The current mathematical models do not promise much relevance on the field.
- More models should be developed targeting the dyad level as they are relatively easy to implement and has significant impact on the overall supply chain. The actual value of the delivery of a SC model can be obtained only if it is considered at a dyad level if not at network level.

It is suggested that findings of the paper should be taken as a guiding source for future research in the field of ASC. It will help academicians develop a comprehensive overview of ASC and avoid repetitive work. The paper provides industry practitioners a direction to work towards while implementing ASC in their firms. It is hoped that it helps making the learning curve of ASC steeper in the right direction.

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Appendix

Source of analysed models

No.	*Source*
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Source of analysed models (continued)

No.	*Source*
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Source of analysed models (continued)

No.	*Source*
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Source of analysed models (continued)

No.	*Source*
39	Christopher, M., Lowson, R. and Peck, H. (2004) 'Creating agile supply chains in the fashion industry', *International Journal of Retail & Distribution Management*, Vol. 32, pp.367–376.
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Analysing the barriers for the adoption of green supply chain management – the Indian plastic industry perspective

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Abstract: Industries are facing pressure to reduce pollution and become more eco-friendly due to increasing environmental awareness among customers and due to government regulations. Because of these reasons, industries are now adopting eco-friendly concepts to reduce pollution in the entire manufacturing process. The green supply chain management (GSCM) concept is a methodology to achieve a pollution free environment from procurement to after sales of products. This paper identifies the foremost barriers to implementing GSCM, ranked on the basis of significant factors in the Indian plastic processing industry. Thirty-eight barriers were identified from the available literature and through consultation with industry experts and academicians. They were statistically analysed on the basis of opinions from experts, using statistical tools like T-test, expectation values and analysis of variance (ANOVA).

Keywords: green supply chain management; GSCM; barriers; analysis of variance; ANOVA; plastic processing industry.

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Varun Baxi is a BTech graduate in the Department of Production Engineering from the National Institute of Technology, Tiruchirappalli, India. His research area is green supply chain management.

1 Introduction

Ramanathan et al. (2010) argued that economic progress and development bring both prosperity and environmental degradation to nations, especially when adequate measures to minimise harmful impacts are not implemented. Currently, the concept of GSCM is of tremendous importance to reduce hazards in an industrial environment. GSCM considers and emphasises environmental issues in supply chain management, in upstream and downstream business enterprises (Shipeng and Linna, 2011). It aims to promote sustainable development in industry and the environment to achieve a pollution-free environment. GSCM has been defined as "integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to consumers as well as end-of-life management of the product after its useful life" [Srivastava, (2007), p.54]. GSCM has focused on the entire supply chain activities like total quality management, lean supply chain management, reverse logistics, life cycle assessment and product stewardship (Srivastava, 2007; Hoejmose et al., 2012).

The plastic industry grew quickly as plastic materials development was exponential, compared to materials like textiles, wood, paper, glass, metals or those with higher hardness and stability (Bienk and Mikkelsen, 1997). Use of plastic does not deplete natural resources, but on the other hand is hazardous as it damages the environment through wastes generated in industrial operations. In India, plastic waste recycling in 2006–2007 was 47% of the total consumption and 60% of plastic waste generated. This is anticipated to be 69% and 35% respectively by 2029–2030 (Gupta et al., 1998; Mutha et al., 2005; Golghate and Pawar, 2012). Also, the total plastic waste collected and recycled in the country is estimated to be 9,205 tonnes per day (approximately 60% of total plastic waste) with another 6,137 tonnes remaining uncollected and which litters the environment (*Times of India*, 2013).

Other developing countries like China already started to investigate environmental management practices in different sectors which is summarised in the literature review section. But, in India, there was a less research, and awareness of environmental management initiatives compared to China. Also, the Confederation of Indian Industries (CII) reported that Indian industries needed to improve infrastructure of supply chain management by adopting recent management concepts like GSCM, SSCM. Because of these reasons, this study is essential in the Indian scenario. This study will be a benchmark for analysing the barriers to GSCM adoption in plastic industries and will also help get more customers by adopting and maintaining the GSCM concept in plastic industries which ultimately will ensure their a green image in the market, aided by stringent government regulations and customer pressure for environmental friendly products and activities.

This paper prioritises the top ten dominant barriers by statistical analysis techniques in the adoption of GSCM in the plastic processing industry. From literature and discussion with industry experts, 38 barriers were identified for implementation of GSCM. Statistical technique was used to rank the 38 recommended barriers.

2 Literature review

2.1 Green supply chain management

With rapid change in the global manufacturing scenario, environmental and social issues are gaining importance in managing business. Due to environmental deterioration and global warming, public concern over sustainability and are demanding environmental friendly products. Increasing awareness of the environment throughout the world (Zhu and Sarkis, 2006), and the overall conditions of natural resources and the environment, made many countries adopt regulations like restriction of hazardous substance in electrical and electronic equipment (RoHS), waste electrical electronic equipment (WEEE), eco-design requirement for energy using product (EUP), etc. (Chen et al., 2012). Miocevic and Crnjak-Karanovic (2012) state that key partner relationships must be considered the source of competitive advantage and a platform for value differentiation (Ulaga and Eggert, 2006) in the supply chain context from previously published articles. Azevedo et al. (2013) proposed an integrated assessment model for green and resilient practices in automotive companies and the related supply chain by using the Delphi technique. They also focused on the link between the supplier and manufacturer. Environmental orientation was long regarded a core concept in the study of environmental management (Chan et al., 2012). The study of this topic is necessary to provide better help to plastic processing organisations on GSCM principles. GSCM improves process and product performance, according to the requirements of the environmental regulations (Hsu and Hu, 2008). Hoejmose et al. (2012) argued that GSCM is often associated with highly visible companies and firms within consumer-focused industries. As such, GSCM has partially been led by the development of consumer awareness on environmental issues. Chan et al. (2012) proposed a model to investigate the relationship between environmental orientation, GSCM activities (green purchase, customer cooperation and investment recovery) and corporate performance through the 194 responses from foreign invested enterprises operating in China. These manufacturing firms have realised that their current manufacturing process would be ineffective, if they did not implement GSCM. Which is why an extensive study is being performed to integrate GSCM practices in various industries and commercial sectors?

According to the researcher, GSCM is described at three levels: green procurement; green manufacturing and green distribution.

As per Ahi and Searcy (2013), statement from in-depth definitions, GSCM were generally narrowly focused than those for SSCM (economic, environmental and social) and emphasised the characteristics of environmental, flow, and coordination focuses. Though some definitions of SSCM overlap definitions of GSCM, it is argued that SSCM is essentially an extension of GSCM. In a literature review, there is no work that analyses obstacles (barriers) for environmental management practices (GSCM) in an Indian plastic industry context. Due to this reason, the problem of this study "analyzing the barriers for GSCM adoption" is undertaken generally. In the future, environmental management practices will be more specific in terms of economic, environmental and social perspectives (SSCM). Presently, plastic industries are starting to adopt GSCM practices, but are struggling to expedite activities due to insufficient analysis. Because of these reasons, SSCM investigation will be undertaken in the future.

2.1.1 Green procurement

Lambert and Cooper (2000) defined "Green procurement as the process of giving due consideration to the sustainability issue while undertaking, procurement of raw material, in addition to traditional purchasing criteria of cost delivery and time". Abdallah et al. (2012) developed a mixed integer programme for a carbon-sensitive supply chain that reduces emissions all over the supply chain by initiating green procurement. Plastic industries are of two types:

1 upstream plastic industries

2 downstream plastic industries.

Raw material for most downstream plastic industries is products of the upstream plastic industries, i.e., higher polymers. Generally, raw material is procured as plastic powder through various modes of transport. Purchasing of upstream and downstream industries is made by considering the environmental impact. Recycling packaging materials used in transportation like pallets will benefit the environment, thereby following the green procurement process.

2.1.2 Green manufacturing

Green manufacturing is defined as "production processes which use inputs with relatively low environmental impacts, which are highly efficient, and generate little or no waste or pollution" (Atlas and Florida, 1998). Inventory material constitutes measured batches of raw material used to produce a definite quantity of inventory. Defective inventory can be recycled and reused, which reduces wastage. Hence, to ensure green manufacturing, these processes must be made greener and Eco friendly.

2.1.3 Green distribution

Finished plastic products need to be distributed to the consumer. Green distribution includes green packaging and green logistics. Packaging characteristics like size, shape, and materials impact distribution due to their effect on the product's transport characteristics. Better packaging, along with rearranged loading patterns can reduce material usage, increase warehouse space utilisation, and trailer, and reduce the amount of handling required (Ninlawan et al., 2010).

2.2 GSCM in plastic industry

Plastic solid waste (PSW) presents challenges and opportunities to societies irrespective of their sustainability consciousness. From the first industrial scale production of synthetic polymers (plastics) in the 1940s, production, consumption and waste generation rate of PSW has increased considerably. Plastics are used in many ways (Salem et al., 2009). Municipal solid waste (MSW) in India contains 1 to 4% weight of plastic waste. India's plastic waste recycling is the highest (60%) in the world compared to other countries (China 10%, Europe, 7%, Japan 12%, South Africa 16%, and USA 10%) (Sikka, 2005). Plastic waste is utilised widely in film packaging and in polyethylene carry bags, followed by blow moulded containers and broken and discarded moulded items. From greenhouses, mulches, coating and wiring to packaging, films, covers, bags and containers, it is only reasonable to find a considerable amount of PSW in the final stream of MSW.

Golghate and Pawar (2012) felt that managing operations at one life stage of plastic film will not minimise environmental burden. Also strategies to manage the environmental burden at sourcing and manufacturing stages alone will not reduce environmental burdens at the end-of-life stages and vice versa. Thus, there is a need to integrate life stages to evaluate the environmental burden. So, a total approach like GSCM is required (Golghate and Pawar, 2012). The plastic industry has tremendous potential for the near future. It is called the sunrise industry due to its scope in the country. This industry has made significant achievements ever since it made a modest but promising beginning by commencing production of Polystyrene in 1957. Bose and Chatterjee (2008) mention the producers of alternate packaging forms, like aluminium, PET, HDPE, etc., which are also threatened by the substitute of cans for plastic packaging.

Min and Kim (2012) found 519 articles from scholarly journals that fit the definition of GSCM, between 1995 to December 31, 2010. Of these 519 articles, only a few were from the Indian perspective (Gandhi et al., 2006; Mudgal et al., 2010; Diabat and Govindan, 2011). Recently, Muduli et al. (2013) analysed the barriers in the mining industry as a case study for identifying factors and sub-factors for the adoption of GSCM using graph theory and matrix approach (GTMA) to quantify the adverse impact of barriers on GSCM implementation.

2.3 Research gap

In India, there are huge small medium enterprise (SMEs) for manufacturing products and services to customers. Due to pressure from customers and regulations, companies were getting greater awareness about ecological management adoption (Mathiyazhagan et al., 2013; Diabat and Govindan, 2011; Mudgal et al., 2010; Toke et al., 2012; Govindan et al., 2013; Mathiyazhagan and Haq, 2013). Also, they are positioned to think of integrating environmental friendly activities in traditional operations, like purchasing material, designing the product, etc. Presently, researchers concentrate on research on

GSCM (Toke et al., 2012; Gupta et al., 1998; Muduli et al., 2013) and analyse reasons for adoption of GSCM in traditional GSCM in Indian perspectives. Following this, SMEs has started to think and a few SMEs have started to adopt this concept, but they struggle to adopt it fully due to many barriers. Many barriers ensure a negative impact to engaging in GSCM adoption. Industries must know which barriers are the biggest obstacles. In this manner many researchers undertake research in the automotive, electrical and electronics and other industries (Mathiyazhagan et al., 2013; Diabat and Govindan, 2011; Mudgal et al., 2010; Diabat et al., 2013) but there is no research from the perspective of Plastic processing industries in India. There is a big gap in the literature which ensures tremendous scope in this area.

Initially, Mudgal et al. (2010) conducted a survey to prioritise the barriers for GSCM adoption through an extensive questionnaire to more than 100 industries in different sectors with the help of ISM. Also, Luthra et al. (2011) have investigated essential barriers to adopting GSCM in the Indian automotive sector context through an ISM approach. Toke et al. (2012) also prioritised and evaluated critical success factors for GSCM adoption in the Indian manufacturing sector with the help of analytical hierarchy approach (AHP). Mathiyazhagan et al. (2013) investigated the relationship between the 26 barriers and identified the most influential barriers for the adoption of GSCM in the automobile industry with the help of ISM from an Indian perspective. Similarly, Muduli et al. (2013) has analysed the factors and sub-factors for the GSCM adoption in the Indian mining industry with the help of GTMA.

For this reason, we selected this problem which fills the research gap as it is evident that there is no work to prioritise the top ten barriers to implementing GSCM in the Indian plastic industry. This research analysed factors which are barriers to implementing GSCM. A survey was undertaken by consulting experts from academia and industry to identify barriers. Those with more than ten years' experience in purchasing, quality and SCM department and environmental management were considered experts.

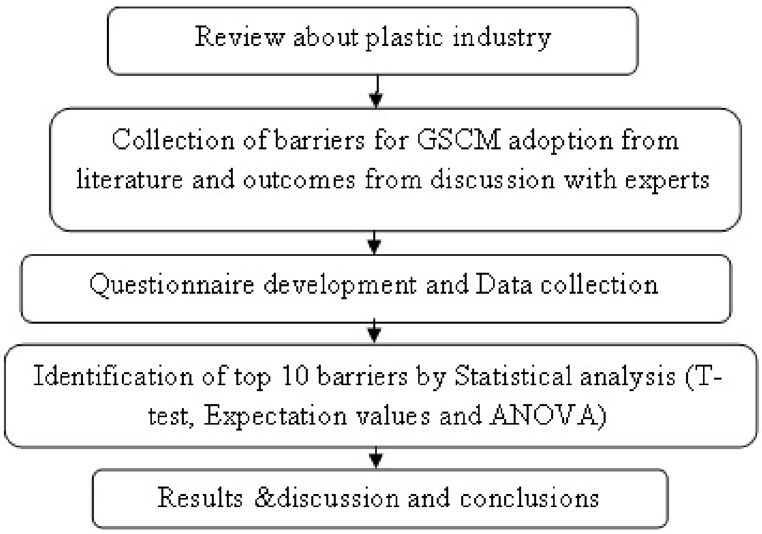
3 Problem description

Due to the emergence of mega-development like improved societal concerns about ecological deterioration and regulators' strict environmental control over business activities, companies face tremendous pressure to adopt pollution free environment concepts (Chan et al, 2012; Diabat and Govindan, 2011; Muduli et al., 2013). The plastic processing industry is a prominent industry in India, but no work has been done to integrate GSCM practices in this industry. To bridge this gap, this research targeted the plastic processing industry. Use of plastic in India, including recycling, will be 26,600 metric ton by 2030 (Mutha et al., 2005; CRISIL, 2007). The consumption of plastics in India for packaging is about 42% due to its sustainability over other materials (Shashvat, 2008). Packaging plastic consumption constitutes 37% of plastic films (Mutha et al., 2005). Plastic processing is a major hazard to the environment. Due to its operation in supply chain management, industries need to reduce negative environmental impact and so want the supply chain to be green. Hence, identification of barriers or factors that are a hindrance to the green revolution is the first step to bring about a change in the existing system. Application of GSCM is dominated by the Industry type, and demographic location and the supply chain model followed in that Industry. Zhu and Sarkis (2006) concluded that different industries had different opinions about each factor for GSCM adoption. It is varied, based on their environment and management systems. The scope of the study is vast, as identification of barrier facilitates the study for the eradication of barriers leading ensuring that the plastic industry is more eco-friendly.

3.1 Research design

Through the literature survey, consultation with academicians and interviewing professionals in the plastic processing industry, prominent barriers that persist in this industry were identified and categorised. Figure 1 shows the methodology followed in this study. This methodology and their results are discussed in the following sections.

Figure 1 Methodology of the barrier analysis



3.2 Barriers for GSCM adoption

One way of addressing the bane of plastic and plastic processing industries is by trying to minimise the negative impact on the environment caused by processing industries. By consulting and interviewing about 30 experts in the plastic processing industry, 15 barriers were identified and through a literature survey, another 23 were located. Thus, a total of 38 barriers was identified and grouped into seven categories based on their similarities. The seven categories and the 38 barriers are given in Table 1.

Table 1 Description of barriers with literature sources

	Barriers	*Sources*
Knowledge – K		
1	Lack of government regulations and legislation regarding the environmental responsibility of the company (K1)	Mudgal et al. (2010)
2	Lack of awareness on the benefits of going green (K2)	Walker et al. (2008)
3	Lack of attention about environmental impact of the industry through its operation (K3)	Shen and Tam (2002)
4	Feeling of 'out of responsibility zone' in caring for the environment (K4)	Shen and Tam (2002)
5	Biodegradable product life time is low (K5)	OCB
	Technological constraints (that can be overcome) – TCO	
6	Outdated technical support system pertaining to information and knowledge related to sustainable operations (TCO1)	Perron (2005)
7	Lack of technology to adopt a green supply chain (TCO2)	Perron (2005)
8	Inefficient disposal technology (TCO3)	OCB
9	Insufficient reverse logistic resources (TCO4)	Mudgal et al. (2010)
10	Lack of inappropriate environmental performance metrics (TCO5)	Mudgal et al. (2010)
11	Lack of high level automation (TCO6)	OCB
12	Lack of flexibility to switch over to a new system (TCO7)	Revell and Rutherfoord (2003)
	Technological constraints (that cannot be overcome) – TCCN	
13	Incapability to design a product to reach existing design standards (TCCN1)	Revell and Rutherfoord (2003)
14	Low level of supply chain integration (TCCN2)	OCB
15	Material used in the product is not easily biodegradable (TCCN3)	OCB
16	Inventory handling and Transportation causes environment impact (TCCN4)	OCB
	Financial – F	
17	High initial Capital cost for the industry to go green (F1)	AlKhidir and Zailani (2009)
18	Difficulty in accessing external financial support (F2)	Perron (2005)
19	Lack of access to funds for environmental projects (F3)	OCB
20	Very high recycling cost (F4)	OCB
21	Biodegradable raw material if used, increases material handling and transportation cost manifold (F5)	OCB

Note: OCB – our contribution barrier.

Table 1 Description of barriers with literature sources (continued)

	Barriers	*Sources*
	External support factors – ESF	
22	Insufficient external resources like third parties to collect recycled materials (ESF1)	OCB
23	Insufficient human resources to meet the need of changed and green technology if adapted (ESF2)	Perron (2005)
24	Lack of cooperation from suppliers to environmental issues (ESF3)	Mudgal et al. (2010)
25	Inflexibility of customers to accept new products (ESF4)	Mudgal et al. (2010)
26	Small market for product (ESF5)	Mudgal et al. (2010)
27	Adoption and maintenance of reverse logistic process in industries being tricky (ESF6)	Beamon (1999) and Mudgal et al. (2010)
	Internal support factors – ISF	
28	Insufficient integrated information system support (ISF1)	Mudgal et al. (2010)
29	Insufficient IT support (ISF2)	Mudgal et al (2010)
30	Communication Gap between management and shop floor workers, causing barriers to flow of information (ISF3)	OCB
31	Toxic gases and chemical effluents are released during production (ISF4)	OCB
	Management – M	
32	Unwillingness to take risks, fearing product failure (M1)	Revell and Rutherfoord (2003)
33	Management fears failure of implementing green supply chain that can lead to loss of competitive advantage (M2)	OCB
34	Resistance of top management, regarding time to implement green supply chain (M3)	OCB
35	Organisation unwilling to invest initially in GSCM implementation (M4)	Hsu and Hu (2008)
36	Return on investment (ROI) period obstructs implementing GSCM (M5)	CB
37	Lack of corporate social responsibility (M6)	Mudgal et al. (2010)
38	Restrictive company policies towards product/process stewardship (M7)	AlKhidir and Zailani (2009)

Note: OCB – our contribution barrier.

3.3 Questionnaire development and data collection

Once all barriers were categorised, a questionnaire was framed and sent to 75 professionals from 52 plastic processing industries in South India, producing various plastic products. They included Extrusion, Injection moulding and Blow Moulding operations. The details of GSCM and the purpose of this research were explained to professionals through documents. Communication for questionnaires was primarily by e-mail and personal meetings. They had to rate the barrier based on its prominence on a scale of 1 to 5.

5 strongly agree

4 agree

3 neither agree nor disagree

2 disagree

1 strongly disagree.

A total of 21 professionals enthusiastically replied to the questionnaire. As the reply came out, merely 28%, which is more than the required 20% were considered for the research calculations (Malhotra and Grover, 1998). As all professionals were individuals with vast experience in the plastic Industry, their rating of barriers showed a clear perspective of the existing situation. Professionals cannot be categorised and thus are considered equal and their answers given equal weightage. The responses for the given barriers were analysed by calculating the expected value of the population at 95% of confidence level of 20 degrees of freedom. The mean and the standard deviation of all the replies for each barrier were determined. Then, the expectation value of 21 replies was calculated. Many plastic industries started to analyse environmental practices with the help of their company SCM team members. But, they were less interested to share activities related to environmental issues with academicians and researchers. Due to this reason, we received replies from only 52 plastic processing industries.

4 Finding

4.1 Expectation test

According to expected values, barriers were ranked in descending order. A barrier with high expected value is more prominent on a population level. Table 2 details the calculations performed. The top ten barriers were identified for implementing GSCM. The barriers impact was checked according to the classes they were classified in, to analyses which had more impact. For this, analysis of variance ANOVA (one way) was used to first confirm if there was a difference in the impact caused by classes to which the barriers were clubbed. Table 2 shows the summary of the class, i.e., the class and the expected mean value of each element of that class. From the table, it is seen that the barriers in the class are not equal in number. So, ANOVA with unequal class interval was applied. Then the mean for each class was calculated and ANOVA applied to confirm the existence of significant difference in the mean of the class. The mean of the class signifies the average impact of all barriers clubbed in that particular class.

Table 2 Details of the expectation test

Barriers		*Mean*	*SD*	*Expected mean of population*	*Rank*
		Knowledge K			
1	K1	2.8095	0.8728	3.1461	24
2	K2	2.6667	0.9660	3.0392	26
3	K3	2.3809	1.2440	2.8607	27
4	K4	3.1428	0.9102	3.4939	16
5	K5	3.1428	0.9102	3.4939	16
		Technological constraints (that can be overcome) TCO			
6	TCO1	3.3809	0.7400	3.6663	11
7	*TCO2*	*4.1904*	*0.8728*	*4.5271*	*1*
8	*TCO3*	*3.8095*	*0.8728*	*4.1461*	*2*
9	*TCO4*	*3.6190*	*1.0235*	*4.0137*	*4*
10	*TCO5*	*3.6190*	*0.7400*	*3.9044*	*6*
11	TCO6	3.0952	1.0442	3.4979	15
12	TCO7	3.1428	0.9102	3.4939	16
		Technological constraints (difficult to overcome) TCCN			
13	TCCN1	2.0476	1.1608	2.4953	35
14	TCCN2	2.9047	0.7003	3.1748	23
15	*TCCN3*	*3.3334*	*1.1972*	*3.7950*	*10*
16	TCCN4	2.9523	0.8047	3.2627	19
		Financial – F			
17	*F1*	*3.4285*	*1.0281*	*3.8250*	*9*
18	F2	2.8571	1.1084	3.2846	21
19	F3	2.7619	0.9436	3.1258	25
20	*F4*	*3.5238*	*0.8728*	*3.8604*	*8*
21	*F5*	*3.7142*	*0.8451*	*4.0402*	*3*
		External support factors – ESF			
22	ESF1	2.1428	1.0141	2.5339	34
23	ESF2	2.3334	1.0645	2.7438	30
24	ESF3	2.4285	1.0281	2.8250	28
25	ESF4	3.3334	0.7302	3.6149	12
26	ESF5	2.1904	0.9283	2.5485	33
27	ESF6	3.0476	1.2835	3.5426	14
		Internal support factors – ISF			
28	ISF1	1.8095	0.7496	2.0986	37
29	ISF2	2.1428	1.0623	2.5525	32
30	ISF3	2.8095	1.0304	3.2069	22
31	ISF4	2.3809	1.0235	2.7756	29

Note: Confidence level 95% DOF 20 p = 1. 724718.

Table 2 Details of the expectation test (continued)

Barriers		*Mean*	*SD*	*Expected mean of population*	*Rank*
			Management – M		
32	M1	3.6190	0.8646	3.9525	5
33	M2	3.1428	0.7270	3.4232	19
34	M3	3.5231	0.9283	3.8818	7
35	M4	3.2500	0.7863	3.5532	13
36	M5	2.9523	0.9206	3.3074	20
37	M6	2.2380	0.8309	2.5585	31
38	M7	1.9523	0.4976	2.1442	36

Note: Confidence level 95% DOF 20 p = 1. 724718.

Table 3 Summary of the classes

Class	*K*	*TCO*	*TCCN*	*F*	*ESF*	*ISF*	*M*
	2.8095	3.3809	2.0476	3.4285	2.1428	1.8095	3.6190
	2.6666	4.1904	2.9047	2.8571	2.3334	2.1428	3.1428
	2.3809	3.8095	3.3334	2.7169	2.4285	2.8095	3.5238
	3.1428	3.6190	2.9523	3.5238	3.3334	2.3809	3.25
	3.1428	3.6190		3.7142	2.1904		2.9523
		3.0952			3.0476		2.2380
		3.1428					1.9523
Sum	14.1428	24.8571	11.2380	16.2857	15.4761	9.1428	20.6785
Mean	2.8285	3.5510	2.8095	3.2571	2.5793	2.2857	2.9540

ANOVA was carried out between classes as usual. Table 4 gives the detailed statistical parameters to carry out ANOVA between classes. A significant number of barriers clubbed in a particular class were calculated, where the sum and the average of the values of the expected mean values of barriers was mentioned. Variance is the root of the sum of the squared value of the deviation of the entries in the class about the mean value of the class.

Table 4 Statistical parameters for ANOVA

Groups	*Count*	*Sum*	*Average*	*Variance*
K	5	14.1428	2.8285	0.1061
TCO	7	24.8571	3.5510	0.1480
TCCN	4	11.2380	2.8095	0.2947
F	5	16.2857	3.2571	0.1786
ESF	6	15.4761	2.5793	0.2425
ISF	4	9.1428	2.2857	0.1768
M	7	20.6785	2.9540	0.4010

ANOVA results were found out through regular ANOVA calculation and are summarised in Table 4. Table 5 shows the ANOVA calculation performed on the classes. ANOVA considers variation source within a class and between classes with the cumulative effect of the variation being judged to conclude whether variation in the mean values is significant. SS value shows the square of the summation of deviation within and between classes. MS values for both sources of variation are obtained by dividing SS values with the degrees of freedom. The 2 MS values are divided into the F-value which is compared to table value 'F-critical'. If obtained F-value is greater than that table value, the variation is significant.

Table 5 ANOVA results

Source of variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F-critical*
Between classes	5.7403	6	0.9567	4.2001	0.0033	2.4094
Within classed	7.0612	31	0.2277			
Total	12.8015	37				

Later, pairwise T-test analysis with uncommon variance was carried out to find which classes had mutually insignificant variation in impact caused by GSCM implementation. A total of 21 pairs were obtained between seven classes. The T-test was carried out at 95% LOS. T-value obtained and critical table values at the given LOS and degrees of freedom were compared. The pair with the T-value greater than critical value has significant differences in their impact as a barrier. Table 6 is a tabular representation of T-values obtained by conducting the T-test and their table values in the pairs with significant difference are highlighted.

Table 6 Details of T-test

Pair	*T-value*	*Table value*
K vs. TCO	*3.5096*	*2.2281*
K vs. TCCN	0.06182	2.5705
K vs. F	–1.7956	2.3060
K vs. ISF	2.1220	2.4469
K vs. ESF	1.0036	2.2621
K vs. M	–0.4479	2.2621
TCO vs. TCCN	2.4077	2.5705
TCO vs. F	2.0477	2.5705
TCO vs. ISF	*4.9490*	*2.4469*
TCO vs. ESF	*3.9157*	*2.2621*
TCO vs. M	2.1314	2.2281
TCCN vs. F	–1.3531	2.4469
TCCN vs. ISF	1.5254	2.4469
TCCN vs. ESF	–1.3531	2.4469
TCCN vs. M	–0.3994	2.3646
F vs. ISF	*3.4354*	*2.3646*
F vs. ESF	*2.4559*	*2.2621*
F vs. M	0.9936	2.2281
ISF vs. ESF	1.0093	2.3646
ISF vs. M	1.0093	2.3646
ESF vs. M	–1.1987	2.2009

Later, classes were rated according to the mean value of their influence, i.e., classes which had different impacts.

5 Discussion

For environmentally responsible manufacturing, GSCM, and correlated principles have become essential strategies for companies to attain profit and gain market share by reducing environmental impact and improving their efficiency (Büyüközkan and Çifçi, 2012). The results of the study were discussed in the following sections.

Table 2 shows details of the expectation test carried out on 38 barriers identified by consulting professionals and referring to literature. Table 2 reveals considerable difference in the impact of various barriers. The top ten barriers are as follows:

5.1 Lack of technology to adopt a green supply chain

With an expectation value of 4.5271, technological insufficiencies are a major barrier. For implementing GSCM, technological capability required in various practices like ‘Procurement, Process, Logistics, etc.’, for making the supply chain Green is insufficient according to experts. Thus, industries demand a technological revolution to minimise environmental impact caused by the plastic industry. Regarding plastic industry, technological backwardness is attributed to lack of eco-friendly machinery, which process plastic without emissions or absorb emissions from plastic processing, technology, which raises durability/strength of bio- plastics or eco-friendly materials that replace traditional plastics.

5.2 Inefficient disposal technology

As material in wastage/end product in the plastic processing industry is a plastic polymer (LDPE, HDPE, PP, PVC, etc.) and as most are non-degradable, they cannot be disposed by burning and traditional disposal techniques. Hence this barrier has a high expectation impact value of 4.1461.

5.3 Biodegradable raw material if used, increases material handling and transportation cost many fold

Material handling has to ensure that the material is perishable to maintain material merit. Biodegradable raw material has a limited life span, and so extra care has to be taken in handling and transportation. This leads to increased production cost, due to which enterprises are reluctant to use biodegradable material. This factor appeared 3rd among the top ten barriers with a value of 4.0402

5.4 Insufficient reverse logistic resources

Reverse logistics stands for all operations related to products/materials reuse. It is “the process of planning, implementing, and controlling an efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. More precisely, reverse logistics is the process of moving products from their final destination for capturing value, or proper disposal. As the end product reaches out to a wider range of consumers, it is difficult to carry out reverse logistic activities. With regard to the plastic industry, as processed plastic is in the form of packaging bags, decorative objects, spare parts for automobiles and other machinery, the end product reaches the market widely. Thus, it is difficult to accumulate products at the last stage of the life cycle to recycle and to re-use them. This is due to the lack of reverse logistic resources. Thus, it is a prominent factor with an expected value of 4.0137

5.5 Unwillingness to take the risk due to fear of product failure

There always exists the possibility of product failure due to various factors. So, companies generally fear replacing an existing product with a new one, or replacing existing technology with something new. As design change may change the physical, chemical or operational characteristics of the product, there is chance that the consumer will not accept the change. It may hike processing cost which will ultimately lead to a rise in the product cost and lead to product failure. It is an important barrier with a value of 3.9525.

5.6 Lack of inappropriate environmental performance metrics

With the 6th highest value of 3.9044 amongst 38 barriers, it is an important barrier, justified by the fact that the plastic industry in India is disorganised, and most companies lack appropriate methods to measure the impact caused by the processes on the environment. For example, wastage of the plastic industry contributes to a major percentage of the solid waste in the country. But, the industries lack sufficient technology to measure the negative impact caused by plastic industry processes on the environment.

5.7 The resistance of top management fearing the time to implement green supply chain

Time is a precious resource, from the perspective of the top management. Time has always been an important parameter in decision making and is reflected from the value which was obtained for the barrier (3.88) and thus is the 7th most prominent barrier. For implementing GSCM a major revolution in technology, Infrastructure, Human resources, and product design is required. This involves a huge amount of time to develop facilities. Generally management is unwilling to divert time for this. This leads to possible loss of grip on the existing market.

5.8 Recycling cost is very high

Some polymers used in the plastic industries are difficult to recycle e.g. PVC. Thus, due to high recycling cost, industries avoid going for plastic recycling. Currently, only about 3.5% of plastics are recycled. Also, recycling requires careful sorting of plastics for, e.g., polyvinyl chloride (PVC) bottles are hard to reuse. But one stray PVC bottle in a melt of 10,000 PET bottles can ruin the entire batch. Equipment for sorting plastics is lacking. Most recyclers still sort plastics by hand. This is expensive and time consuming. Thus, this barrier reflects a high value of 3.8664

5.9 High initial Capital cost for changes in the industry to go green

This is attributed to the infrastructure development and other technological changes necessary to make the supply chain green. Capital is required for the training of labour and staff and also to develop new designs and procure improved machinery and infrastructure. High capital cost is required by the management to convert traditional activities to green activities. This is also a reason that experts gave an important rating of 3.8250.

5.10 Material used in the product is not easily biodegradable

With relatively high value of 3.7950, this barrier is rated as the 10th most effective in the implementation of GSCM of the 38 barriers. As the material in plastic processing is a plastic polymer (LDPE, HDPE, PP, PVC, etc.) and as most are non-biodegradable, they lead to accumulation of solid waste. Also, traditional disposal techniques cause environmental pollution through emission of hazardous gases. It is one of the main reasons for a negative environmental impact by plastic industries.

Later, the classes of the 38 barriers were analysed by ANOVA to see if there was significant difference regarding hindrance for the implementation of GSCM. This table gives details of the classes and the mean values of barriers clubbed in a particular class. The mean of the particular classes is also mentioned.

From the table, the value of F (critical) is less than the F-value that is calculated. It is concluded that, there exists a difference in the hindrance caused by barriers clubbed in various classes for the implementation of GSCM. ANOVA tests for consistency values of the means of the classes infer that it cannot be concluded if the values of all the classes differ from each other or only particular classes differ in the values. This is checked by performing the pairwise t-test between all classes. This yielded five pairs of classes that vary significantly in their level of hindrance to GSCM implementation.

1 *Technological constraints (removable) and knowledge* with t value calculated as –3.5096 against that of the table value for 5% level of significance and 10 degrees of freedom equal to 2.22.

2 *Technological constraints (removable) and external factors* with t value calculated as 3.91 against table value for 5% level of significance and 9 degrees of freedom equal to 2.26.

3 *Technological constraints (removable) and internal factors* with t value calculated as 4.949 against table value for 5% level of significance and 6 degrees of freedom equal to 2.44.

5 *Financial and external factors* with t value calculated as 2.455 against table value for 5% level of significance and 9 degrees of freedom equal to 2.2621.

6 *Financial and internal factors* with t value calculated as 3.43 against able value for 5% level of significance and 7 degrees of freedom equal to 2.36.

Thus, it is seen that highest impact is by the barriers clubbed into *technological constraints that can be removed with a mean of 3.55102041* and there is no significant difference between the impact of *financial constraints and technological constraints that* *can be removed*. Thus, it can be comfortably assumed that both classes have the same maximum impact as a hindrance to GSCM implementation.

6 Conclusions and implication

Recently, GSCM has given special attention to fulfil employee's expectations of industries and government firms realising GSCM benefits, like cost reduction, improved product and process quality, risk reduction and improved financial performance (Hoejmose et al., 2012). Ecological damage can be minimised if all production stages are designed to be environmentally sustainable. With requirement and awareness of environmental protection, increasing daily, it is imperative that plastic processing industries which play an important role in a country's economy should adopt GSCM as their strategy. Manufacturers have a special responsibility to maintain international ecological standards. Barriers that hinder GSCM implementation create considerable challenges for both technical experts and industry managers. Before adoption of GSCM in plastic processing industries, it is necessary to identify various regulatory, institutional, market, financial, technical, informational, managerial and organisational barrier impacts to facilitate easy eradication /removal of all barriers.

Some of the major barriers were considered in the present study by consulting experts from academia, literature and industry. Based on inputs from an expert in the industry, the questionnaire was drafted and feedback from industrial experts was analysed by calculating its expectation value. The class with highest impact was determined using ANOVA and paired T-test. The top ten barriers that hinder implementation of GSCM in plastic industry were found and the main barrier was Lack of technology for adopting GSCM, and inefficient disposal technologies. Biodegradable raw material if used, increases material handling and transportation cost, Insufficient reverse logistic resources, Unwillingness to take risks, fear of product failure, Lack of inappropriate environmental performance metrics, Resistance of top management fearing time overruns to implement green supply chain, high recycling cost, high initial capital to start changes in the industry to go green and material used in the product being not easily biodegradable. Thus, by alleviating the above mentioned ten barriers, the supply chain can be made environmentally friendly to a considerable extent. Hence, this study paves the way for overcoming the above mentioned barriers to implement GSCM in the plastic processing industries. ANOVA and T-test yielded classes which had the highest impact. Overall financial constraints and technological barriers that can be removed were seen to being the top hindrance to implementing GSCM in the plastic Industry.

6.1 Limitations and future scope

In this study, we considered only 38 barriers, but India has many barriers available. Also, the interrelationship with barriers and barrier categories was not found. It is possible to rank important barriers with AHP. This ensures a direction for the future.

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Integration of directional distance formulation of DEA and canonical correlation

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Abstract: Data envelopment analysis (DEA) which has been widely used in recent times for measuring productive efficiency of decision making units (DMUs). The main limitation of DEA is that many numbers of DMUs comes out to be efficient when there are relatively large number of input and output variables as compared to number of DMUs under evaluation. In extreme cases may cause the majority of the units to be efficient. Tackle this limitation canonical correlation analysis (CCA) is applied in this paper. This paper develops a method that integrates the directional distance formulation of DEA and CCA to measure the efficiency and rank the DMUs. There are situations in which more than one significant canonical correlation exists with both positive and negative values. This problem is addressed in this paper by using directional distance function approach to measure the efficiency, where negative canonical correlation exists. This method can also be applied where two or more canonical correlations are significant.

Keywords: data envelopment analysis; DEA; canonical correlation; directional distance function; efficiency.

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1 Introduction

Data envelopment analysis (DEA) is a non-parametric technique of frontier estimation that determines both the relative efficiency of a number of decision-making units (DMUs) and the targets for their improvement. DMUs can represent any set of organisations or departments that perform fundamentally the same task with the same set of variables. DEA measures the relative efficiency of DMUs with multiple inputs and outputs and assumes neither a specific functional form for the production function nor the inefficiency distribution, in contrast to parametric statistical approaches. Problems related to discrimination arise when there are relatively large number of variables as compared to DMUs in extreme cases may cause the majority of observations to be defined as efficient.

A DMU is said to be efficient if its performance relative to other cannot be improved. DEA is a methodology based on linear programming model for assessing the relative efficiency of DMUs, is developed by Charnes et al. (1978) and later extended by Banker et al. (1984) to variable returns to scale. The strength of DEA is that it is able to compare the efficiency of DMUs in terms of several inputs and outputs. In DEA model the efficiency of each DMU should be assessed as high as possible by assigning favourable weights to the inputs and outputs. This will results the weights assigned with respect to one DMU is often to be differing from the other. The idea of filtering out inefficient units before fitting a parametric model has been used by Thiry and Tulkens (1992) and also Simar (1992). They refer this as a semiparametric approach. Although they did not use DEA for screening out the inefficient units, instead they applied a free disposal hull (FDH) method. Their work uses regression to fit the frontier model and so is restricted to a single output as dependent variable.

The main drawback of DEA is that substantial number of DMUs comes out to be efficient, particularly when the number of DMUs is less compared to number of inputs and outputs. There are situations in which number of inputs and outputs are relatively higher proportions as compared to number of DMUs and this leads to majority of DMUs comes out to be efficient. There are different rules for minimum number of units required for efficiency measurement. Nunamaker (1985) argued that number of units in the study should be at least three times greater than the sum of the number of inputs and outputs. But many applications of DEA violate this restriction and majority of DMUs comes out to be efficient in the analysis. Our study focuses to address this problem by reducing dimension of inputs/outputs through canonical correlation. Friedman and Sinuany-Stern (1997) applied the canonical correlation for scaling DMUs. They used one set of positive canonical variates and their purpose was to generate a common set of weights for the exercise of ranking units on the common scale. But in many practical situations more than one significant canonical correlation may exist and also both positive and negative canonical variates may also be prevalent. We address this problem by using the improved efficiency measure through directional distance formulation of DEA approach to measure the efficiency developed by Diabet et al. (2013). This approach is an integration of directional distance formulation of DEA and canonical correlation.

2 Canonical correlation analysis

Canonical correlation analysis (CCA) uses multiple inputs and outputs and focuses on the correlation between a linear combination of the variables in one set and a linear combination of the variables in another set. The idea is, first to determine linear combinations of variables in the sets that have maximum correlation. Then a subsequent linear combination in each set is sought such that the correlation between these pair is maximum of correlation and linear combinations that are uncorrelated with the other linear combinations. The pairs of linear combinations are called the canonical variables and their correlations are called canonical correlations. Usually, first a few canonical correlations will be significant and remaining canonical correlations are insignificant. Canonical variates corresponding to insignificant canonical correlations are dropped. This will reduce the dimension of variables. CCA measures linear relationship between two groups of canonical variables V and U. The linear combination of the variables V and U is defined as

$$\begin{aligned} Z_j &= V_1 x_{1j} + V_2 x_{2j} + \cdots + V_m x_{mj} \\ W_j &= U_1 y_{1j} + U_2 y_{2j} + \cdots + U_s y_{sj} \\ j &= 1, 2, \cdots, n \end{aligned} \tag{E1}$$

The aim of CCA is to identify and quantify the relations between m-dimensional random variable X and s-dimensional random variable Y. The coefficients V_i, $i = 1, 2, \ldots, m$ and U_r, $r = 1, 2, \ldots, s$ must be such that the square of the correlation between Z and W will be maximum.

$$\begin{aligned} &Max\ r_{zw} = V'S_{xy}U \Big/ \sqrt{\left(V'S_{xx}V\right)\left(U'S_{yy}U\right)} \\ &\text{subject to} \quad V'S_{xx}V = 11 \\ &\qquad\qquad\quad U'S_{yy}U = 1 \end{aligned} \tag{E2}$$

It is assumed that the variables of the two groups are linearly independent, i.e., the rank $X_{m\times n} = m$ and the rank $Y_{s\times n} = s$. In the case $m \le s$ the optimal solution for V' in this problem is the eigenvector corresponding to the largest eigenvalue of the quadruple matrix product $S_{xx}^{-1}S_{xy}S_{yy}^{-1}S_{yx}$. Its rank is less than or equal to m.

$$\left(S_{xx}^{-1}S_{xy}S_{yy}^{-1}S_{yx} - \lambda I\right)V = 0 \tag{E3}$$

λ is the eigenvalue of the quadruple matrix product (E3) and its eigenvector is V. There are at most 'm' solutions for λ and the largest eigenvalue λ_1 gives the square of maximum r_{zw} and the eigenvector V_1 provide the weights by which the set of the inputs should be linearly combined in order to achieve the maximal correlation. The vector of the combined weights of the outputs U_1 is obtained by

$$U_1 = \frac{S_{yy}^{-1}S_{yx}}{\sqrt{\lambda_1}} V_1 \tag{E4}$$

Friedman and Sinuany-Stern (1997) used the CCA method by defining scaling ratio score, T as a ratio of linear combinations of inputs and outputs. Then they utilise the common weights for the linear combinations that are drawn from the largest eigenvalue of the CCA method, as shown below:

$$T_j = \frac{W_j}{Z_j} = \frac{\sum_{r=1}^{s} U_{1r} Y_{rj}}{\sum_{i=1}^{m} V_{1i} X_{ij}} \qquad j = 1, 2, \cdots, n \tag{E5}$$

While DEA efficiency ratio is bounded above by 1, the scaling ratio T_j of the CCA is unbounded.

The rank of the product matrices $S_{xx}^{-1} S_{xy} S_{yy}^{-1} S_{yx}$ and $S_{yy}^{-1} S_{yx} S_{xx}^{-1} S_{xy}$ is min (m, s). Therefore at most m ($m \leq s$) canonical variates can be extracted. λ_1 refers to the first and largest eigenvalue of the matrix $S_{xx}^{-1} S_{xy} S_{yy}^{-1} S_{yx}$, V_1 and U_1 are the corresponding eigenvectors associated with λ_1. Successive canonical variates are extracted so that the second pair is the second most highly correlated pair out of all possible linear combinations that are uncorrelated with the first canonical variate pair, the third pair is the third most highly correlated pair out of all possible linear combinations that are mutually uncorrelated with the first and second canonical variate and so on. These properties are applied to the subsequent canonical variates and altogether 'm' pairs of canonical variates are generated. The 'm' canonical variates associated with the Y's are uncorrelated and as the case of X's. The correlation between the j^{th} canonical variates for the X's and the k^{th} ($k \neq j$) canonical variate for the Y's is zero.

The approach we are suggesting in this paper is the integration of directional distance formulation of DEA and canonical correlation. The canonical model selects linear functions that have maximum covariances between set of variables and again to restrictions on orthogonality. The techniques may therefore be loosely characterised as a sort of double barrelled principal components analysis. It identifies the components of one set of variables that are highly linearly related to the components of the other set of variables.

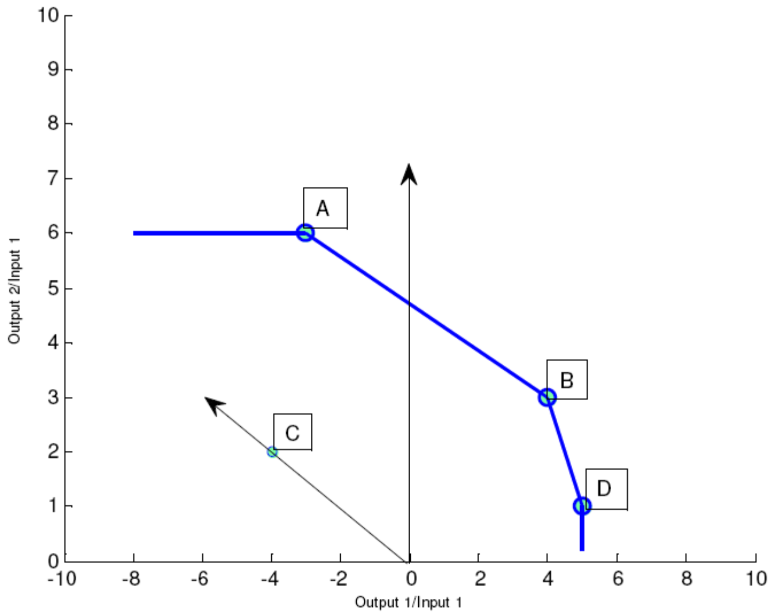
Canonical correlation has been used to measure efficiency by Friedman and Sinuany-Stern (1997) but on the full set of DMUs. Their purpose was to generate a common set of weights for the purpose of ranking units on the common scale. They pointed out that negative set of weights could arise and that would be problematic. Their advice for dealing with negative set of weights was that first check if an input had been misclassified as an output or vice versa. If this is not the case, they suggest removing those variables. But in many practical situations, more than one significant canonical correlation exists and also both positive and negative canonical variates may be prevalent. This problem can be addressed by using the directional distance function approach to measure efficiency. Here, discussion is made when two significant canonical correlations are present. However, this could be easily generalised when more than two canonical correlations are significant. The method of canonical correlation constructs the composite inputs and outputs by choosing optimal weights of the inputs and outputs. Since DEA model can be viewed as an alternative approach for selecting suitable weights for combining various inputs and outputs, integration would enhance the potential applicability of directional distance formulation of DEA models. In the integration approach, first, find the significant canonical correlation by maximising the correlation between bundle of inputs and outputs. Find the canonical variant for the inputs and outputs that come from the largest and significant eigenvalue of the CCA. Then utilise the common weights which have come from all the units to find the linear combinations of the outputs (W_{kj}) and inputs (Z_{kj}) for all significant canonical correlations. Afterwards, use the IEM model to measure the efficiency of DMUs.

3 Directional distance formulation of DEA

Over the last few years, DEA has been used through directional distance formulation in the measurement of efficiency. Specifically, this approach is used where performance measurement of the production units involves undesirable outputs and inputs. In the presence of negative data, the use of radial measures of efficiency traditionally used in DEA is problematic. Positive radial expansion factors applied to negative data lead in the opposite direction to the one would wish to improve the performance. The treatment of undesirable outputs has similarities with the treatment of negative outputs since both should be contracted rather than expanded. Any output which incurs cost instead of revenue can also be considered as undesirable outputs. Several approaches exist to deal with undesirable outputs as can be seen in the literature. Chambers et al. (1996) introduced the directional distance function based on Luenberger benefit function to obtain a measure of technical efficiency reflecting the potential for increasing the outputs while reducing the inputs simultaneously. The directional distance function measures the amount that one can translate an input and/or output of a DMU radially from itself to the technology frontier in a pre-assigned direction. This issue is addressed in Chung et al. (1997), they resolve it by solving two BCC models; one where the objective function is maximised and another where it is minimised. This approach is, however, only valid when all the units have negative values on a variable. Later, Scheel (2001) extended this approach for the case of undesirable outputs.

To illustrate the point, consider the example in Figure 1 where two outputs are taken and all DMUs have the unit input. Assessing the efficiency of unit '*C*' using the radial output oriented BCC model (Banker et al., 1984), implies an expansion of both outputs by a multiple greater than one. This however, implies a movement of the inefficient unit '*C*' to the frontier in the direction shown in Figure 1. This movement is not desired since the negative output is being expanded making it even worse. Clearly positive radial expansion factors applied to negative data lead in the opposite direction to the one we would wish to follow to improve the performance.

Figure 1 Illustration with negative data (see online version for colours)



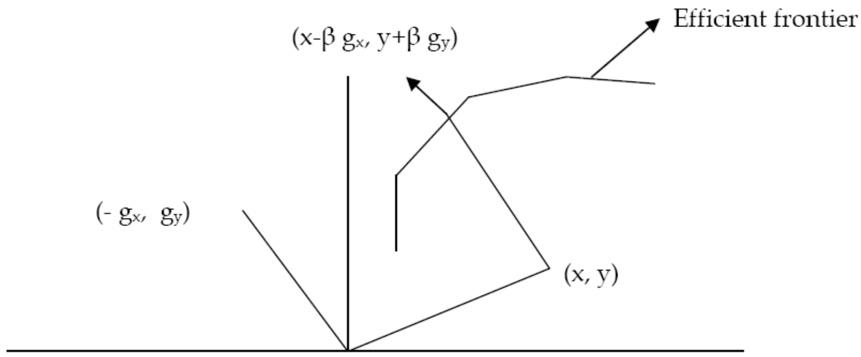
Translation invariant of the additive DEA model is subject to it being specified under VRS. Banker et al. (1984) showed that CRS models are not translation invariant because they do not impose the sum of the intensity variables (weights corresponding to reference DMU) equal to one, i.e., dual decision variables $\sum_{j=1}^{n} \lambda_j = 1$. In the presence of negative data, the CRS model cannot be used. This model assumes any activity can be radially expanded or contracted to form other feasible activities.

Consider a set of units $j = 1, 2, \ldots, n$, with input levels x_{ij}, $i = 1, 2, \ldots, m$ and output levels y_{rj}, $r = 1, 2, \ldots, s$, and DMU_o which is to be assessed. Let $x_j \in R^m$ denote inputs and $y_j \in R^s$ outputs $i = 1, 2, \ldots, m$; $r = 1, 2, \ldots, s$; $j = 1, 2, \ldots, n$. Consider a pair of input-output bundle (x_o, y_o) and the reference input and output bundle be (g_x, g_y). Then with reference to some production possibility set, T, the directional distance function can be defined as

$$\begin{aligned} &\vec{D}\left(x_o, y_o, g_x, g_y\right) = Max\beta : \left(x_o - \beta g_x, y_o + \beta g_y\right) \in T \\ &\text{if } \left(x_o - \beta g_x, y_o + \beta g_y\right) \in T \text{ for some } \beta \end{aligned} \tag{E6}$$

The directional distance function evaluated at any specific input-output bundle will depend on reference input-output bundle $(-g_x, g_y)$, i.e., the direction vector. The directional distance function measures the amount that one can translate an input and or output of a DMU radially from itself to the technology frontier in a pre assigned direction.

Figure 2 Single input and output directional distance function



In other words, we seek to increase the output and reduce the input by the proportion of β. This is illustrated diagrammatically as in Figure 2.

Distance functions viewed as applied tools in performance measurement. In DEA, one frequently distinguishes between input and output orientations, i.e., between input and output distance functions. These functions are reciprocal to each other. The input distance function is associated with input minimisation and output distance function is associated with output maximisation. The direction in which the traditional input and output distance functions evaluate efficiency is determined by the input-output data from an observation or DMU itself. For the directional distance functions, the direction in which DMUs are to be evaluated is a choice variable. These distance functions allow the researcher to choose the direction based on certain criteria to estimate technical efficiency. This may be an important consideration in some applications, e.g., when desirable and undesirable outputs are jointly produced and in the case of negative variables.

The VRS DEA formulation for the directional distance function for the production possibility set is developed by Chambers et al. (1998) is

$$\left.\begin{aligned}
&Max\beta \\
\text{subject to } &\sum_{j=1}^{n} \lambda_j y_{rj} - \beta y_{ro} \geq y_{ro} && (1a) \\
&\sum_{j=1}^{n} \lambda_j x_{ij} + \beta x_{io} \leq x_{io}; && (1b) \\
&\sum_{j=1}^{n} \lambda_j = 1, \quad \lambda_j \geq 0; && (1c) \\
&x_{io}, y_{ro} \geq 0 && (1d) \\
&\beta \text{ unrestricted} \\
&i = 1, 2, \cdots, m; r = 1, 2, , s; j = 1, 2, \cdots, n
\end{aligned}\right\} \qquad (M1)$$

The factor β is the measure of technical inefficiency of the unit and its efficiency is $(1 - \beta)$.

3.1 *Improved efficiency measure through directional distance formulation of DEA*

In this section, we discuss a generalised efficiency model for measuring the Pareto-Koopmans efficiency based on non-oriented and non-radial model with superior discrimination ability as developed by Diabet et al. (2013). This model is applicable for production technology involving either input variables or output variables or both possibly are having negative values. The model is known as an improved efficiency measure through directional distance formulation of DEA-minimisation model by formulating the following fractional programme, referred to as IEM.

$$\left.\begin{aligned}
&\min S(x_o, y_o) = \eta = \frac{1-\sum_{i=1}^{m} W_i \beta_{io}^{-}}{1+\sum_{r=1}^{s} Z_r \beta_{ro}^{+}} && (2a)\\
&\text{subject to} \quad \sum_{j=1}^{n} \lambda_j y_{rj} - \beta_{ro}^{+} R_{ro}^{+} \geq y_{ro} && (2b)\\
&\sum_{j=1}^{n} \lambda_j x_{ij} + \beta_{io}^{-} R_{io}^{-} \leq x_{io} && (2c)\\
&\sum_{j=1}^{m} \lambda_j = 1 && (2d)\\
&\sum_{i=1}^{m} W_i = 1, \qquad \sum_{r=1}^{s} Z_r = 1 && (2e)\\
&\lambda_j \geq 0,\ j = 1, 2, \cdots, n;\ i = 1, 2, \cdots, m;\ r = 1, 2, ..., k\\
&\beta_{ro}^{+}, \beta_{io}^{-} \text{ are unrestricted.}
\end{aligned}\right\} \quad \text{(M2)}$$

The directional vectors R_{ro}^{+} and R_{io}^{-} shown in (M2) are

$$R_{ro}^{+} = \underset{j}{Max}\{y_{rj}\} - y_{ro},\ r = 1, 2, \cdots, s \tag{E7}$$

$$R_{io}^{-} = x_{io} - \underset{j}{Min}\{x_{ij}\},\ i = 1, 2, \cdots, m;\ j = 1, 2, \cdots, n \tag{E8}$$

In the numerator of equation (2a) β_{io}^{-} is the relative reduction rate in the input '*i*' for $i = 1, 2, \ldots, m$, and $\sum_{i=1}^{m} W_i \beta_{io}^{-}$ is the possible weighted mean reduction of inputs or it is the input inefficiency and $1-\sum_{i=1}^{m} W_i \beta_{io}^{-}$ is the efficiency of inputs. β_{ro}^{+} in denominator evaluates the expansion of output '*r*' and $\sum_{r=1}^{s} Z_r \beta_{ro}^{+}$ is the possible weighted mean expansion of outputs and the inverse $\left(1+\sum_{r=1}^{s} Z_r \beta_{ro}^{+}\right)^{-1}$ measures the output efficiency. So 'η' is the product of input and output efficiencies. It measures maximum non-radial contraction of inputs and expansion of the outputs consistent with technical feasibility in the direction of ideal DMU. This model allows us to alter the variable weights. Decision-maker's value judgement can be incorporated to measure the inefficiency in this model. Here, W_i and Z_r are the weights of input and output variables respectively derived based on the auxiliary information available on the importance of the variable. If such information is not available, the weights of the variables can also be derived from the data by taking inversely proportional to the coefficient of variation for each input and output variables or an equal weight for all inputs and outputs. Efficiency of the IEM lies between zero and one. A DMU_o is said to be Pareto-Koopmans efficient if $\eta^* = 1$. This is equivalent to all $\beta_{io}^{-} = 0$ and $\beta_{ro}^{+} = 0$. This implies that there is no excess input and output shortfalls in the optimal solution relative to other DMUs.

Applying the Charnes and Cooper (1962) transformation to fractional programming of IEM, it can be converted into following linear programming as in the Tone (2001). Multiply a scalar variable 't' (> 0) to both denominator and numerator of (2a). This does not cause any change in the value of η. Further, we adjust 't', so that the denominator becomes one. The adjusted expression of the denominator term is included as a constraint.

$$\left.\begin{aligned}
& Min\ \tau = t - \sum_{i=1}^{m} W_i B_{io}^{-} && (3a)\\
\text{subject to}\quad & t + \sum_{r=1}^{s} Z_r B_{ro}^{+} = 1 && (3b)\\
& \sum_{j=1}^{n} \Lambda_j y_{rj} - B_{ro}^{+} R_{ro}^{+} \geq t y_{ro} && (3c)\\
& \sum_{j=1}^{n} \Lambda_j x_{ij} + B_{io}^{-} R_{io}^{-} \leq t x_{io} && (3d)\\
& \sum_{j=1}^{n} \Lambda_j = t && (3e)\\
& \sum_{i=1}^{m} W_i = 1, \qquad \sum_{r=1}^{s} Z_r = 1 && (3f)\\
& \Lambda_j \geq 0,\ j = 1, 2, \cdots, n;\ i = 1, 2, \cdots, m;\ r = 1, 2, \cdots, k &&\\
& B_{io}^{-}, B_{ro}^{+} \text{ are unrestricted} &&
\end{aligned}\right\} \qquad \text{(M3)}$$

Let the optimal solution for (M3) be $(\tau^*, t^*, \Lambda^*, B_{io}^{-*}, B_{ro}^{-*})$, then we have the optimal solution of IEM defined as $(\eta^* = \tau^*, \lambda^* = \Lambda^* / t^*, \beta_{io}^{-*} = B_{io}^{-*} / t^*, \beta_{ro}^{+*} = B_{ro}^{+*} / t^*)$. Based on the optimal solution we can determine the efficiency of the DMUs. A DMU_o is Pareto-Koopmans efficient if $\eta^* = 1$ otherwise it is inefficient. Pareto-Koopmans efficient input-output projection for an inefficient DMU_o for (M3) is

$$x_{io}^{*} = x_{io} - \beta_{io}^{-} R_{io}^{-} = \sum_{j=1}^{n} \lambda_j^{*} x_{ij} \leq x_{io} \text{ for all } 'i'$$

$$y_{ro}^{*} = y_{ro} + \beta_{ro}^{+} R_{ro}^{+} = \sum_{j=1}^{n} \lambda_j^{*} y_{ij} \leq y_{ro} \text{ for all } 'r'$$

A DMU_o is Pareto-Koopmans efficiency if and only if

$\beta_{ro}^{+} = 0$ for each output 'r'

$\beta_{io}^{-} = 0$ for each input 't' implies $\eta^{*} = 1$.

4 An illustrative example

In order to illustrate the integration of CCA and directional distance formulation of DEA, we have taken dataset of 30 private domestic banks for the year 1998. It consists of four output and four input variables. The inputs are deposits (D), borrowings (B), labour (L), fixed assets (FA). The outputs are net interest margin (NIM), non-interest income (NII), credits (C) and investments (I). First, we applied DEA-VRS model to the entire dataset. According to this model, 23 banks were found to be efficient. In the second stage, we apply CCA to all the DMUs and the values of the input and output weights were derived. The values of the input and output weights V_1, V_2, V_3, V_4 and U_1, U_2, U_3 and U_4 are given in Table 1. In this example, two canonical correlations are found to be significant as tested by the Bartlett's test with the p-value less than 0.01. The canonical correlation is given in column 2 and canonical variates are given in column 3 to 10 of Table 1.

Table 1 Significant canonical correlation and their canonical variates

Canonical variate	*Canonical correlation*	*V1*	*V2*	*V3*	*V4*
1	2	3	4	5	6
1	0.9979	–0.9941	–0.0196	–0.0098	0.1067
2	0.8645	–0.3120	0.4087	–0.5863	0.6261

Canonical variate	*U1*	*U2*	*U3*	*U4*
1	7	8	9	10
1	0.0711	–0.0668	–0.5907	–0.3544
2	0.1880	–1.0121	–0.0665	0.7591

To each banks weighted output w_{kj} and weighted input z_{kj} were calculated. Also, we calculated the composite input and output for each canonical variate and for each DMUs. Further, we applied the improved directional distance model developed in Section 3 to the input and output canonical variates. Here, the number of efficient DMUs will be reduced to 9 as shown in column 7 of Table 2. VRS-DEA efficiency score are recorded in column 2 of Table 2. Moreover all efficient DMUs in the IEM model are also efficient VRS-DEA model.

Table 2 Efficiency measurement through application of CCA

Bank name	*DEA efficiency*	Z_{1j}	Z_{2j}	W_{1j}	W_{2j}	*IEM efficiency*
Bank of Rajasthan	0.9491	–1.5415	0.4781	–1.6100	1.5542	0.9296
Catholic Syrian Bank	0.9176	–0.9939	0.7578	–0.9762	0.9940	0.9730
Bank of Punjab	1	–0.8061	–0.6447	–0.8759	0.2059	0.9589
Bharat Overseas Bank	1	–0.6410	0.3575	–0.5586	0.7004	1
Development Credit Bank	1	–0.8732	–0.4852	–1.0069	–0.1368	0.9279
City Union Bank	0.9786	–0.5701	0.27891	–0.55081	0.4277	0.9811
Global Trust Bank	1	–2.0616	–2.4970	–1.9963	–0.1599	1
Hdfc Bank	1	–1.3474	–0.6570	–1.3721	0.6626	0.9643
Centurion Bank	1	–0.7914	–0.2363	–0.7077	0.4274	1
Federal Bank	1	–3.7463	1.2103	–3.8365	3.6228	1
Dhanalakshmi Bank	0.9565	–0.5818	0.30948	–0.5424	0.6404	0.9890
Ganesh Bank of Kurundwad	1	–0.04725	0.004151	–0.03955	0.066873	1
Indusind Bank	1	–2.6801	–1.3082	–2.7142	0.1626	0.8803
Icici Bank	0.9061	–1.6833	–0.4281	–1.4803	0.3518	0.9823
Karur Vysya Bank	1	–1.2173	0.6836	–1.1967	0.4801	0.9537
Lakshmi Vilas Bank	0.9289	–0.7951	0.4791	–0.7821	0.4842	0.9709
Karnataka Bank	1	–1.9453	0.7441	–1.8276	2.2199	1
Lord Krishna Bank	1	–0.3959	0.3568	–0.3902	0.2982	0.9822
Jammu and Kashmir Bank	1	–2.7024	0.9026	–2.6599	3.4466	1
Idbi Bank	1	–1.1928	0.3762	–1.1251	1.2695	0.9911
Nedungadi Bank	1	–0.4317	0.4199	–0.4589	0.4071	0.9725
Ratnakar Bank	1	–0.1456	0.131434	–0.14539	0.183391	0.9901
Sangli Bank	1	–0.5480	0.2410	–0.5441	0.4215	0.9773
Tamilnad Mercantile Bank	1	–0.9028	0.5455	–0.9343	0.6441	0.9540
Nainital Bank	1	–0.1702	0.1138	–0.1256	0.2910	1
South Indian Bank	1	–1.5080	0.7380	–1.4965	1.9590	0.9923
Sbi Commercial and International	1	–0.2858	–0.1790	–0.2615	0.0729	0.9987
Uti Bank	1	–1.7377	0.2311	–1.6564	0.8951	0.9594
Vysya Bank	1	–3.3013	–0.3191	–3.1418	1.7429	1
United Western Bank	0.8935	–1.4971	0.3110	–1.4772	0.6376	0.9419

5 Conclusions

In this paper, CCA is integrated with the improved efficiency measure through directional distance formulation of DEA. This is particularly useful when number of inputs and outputs are relatively more as compared to number of DMUs. Application of canonical correlation will reduce the dimension of inputs and outputs, therefore, the method has more discriminative power. Another advantage of directional distance function is that it allows the evaluation of the degree of efficiency in any direction from the observation points. The new model allows us to alter the variable weights. Decision-maker's value judgement can be incorporated to measure the inefficiency in this model. The IEM is a more generalised model. In this model, efficiencies take into account the individual input and output variables. It represents the solution for the model with non-zero slacks when measuring efficiency. Hence, it leads to the Pareto-Koopmans measure of technical efficiency. Efficiency measure is bounded by zero and one, monotonically decreases for any increase in outputs and/or reduction in inputs or increases monotonically for decrease in outputs and or increase in inputs. This model is translation and unit invariant. This measure of efficiency is easily interpreted for use in a variety of managerial and scientific contexts.

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