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Flexibility and Sustainability of Supply Chains: Are They Together?

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Abstract

Sustainability of supply chains has caught attention of researchers worldwide in the wake of problems like global warming and climate change. A revisit to various strategies of supply chains is warranted to assess their impacts on environment and society. Flexibility in supply chains has enabled responsiveness of chains to achieve higher service level, faster delivery and customization of products but cost of achieving these flexibilities has not been generally accounted for and their implication on the environment has been overlooked mostly. In this study, an attempt has been made to investigate flexibility of supply chains in the light of sustainability and to find whether flexibility incorporation adversely affects or collaborates with sustainability. A three dimensional composite index based on suitability, scalability and sustainability is proposed to evaluate various flexibility options in the supply chains. A typology of supply chains is also proposed based on flexibility and sustainability.

Keywords: flexibility, supply chain management, supply chain performance, sustainability

Introduction

Efforts to make supply chains more environmentally friendly have gained top most priority due to increasing threats arising out of phenomena like global warming and climate change (Shukla et al. 2009b). In fact, researchers have started advocating radical changes in the way supply chains are managed so far with profit as the sole aim. Corporate sustainability has been focused with attention drawn toward the triple bottom line; people, planet, and profit (P3), or 3E (equity, environment, and economics) (Anderson 2006; Kleindorfer et al. 2005). This paradigm shift in the approach has opened the gate for revisiting various established strategies of supply chain management (SCM) to reassess their viability with new angle of sustainability in general and greening specially (Stonebraker et al. 2009). Supply chain flexibility is one such strategy which got prominence in achieving agility and high responsiveness of supply chains (Duclose et al. 2003, Siddiqui et al. 2009). However, little has been done so far to investigate the impact of incorporating flexibility in supply chain designs and consequent operations on environmental performance measures. It is argued that different dimensions of flexibility may lead to detrimental impact on the environment and smaller and non-focal partners of the extended supply chains. In recent past, emergence of customer driven markets has resulted in rapid changes in strategies adopted by the organizations. Supply chain integration was made possible through remarkable development in information and communication technology (ICT). At the same time, competition among the supply chains demanded lot of inbuilt flexibility to meet the challenges of diversity and uncertainty in the global market. Ever changing requirements of customers paved ways for mass customization, high responsiveness and increased service levels (Holweg 2005). Initially, flexibility in manufacturing systems has gained lot of attention and lead to creation of new manufacturing systems like flexible manufacturing systems (FMS), group technology (GT) and computer integrated manufacturing (CIM). With advent of SCM, researcher addressed the vital question of introducing the flexibility outside the walls of the company resulting in flexibility in supply chains representing a potential source to improve the company's efficiency and may be a significant measure of supply chain performance (Vickery et al. 1999).

Cost of flexibility is another domain where not much research has been done and when Upton (1994) talked about little penalty, it is obviously in terms of extra money which one has to spent in host of measures to incorporate flexibility. Actions like buying flexible machines, efficient information systems to share data in real time, capacity enhancement to tackle sudden demand, extra manpower which must be kept in readiness to cope with extra production volumes and decreased

time of production, selecting, developing and nurturing of highly dependable multiple suppliers to provide supply flexibility, developing capability for faster transportation in terms of larger fleet, technological upgradation and ICT gadgets installation in vehicle and warehousing capability development are all capital intensive. Naturally, other costs associated with flexibility like cost of damage to environment, excessive use of natural resources, extra material consumption, waste disposal, recycling, increased emission of green house gases (GHG) in atmosphere, congestion and traffic problems like accidents, delays are completely overlooked.

Different dimensions of flexibility may lead to detrimental impact on the environment and smaller and non-focal partners of the extended supply chains.

Another important but often ignored aspect is applicability of supply chain flexibilities in Micro, Small and Medium scale enterprises (MSMEs). These organizations are easily dovetailed in to production systems of large enterprises precisely due to their larger manufacturing flexibility to cope with uncertainty in terms of volumes, product range and variety. But does this make them automatically a better player to absorb flexibility of supply chains? It can be argued that limited resources, less expertise in integrative technologies and restricted knowledge to their specialized core competences can make MSMEs weak partners in adoption of flexibility of supply chain. It is argued in this paper that a comprehensive look in to these macro aspects of flexibility incorporation in supply chains is urgently needed to develop a holistic cost-value analysis to address three vital aspects like suitability, scalability and sustainability (S^3). Suitability identifies the ease, need and possibility of successful implementation of any strategy, flexibility in our case, where as scalability is measure of adaptability of strategy which enables it to scale up or scale down in its magnitude and scope to become implementable in different organizations which may differ in scale and style of operations, and sustainability in its broader scope covers famous triple bottom line that are society, environment and economic considerations.

Costs associated with flexibility like cost of damage to environment, excessive use of natural resources, extra material consumption, waste disposal, recycling, increased emission of green house gases (GHG) in atmosphere, congestion and traffic problems like accidents, delays are completely overlooked.

This paper consists of 5 sections; literature review is presented in section 2 while section 3 presents comparison of measures of flexibility and sustainability. Section 4 describes the composite index designed for measuring suitability, scalability and sustainability of the flexibility measures and section 5 presents the discussion and conclusions.

Review of Literature

A structured review of literature is carried out to cover the relevant aspects of flexibility and sustainability of the supply chains.

Flexibility

The notion, any kind of flexibility will not come free but will be costing in terms of money and other parameters, was supported by early researchers of flexibility. According to Upton (1995), flexibility reflects the ability of a system to change or react with little penalty in time, effort, cost or performance. Manufacturing flexibility has been explored widely (Oke 2003; Oke 2005; Kara and Kayis 2004; Schmenner and Tatikonda, 2005) along with sporadic attempt to extend the flexibility to other echelons of supply chains like warehouse (Baker and Halim 2007), volume flexibility (Salvador et al. 2007), supplier role in manufacturing flexibility (Kayis and Kara 2005).

With growing interest in supply chains management, system wide flexibility was extended to supply chain flexibility (Beamon 1999; Prater et al. 2001; Adrian et al. 2007; Miemczyk and Howard 2008). Flexibility in supply chain encompasses those flexibility dimensions that directly impact a firm's customers and are the shared responsibility of two or more functions along the supply chain, whether internal (marketing, manufacturing) or external (suppliers, channel members) to the firm (Sanchez 2005). Various dimensions of flexibility in supply chains are identified and categorized such that the first three flexibility dimensions namely product flexibility, volume flexibility and routing flexibility are shop floor capabilities that impact on supply chain (basic flexibility); secondly other three dimensions like delivery flexibility, trans-shipment flexibility and postponement flexibility are hierarchically located at company level (system flexibility); while other four flexibility dimensions i.e. sourcing flexibility, response to market flexibility, new product development or launch flexibility and distribution or access flexibility are linked to the customer-supplier relationships in the supply chain (aggregate flexibility) (Wadhwa et al. 2009a; 2009b). For example, a reduction in system resources may negatively affect the supply chain's flexibility. A supply chain may be currently utilizing its resources efficiently, and producing the desired output, but will the supply chain be able to adjust to changes in, for example: product demand, manufacturing unreliability, the introduction of new products, or supplier shortages? From these perspectives, flexibility is an important consideration in supply chain performance (Kumar and Deshmukh 2006).

Similarly, Fantanzy et al. (2009) suggested that despite the substantial benefits of supply chain flexibility, its implementation and management is also associated with risks, costs, and challenges. They suggest that, from all the different types of supply chain flexibility there are five

critical or fundamental types of supply chain flexibility: New product flexibility; Sourcing flexibility; Product flexibility; Delivery flexibility and Information systems flexibility. In their study they found the relationship of flexibilities on the supply chain performance. Performance measures they adopted were both financial performance (net profit and sales growth) and non-financial performance measurement (customer satisfaction performance and lead-time performance). Here also no environmental conscious performance measure was included.

Limited resources, less expertise in integrative technologies and restricted knowledge to their specialized core competences can make MSMEs weak partners in adoption of flexibility of supply chain.

Stevenson (2007) identified four levels of flexibility and following six flexibilities at network level of the supply chains:

i) **Robustness:** Range of market change with which the existing supply chain configuration is able to cope.

ii) **Re-configuration:** Potential to re-align or reinvent the supply chain in response to (or in anticipation of) market change.

iii) **Relationship:** Ability to build collaborative relationships both up and downstream, including for new product development.

iv) **Logistics:** Potential to rapidly send and receive products cost effectively as customers and sources of supply.

v) **Organizational:** Ability to align (or re-distribute) skills to meet the current needs of the whole supply chain.

vi) **Inter-organizational information system:** Ability to align information systems with existing supply chain entities to meet changing information needs.

Though many studies are reported to identify various components of the flexibility as applicable to large scope of SCM (Wadhwa et al. 2006) but there are fewer studies about the relationship between supply chain flexibility and firm performance, which offers a research opportunity (Dangayach and Deshmukh 2001). Many existing investigations focus on evaluation of flexible versus non-flexible supply chains without detailed analysis of flexibility costs, such as costs of flexible logistics systems and how to achieve projected flexibility benefits. This is also an interesting area for further cross-sectional research (Chandra and Grabis 2009). Thus, there is gap in literature about the non financial performance measurement of flexibility and about its impact on sustainability the literature is almost silent.

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Sustainability

The Brundtland commission defined the term sustainability as (World Commission on Environment and Development, 1987) "development that meets the needs of the present without compromising the ability of future generations to meet their needs." This is a very broad definition and often organizations do not fathom their role or responsibility in this macro socio-economic scenario. Starik and Rands (1995) defined sustainability as the "ability of one or more entities, either individually or collectively, to exist and flourish (either unchanged or in evolved terms) for lengthy timeframes, in such a manner that the existence and flourishing of other collectivities of entities is permitted at related levels and in related systems". The scope of the sustainability of supply chains has been outlined by Shrivastava (1995), who advocates that "within the context of sustainability, an organization must manage not only short-term financial results, but also risk factors such as harm resulting from its products, environmental waste, and worker and public safety". Similarly, Gladwin et al. (1995) state that sustainable development must encompass the concept of security, which, "demands safety from chronic threats and protection from harmful disruption" including, "biodiversity loss, climate change, freshwater scarcity, food, insecurity, and population growth." These were the definitions of sustainability in terms of the production and operations. Later on, it was attempted to define it for supply chains.

Extended supply chains create great stress on the physical environment and management becomes increasingly accountable for processes and events that are beyond their traditional sphere of control (Tebo 2005; Iansiti and Levin 2004). Because of the costs and fragility of supply chains, the operations field has also become the focus of serious concerns about environmental sustainability, often involving the 3Ps: planet, people, and profit (Stonebreaker et al. 2009). Wadhwa et al. (2009) proposed a generic model to enterprises engaged in or to be engaged in product recovery processes which helps in increased sustainability. There are certain enablers of SSCM (Faisal 2010) that help in attaining sustainability in different practices of supply chains like 3PL (Wolf and Seuring 2010). Many researchers have called for undertaking sustainability in supply chains more seriously as it has a potential to contribute significant improvement in sustainability aspects as defined earlier (Halldorsson and Kovacs 2010).

Comparison of Flexibility and Sustainability

Three distinct phases of supply chain are identified in the literature (Shukla 2004) namely:

Inbound Supply Chain

Inbound supply chain ensures value addition to raw materials in terms of selection, segregation, packing, transportation (both at ambient temperature and cold

transportation in refrigerated or composite vehicles), cold storing, warehousing, further transportation, consolidation and deconsolidation etc. There are host of intermediate echelons like consolidators, traders, commission agents, wholesalers, retailers, third party logistics, cold storing agency etc., which results in very high complexity.

Manufacturing Supply Chain or Internal Supply Chain

Value addition is done during manufacturing or production of goods like in case of handicrafts, customized product, and products involving lot of manual specialized skills. Here functions like material flow, material handling and inventory management are predominant and flexibility can be achieved by focusing on these aspects.

Outbound Supply Chain

The distribution channel operations are of paramount importance and issues like warehouse location, mode of transportation and inventory management at retail and wholesaler level are critical issues. Lot of strategic planning is required to achieve desired flexibility, service level and responsiveness.

At each phase of supply chain there are impacts on environment and sustainability measures like, implementation of environment system (EMS), ISO 14000 certification, and selection of suppliers who are ISO 14000. compliant, are adopted to counter them (Shukla et al. 2009a). Annexure-I presents the comparison of impact of sustainability and flexibility measures on various activities of these 3 phases of supply chains. Along with the support from literature, opinion of a team of 3 experts (from academics and Industry), who are highly experienced and have in-depth knowledge in the field of supply chain management is sought for comparison purpose.

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It is evident that many measures for increasing flexibility do not go well with sustainability measures and it leads to an important conclusion that there is a trade off between flexibility and sustainability of supply chains.

Sustainable Flexibility

One needs to address the uncertainty and make supply chains competitive through incorporation of various flexibilities at appropriate level but at the same time they are expected to be green and sustainable. An attempt is made to define a typology for various supply chains based on flexibility and sustainability using a two by two matrix. Supply chains are classified into 4 categories. At low levels of both parameters, traditional approach of supply chains is placed, where rigid and unconcerned attitude dominates the supply chain objectives. Supply chains which are operating in near monopolistic environment and under high degree of certainty may fall in this category. Public distribution system in India is a typical example of traditional supply chains. Second category is benevolent supply chains, where the sustainability concerns of supply chain dominate the economic and other performances. These supply chains are rigid and haven't exhibited much flexibility in years but take sustainability as their mission and exhibit high level of responsibility towards social and environmental aspects. Unfortunately, not many examples can be found in this category but many not-for-profit organizations and their supply chains may fall in this category. Those supply chains, which exhibit lot of flexibility to achieve high levels of responsiveness and agility with low levels of concerns for the environment, society, planet earth and primarily driven by the profit-at-any cost, are termed as self-centric supply chains. Many of the modern supply chains fall under this class and FMCG, apparel, electronics goods are few examples. Fourth category with high levels of both flexibility and sustainability is desired in today's context and thus named trend-setter. These supply chains are highly flexible and able to achieve better customer satisfaction through high service levels and greater responsiveness. They leverage the profit earned in developing the partners and systems in such a manner that they become more environmentally friendly in their operations and address the social concerns with greater care and involvement. Supplier selection, material selection, technology adoption, machines purchase and distribution network design are few issues where flexibility can be achieved through sustainable means. In other cases like logistics flexibility, volume flexibility etc. sustainable efforts are though difficult to achieve but with appropriate involvement of the supply chain partners, they can be achieved. All supply chains must strive to migrate to this category of trendsetter with a judicious mix of flexibility and sustainability. Figure 1 shows this matrix and marks all four types.

Various sources for achieving flexibility in supply chains are discussed in literature (Tachizawa et al. 2007; Kumar et

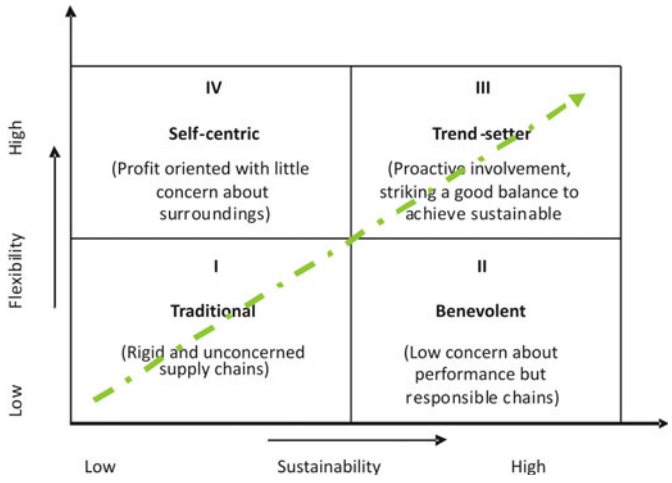

Figure 1: Typology of Supply Chains Based on Sustainability and Flexibility

al. 2008). These sources come at a price and have to be viewed from the perspective of their potential of adversely affecting the sustainability of the supply chains. Table 1 presents possible impacts of select few sources of flexibilities in supply chains on environment and other aspects.

Concept of logistics flexibility and it's separation in to flexible logistics competence (physical supply and purchasing flexibilities) from capability (physical distribution and demand management flexibilities) along with definition of range that is the firm's ability to design, make, and distribute different products is suggested (Zhang et al. 2005; Naim et al. 2006) in literature. Range is high when the number of products is large and the degree of difference among the products is great. Also defined mobility that is the speed at which a firm can change from one product to another. But how one can achieve these flexibilities without increasing the cost and affecting the performance level has not been elaborated. Only customer satisfaction has been considered and obviously environmental concerns are not taken into account while advocating the benefits of the flexibility. It is necessary to investigate, in detail, the kind of impacts flexibility measures may have and out of many flexibilities discussed in literature, a detailed impact analysis has been presented in Table 2 for the logistics flexibility and its components, namely physical supply flexibility, purchasing flexibility, physical distribution flexibility, and demand management flexibility as defined by Zhang et al. (2005). A similar exercise can be done for each type of flexibility.

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Supplier selection, material selection, technology adoption, machines purchase and distribution network design are few issues where flexibility can be achieved through sustainable means.

Composite Index S^3

It is argued that a comprehensive look into the macro aspects of flexibility incorporation in supply chains is urgently needed to develop a holistic cost-value analysis model based on three vital dimensions namely suitability, scalability and sustainability (S^3). Suitability identifies the ease, need and possibility of successful implementation of any strategy, flexibility in our case, where as scalability is measure of adaptability of strategy which enables it's scaling up or down in terms of magnitude and scope to become implementable in different organizations which may differ in scale and style of operations, and sustainability in its broader scope covers famous triple bottom line that is society, environment and economic considerations. A composite index 'S^3' is proposed in this section which can evaluate various SCM practices on these three dimensions.

Table 1: Impact of Supply Chain Flexibility Sources on Sustainability

S. No.	Source	Author	Impacts on Sustainability
1	Single v/s Multiple suppliers	(Pujawan 2004; Swafford et al. 2006)	Choice of having multiple suppliers help in social measures as it widens the supplier base but may not suit the environmental concerns as it will result in extra KMs of transportation, unutilized capacity.
2	Global v/s domestic sourcing	(Stratton & Warburton, 2003; Jin 2004)	Global sourcing have high detrimental effects on environment due to high carbon foot prints.
3.	Supplier Selection	(Stratton and Warburton 2003; Swafford et al. 2006),	Selection of flexible supplier is based on enhanced capacity, higher inventory and surplus delivery capabilities.
4	Supplier development and certification	(Zsidisin and Ellram 2003)	Environmental aspects are generally overlooked or given low priority for vendor capability developments. Decisions are based on low cost, fast delivery and technological capability of supplier.
5	Joint product development with supplier	(Lee 2002)	Based on compression of time for new product development by using supplier expertise & this at times at extra cost and resources consumption.
6	Long-term relationships with supplier	(Bruce et al. 2004)	Based of suitability of suppliers for future demands. Shuts gate for new entrants and may set complacency in the present supplier. Defies the law of equity.
7	Third party logistics providers	(Chung et al. 2004; Pujawan 2004)	Based on fleet strength and options of transportation, Multiple handling of goods and automation have social costs and not energy efficient.
8	Alternative mode of transportation	(Pujawan 2004; Swafford et al. 2006)	Multi-modal transportation results in excess carbon foot prints.
9	External integration	(Chung et al. 2004; Swafford et al. 2006)	Based on ICT use and commonality of management style and policies. Can be positively used for sustainability also, but suppliers and customers may lack green awareness and may not support initiatives.
10	Internal integration	(Pagell 2004; Swafford et al. 2006)	Based on ERP and systems approach, Integration of Environmental management system (EMS) needs to be done.

Table 2: Impacts and Implications of Logistics Flexibility on Sustainability

S.No.	Type of Flexibility	Range	Mobility	Impacts	Implications
1	Physical supply Flexibility (Zhang et al. 2005)	Variety of materials suppliedand the number of inbound transportation modes	Time and efficiency of different materials moved	Excessive material use Frequent shipments Half truck loads Increased kilometers Smaller quantity of purchased material Increased storage space & work	Increased transportation resulting in increased carbon foot prints, congestion on roads, wastage of material, Disposal challenges
2	Purchasing Flexibility (Zhang et al. 2005)	Different types of materials purchased	Time and cost to fill the different requests	More suppliers Difficulty in selection of green suppliers Increased handling & movement Increased material consumption Increased waste Increased need for packaging	Overlooking the green potential of suppliers, Depletion of more resources, Increase in demand for virgin materials, Increased energy consumption and emission of GHG. Increased wastevity.
3	Physical distribution flexibility (Zhang et al. 2005)	Different types of packaging & the number of modes of transportation	Time and cost to use different modes of transportation anddifferent package	Use of Non-green modes Inter modal handling Excessive packaging Non-biodegradable packaging Suboptimal transportation	More vehicles needed, Increased pollution and congestion, Under utilization of capacity, energy consumption and increased need for land fill and safe disposal of packing material.
4	Demand management flexibility (Zhang et al. 2005)	Variety of customer needsthat can be served	Time and cost to respondto various customer request	To much variety needs surplus capabilities Poor customer awareness about environment protection Increased burden on transportation Excessive customization creates superfluous demand Increased geographical spread	Under utilization of capacity, More consumption and false demand creation, Increased transportation

Scale and Template for Composite Index S[3]

A composite score for assessing the flexibility measures to meet the requirements of the supply chain based on these three different but integrated dimensions namely suitability, scalability and sustainability is proposed. Any measure to introduce additional flexibility in the supply chain must be evaluated on these dimensions to assess the cost of flexibility with special focus on environmental, social impacts and scale of operations of the partnering firms. A number of criteria are listed under each dimension and impacts of flexibility measure on each of them are judged on the scale of 1-9. Value 5 being in the middle of the scale shows the neutrality of the criteria, while 1 reflects large negative impact and 9 represents large positive impact. Scale of 1-9 is used for its wider range to capture the minute difference in intensity of the measurement. Overall scores are calculated by summing up vertically for each category and averaging out then depending upon the context of the study and nature of the organizations involved, different weightages could be assigned to three indices so that the weighted sum of the three gives a composite index for the overall impact and one can identify whether it is a positive, negative or neutral in nature.

In all 9 supply chain flexibilities are considered and all together 53 means to achieve these flexibilities are considered.

Annexure - II shows the developed template for evaluation of composite index for flexibility of supply chains. Expert opinion from a team of 3 experts (from academics and Industry), who are highly experienced and have in-depth knowledge in the field of supply chain management and flexibility in supply chains, is sought for assigning scores from 1 to 9. In all 9 supply chain flexibilities are considered and all together 53 means to achieve these flexibilities are considered. For example, distribution flexibility is achieved through geographical spread of network, vehicle fleet strength, manpower availability, ability to speak same language (ICT compatibility), point of sale (POS) data transfer and use of bar-coding and radio frequency identification (RFID) system. For each of the 53 means their impact on the suitability, scalability and sustainability of supply chain has been considered. For sustainability, supply chain is further categorized in to inbound, manufacturing and outbound supply chains to cover complete activities of supply chains. For scalability, for different aspects are considered including scale of partner organizations, technological capabilities, ICT platform compatibility, and skills and knowledge. Suitability is covered in 3 different aspects namely, nature of business, external environment and local and social needs. Figure 2 shows the schematic

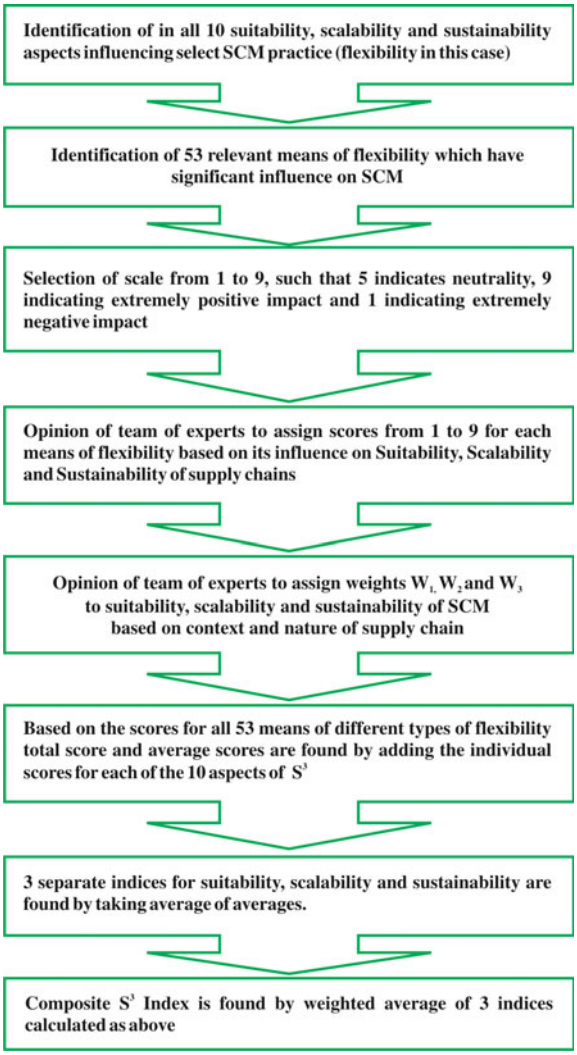

Figure 2: Schematics of Procedure Adopted in Developing S^3 Index for SCM Flexibility

diagram of the procedure adopted for developing 'S^3' index for flexibility of supply chains.

Based on experts' opinion, weights for suitability, scalability and sustainability are chosen to be 0.25, 0.30 and 0.40 respectively. Depending on the context and nature of supply chain these can be varied suitably. On sustainability dimension the average score is '4.54' which is less than the neutral score '5'. It means SCM flexibilities negatively impact the sustainability of supply chains. Similarly, scalability score is '2.76' indicating that flexibility measures are highly unscalable and for MSMEs it is extremely difficult to implement them. Suitability score is '3.62' indicating a negative impact due to poor infrastructure, technological capabilities and other Indian conditions. Together these three indices when multiplied by respective weights give the composite Index 'S^3' which is '3.7' for flexibility practice of supply chain management.

A scale is designed to indicate the nature of impact of SCM practices on S^3 measures. It gives, at a glance, the current status of SCM practice and the directions in which management has to act in order to increase the applicability of SCM practices through making it more suitable, scalable and sustainable."

Figure 3 shows these scores on scale of 1 to 9. This scale is designed to indicate the nature of impact of SCM practices on S^3 measures. It gives, at a glance, the current status of SCM practice and the directions in which management has to act in order to increase the applicability of SCM practices through making it more suitable, scalable and sustainable. This is a handy tool for practicing managers to assess the supply chain management practices and processes.

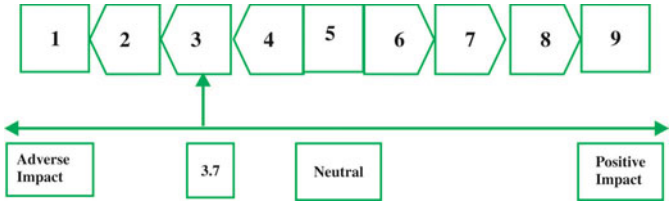

Figure 3: Scale of S^3 Index for Supply Chain Practices

Composite Index S^3 captures environmental and social impacts along with the degree of suitability of flexibility measures. It also captures scalability of the measures for its feasibility when context, scale and external business environment is changed. It can be a very powerful tool to evaluate impact of any other SCM practices like just-in-time (JIT) inventory management, collaborative planning, forecasting and replenishment (CPFR) and vendor managed inventory (VMI) etc.

Concluding Remarks

Supply chains are under scanner due to increased pressure from quarters that feel SCM is promoting the consumption of resources beyond the regenerative capacity of the nature and planet earth. Sustainability of supply chains encompasses all activities in it and a comprehensive analysis is done to investigate the role of various supply chain practice on it. Flexibility is achieved at the expense of extra cost and its cost on sustainability measures of supply chain are not accounted so far. Cost of some natural resources like water, minerals and wood and other utility items like energy, steam, compressed gases, sewage, drainage etc. are not realistic and in fact highly subsidized by the Governments. In fact, one must take these hidden costs of ultra-cheap resources into account when making a cost-value analysis of a particular supply chain. This gap has been addressed and a way of measuring this impact is proposed. The composite Index S^3 captures environmental and social impacts along with the degree of suitability of flexible measures and scalability of the measures for its feasibility when context, scale and external business environment is

Proposed composite index 'S^3' helps management to evaluate various supply chain management practices on three dimensions of suitability, scalability and sustainability.

changed. It, thus address the issues faced by MSMSEs also. A two by two matrix between flexible and sustainable supply chains is also presented that provides typology of supply and helps in identifying the strategic direction to make the chains sustainable and flexible together. This paper draws the attention towards this important link. Specially, in Indian context, relevance of sustainable flexible supply chains can not be overemphasized.

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Annexure - I

Comparison of Sustainability and Flexibility Measures

(*Source:* Hervani et al. 2005; Sarkis 2006; Rao 2008 and Shukla et al. 2009)

S. No.	Impact on	Sustainability Measures	Flexibility Measures
Inbound Supply Chain			
1.	Material usage	Reduction in overall material use	Increase due to variety of work process & less time for production
2.	Material variety	Minimization	Increase due to customization of product
3.	Fuel	Reduction	Increase due to more transportation
4.	Natural resource consumption	Reduction	Increase due to increased geographical spread
5.	Energy consumption	Reduction	Increase due to automation
6.	Packaging	Reduction	May increased to achieve fast delivery
7.	Utilities usage	Reduction	May increase
8.	VOC (Volatile Organic compounds)	Reduction	May increase
9.	Consumption of Consumables	Reduction	Increase due to over work
10.	Other MRO Items	Reduction	Increase due to overwork
11.	No. of suppliers	Increase for widening the base (Social reasons)	Increase for want of variety of resources
12.	Use of clean fuel like CNG in inbound logistics	Promote	Overlook to achieve flexibility
13.	Design for environment (DFE)	Promote	May resist due to loss of flexibility
14.	Supplier integration in design phase	Promote for adoption of green measures	Promote for faster development of the new products
15.	Vendor development	Promote to adopt green technology	Promote for flexibility reasons
Internal Supply Chain			
16.	Green house Gases emission	Reduction	Increase
17.	Soil Pollution	Reduction	Unconcerned
18.	Noise Pollution	Reduction	Unconcerned
19.	Air Pollution	Reduction	Increase
20.	Water Pollution	Reduction	Unconcerned
21.	CFC free Technology	Ban	May promote
22.	PCB (Polychlorinated Biphenyl) free Material	Ban	May promote
23.	Use of Non biodegradable Material	Promote	May not suite the flexibility
24.	Generation of solid and liquid waste	Reduction	May Increase in order to achieve higher responsiveness
25.	Land Contamination	Reduction	May increase
26.	Use of hazardous chemicals	Reduction	May increase
27.	Use of Toxin	Reduction	May Increase
28.	Use of excessive lube oil, greases, coolant etc.	Caution in use	May Increase due to new/ increased capacity machines
Outbound Supply Chain			
29.	Transportation KMs	Reduction	Increase due to increase in empty movement
30.	No of vehicles in fleet	Reduction	Increase to meet delivery schedules
31.	Modes of transportation	Reduction and standardization	Increase and more variety of modes used
32.	Load consolidation	Increase	Decrease to save time
33.	Partial truck load deliveries	Reduction	Increase to satisfy customer needs quickly
34.	Frequency of deliveries	Reduction	Increase to achieve higher speed
35.	Number of distribution channel	Reduction	Increase

S. No.	Impact on	Sustainability Measures	Flexibility Measures
36.	Number of warehouses	Reduction	Increase
37.	Emission free vehicles	Promote	May discourage for want of availability and speed
38.	Stringent safety measures and use of protective gears	Promote to safe guard people	May discourage for want of speed and scares resources
39.	Conservation of fuel & energy	Promote to save energy and fuel	Increase in consumption to achieve fast paced service
40.	Automation of warehouse	Discourage for energy usage and unemployment reasons	Promote to achieve speed and reach
41.	Waste Disposal	Safe and timely disposal, management of waste	Not a focus area
42.	Recycling of scrape	Material saving & waste reduction	May not support recycling
43.	Reuse of components & material	Material saving & waste reduction	May not support recycling
44.	Refurbishing	Promote	Increased dependence will reduce flexibility
45.	Repair	Promote	Encourages change of components
46.	Remanufacture of items	Promote	Use and throw
47.	Byproduct management	Promote	Unconcerned

Annexure - II

Template for Calculating the Composite Index S^3

Parameters / Flexibility	Sustainability			Scalability				Suitability		
	Inbound Supply Chain 1-9	Mfg. Supply Chain 1-9	Outbound Supply Chain 1-9	Scale of Partner Organization 1-9	Techno-logical Capabilities 1-9	ICT Platform Compatibility 1-9	Skills & Knowledge Set 1-9	Nature of Business 1-9	External Environ-ment 1-9	Local & Social Needs 1-9
Product Flexibility										
Customization	2	3	3	3	2	4	2	3	3	2
Numerous features	3	2	4	4	3	4	4	4	3	3
Large No. of Sizes	2	2	2	4	4	5	5	2	3	6
Large No. of colours	2	2	3	2	2	4	3	3	3	4
Variety of products	3	2	1	2	2	4	3	3	3	5
Differentiated product	2	2	3	2	2	4	2	3	4	2
Volume Flexibility										
Variation in aggregate prod.	3	2	4	2	2	4	2	4	3	5
Surplus Machine capacity	1	1	5	1	1	3	2	1	3	4
Inventory Buffers	1	1	1	3	2	1	2	3	3	4
Delayed Differentiation	5	8	8	2	2	1	2	1	2	2
Routing Flexibility										
Alternative machines	2	1	5	1	2	2	2	2	5	5
Outsourcing	8	8	2	7	8	3	8	3	2	8
Flexible Material handling	2	2	2	2	1	5	3	2	2	2
Flexible Transportation network	2	2	1	2	2	1	2	2	2	3
Automation	2	8	2	1	2	2	2	2	2	2
Delivery Flexibility										
Alternative transportation mode	7	2	7	2	2	3	3	8	7	7
3PL providers	3	8	8	2	2	2	2	3	2	2
JIT deliveries	2	7	3	2	1	2	2	2	2	3
Low volume delivery	2	7	3	2	2	2	2	2	2	3
Multiple delivery	2	7	2	2	2	2	3	2	1	2
Tracking of goods in transit	7	7	7	2	2	1	1	2	2	5
Larger distribution network	2	2	1	2	2	1	2	2	3	3

Parameters / Flexibility	Sustainability			Scalability				Suitability		
	Inbound Supply Chain 1-9	Mfg. Supply Chain 1-9	Outbound Supply Chain 1-9	Scale of Partner Organization 1-9	Techno-logical Capabilities 1-9	ICT Platform Compatibility 1-9	Skills & Knowledge Set 1-9	Nature of Business 1-9	External Environ-ment 1-9	Local & Social Needs 1-9
Transshipment Flexibility										
Linking of same level of echelons	7	5	8	2	3	2	3	2	2	3
Fast movement	1	3	1	3	2	1	3	2	1	3
Small vehicles	2	3	2	2	3	3	2	2	2	7
Information system	7	8	8	3	3	2	2	7	3	7
Trust among partners	8	8	8	3	5	2	3	5	3	8
Postponement Flexibility	8	8	8	2	2	2	2	2	2	2
Semi finished Inventory	5	5	5	3	4	4	4	3	5	5
Automation	2	2	2	2	1	3	2	2	2	1
Capability to assemble at retail level	5	2	2	2	2	2	2	2	2	2
Sourcing Flexibility										
Global sourcing	1	3	5	1	1	1	2	2	2	1
SupplierCapabilities enhancement	7	7	7	7	7	7	7	8	3	8
Long-term relations with supplier	8	7	8	2	2	3	2	7	7	7
Multiple suppliers	8	8	8	8	8	8	8	8	8	8
High inventory at supplier end	2	8	5	2	2	2	2	2	2	2
Response to Market Flexibility										
Ability to change	2	2	2	2	2	2	2	2	2	2
Adaptation	2	2	2	2	2	2	3	3	3	3
Capacity building	2	2	2	3	3	3	2	2	2	8
Superior capabilities	7	8	8	7	7	7	7	6	6	7
Strong Information system	8	8	8	2	2	3	2	3	3	3
New Product Development Flexibility										
Supplier integration	2	8	8	2	2	2	3	8	8	8
R&D capabilities	2	8	2	1	1	1	1	2	2	2
Rapid Prototyping	2	8	2	2	2	2	2	2	2	2
Knowledge Sharing	8	8	8	8	8	8	8	8	8	8
Flexible suppliers	2	8	2	2	2	3	3	3	3	3
Infn. network	7	7	8	2	2	2	2	2	2	3
Distribution Flexibility										
Geographical spread of network	2	5	7	2	2	2	2	3	3	3
Vehicle fleet strength	2	3	3	2	2	2	2	2	2	2
Manpower availability	3	8	8	3	3	3	3	7	8	8
Ability to speak same language	2	7	8	3	2	2	3	3	3	3
POS data transfer	7	8	8	2	2	3	3	8	8	8
Bar code and RFID	8	8	8	2	2	2	3	3	3	3
Total Score	204	271	248	141	141	151	154	180	174	222
Average Score	3.84	5.11	4.67	2.66	2.66	2.84	2.90	3.39	3.28	4.18
Three Indices	4.54	2.76	3.62							
Weights	0.45	0.30	0.25							
Composite Index S^3	3.7									

Research Questions

1. What are the costs of supply chain flexibility? Is it always possible to evaluate these costs in monetary terms?
2. How concept of supply chain sustainability is linked to flexibility? Is flexibility detrimental to sustainability of supply chains?
3. How various supply chain flexibilities can be incorporated without compromising sustainability and how would you evaluate flexibility measures for their impact on sustainability.
4. Why sustainable and flexible supply chains are relevant in Indian context? What efforts at policy level should be made to improve the current situation?

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