Managing risks in sustainable supply chains

Invited paper

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Abstract

Purpose of the paper: *The aim of this paper is to discuss the emerging challenges that modern supply chains face from the perspective of sustainability, highlighting the opportunities and the risks that these organizations encounter.*

Methodology*: The paper is theoretical, and provides an analysis of trends and challenges for sustainable supply chains and the management of related risks, highlighting some gaps in the literature.*

Findings*: The paper categorizes the priorities for modern sustainable supply chains and provides a clear differentiation between the concept of 'sustainability risk management' and the categorization of 'risks in sustainable supply chains'.*

Implications and originality/value of the paper*: The paper addresses different gaps in the literature of sustainable supply chains and provides the managers with helpful directions for their supply chain management agenda. In detail, authors identifies trends that seem to make supply chains more vulnerable and exposed to the risk, key risk-related questions for managing sustainable supply chain, suggesting a number of important issues which need to be weighed when supply chain design decisions are taken.*

Research limitations*: The theoretical approach of the paper can benefit from future in-depth analyses based on case studies.*

Key words: sustainable supply chains; sustainability risk management; risks; supply chain management

1. Introduction

There is no doubt that in recent years the business environment has become more turbulent, and hence less predictable, and characterized by the presence of more competitive opportunities and - at the same time - sources of vulnerability. Whereas in the past it was standard practice to plan ahead - with a time horizon of months, if not years - now the challenge is to find ways to become much more responsive to events as they happen. At the same time, organizations are now required to be more responsible in terms of the environmental, economic and societal impacts of their actions.

A number of authors have identified key strategic Supply Chain Management (SCM) challenges that are of increasing concern to organisations. For example, Naslund and Williamson (2010) identified three such concerns: integration of supply chain activities and processes; collaboration across the supply chain members; and sustainability. Indeed, across all the different emerging themes in Supply Chain Management literature, sustainability is one of the most cited. There is a growing awareness

of the need for companies to take a more pro-active approach towards building the principles of sustainability into their business strategies.

Implementing sustainable strategies can enable companies to increase their competitiveness and to improve customer and supplier relationships. Whilst a greater focus on sustainability leads companies to embed social, environmental and economic considerations into their supply chain strategy, it also means facing and controlling new risks in their business (United Nations, 2011).

Sustainability and the increased exposure to risks are strongly related. Organizations must become aware of their role in mitigating the impact of the increased global competition and the multi-faceted risks that are inherent in global operations. For example, the generation of extra stocks of products due to forecasting errors represents a risk for organizations in terms of costs, but also in terms of social responsibility and macro-economic sustainability. Traditionally, businesses have been forecast-driven i.e. they have been run on the basis of projections of future demand, often based on past history. Such an approach works well when the business environment is relatively stable; clearly it is less effective in the uncertain conditions that many organisations face today, for example with respect to commodity prices such as oil and gas which are more volatile, or considering the variable availability of raw materials like oil and gas, or the impact of political instability in where raw materials are sourced. In addition, the progressive scarcity of water or some agricultural commodities make these political and social issues, not only managerial challenges.

It is also the case that many firms are dependent on supply chain networks that were designed some years ago when the world was a more of a certain place and the assumption was that the future would be more like the past. Now, in the significantly changed circumstances that many businesses confront, it may be the case that those supply chain solutions are no longer fit for purpose.

The optimization of transport and storage costs represents a challenge for sustainable supply chains. Conventional supply chain design was often based on so-called 'network optimisation' principles. More often than not the factor being optimised in those exercises was the firm's operating cost. Thus, the aim was to design a network which would minimise logistics costs for the organisation, particularly transport and storage costs. Also the analysis was static, not dynamic - meaning that it used the costs prevailing at a single point in time as the basis for the calculation. As a result those companies, operating logistics networks designed ten or twenty years ago, may need to revisit those design decisions and re-work the analysis to incorporate the major changes that have taken place in the cost parameters. From a sustainability perspective, the scope of network optimization should be extended in order to include environmental considerations as well.

Hence, the management of risks related to sustainable operations and the development of risk management tools that can positively assist sustainability are fast becoming a priority for businesses in every sector. Thus, the aim of this paper is to discuss the emerging challenges that face

modern supply chains from the perspective of sustainability, highlighting the opportunities and risks that these organizations face.

2. Trends and challenges for sustainable supply chains

Starik and Rands (1995, p. 909) define 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".

Carter and Rogers (2008) and Carter and Easton (2011) introduce sustainability to the field of supply chain management, and provide a framework of sustainable supply chain management (SSCM) based on resource dependence theory, transaction cost economics, population ecology, and the resource-based view of the firm. In their view, the literature suggests that organizational sustainability, at a broader level, consists of three components: natural environment, society, and economic performance. They define SSCM as the strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key interorganizational business processes for improving the long-term economic performance of the individual company and its supply chains.

Recent studies analyse the ways companies are practically focusing on sustainability. The issues related to so-called green supply chains are particularly worth of mention. Still in October 2008, the United Nations launched, in the Environment Programme, the Green Initiative along with top economists and the support of the governements, including Germany and the European Commission. The pillars of this new initiative were clean energy and clean technologies, including recycling; rural energy, including renewables and sustainable biomass; sustainble agriculture and ecosystem infrastructure; sustainable cities, including planning, transportation and green building. All the topics related to raw material consumption, storage, waste reduction, transportation and recycling are significantly related to logistics and supply chain management.

In this sense, sustainability is related to "green" - environmentally responsible - supply chains that eliminate waste, reduce pollution and contribute in a positive manner to improving the quality of the environment through eco-friendly processes, subassemblies and finished goods. Carbon footprint reduction along with the supply chain is one example.

Already in 2010 Simchi-Levi highlighted how in some industries 'being green' will play out as lead to an increase in regulations that companies will have to follow, and will require thinking about how much carbon the supply chain produces.

Authors (Simchi-Levi, 2010; Naslund and Williamson, 2010; Gold *et al.,* 2010; Seuring, 2011) defined the priorities of modern supply chains as summarized in Table 1.

Tab. 1: Priorities of modern supply chains

OUTCOME	OBJECTIVE	KEY DESIGN TRAITS
Cost	Reduce product costs, ensure timely and reliable delivery and maintain quality.	Reduced use of slack in its three forms - inventory, lead time and capacity. Standardization of products and processes where possible. Emphasis on reducing waste and variance across the supply chain. Modular supply chain design, involving close interaction and integration with immediate customers and first-tier suppliers (other suppliers are expected to manage their own suppliers).
Responsiveness	Respond to changes in demand (volume, mix, location) quickly and at reasonable cost.	Close information linkages with critical customers and suppliers to monitor demand, facilitate/improve forecasting and monitor state of supply. Excess capacity - redundancy - in the supply chain (especially on the upstream side). Supply planning to include not only production capacity but also logistics capacity. Prequalified suppliers. Emphasis on small-lot production. Extensive supplier development and supplier assessment systems. Information systems to coordinate production/ information flows.
Risk	Ensure that supplies coming through the supply chain are protected from disruption because of external threats. Protect product integrity and consistency.	Emphasis on visibility and transparency, provided through integrated information systems (or, in extreme cases, vertical integration) throughout the supply chain. Redundancy of resources in case of a problem with a supplier. Limited number of partners (fewer opportunities/ entry points for a possible threat). Mapping of the supply chain to identify possible weak points. Comprehensive and integrated supply chain planning and management. Emphasis on control through certification, extensive auditing or other means.
Sustainability	Provide products through a supply chain that ensures controlled and minimal resource impact, both today and in the future. Ultimately implement and maintain a "cradle to cradle" perspective.	Visibility/transparency throughout the supply chain to ensure that all members are aware of threats or opportunities. Greater emphasis on the Three Ps (product design, process, packaging). Integrated supply chain planning and management, in recognition that design must begin with resource extraction and end with product disposal/renewal. Use of broader performance measurement systems and measures (total cost of owner- ship, triple bottom line). Extensive supplier prequalification and assessment to ensure that the "right" suppliers are selected and that they understand what is required. Extensive use of audits and certification standards throughout the supply chain (ISO 14001). Introduction of systems for product takeback (reverse logistics) and marketing waste.

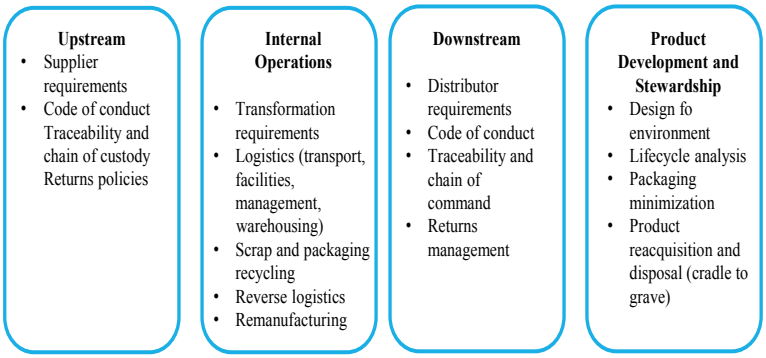
Resilience	Develop a system that can identify, monitor and reduce supply chain risks and disruptions, as well as react quickly and cost-effectively. Offer the critical customer "peace of mind."	Emphasis on visibility and transparency, provided through integrated information systems (or, in extreme cases, vertical integration) throughout the supply chain. Acceptance of the need for excess resources (inventory, capacity, lead times). Mapping of the supply chain to identify possible weak points. Integrated supply chain planning and management. A focus on possible threats not only to suppliers but also to logistics linkages. Presence of precertified/prequalified suppliers. Extensive use of contingency planning ("What if?" analysis).
Innovation	Provide critical customers with a stream of products and services that not only are new but also address needs that competitors have neglected or not served well. Provide new ways of producing, delivering or distributing products.	Development and protection of intellectual property, due to cooperation with key suppliers. Deliberate presence of excess resources. Viewing suppliers as sources of "close innovations" - developed to solve problems in other markets but that have to be refined before they can be used to address current customer needs. Close integration, especially with critical customers and suppliers, so as to innovate jointly. Encouragement of a wide range of different perspectives and solutions. Avoidance, during early stages of product development, of specific performance metrics so as not to stifle innovation. Offering a wide range of supply chain structures ranging from purely modular to purely integrated, depending on the type of innovation being pursued.

Source: Adapted from: Simchi-Levi (2010)

Global supply chains today are particularly exposed to stricter regulations, audits and certifications in fields of sustainability, in particular pollution, gas emission, waste reduction and reverse logistics. In recent years, issues related to product design have become paramount as companies try to focus more on reusable and recyclable products and parts.

All the above-mentioned issues related to sustainable supply chains can be categorized in the areas of upstream relationships, internal operations, downstream relationships and product development (Mollenkopf, 2006) as indicated in Figure 1.

Fig. 1: Pillars of sustainable supply chains



Source: Adapted from: Mollenkopf (2006)

Considering the issues related to sustainability in supply chain management, there are still some questions that are not fully addressed by the literature (EIU Report, 2010a; EIU Report, 2010b; Wittstruck and Teuteberg, 2012).

The macro-economic crisis may represent an obstacle to pursuing sustainability.

The organization's immediate financial and competitive goals are of higher priority than sustainability. The economic crisis may represent a leading obstacle to embracing sustainability.

The link between sustainability and profitability remains unclear.

While there is a strong link between financial performance and commitment to sustainability, organizations seem to consider this link strong in the long term and not in the short term (Laszlo and Zhexembayeva, 2011).

Sustainability can lead to new supply chain strategies.

Different authors emphasise the increasing strategic attention to - in particular - environmental protection, green transports and development of green products. As a consequence, hopefully, companies will also increase the communication of social sustainability goals, through codes of ethics and communication for example (Carter and Easton, 2011).

Organizations should embed sustainability into various corporate functions.

The EIU Report (2010a) on sustainability highlights that companies include sustainability in a variety of corporate functions, including supply chain relationships (29%), improving energy efficiency (38%), educating employees on sustainability (32%) and engaging employees in sustainability-related activities. In addition, considering the strategic role of sustainability efforts, these should be led by senior management and supported by various stakeholders. A different research conducted by EIU

Report (2010b) revealed that sustainability initiatives are very important to the boards at for the 44% of the companies, and to senior management at a 36%. However, these figures are much higher than those of any other stakeholder, whether it is middle management inside the company (19%), employees (20%) and investors (23%) - or external local communities (28%), customers (23%) and suppliers (9%). This indicates that management needs to do more to educate both internal and external groups on the importance of sustainability to corporate strategy.

3. Understanding risk in sustainable supply chains

Shrivastava (1995, p. 955) provided a description of sustainability which is directly related to risk. Sustainability means offering, "the potential for reducing long-term risks associated with resource depletion, fluctuations in energy costs, product liabilities, and pollution and waste management".

Recently, Spekman and Davis (2004, p. 418) suggest this one "[...] dimension of risk relates to the concept of corporate social responsibility and to the extent of which supply chain members' reputation and image can be tainted by the actions of another member who engages in activities that result in public sentiment or outcry or, even worse, is accused of criminal behavior where liability extends up and down the supply chain".

Sustainability and Risk are evidently related.

In the risk management literature, an existing gap is related to the absence of a clear differentiation between the concept of 'sustainability risk management' and the categorization of 'risks in sustainable supply chains'.

Sustainability risk management is a business strategy that aligns profit goals with a company's environmental policies (Anderson and Anderson, 2009). Organizations implementing sustainability risk management generally focus on the environmental effects of each business process individually and then look for ways to minimize them. An effective sustainability risk management framework can help in identifying emerging issues of concern that may affect supply chain, operations and production. Examples of emerging issues include the availability of renewable energy sources and the depletion of non-renewable resources or changing. In addition, Ernst and Young Co. recognized that 'sustainability risks' affect five domains of the organization: reputational, compliance, financial, operational and strategic (Ernst and Young, 2010).

However, in the last 10 years, research on supply chain risk management has rarely analysed sustainability issues in supply chains (e.g., Spekman and Davis, 2004; Anderson, 2006), and has seldom integrated sustainability issues into the existing supply chain risk literature (Chopra and Sodhi, 2004; Harwood and Humby, 2008; Borghesi and Gaudenzi, 2012; Christopher and Gaudenzi, 2009). In fact, current supply chain risk management frameworks do not provide insights of how sustainability issues materialise as risks. Thus, they also fail to delineate specific risk management approaches.

Recently, the supply chain management literature has placed more emphasis on the issues of sustainability (Foerstl *et al.,* 2010; Christopher *et al.,* 2011; Hofmann *et al.,* 2014). As supply chains become increasingly

global, sustainability and vulnerability simultaneously become more important.

Global supply chains often involve offshore and outsourced activities. In this scenario, social and environmental activities occur beyond a firm's direct control, increasing risk exposure. In addition, there is a need for more attention to be paid towards the environmental footprint and how it might be impacted by the increased need for transportation in order to move goods around the world (Mollenkopft, 2006).

For these reasons, one of the distinguishing characteristics of modern supply chains is that they operate in an environment of heightened uncertainty and business risk. Currently supply chains are probably more vulnerable to disruption than they have been for many years.

Recent events have highlighted once again how vulnerable to disruption our increasingly global supply chains are. Natural disasters such as earthquakes, hurricanes and floods often have tragic consequences and thus capture significant media attention. It is also evident that events such as these can have considerable impacts on supply chains. The effects of the 2011 earthquake and tsunami in Japan were felt in a multitude of companies around the world as a result of disruption to supply arrangements. However, what is not always recognised is that the major part of the risk to supply chain continuity is often created by decisions that are taken by managers on the design of the supply chain itself. We could label such risks as 'systemic' because they lie within the supply chain itself rather than in the wider business environment. Hence it can be argued that the shape of the supply chain risk profile is largely determined by managerial decisions and actions and not just by the exposure to external risk sources.

Very few studies, however, explore and analyse the specific risks brought about by sustainable operations. Cousins *et al.* (2004), Teuscher *et al.* (2006) consider the nature of risk emanating from sustainable strategies, but there is dearth of research that addresses management strategies of these risks in sustainable environments. This study draws upon the literatures of supply chain risk, risk management and sustainable operations to develop synthetic conceptual insights into the existence of specific sustainability risks. Through an extensive literature review it explores and identifies salient types of risks and develops an analytical framework for the mitigation of risks associated to sustainable operations.

Risks faced by sustainable supply chains can be classified into environmental risks (Pollard and Stephen, 2008), financial risks (Chapman, 2006), social risks (Giannakis and Louis, 2011) and operational risks (Blackburn, 2007). Pollard and Stephen (2008) for example distinguished environmental risks into "inside-out" risks and "outside-in" risks. The first category of risk factors includes environmental issues arising from the company's products, services or activities that have a significant impact on the environment. The second involves risk in global environment that has an impact on each organisational unit. Financial risks are those external financial events that could have an adverse impact on financial performance, such as interest rates, exchange rates, credit variability, commodity prices (Chapman, 2006; Pollard

and Stephen, 2008). However, there are also financial risk issues internal to organizations. These can arise from environmental and operational risk events that include brand strength, cash flow dynamics, unsold products, profit and sales (Blackburn, 2007).

These risks are also correlated. For instance, environmental issues such as pollution or product waste problems can damage the company's reputation, which in return will most likely decrease sales and profit, damage brand strength and cash flows. Possible risk categories are summarized in Table 2, through a synthesis of different classifications found in the literature (Giannakis and Louis, 2011); Chapman, 2006; Anderson, 2006; Blackburn, 2007).

Tab. 2: Risks faced by sustainable supply chains

Environmental risks (inside in)	• Environmental incidents (e.g. Fires, explosions, accidents) • Pollution (air, water, soil) • Industrial emissions • Greenhouse gases • Energy consumption (unproductive use of energy) • Packaging
Environmental risks (outside in)	• Natural disasters (e.g. hurricanes, floods, eartquakes) • Social uncertainty • Political instability • Industry/market risk
Social risks	• Unsocial working hours; unbalanced employee work life • Wages (unfair payment) • Child labour/forced labour • Discrimination (race, sex, religion) • Employee health and safety risk • Workplace health and safety risk • Exploitative hiring policies • Human rights (infringe on the rights of others)
Financial risks	• Interest rate risk • Fiscal risk (tax related risk) • Exchange rate risk (currency fluctuations) • Credit uncertainty • R&D investment risk • Changes in relative prices (volatile oil/fuel prices) • Economic recession
Operations risks	• Demand volatility/Seasonality • Inaccuracy in forecast • Quality related risk • Lack of availability of raw material • Product design changes • Fluctuation in lead time • Contraint on supplier capacity • Supplier bankruptcy • Labour strikes in supplier's company • Losing the competitive advantage of supplier • Non-confirming products • Excess inventory risk • Inventory stock-out

Source: our elaboration

There is a number of trends that seem to make supply chains more vulnerable and exposed to the risk of disruption than was perhaps the case in the past. These include:

- the trend to 'lean' supply chains and just-in-time practices. Many companies have actively sought to improve the efficiency of their supply chains by introducing just-in-time arrangements and have sought to 'lean' down their operations. This approach, whilst undoubtedly of merit in stable market conditions, may become less viable as volatility in the business environment increases;
- the globalisation of supply chains. There has been a dramatic shift away from the predominantly 'local-for-local' manufacturing and marketing strategies of the past. Now, as a result of offshore sourcing, manufacturing and assembly, supply chains extend from one side of the globe to the other. As a consequence there can be an exposure to geo-political risks as well as exchange rate changes and longer, more variable lead-times;
- focussed factories and centralised distribution. In an attempt to capture the economies of scale, many companies have rationalised their production facilities and centralised their distribution. Thus, instead of many smaller and often local factories and warehouses serving local markets, those companies now seek to serve global markets from fewer but bigger facilities. As a result, the risk to the system as a whole increases if one of those facilities becomes inoperable.

As a result of these and other trends today's sustainable supply chains have undoubtedly become more complex and vulnerable. Complexity, properly defined, is not just about how complicated these networks are but rather about how inter-connected they are. The typical supply chain today will often have more nodes and links than in the past. This makes the task of controlling the network more difficult. As an example, Henry Ford 1 producing the Model T Ford owned most of the end-to-end supply chain including steel mills, rubber plantations and component manufacturing factories. Today, Ford is a totally different business, reliant on thousands of independent suppliers and partners located in a multitude of countries. As a result, the potential for unexpected events that could impact any of the myriad of nodes and links in the system and hence disrupt its continuity is increased.

In order to support organizations in including sustainability issues in their supply chain management agenda, there are some questions that supply chain managers should ask and respond to (Table 3).

Tab. 3: Questions for supply chain managers

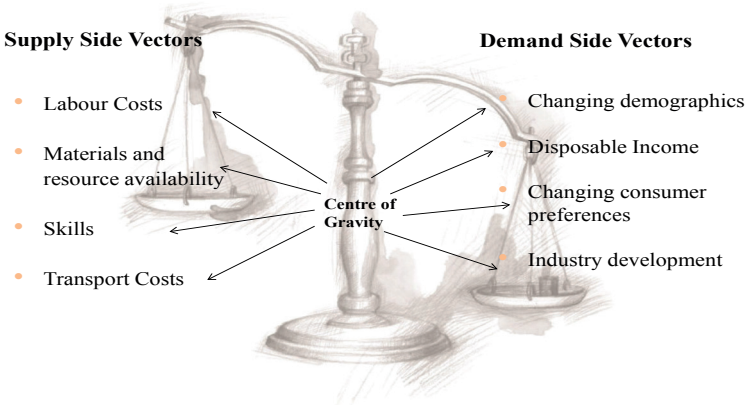
Strategic risk	- Is SCM integrated into sustainability strategic planning? - Does the organization fully understand and address the strategic implications of sustainability risk to the supply chain? - Does the SCM team have skills and people to evaluate these risks? - What sustainability risks in the supply chain can be turned into new business opportunities? - Is SCM involved in researching, developing and designing new products? - Are social risks and environmental risks considered in stainability strategic planning?
Compliance risk	- Are policy and regulations clear in the field of sustainability? - Is SCM a part of the organization's sustainability strategy and reporting? - Are the SC performance measures and reporting aligned with industry standards for compliance and transparency with stakeholders? - What regulatory and customer requirements might be established that affect SCM, and how prepared is SCM to respond? - Is your company subject to any green supplier program requirements, and if so, are you complying? - Does your organization have a green supplier program in place, and if so, how are you tracking compliance by your suppliers?
Financial risk	- Are the SCM functions up to date on the fiscal and financial controls related to sustainability programms? - To what extent has sustainability costs been contemplated in supply chain decision-making? - How can SCM help to prioritize projects and control expenses related to sustainable programms? - Has the organization decided on what is material for financial and non-financial supply chain reporting purposes? - Is SCM involved in reaching financial goals related to sustainable programms?
Reputational risk	- To what extent does the organization engage in ongoing dialogue with its suppliers around sustainability? - Does the organization conduct supplier audits and/or maintain supplier scorecards, including sustainability issues? - What opportunities can be captured from SCM collaborating with other business functions, such as sales and marketing or product development? - Is reputational risk at the forefront when sustainability strategy is developed and implemented within the supply chain? - Is SCM working with the organization's internal and external auditors to enable transparent reporting of its data? - Does SCM currently have adequate controls and processes in place in the event that sustainable supply chain risks become part of the annual financial statement disclosures in the future?
Operational risk	- Has the company assessed the supply chain for key cost-saving (and carbon-reducing and/or waste-reducing) opportunities? - Has SCM estimated how a long-term change in weather patterns, a new price for carbon emissions, or higher energy costs would affect the entire supply chain and margins? - Has the company calculated the greenhouse gas emissions from its supply chain? - Has the company calculated the environmental impact from its products (lifecycle assessment), and is that data being used effectively to make better decisions? - Does SCM understand its contribution to sustainability measures and where to focus efforts to improve them? - What management systems and internal controls are in place to identify, monitor and quantify the risks and opportunities of sustainability-related issues in SCM?

Source: Adapted from: Ernst and Young (2010)

4. Changing centres of gravity

All supply chains have a 'centre of gravity' which is determined by the combined effects of the 'pull' of various forces on the demand side and the supply side of the firm. The resultant centre of gravity impacts decisions on where factories should be located, where materials should be sourced and where strategic inventories should be positioned. Figure I below suggests that a number of important issues need to be weighed in the balance when supply chain design decisions are taken.

Fig. 2: The supply chain's centre of gravity is shifting



Source: Picture source: http-//www.troyrawlings.com/images/scales_20of_20justice.jpg

On the demand side the forces or vectors that will impact the centre of gravity include:

Changing demographics

As a result of population growth dynamics and changing age profiles, some markets globally are growing more rapidly whilst others are shrinking. For example, Unilever now reports that over half its turnover comes from developing countries.

Differences in disposable income

A major change is taking place regarding the relative growth in spending power in different countries. Traditional markets in the West, which once dominated global spending, are now being overtaken, by the emerging economies in terms of expenditure.

Changing consumer preferences

As populations change from being predominately rural towards increasingly urban and as their disposable income rises, so does the pattern of consumption. The massive growth in the demand for cars in China and India provides a good example of this, as do the changes in diet, now occurring in many emerging economies with a consequent rise in the demand for dairy and meat products.

Industry development

The major shift in industrial production away from Western economies to low cost countries has had a significant impact on trade flows and the level of demand for raw materials. Serving these fast growing markets, whilst still needing to maintain a presence in static or declining markets, is a challenge many companies face today.

Similarly, on the supply side, a number of factors will act as countervailing forces impacting the centre of gravity. These include:

Labour costs

Many sourcing decisions in recent decades have been motivated by the desire to take advantage of lower labour costs. So-called 'low cost country sourcing' has been based on the desire to improve competiveness by manufacturing or sourcing in locations where labour costs are a fraction of more traditional locations. However, what were once significant differentials in labour costs has often been eroded by wage inflation. Likewise, new potential contenders for the description of low cost countries have emerged.

Material and resource availability

Inevitably, the availability and the cost of key input materials and resources such as metals, energy, chemicals and other commodities are a major influence on location decisions. With rising demand and, in some cases, declining supply the availability and prices of these critical input factors can be dramatically affected. There is a growing realisation amongst some established manufacturing companies that they will have to re-assess their current supply chain arrangements as production economics that prevailed in the past may no longer apply.

Skills

As industries continue to become more knowledge-intensive and dependent upon specific skills and capabilities, access to them becomes ever-more critical. Even in times of high unemployment companies in many sectors find that they face skills shortages, for example information technology specialists, software designers and engineers. Whereas once it was the Western world that pre-dominated in the supply of these skills, this is rapidly changing as the levels of education and training in the newly emerging economies accelerates.

Transport costs

Due to the fact that the major part of transport is dependent on oil-based fuel, it is inescapable that transport costs will be impacted by variations in the cost of oil. When many of today's supply chains were originally designed, the cost of oil was a fraction of what tends to be today. Whilst the current volatility in fuel prices make it impossible to assess future trends, it is quite possible that if oil prices were to rise over time, current supply chain arrangements will prove to be too expensive.

5. The search for structural flexibility

Due to the likelihood that the centre of gravity of a supply chain is going to change more frequently in the future, given the volatility of the business environment, the need for flexibility in the supply/demand network increases. Many companies find themselves in a situation where they have invested in specific supply chain solutions which are often fixed for a period of time e.g. factories, distribution centres, supply arrangements etc. As a result, they may find it difficult to re-configure the network as conditions change. This ability to quickly change actual shape of a supply/demand network can be called structural flexibility.

What are the key enablers of structural flexibility?

Perhaps the most critical enabler, but the most difficult one to achieve, is a corporate culture and 'mindset' that is open to change and is comfortable with frequent changes to processes and working practices. Also, because of the fact that some of the enablers of structural flexibility - discussed below - involve much higher levels of collaborative working across organisational boundaries, there needs to be a willingness to actively create 'win-win' partnerships across the supply chain.

Given that this co-operative approach to working across the extended enterprise can be achieved, the main elements that underpin structural flexibility include:

Visibility and information sharing

The ability to see from one end of the pipeline to another is essential. It is important to be able to see the changes that are on the horizon both upstream and downstream. Information sharing provides a powerful platform on which collaborative working relationships across the supply chain could be built.

Access to capacity

An important facilitator of flexible supply chain management is the ability to access additional capacity when required. Capacity in this case refers not only to manufacturing but also to transport and warehousing. Furthermore, that capacity may not be owned by the firm in question, it could come from partners across the network, third party providers or even competitors.

Access to knowledge and talent

Given the rapid rate of change in both markets and technologies, a major challenge to organisations today is to ensure that they have access to knowledge in terms of the potential for product and process innovation. Equally critical is the access to people who are capable of exploiting that knowledge. 'Open innovation' and technology sharing agreements are ideas that are rapidly gaining ground. Once again, companies are increasingly turning to external sources of knowledge and talent to provide adaptive capabilities.

Inter-operability of processes and information systems

In an ideal world, organisations would be able to alter the architecture of their physical supply chains in short time frames with minimal cost or disruption involved. Equally, those same companies need the ability to manage multiple supply chains serving specific market segments. To enable this re-configuration, it greatly helps if the nodes and links of the supply chain are 'inter-operable'. In other words, they can be plugged together in a variety of ways to enable specific supply chain solutions to be easily constructed. Standard processes and information systems help greatly in creating inter-operability.

Network orchestration

Due to the fact that the achievement of higher levels of adaptability generally requires inputs from a variety of other entities in the wider supply/demand network, the need for co-ordination across the network arises. As supply chains become more 'virtual' than 'vertical' there is a growing requirement for orchestration. Whether that orchestration task is performed by the firm itself or by a specialist external logistics service provider, the ability to structure appropriate networks and to synchronise activities across the nodes and links of those networks is paramount.

6. Conclusion

When the concept of supply chain management first emerged, the world was a different place. Whilst the original underlying principles of supply chain management still apply today, the idea that networks can be 'optimised' in terms of cost, impact on the natural environment and sustainability has to give way to a design philosophy that is grounded on the premise that the best decisions in conditions of uncertainty are those that keep the most options open. Hence, there is the need to constantly seek supply chain solutions that are flexible and resilient enough to respond to events as they happen.

Supply Chain managers need to be aware of the risks and opportunities that sustainability poses for the organization. Supply Chain Management offers multiple opportunities to reduce costs and mitigate risk as part of an effective sustainability strategy, for example, green product design and packaging specifications that minimize waste, extend life, utilize recycled content and increase recyclability. Moreover, logistics and distribution network redesign that optimizes routing, and reduces carbon emissions can contribute to a more sustainable outcome.

From a more operational perspective, efficient manufacturing and process improvements for lower energy consumption along with an emphasis on waste management and alternative energy sources can only be to the advantage of the business.

As the pressure on companies to improve their sustainability grows, so does the need for them to understand the risk, inherent in supply chain design decisions. In this way, the twin goals of enhanced sustainability and risk reduction may be achieved.

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italian journal of management
Vol. 33, N. 96, 2015

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ISSN 0393-5108
DOI 10.7433/s96.2015.04
pp. 57-74

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