"Supply Chain 2.0": Managing supply chains in the era of turbulence

Article *in* International Journal of Physical Distribution & Logistics Management · February 2011

DOI: 10.1108/09600031111101439

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"Supply Chain 2.0": managing supply chains in the era of turbulence

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Abstract

Purpose – An underlying principle of supply chain management is to establish control of the end-to-end process in order to create a seamless flow of goods. The basic idea is that variability is detrimental to performance as it causes cost in the form of stock-outs, poor capacity utilisation, and costly buffers. This paper questions this approach and argues that in the light of increasing turbulence a different approach to supply chain management is needed.

Design/methodology/approach – The paper reports on the authors' work on a Supply Chain Volatility Index and shows how current supply chain practices may no longer fit the context most businesses now operate in – primarily because these practices were developed under assumptions of stability that no longer hold true. The paper illustrates the findings with case study evidence of firms that have had to adjust to various aspects of turbulence.

Findings – The paper is able to show that most current supply chain management models emanate from a period of relative stability, and second, that there is considerable evidence that we will experience increasing turbulence in the future. This calls into question whether current supply chain models that feature some dynamic flexibility, yet are built on the general premise of control, will be suitable to meet the challenge of increased turbulence.

Practical implications – It is argued that what is needed to master the era of turbulence is structural flexibility which builds flexible options into the design of supply chains. This marks a major departure from current thinking and will require revisiting the management accounting procedures that are used to evaluate different supply chain decisions. The paper presents guidelines on how to manage supply chains in the age of turbulence: by embracing volatility as an opportunity rather than viewing it as a risk, by understanding its nature and impact, and finally by shifting the exposure to risk by building hedges into the supply chain design.

Originality/value – The paper questions the fundamental premise upon which current supply chain models are built and proposes an alternative approach to build structural flexibility into supply chain decision making, which would create the level of adaptability needed to remain competitive in the face of turbulence.

Keywords Volatility, Adaptability, Supply chain management

Paper type Research paper

Supply chain management, as we know it

Supply chain management (SCM) as a concept is now well established, and its adoption has helped many firms to gain a competitive edge. What we often forget is that SCM as an idea is relatively new – it first emerged in an early form less than 30 years ago[1] – but was quickly picked up by academics, consultants, and practitioners and amended and re-shaped to reflect the insights gained through the experience of implementation.

International Journal of Physical Distribution & Logistics Management
Vol. 41 No. 1, 2011
pp. 63-82

0960-0035
DOI 10.1108/09600031111101439

Since then, SCM has quite literally transformed our thinking about how markets may best be served, and how significant competitive advantage can be gained, and lost if it is neglected.

However, as we shall argue, what has now become the "conventional wisdom" of SCM may need some radical re-thinking in the light of major changes in the global business environment in recent years. Our current SCM models were all invented during a long period of relative stability, and as we will show below, this assumption of stability no longer hold. We illustrate the nature of volatility in key business parameters that future supply chains will have to be able to adapt to – a setting we refer to as "turbulence".

Current SCM practice has sought to create what we term dynamic flexibility, which allows firms to cope with certain shifts in demand and technology, but only within the set structure of their existing supply chain design. However, as we shall argue, to meet the challenges of a turbulent business environment, we need structural flexibility that builds flexible options into the design of supply chains. This marks a major departure from current thinking and, as we will show, will require revisiting the management accounting procedures that are used to evaluate different supply chain decisions. We need to move away from a focus on the achievement of "lowest global cost" to serving the centres of gravity within a flexible supply chain structure. This, for example, means favouring "local for local" over "single global sourcing" models that are built on the premise of the low cost of a single commodity, namely the oil price or labour cost, that in the past have allowed us to ship goods half way around the world at competitive prices.

In this paper, we report on two aspects of our work on turbulence: first, we present the "Supply Chain Volatility Index" that seeks to empirically quantify the degree of turbulence supply chains have been experiencing over time, and second, we critically review the degree to which our current SCM models still hold under these changing conditions. We underpin our arguments with case study evidence from a range of firms that have been forced to deal with aspects of turbulence: we report on the cases of World Duty Free (WDF), Hewlett Packard (HP), and Toyota, who each have taken different steps towards redesigning their supply chain to meet these new challenges. We conclude with guidelines on how to adapt supply chain design decisions to promote structural flexibility.

An increasingly global, complex, and uncertain world

It has become common practice for academics and practitioners alike to open papers and speeches with a general statement about the increasingly global nature of business, the increasingly demanding customer, or the increasing uncertainty in global markets. If these perceptions were indeed true, however, they would have serious ramifications for the globe-spanning supply networks that characterise most firms these days. And sure enough, we have seen a range of crises and shocks, even prior to the global financial crisis that started to impact supply chains from 2008 onwards: for example, constraints in container shipping capacity saw the Baltic Dry Index (as a proxy for shipping cost) spiral upwards in 2003, the oil price rose to $140/barrel in the light of growing demand from the Brazil, Russia, India and China countries in 2008 amidst general concerns that we had reached the infamous point of "peak oil" (Hubbert, 1956; Leggett, 2006). Then, the global financial crisis of 2008 saw demand for many goods and services slashed, requiring considerable flexibility to downscale capacity in many sectors.

If such "turbulence" is indeed a likely feature of times to come, the obvious question this raises is whether or not our current SCM models are indeed fit for purpose? A further stimulus in this direction was two separate studies the authors undertook into the phenomena of global sourcing and off-shoring ventures, in which we found a surprising number of companies who were not necessarily gaining real benefits from these strategies (Christopher *et al.*, 2007; Holweg *et al.*, 2011). How could this be, given that the labour cost saving in the countries these firms were sourcing from (or manufacturing in) should by far have outweighed the additional transport cost? Upon further investigation, it soon transpired that an increasing turbulence in different business parameters was leading to higher levels of supply chain risk. A hypothesis was born, which we have since taken forward and investigated with a range of firms we have worked with.

We initially asked senior operations managers about the main challenges in running their supply chains, and although the specific answers differed, the underlying message was the same: the consistent perception was that the business world in which they are operating is inherently unstable. However, despite overwhelming qualitative evidence of a perceived increase in volatility, the lack of empirical evidence was unsatisfactory. Hence, we set out to produce just that – an index of the key business parameters that potentially impact supply chain performance.

The Supply Chain Volatility Index

The overriding question that drove the creation of this index was simple: will the seismic events of the last two years – shipping cost and oil price hikes, financial meltdown, recession, collapse in consumer, and business confidence – pass by, as have many shocks to the system before, or is there now something fundamentally different impacting almost every aspect of the business environment? After all, there have been oil shocks and terrorist attacks before, and each time we saw a timely return to stability. However, there is a crucial difference: this time, we have seen unprecedented levels of volatility in several key business parameters simultaneously, not only in the price of oil but also in the price of many commodities and raw materials. We argue that we are not facing a temporary shock that will quickly pass, but in fact are on the verge of an "era of turbulence", that will feature higher variance in key business parameters: from energy cost, to raw materials, and currency exchange rates.

To illustrate, Table I shows some statistical data for key business parameters: exchange rates, sample commodity and raw material prices, interest rates, and shipping costs. For some, there is more variability over time, for others less. What does this tell us? Actually, very little: there is a wide range of variation in many key business indicators, but often not at the same time. A key argument in our analysis is that we tend to focus our attention on the absolute swings in parameters, which are important in the impact they have on business generally, but we often neglect the much more critical rate of change, which has increased in recent years. Clearly, both aspects of volatility matter, even though the latter is generally not reported in the media, and thus tends to be neglected. We argue that this is a dangerous omission and thus consider both aspects in our measurements.

Table I.
Volatility in key business parameters

	US$ to GBP (WMR) – exchange rate (£)	UK inter bank three months middle rate (%)	UK clearing banks base rate (%)	Crude Oil-Brent current month FOB U$/barrel	Gold Bullion LBM U$/troy ounce	LME-Copper, grade A three month £/MT	MB-steel CR coil $/MT	Baltic Dry Index, in US$
Period	Since 1970	Since 1975	Since 1970	Since 1970	Since 1970	Since 1970	Since 1989	Since 1985
Minimum	1.07	3.44	2.00	1.80	34.87	403.50	250.00	568.00
Maximum	2.62	18.47	17.00	123.62	957.80	4,350.94	1,205.00	11,465.00
Mean	1.81	8.78	8.57	22.77	341.21	1,288.89	456.31	2,099.14
SD	0.33	3.66	3.51	18.50	173.63	782.95	182.94	1,872.65
CoV	0.18	0.42	0.41	0.81	0.51	0.61	0.40	0.89
Compound average growth rate	−0.36	−0.68	−0.74	24.09	23.74	2.11	1.30	−0.16

Notes: FOB – Free on board; LBM – London Bullion Market

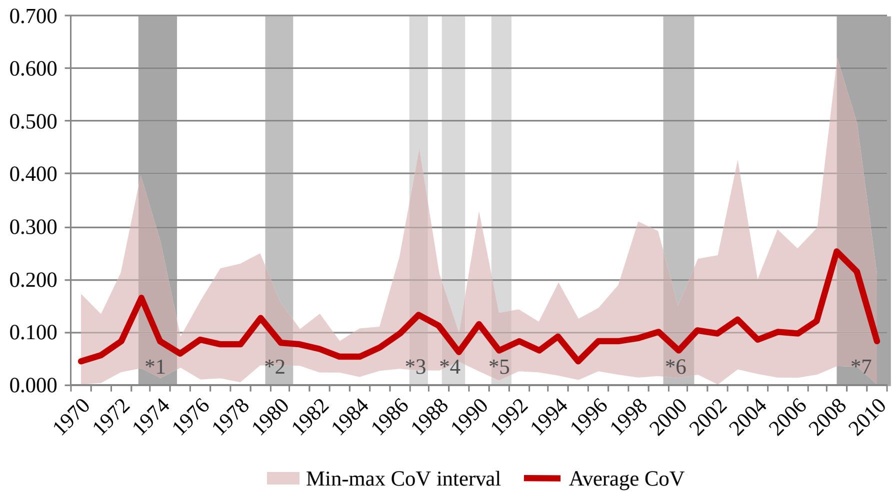
In order to illustrate the degree to which overall turbulence in our business environment is changing over time, we have created a Supply Chain Volatility Index. To this effect, we use the coefficient of variation (CoV) as a normalised and scale-free measurement of volatility, which allows us to simultaneously compare seemingly incompatible business parameters. Specifically, we consider the following indicators, as shown in Table II. Arguably, this list is an arbitrary selection, and we do not claim it is the only possible set one could consider. However, we would argue that it is a good balance between simplicity and a comprehensive coverage of financial, stock market, material, and transportation cost-related indicators.

For each of these, we show the band of annual volatility in their CoV. As we pointed out before, not all indices move at the same time. Many are correlated, but not all react to events or global shifts in the same way. So, what we get is a "band of volatility", the light area in Figure 1. To illustrate how the overall business environment is shifting, we have added an aggregate or meta-index of variation to the chart (the red line). This is the mean CoV across all eight indices. Our argument here is that it does not matter whether there is an increased level of volatility in the oil price, the exchange rate, or the London Inter-Bank Overnight Rate rate. What does matter is when several of these indicators move together, as these changes the general frame of reference.

The most important observation from this analysis is that we have seen shocks before, such as oil crises and "dot.com" bubbles, or political instability and terrorism, but what we are now experiencing is fundamentally different from any of these previous events. As of 2008, we have left an almost 30-year lasting period of stability behind and are now entering a period of turbulence that was last seen during the oil crisis of 1973. In fact, the index value for 1973 was 0.166, and then never exceeded 0.132, before reaching 0.254 in 2008. Furthermore, we see that over the past four decades, there have – on many occasions – been oscillations in particular business parameters. However, as the index shows in relation to the maximum values, just because a single value is showing a drastic increase does not necessarily lead to an

Type	Parameter	Source	Availability of data
Financial	EUR/GBP (WMR&DS) exchange rate	Thomson Reuters Datastream	Since 1970
Financial	USD/GBP (WMR&DS) exchange rate	Thomson Reuters Datastream	Since 1970
Financial	UK clearing banks base rate – middle rate	Thomson Reuters Datastream	Since 1970
Raw materials	Crude Oil-Brent FOB U$/BBL	Energy Information Administration (EIA)	Since 1970
Raw materials	Gold Bullion LBM U$/troy ounce	Thomson Reuters Datastream	Since 1970
Raw materials	LME-Copper, grade A three month £/MT	Thomson Reuters Datastream	Since 1970
Stock market	VIX – Chicago Board Options Exchange Market Volatility Index	Chicago Board Options Exchange	Since 1986
Shipping cost	Baltic Dry Index	Thomson Reuters Datastream	Since 1985

Table II.
Key business parameters considered



Notes: *1, Arab Oil Embargo; 2, Iranian Revolution; 3, Saudi Arabia abandons swing producer role; 4, Black Monday; 5, Invasion of Kuwait; 6, Asian Economic Crisis; 7, Global Financial Crisis. All data up until October 2010 is included in the index. For updated versions please go to: www.innovation.jbs.cam.ac.uk; [a]list of constituents: EUR/GBP (WMR&DS) exchange rate; USD/GBP (WMR&DS) exchange rate; Crude Oil-Brent FOB U$/BBL; Gold Bullion LBM U$/troy ounce; LME-Copper, grade A three month £/MT; UK clearing banks base rate -middle rate; VIX from 1986; Baltic Dry Index 1985; yearly average coefficients
Sources: Datastream; EIA (for crude oil data); Chicago Board Options Exchange (for VIX data)

Figure 1.
The Supply Chain Volatility Index, 1970-2010

overall increase in the index. Clearly, the level of dependence across indicators is far simpler, and it would be foolish to assume that one could predict seismic shifts by inference from the motion of single indicators.

This finding is in particular of great significance, as ever since we have started talking about "supply chain management" in the early 1980s, the average band of variation across the key indicators has been reasonably stable. We have seen isolated shocks, but not only did we revert back to stability fairly quickly, the volatility index – as a measure of all indicators – never really showed any major oscillations. And it is this stability that has led us to design the supply chain structures that we have today – many of which are built on the premise of the low price of a single commodity, such as oil, or low labour cost. Yet, the environment in which we do business is changing, and so must our supply chain strategies. We must question all our supply chain models that were developed under the assumption of overall stability.

Approaches for dealing with turbulence

The basic problem we are dealing with in this paper is not novel. Uncertainty creates risks in the supply chain, and in fact, we already have a wide range of concepts on hand on how to deal with it. Given the ample work already done on supply chain risk, robustness, resilience, is there a need for this paper?

There is, and for two reasons: first, resilience invariably causes additional cost, in the form of slack resources (e.g. inventory and capacity), as well as higher coordination cost (e.g. due to multiple sourcing). While conceptually sensible, under stable conditions, this will place any firm at a competitive disadvantage: if the supply chain is stable, the resources spent on creating that resilience are wasted. As Christopher and Peck (2004) state this "[. . .] question will have to be answered if the commercial community is voluntarily to sacrifice short-term cost optimisation in favour of improved and sustainable supply chain-wide resilience."

Second, what we are talking about are uncertainties that arise from all sorts of areas, some of which can be controlled, some others which cannot. These are not isolated incidents (such as 9/11 or an earthquake), but fundamental shifts in many key variables that determine our business environment. In that sense, we argue that we need to rethink how we operate supply chains in the era of uncertainty and create supply chains that are adaptable to such changes. Some attempts to discuss the notion of supply chain "adaptability" have been made, albeit without any reference to the kinds of turbulence we are debating in this paper (Lee, 2004). Now let us discuss the measures that can be taken to deal with turbulence, in order to create such levels of adaptability, and how these differ from traditional SCM.

Control: the traditional approach to SCM

Any variability is traditionally viewed as threatening and counter-productive in the operations management world. This view has given rise to operational practices such as lean, SIX SIGMA, push-based production strategies that enable firms to produce against a long-term stable forecast, and strategic initiatives including advance contracts ("pay-as-billed"), outsourcing, contract manufacture, etc. On the information flow side, we have seen many concepts that aim to improve visibility, such as vendor-managed inventory (VMI), collaborative planning, forecasting and replenishment (CPFR) and the like (Holweg *et al.*, 2005).

All these approaches help to eradicate variability, prevent costly dynamic distortions such as the "bullwhip", and spread the operational risk. The key objective is to reduce cost through increased control, which in a stable world certainly does enhance profitability. In a volatile environment, however, control efforts result in a rigidity of supply chain structures and interactions. This rigidity may result in amplification rather than dampening of variability. Thus, the more variation in the input parameters is present, the less effective our control model tends to become. The variability that hurts performance and is related to supply chain design can emanate from a wide range of factors: from the demand side (e.g. shifts in consumer demand for products), the supply side (e.g. hikes in steel, copper, and gold prices), regulation (e.g. shift in consumer perception towards climate change), political (e.g. opening of markets and growth in East Asia, but also political rows and regional conflict), energy cost (e.g. the price for oil, gas and electricity, and the implications for transportation cost), financial (e.g. exchange rates, currency fluctuations, and availability of credit), and technology (e.g. shifts in dominant designs, disruptive innovations). Given that these factors are of a very different nature, we need a generic strategy that anticipates, rather than reacts to, turbulence.

The need to move from dynamic to structural flexibility

Most firms by now have learned how to build dynamic flexibility into their supply chains. They have made the transition from a supply chain geared exclusively for factory efficiency, which was riddled with bullwhip and other dynamic distortions, to a stable supply chain that managed seamless flows across tiers in the network. This is the key tenet of what the SCM literature has discussed ever since 1982. Very few firms, however, have learned how to build structural flexibility into their supply chains. Two well-published cases are Dell and Zara (Ferdows *et al.*, 2004; Fugate and Mentzer, 2004; Kapuscinski *et al.*, 2004), which are amongst the few firms that not only manage endogenous turbulence, but have also attempted to extend their strategies into managing demand-driven exogenous turbulence. Dell manages the demand for its components by adjusting prices. Zara has developed a "rapid-fire" supply chain that is able to respond very quickly to changes in fashion and demand by drawing upon what can be best described as a set of "modular" small factories in Northern Spain. However, such competitive advantage can be short-lived, as the case of Crocs vividly illustrates (Marks *et al.*, 2007). The reason is that the ideas and practices of SCM have largely emerged over a period of relative stability – as demonstrated by the Volatility Index – they have not been tested until recently in more turbulent conditions.

We need a new mental model for how to deal with turbulence in the supply chain, by shifting away from a single-minded quest for efficiency to a balanced view on how to create adaptable supply chain structures (Table III). In many ways, the departure from the traditional "efficient" supply chain, to one that is able to cope with dynamic distortions (using tools such as CPFR, VMI, and information sharing), to a supply chain that is able to adapt structurally is a natural transition (Figure 2). However, it does require a fundamentally different perception of what a "good" supply chain design should look like. Let us define in more detail what is meant by structural flexibility.

What exactly is structural flexibility?

Structural flexibility refers to the ability of the supply chain to adapt to fundamental changes in the business environment. Here, we first and foremost consider the centres of gravity in a firms' supply chain system. We can broadly define "centre of gravity" in this context as the nexus between supply and demand. Using a mechanical analogy, if each customer has a string to pull products from your factory (the more items, the stronger the pull) and major raw material and component suppliers hold strings that pull the location of the manufacturing plants towards them: on balance, your centre of gravity would be where all forces even each other out. And there might well be several centres that emerge, in many cases by product category, or by market region.

Why does this matter? The centre of gravity minimises the distance to your customers, so this would be the best "local for local" solution. A firm might also have

Table III.
Efficient versus adaptable supply chain

	Efficient supply chain	Adaptable supply chain
Focus	Establish control to reduce variability and thus cost to compete	Embrace volatility and develop superior ability to adapt
Decision time horizon	Short-term, quarterly results	Long-term viability, while maintaining positive cash flow
View on turbulence	Bad, as it causes instability and cost	Inevitable, hence the need to pre-empt it by creating adaptable structures
Approach to dealing with turbulence	Use SIX SIGMA and other tools to eradicate it where possible	Use tools to increase flexibility "bandwidth" to cope

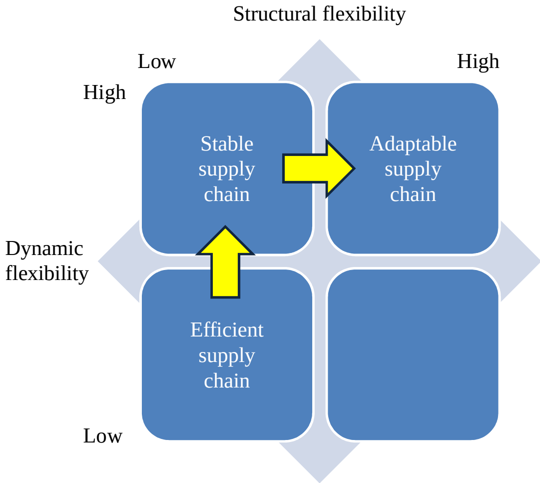


Figure 2.
Moving from dynamic to structural flexibility

several centres across the world. In this case, consider having a plant in each of them. Arrange your supply chain accordingly. For example, it might well make sense to have key suppliers in each of your main market regions, so that jumps in transportation cost can be offset. To illustrate this point, consider the case of Procter and Gamble's snack food, Pringles. Pringles can be bought around the world, in their classic tubular packaging. Yet, they are made in only two factories (one in the Carolinas in the USA, and one in Belgium). Does this make sense? Under conditions of stability, it certainly does. However, as shipment costs are a significant fraction of the overall product cost, which has a low value density, this leaves Pringles open to any shift in transportation cost when serving centres of gravity outside the USA or Europe.

The key question is if the "centre of gravity" in terms of market demand and supply characteristics changes can the supply chain be easily re-configured to cope with that change? Most supply chains lack the ability to adapt quickly to changed market and environmental conditions. This is primarily because they have been designed with efficiency rather than flexibility in mind. Supply chains that exhibit structural flexibility typically will have achieved that status through a number of actions, of which we would argue the main ones include:

- *Dual sourcing*, by having alternative sources for key raw materials and major components.
- *Asset sharing*, i.e. being prepared to share physical assets such as factories, distribution centres or trucks with other companies, including competitors. For example, several major British retailers and their biggest suppliers are examining the opportunities to share distribution centres and transportation in order to create additional economies of scale.
- *Separating "base" from "surge" demand*, by recognising that most products will have a base level of predictable demand that can be planned for. Demand above the base level ("surge") may be managed through the use of postponement techniques.

- *Postponement*, by holding the base materials, sub-assemblies, and modules as strategic inventory and assembling or configuring the product against actual orders. Often this is referred to as the "vanilla product" strategy, whereby the generic "vanilla" product is shipped, before it is converted into customised products locally, close to the end customer.
- *Flexible labour arrangements*, by utilising "annual hours" agreements or by making use of agency personnel, so that the labour force can be adjusted – with little or no cost penalty – to meet seasonal demand swings throughout the year, as well as shifts in demand over the product life cycle.
- *Rapid manufacture*, by using new technology to enable the economic manufacture of products in small batches in relatively small facilities, thus permitting dispersed manufacturing. The development of "mini-mills" in the steel industry which are much more flexible than traditional steel making facilities is a good example of this idea.
- *Outsourcing*, to external providers, such as contract manufacturers and third-party logistics firms, to gain access to capacity when required and convert fixed costs into variable costs. For example, DHL is currently working with several vehicle manufacturers in order to create joint aftermarket logistics systems that share trucks and warehousing facilities.

Let us consider how HP, a long-established manufacturer of a range of electronic products including computers, printers, and related equipment, built structural flexibility into its supply chain, and why. The computer and printer industry today is highly competitive and many of the products are almost commodities, i.e. there is little technical or physical differentiation between competing brands. In part, this commoditisation has been accelerated by the continuing price erosion that the industry has experienced. At the same time, the rate of innovation is growing as product life cycles reduce. A further characterisation of the market is that customers – both intermediaries and end-users – have become more demanding, particularly in terms of delivery performance. New distribution channels such as the internet have enabled customers to make comparisons more easily and there is a greater tendency for those customers to "shop around".

The combined impact of all these trends is that demand for computers and printers has become more volatile making forecasting much more difficult. The common perception in the firm is that supply chain complexity has increased at HP, as indeed it has for most companies. Because of the constant flow of new product introduction and the inevitable increase in product variety, the search for complexity reduction has intensified in recent years. Some of the ways that HP has sought to combat supply chain complexity have been through:

- *Late product configuration*. HP was an early pioneer in the design of products to enable late configuration. Their experience with their printer range is well documented but essentially involved the building of a generic product which is only localised once its final destination is known. The challenge is to extend this concept across their other product families.
- *Increased "local for local" production*. The previous trend of manufacturing in low-cost countries has been reversed with a "near sourcing" strategy;

i.e. manufacturing in countries (still low cost) that are nearer to their markets. This enables shorter lead-times and a greater ability to late configure products. Manufacturing in countries such as China still continues, but increasingly products made there are sold there. The principle is to bring supply closer to demand.

- *Use of alternative distribution channels*. While the majority of HPs sales are through traditional distributor and retail channels, their internet channel now accounts for 40 percent of the total volume. To enable a greater degree of customisation, they have introduced a "hybrid" channel with in-store kiosks where customers can configure and order products. In those markets where they have limited volume, they use traditional distributors.
- *Greater use of contract manufacturers*. About 92 percent of HPs manufacturing of computer and printer products is out-sourced to contract manufacturers. The strategy is to out-source the basic manufacturing but to use their own factories for late configuration and for the manufacture of more complex products. They have introduced a "Factory Express" idea where they are using manufacturing execution systems to achieve a much higher level of flexibility enabling the production of different models on the same assembly line.
- *Centralising inventory and logistics management*. To ensure greater control of inventory, HP manages their inventory globally and centralises the physical stock-holding. This enables HP to balance off "peaks" and "troughs" in demand in different countries. They have their own in-house "4PL" to co-ordinate 119 external logistics service providers. This in-house team comprises almost 400 people who plan and manage the end-to-end supply chain.
- *Introducing VMI*. HP is working with their major distributors to implement a system of "dynamic replenishment". Effectively, this is based on the principles of VMI whereby following a weekly update of sales from those customers, HP automatically replenishes against jointly agreed upper and lower stock bands. A major priority at HP is to improve visibility of real demand and to use that information to drive their manufacturing and replenishment strategies.

Underpinning these specific initiatives is a constant search for ways to further improve agility through the management of complexity. They are increasingly using simulation as a tool to move away from single-point forecasts and identify options that provide the greatest flexibility, while taking decisions based upon a wider definition of supply chain cost. This is the concept of "inventory-driven costs" (Callioni *et al.*, 2005) which seeks to measure the total cost implication of particular supply chain decisions.

In other words, "structural" flexibility enables a supply chain to adjust to shifts in its centre, or centres, of gravity. Supply chain design decisions are taken with the deliberate intention of building flexibility into the structure of the system. And herein lies the key problem: how to justify the investment in this flexibility.

How to value structural flexibility

While making the step from dynamic to structural flexibility might seem an obvious one; unfortunately, it does collide quite strongly with current management accounting practices. In our view, this "accounting trap" or "justification gap" (Fine and Freund, 1990) is by far the greatest impediment to firms making better informed supply chain decisions in the era of turbulence. To give an example: for many years, now one of the most prevalent features of the globalisation of supply chains has been the tendency to move away from local facilities, be they factories or distribution centres, towards regional or even global facilities. Thus, companies that previously may have had "local-for-local" manufacturing and distribution arrangements have rationalised those facilities and centralised both manufacturing and distribution. A major motivation behind these moves has been the search for economies of scale in manufacturing, and inventory reduction across the logistics system. Underpinning the rationale for seeking inventory reduction through centralisation is the "Square Root Law" (Maister, 1976; Zinn *et al.*, 1989) which suggests that the aggregate level of stock in a logistics system before and after a rationalisation of stock locations (e.g. distribution centres) can be estimated by the square root of the ratio of the number of locations post and prior to the rationalisation.

Even though both centralised manufacturing and centralised distribution will normally lead to higher transportation costs, it is generally assumed that these higher costs can easily be paid for by the reduction in the costs of manufacture (through greater economies of scale) and through reduced inventory holding costs (as a result of the "square root law"). However, in conditions of increased turbulence and uncertainty, as we argue, too high a degree of centralisation brings with it its own risks and possibly a reduction in agility and responsiveness as a result of longer lead-times.

The cost accounting trap

The main justification for centralisation – particularly of manufacturing and distribution operations – was the ability to leverage the economies of scale. In other words, by putting a greater volume of activity through the same facility, the unit cost of that activity could be reduced. This is certainly true when the level of fixed costs associated with an activity is high. However, it could be argued that many of these supposed economies of scale may be a result of the accounting principles used in the first place. In conventional "full cost" accounting, all the costs associated with an activity have to be shared across all the entities served by that activity (e.g. products housed in a warehouse). The reality though is that many of these costs may actually be sunk costs – the money having been spent in the past. Even depreciation can mislead since it is not a cost but a non-cash expense. The only costs that are relevant to the economies of scale argument are what are the "avoidable" costs of an activity – in other words, if the activity ceased what costs would disappear?

Under the assumption of stable conditions, discounted cash flow (DCF) models, such as net present value (NPV)-type calculations will always favour centralised, global sourcing and manufacturing decisions (Kaplan, 1986). The reason is that NPV-based models will assume a linear trend (discounting factor) that devalues future savings. In a world of growing uncertainty, this type of approach does not work. In fact, there are three fundamental problems with current cost accounting measures, and how we deal with location and sourcing decisions:

- The use of single-point forecasts for key variables, even though those forecasts are generally wrong. These single-point forecasts (such as, for example, "The oil price in 2020 is likely to be $85/barrel") then create a false sense of security, as managers are now able to quantify the NPV. To remedy this problem, sometimes scenarios are added. While a little better, they still are essentially subjective single-point forecasts, yet simply more of them. Overall, these models assume a blanket risk factor (in NPV, the overall discount factor applied to future earnings). This is inadequate to make informed decisions if there is a high level of bi-directional volatility as generally the discount factor assumes all costs go up uniformly.

- Discounted cash flow methods assume a static system, in other words, they are not capable of considering the effect that a flexible option, which could be executed at any time, might have on the performance of the configuration under scrutiny. This restricts the option for altering the design of the system later on.
- They tend to fall into the trap of the "Flaw of averages" (Savage, 2002): a common mistake is to devise future projections of metrics such as demand, prices and costs as a single "average" or "base case" value, which serves as input to the calculations. The resulting performance is then expressed as an "average" output, which is justified as the "best estimate" scenario. The DCF uses average values of key variables; however, the assumption that the average expected return is equal to the return on average inputs is wrong and dangerous because the system is punished for troughs in demand but, due to capacity constraints, will not be able to realise the entire gain for a peak in demand. Thus, to base the expected return on an average demand level is statistically simply wrong.

So, if we use planning tools that were not designed to cope with conditions of volatility and uncertainty, we should not be surprised if the resultant supply chain is inadequate for today's turbulent environment. Current methods will by default decide against the flexible route in supply chain design. Perhaps, the biggest problem with most approaches to supply chain design is that fundamentally they tend to seek the lowest cost solution consistent with the requisite level of service. In a world characterised by turbulence, a case can be made for looking instead for solutions that will ensure the greatest level of adaptability. To illustrate the two contrasting approaches and their implications on the return on investment (ROI) over time, see Figure 3. This chart builds on Cooper and Maskell (2008), who observed a similar phenomenon in process improvement: the initial returns tend to be worse than before, while in the long term the pay-offs are greater. Unless one rigorously challenges the assumptions under which decisions are made, any investment in flexibility is virtually impossible to show a positive return.

What is the financial value of a supply chain "real option?"

Given the problems, how does one convince senior management, e.g. the CFO, that investing in flexible supply chain structures does make sense financially? As we have seen above, conventional cost accounting methods will always favour the traditional route. This is not a new insight: Kaplan (1986) acknowledged that even a careful application of a DCF-technique to evaluate a potential investment will not capture the strategic benefits of flexibility. What we need is a fundamentally new way of evaluating supply chain design options.

The most obvious approach is through "real options" analysis. Real options take the Black and Scholes (1973) model from valuing financial options into the "real" world, to evaluate "real" options as in the case of investments, for example.

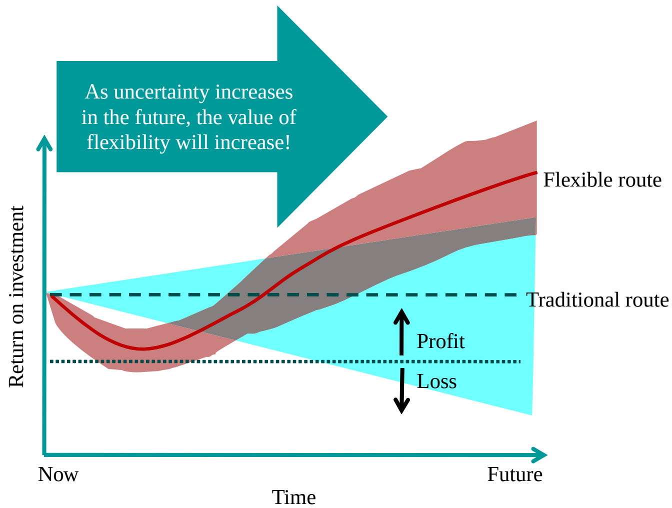


Figure 3.
The flexible route looks less attractive initially under the assumption of stable conditions but structural flexibility shifts the exposure to risk as uncertainty increases

Real options theory derives from corporate finance. A real option is the opportunity to choose to make, or not to make, a particular decision – usually a capital investment decision. It provides a natural alternative to traditional DCF methods in that it recognises the value that flexibility can provide. Thus, supply chain decisions that keep the most options open will normally be preferable to those decisions that shut options down.

It has been argued for some time that supply chain planners might benefit from applying some of the tools emerging from real options theory, and several papers have made attempts in this field: Fine and Freund (1990) develop a model that is capable of valuing flexibility, Huchzermeier and Cohen (1996) consider the value of flexibility as a hedge against exchange rate risk, while Amram and Kulatilaka (1999) apply the logic to investing in flexible product designs. More recently, Burnetas and Ritchken (2005) apply the real options logic to supply chain contracts.

Conceptually, these supply chain options can be treated similarly to financial ones, despite the fact that there are some differences (Pochard, 2003): first, there is no market for real options. Also, unlike financial options, the characteristics are not as easily known. It is more difficult to get hold of this information for real options. Yet, although we have this knowledge already, the underlying mathematics are as elegant as they are impractical, which essentially renders the original Black and Scholes model largely unusable for "everyday use" in SCM.

There are other ways to implement real options in supply chain design: apart from the partial differential equations that Black and Scholes use, one could also use binomial lattice models that are at least visually more intuitive. These are still complex to calculate, but feature the probabilities at each time period, and are thus more intuitive to use. A joint limitation to both these mathematical models is their assumptions: often it is assumed that key variables are mean-reverting, or follow a Brownian motion (that is with a long tail to the right). As we have noted above, these assumptions seem very limiting and would reduce the practical value of any analysis. So, while the "real options" logic is indeed very useful, the valuation methods that are proposed are not. This, in our view, is the main reason why the real options theory has not caught on in SCM: it is simply too complex and too limiting in its assumptions.

The last option is Monte Carlo simulation, which we believe offers the greatest promise for supply chain design. Monte Carlo methods tend to be used when it is unfeasible or impossible to compute an exact result with a deterministic algorithm. There is no single Monte Carlo method; instead, the term describes a large and widely used class of approaches. These models are easy to build and use, and the ability to run many thousands of simulation runs provides the perfect opportunity to understand the impact of variability on the system. Using Monte Carlo methods will enable different supply chain solutions to be evaluated in terms of their ability to cope with volatility in the underpinning parameters (e.g. transport cost) and will ensure that the resulting supply chain design is not based on the value of a single factor (e.g. low labour cost).

Either way, it is important to understand that underlying any of these valuations models, whether based on DCF's or real options, are assumptions. We tend to focus on tools in order to give us "hard" evidence, but really, at the end of the day it all comes down to a qualitative assessment whether or not we believe in the assumptions these models are based on, essentially a "leap of faith". In the following section, we will present some guidelines on how to go about building structural flexibility.

Managing supply chains under turbulence

The first step in building structural flexibility into supply chain strategy is to really understand the sources of variability and build simple models that can help mitigate this variability. It is not enough to simply build some flexibility into the system, as the case of Crocs, the maker of the briefly popular multicoloured plastic shoes, illustrates: Crocs actually became the subject of a best-practice case study (Marks *et al.*, 2007), highlighting how Crocs developed an "extremely flexible supply chain" that allowed it to adjust to changes in the marketplace. This flexibility was achieved through building excess manufacturing capacity. The model worked very well for as long as demand exceeded supply, but Crocs management had not considered the implications of receding demand. A sensitivity analysis would have shown to what degree their supply chain structure was vulnerable to a downturn in demand. In 2009, demand turned down, and soon revenues were down a third, while losses were mounting. Crocs model was flexible, but only in one direction. The key is to accept volatility, understand its impact for both upwards and downwards swings, and to build hedges against it. Let us go through these aspects in more detail.

Embrace volatility, do not fight it

Turbulence does create risk, but this risk also provides an opportunity. Uncertainty cannot be changed, but the exposure to the risk it creates can be managed. In that sense, it is vital to accept turbulence as a given, and to understand its impact. Consider the case of WDF, the UK's largest duty-free retailer that operates at major airports. Even though WDF has experienced significant growth in recent years (partly organic and partly through merger – in particularly the merger in 2009 with Spanish duty-free retailer, Alpha), it has been faced with an increasing degree of market turbulence and volatility of late. At the macro level, the world recession has had a big impact on passenger numbers generally, particularly at regional airports which have a higher proportion of leisure passengers. Sources of volatility at a micro level include such factors as the security arrangements at airports where the length of time taken to process passengers will vary according to daily changes in procedures (e.g. requesting passengers to remove their shoes) which itself directly impacts the amount of time individual passengers will have available for duty-free shopping. Further, sources of volatility at a micro level can be airlines changing their departure times – for example, passengers leaving the UK for non-EU destinations can generally buy goods at a lower price, and if the time of the flight changes or the plane is delayed, there can be a significant change in demand patterns. A further impact on sales is created when airlines either withdraw a service or change airports – Ryanair (a European low-cost airline) moving some of its services from one airport to another because of lower landing charges is a case in point.

Against this background of uncertainty and increasingly unpredictable demand WDF is seeking to make the transition from a "forecast-driven" to a "demand-driven" business. The main thrust behind this decision is to break the structural rigidity that was built into is current forecast-driven supply chain, which often featured long replenishment lead-times and high inventory levels for its 15,000 stock keeping units (SKUs). Instead, WDF aims for a responsive supply chain structure that can adapt to shifts in costumer flows and buying behaviours.

One of the strategies WDF has adopted is to focus on its single distribution centre (based near London Heathrow Airport) to find ways in which its existing capacity can be used more flexibly. Using what are in effect "SIX SIGMA" methodologies, WDF has been able to improve the utilisation of capacity and to improve flow-through so that it can cope better with the peaks and troughs in demand. So successful has this strategy been that WDF was able to cope with the opening of Terminal five without additional warehousing capacity. A further degree of flexibility in the Heathrow distribution centre is through the use of agency staff.

Becoming demand driven requires a "just-in-time" delivery philosophy based upon more frequent deliveries to their air-side outlets based on more frequent demand signals, i.e. point of sale data polls. The intention is, where possible, to move to a "continuous replenishment" philosophy where as products are sold they are rapidly replenished. WDF has recognised that demand-driven supply chains require suppliers to be highly responsive. They are actively examining ways in which in-bound lead-times from suppliers can be reduced – particularly through a greater level of shared information and the introduction of VMI arrangements.

Understand the nature and impact of turbulence

The impact of turbulence will vary by supply chain. Not all firms are equally affected, so managers need to ask themselves whether they really know how much their unit cost increases if, for example, the oil price doubles? It is often a good idea to make use of the Pareto 80/20 rule and separate the relatively small number of product lines which provide most of the volume from the "long tail" of slow moving (and hence less predictable) lines. The fast movers, because they tend to be more predictable, can be made to forecast whereas the slow movers need to be demand driven. These slow movers pose the greatest danger, and here the exposure needs to be managed. In the case of WDF, for example, with a product range of approximately 15,000 SKUs, there is inevitably a "long-tail" on their sales Pareto curve. A full 88 percent of their SKUs sell <1 unit per day per store. One response to this issue has been a focus on range rationalisation. Keeping control of variety is a continuing challenge with new product launches and promotions increasing every year. There are more and more niche segments, e.g. vodka with different flavours, different price points, and positioning strategies. About half WDF's SKUs change each year making it difficult to use traditional methods of sales forecasting. So, the case for placing your operations (be it manufacturing or distribution) nearer to the centres of gravity strengthens.

Before managers make this decision, they will need to understand how changes in demand and transportation costs might affect the profitability of their supply chain structure. There has been a tendency to outsource "surge" demand, and to produce the base in house. Is this the right way to go?

Challenge the economies of scale mindset

Keeping options open and remembering that big is not always beautiful are helpful advice. In fact, in the previous studies, we have shown how small-scale facilities can have a range of benefits (Pil and Holweg, 2003). The need to create large-scale plants is no longer there. The economies of scale argument are still valid, but it does assume stability to realise the returns predicted. It simply should no longer be the overriding argument in determining supply chain decisions! Thus, a diversified manufacturing and sourcing footprint is clearly a good way to build structural flexibility: why not make/source the base load in China, and the surge demand locally in the UK and USA?

Here, Toyota offers an interesting and counter-intuitive insight. Renowned for its efficiency, Toyota manufacturing plants have an average volume of 400,000 units per annum. Yet right in Tokyo, in what still is one of the most expensive real estates in the world, is a wholly owned subsidiary of Toyota, Central Motors. Central Motors used to be an independent spin-off of Toyota (set up by workers made redundant from the Kamato truck plant during the crisis of 1950), and ever since produced niche vehicles for Toyota as contract manufacturer. It currently produces 11,000 vehicles per year across three models. Amongst these is the Corolla Axio, which is also produced by Toyota's Takaoka plant that is not even two hours away by train. Not only does the factory sit right in the centre of Tokyo, the most expensive land for industrial production, it is also locked in residential areas. It is a small-scale producer of 11,000 cars per year, in one of the most expensive labour cost regions. Why would Toyota keep this seemingly inefficient plant open? The reason is simple: experimentation. As Kanji Ishii, formerly Toyota's head of the NUMMI plant in California, and now president of Central Motors confirmed: Toyota is using Central Motors as an experimental lab of how to work efficiently at small scale. There might not be a case for setting up a full-scale plant, but once it can be shown to work efficiently at lower volume, the case for establishing small local-for-local factories increases a lot. And with astonishing results: Central Motors produces the Corolla, one of Toyota's main volume models globally, and comes within 20,000 Yen (about $220) of cost at the main large-scale Toyota sister plant. In terms of labour cost, this is a <10 percent disadvantage, while the overall plant volume is 36 times smaller! Mr Ishii even talked about plans to undercut the sister plant in the near future. Toyota's logic is simple: if you can produce competitively on a small scale in Japan, you also can in any other market. So, Central Motors becomes the blueprint for small-scale "local-for-local" manufacturing units that serve regional markets with local products.

Outlook

Volatility in the business environment has increased significantly and is very likely to continue to be a prominent feature of the supply chain landscape for the foreseeable future. We argue that this volatility is very likely to increase, and we must consider not only the absolute change in key business parameters, but even more so their rate of change which will have significant implications for the way we design and run supply chains. In short, the risks associated with both firm-specific and external turbulence are now greater than they have ever been since the concept of SCM was first presented.

Current supply chains are built upon an assumption of stability, very often using NPV-based models to assess the economic viability of off-shoring and global sourcing scenarios. There is a major flaw in this logic, as the assumption of stability clearly no longer holds, and firms now suffer from their self-inflicted rigidity. As a result, much of the conventional wisdom about supply chain design needs to be reviewed. We used to aim for efficiency through "optimised" supply chains that aimed at controlling variation, but this notion no longer works. Faced with increasing turbulence, such rigid structures will lack the flexibility to cope with unexpected changes in demand or supply conditions. Any competitive advantage is temporary, so it is important to build supply chains that are adaptable to turbulence, be it up- and downswings in demand, or supply-side factors such as oil price fluctuations.

Several firms are already experimenting with such structural flexibility, as the cases of WDF, Toyota and HP have shown. Yet, there is no "silver bullet" to managing supply chains in this era of turbulence; the tools at hand remain largely the same, but we need to apply them in a new "mindset" that considers the option value of flexibility. While such flexible options will not always pay-off, on average they will, so we argue that firms that are considering flexibility in their supply chain design will be much better equipped to deal with this era of turbulence. We need to move away from the "control" mindset that seeks to eradicate variability, towards building structures that can cope with turbulence, and embrace volatility as an opportunity. As paradoxical as it might sound, the current crisis is also an opportunity: as we have witnessed at many firms, the crisis aftermath is now permitting managers to question the most fundamental supply chain decisions in the firm. Previously widely accepted mantras such as that the "low-cost country advantage" generally outweighs the transportation cost in global supply chains no longer holds. We can neither afford any longer to assume stability in our financial planning, nor can we afford to build supply chains on the premise of a single commodity price. The era of turbulence demands a new mental framework to designing and managing supply chains – a "Supply Chain 2.0".

Note

1. On June 4, 1982, the Financial Times published an article by Arnold Kransdorff on Booz Allen's new "supply chain management" concept. A more detailed report was published later by Oliver and Webber called "Supply-chain management: logistics catches up with strategy" (published in the "Outlook" magazine by Booz, Allen and Hamilton, and reprinted 1992) in Christopher (1992).

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Further reading

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