

IMPROVING THE MANAGEMENT OF SUPPLY CHAIN VULNERABILITY IN UK AEROSPACE MANUFACTURING

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ABSTRACT

Recent high profile disruptions to trade arising from natural disasters, accidents, protests and acts of war have pushed the issue of supply chain resilience higher than ever before up corporate and political agendas. This paper reports on an empirical study into the drivers of risk and the management of supply chain vulnerability in aerospace manufacturing. The work forms part of a wider cross-industry programme of research, funded by the UK Department for Transport, into the development of a managerial tool kit to help organisations improve the resilience of their supply chains.

Keywords : Supply Chain Risk, Networks, Vulnerability

INTRODUCTION

In recent years a number of managerial trends, including JIT delivery, supplier rationalisation programmes and widespread outsourcing of non-core activities have all served to increase the efficiency of supply networks. There are concerns however that these measures may be making supply chains more vulnerable, particularly when these practices are combined with the overall trends towards the globalisation of supply chains and the centralisation of manufacturing and distribution facilities (Braithwaite and Hall 1999a,b; McGillivray 2000; Sheffi 2001). In response to these concerns, the UK government commissioned a study of supply chain vulnerability across a spectrum of industries (Christopher et al 2002). The research confirmed that supply chain risk is inadequately understood and identified a requirement for a generally applicable tool kit, to assist organisations in the identification and management of supply chain vulnerability. To that end, a single in-depth exploratory case study of one industry sector was first undertaken to identify drivers of supply chain risk and ascertain the adequacy of currently available managerial tools. The case provides the basis for subsequent cross-sector comparisons and the development of a generally applicable toolkit.

RESEARCH DESIGN AND DATA COLLECTION

In line with the best practice case study research, the case represented ‘a unique, extreme or revelatory situation’ (Yin 1989). A study of commercial supply chains engaged in the manufacture of high performance military aircraft met the criteria. The industry operates

in an extreme risk environment, characterised by high levels of commercial, technological and political risk as well as the inherent product safety issues.

Developing an appropriate research design was central to this stage of the research. Few studies of supply chain risk have been published to date. Those that have tend to follow the pattern of more general supply chain management research, adopting either a 'lateral' or a 'vertical' design. Lateral studies typically examine interactions at one level or tier in the supply chain, looking at a given issue either within a single firm or between a focal firm and adjacent organisations. In the context of supply chain vulnerability lateral studies typically examine perceptions of supply chain related risk in an organisation's purchasing department or its first tier supplier base (Svensson 2000; Zsidin 2002). A lateral study was rejected because it would have failed to identify the full magnitude of problems such as the one outlined below, potentially affecting all aircraft programmes:

"We introduced a new system [subassembly] into some of our products...we had a review meeting with first tier suppliers where we called them all together and said to them 'how are you getting on with the production of this item'. They all said that they were waiting for a part, this was the same with several suppliers, when we looked into it there was a common theme, they were all waiting for panels. What we found was that we were buying these assemblies from different first tier suppliers who all used the same subcontractor. We found the subcontractor who was actually building all the panels for all the displays. He suddenly went from being a second/third tier suppliers to a very strategic supplier to us... We had to go in of course to help him manage his business, because he was getting contracts from all and sundry for this one kind of component...He was finding he couldn't satisfy all his customers at one go because he was a single source for all these panels [Systems Supply Chain and Procurement Managers, Prime Contractor, September 2001].

Vertical studies in contrast are likely to involve the mapping and analysis of one or more representative product lines or 'value-streams' through a series of consecutive activities and/or organisations. Harland and Brenchley (2001) adopted this approach for their research into supply chain risk associated with non-trade compliance in the product supply network of an electronics manufacturer. The task of mapping end-to-end for an entire aircraft would have been impractical, given the timeframe and resources available for this research.

The fundamental difficulty is that popular approaches to the study of supply chains reflect prevailing supply chain management approaches and concerns. Both demand economy of effort and either truncate the supply chain or limit the definition of the problem to the point where only the most obvious or immediate vulnerabilities are likely to be detected. In simplifying the problem in this way there is a danger that the research would exclude the very phenomena that were suspected to be undermining the resilience of the networks. To overcome this problem and uncover the widest possible panoply of issues, a design that was both vertical and lateral has been used.

Semi-structured interviews with 47 managers drawn from the various levels of the supply networks provided the principal means of data collection. Where appropriate archival evidence was also used. Interviewees were selected using ‘purposive sampling’, a the process of “choosing people whose views are relevant to an issue because you make a judgement and/or your collaborators persuade you that their views are particularly worth obtaining and typify important varieties of viewpoints” (Jankowicz 1995).

This purposive sampling allowed multiple levels of the supply chain networks to be included in the study, ranging from the focal firm’s customer (purchasing organisations for the armed forces of national governments), through two tiers of suppliers above the Prime. In addition, input came from two industry bodies representing small and medium enterprises (SMEs) nestling in the higher reaches of the supply networks. It was clear however that at least six or seven tiers existed upstream of the Prime Contractor and downstream the final consumers (pilots and other users) remained unvisited. Those selected were all experienced managers with direct interests in downstream and upstream supply chain management activities. Their responsibilities included sales and marketing, supplier management, supplier development, supplier audit, customer management, operations management and supply chain design. Each manager was asked to discuss: (1) What they considered to be the vulnerabilities within their supply chains; (2) What are the sources of those risks, (3) What tools they were using to identify and manage the risks; (4) Additional tools/alternative techniques/approaches they were aware of (if any) that might offer an improvement; (5) How the tools/techniques be modified to improve their performance in the management of supply chain vulnerability

Supply chain risk and vulnerability is known to be a commercially sensitive issue, interviews were therefore conducted on a one-to-one basis with assurances given to informants that the anonymity of all respondents, departments and organisations would be protected. The results of subsequent analysis were validated through a return to the literature, academic peer review and group practitioner review. The practitioners involved in the validation process were selected to represent a broad range of aerospace manufacturing organisations. The individuals concerned had not participated in earlier interviews.

FINDINGS: SOURCES OF RISK

Several clear themes emerged. First, the respondents did not deal with either the precise geographical *location* of a problem or on the impact of other ‘external’ sources of risks - i.e. those that were directly attributable to accidents, malicious acts or natural disasters. Instead the aerospace managers related the term ‘sources of risk’ to the side effects or consequential risks arising from managerial practices or industry trends that were known or thought likely to pose a threat to the performance of manufacturing processes. In fact several of the managers interviewed related the sources of risk directly back to the Critical Success Factors (CSFs) for the focal firm’s Strategic Supplier and Commodity Management processes: Cost Focussed Decisions; Extreme Quality/Performance Requirements; Delivery Schedule Adherence; Customer-Supplier Relationships.

The CSFs reflect current ‘best practice’ thinking on integrated supply chain management. As such they are in keeping with ‘lean’ thinking and in this instance the CSFs echo the fundamental characteristics of an agile supply chain (Christopher 2001): Cheaper process costs; better process quality; faster demand satisfaction; closer customer-supplier relationships. Nevertheless, the examples put forward by interviewees highlighted tensions between them. The link between interviewees’ perceptions of ‘sources of risk’ and process CSFs was upheld by members of the industry focus groups involved in the validation exercise, with one important exception. Some focus group members claimed that many of the risks were actually related to a ‘price’ rather than a ‘cost’ focus. The findings of this part of the analysis have since been corroborated by unrelated research, undertaken in North America, into perceptions of sources of risk amongst purchasing managers in aerospace and electronics companies. The North America study classified perceived sources of risk into the same four broad categories (Zsidisn 2002).

The second theme to emerge was that managers frequently defined a source of risk with reference to acknowledged or perceived constraints imposed by the nature of the product and the structure of the industry. Cost pressures -including those related to technology development, performance and quality - were driving industry consolidation on a global scale, extending the span of the supply chains. Political/geopolitical influences and other market-driven trends were also influencing demand and ultimately forcing further reconfigurations of the networks. On an operational level these were undermining efforts to maximise efficiency.

IDENTIFYING AND ORGANISING AVAILALABLE TOOLS AND TECHNIQUES

A wide variety of supply chain management tools, techniques and higher-level principles were being utilised within the networks to identify, manage and mitigate the effects of risk within the supply chains. The tools were well known managerial devices, appropriate for one or more of three categories of supply chain management activity: Supply Chain Planning; Supply Chain Management; and Supply Chain Change Management. The first two, Supply Chain Planning and Supply Chain Management share the basic assumptions and respective time-horizons of long-term ‘strategic’ and everyday ‘operational’ supply chain management software solutions (Shapiro 2002). The third corresponds with medium-term ‘tactical’ refinements and incorporates elements of the previous two. Taken together the three categories describe a spectrum of supply chain management activity. Figure 1 illustrates how the three categories relate to one another, overlap and combine.



Figure 1. - The Spectrum of Supply Chain Management Activity.

The extreme left of the spectrum is occupied by pure supply chain planning, which in an ‘ideal world’ would be unencumbered by the legacy commitments of existing production

facilities or supplier contracts. The right by pure supply chain management activities. These are the day-to-day activities undertaken in the management of a mature established supply chain. It is the stage where volumes have gone from developmental prototypes, through the step change to full-scale production, where demand patterns are expected to follow a more predictable pattern. The well-managed supply chain should, in theory, be operating in a stable 'steady state' with supply and demand perfectly balanced. In this steady state processes are not impacted by the sources of risk from planned process changes or new product introductions. The centre of the spectrum is occupied by supply chain change management activities. It represents the times when planned modifications to existing supply chain processes are implemented.

Many interviewees felt that the supply chains were most vulnerable during periods of change, as the risk profiles affecting their supply chains were also changing. Technology upgrades, Total Quality Management and other process improvement initiatives, together with pressure to reduce costs and outsource non-core activities mean that change is almost constant. In practice, the practitioners felt that the supply chains never reached that mature, stable 'steady state' in their industry. As a result they reported that the majority of their time was actually occupied with supply chain change management related activity, hence the relative importance indicated in Figure 1.

The principles, tools and mitigation strategies were arranged by class of supply chain activity and in relation to the CSF-defined sources of risk, into a 12-cell matrix is shown in Figure 2. However, it is important to recognise that Figure 2 represents only a summary of what *is* or *could be* in use *somewhere* in the network. Each cell contains a set of one or more tools, techniques or principles. Collectively they offered the basis for a cohesive process risk management tool kit. Figure 2 shows that some monitoring devices e.g. Current Supplier Database, detailing costs, qualified component characteristics, capabilities and performance, though not currently in use emerged as being useful to organisations in this industry in times of change, to mitigate the effects of all manner of risks, regardless of the source or driver.

However, other tools and mitigation techniques again suggest contradictory requirements. For example, to mitigate cost-related risks, lean manufacturing techniques were being used (Set 5), while elsewhere someone is using inventory, capacity and capability buffers on a regular or temporary basis to mitigate delivery or schedule adherence problems (Set 7 and 11). Again this highlights the tensions between the market-driven demands of the critical success factors and the impact of industry constraints, resulting in conflicting operational imperatives. There were also some risks that the supply chain managers were unable to manage or mitigate. These emerged as a result of strategic business decisions taken elsewhere in their own organisations or in those of customers or suppliers.

IMPLEMENTATION: OVERCOMING THE 'FOG OF CONFUSION'

The final theme of this case study was improving the application of available tools. Three key issues identified as barriers to effective implementation. The first was staff training, there was quite a widespread recognition that existing tools could be much more effective

SUPPLY CHAIN MANAGEMENT ACTIVITIES

SUPPLY CHAIN RISKS

	Supply Chain Planning	Supply Chain Change Management	Supply Chain Management
Cost	<p align="center">SET 1</p> <ul style="list-style-type: none"> * Trade-Off Analysis to achieve lowest total process cost. * Supply Chain Mapping/Situational awareness - to understand quality and delivery cost pressures on direct/indirect. Customers/suppliers * Design supply chain for maximum simplicity. * Design product components for maximum simplicity. 	<p align="center">SET5</p> <ul style="list-style-type: none"> * Lessons learned feedback and corporate knowledge database. * Process innovation. * Supplier Development Programme within collaborative customer-supplier relationships. * Lean manufacturing techniques, to benefit from higher resources utilisation and lower inventories. * <i>Current supplier database - costs, qualified components' characteristics, capabilities and performance.</i> 	<p align="center">SET 9</p> <ul style="list-style-type: none"> * Open-book accounting. * Contingency funds for impact of risks. * e-commerce techniques to improve demand data transmission and reduce costs. * Appreciate Frozen Horizons. * <i>Standardised quality requirements.</i>
Quality	<p align="center">SET 2</p> <ul style="list-style-type: none"> * Supplier Quality Audits. 	<p align="center">SET6</p> <ul style="list-style-type: none"> * Lessons Learned feedback and corporate knowledge database. * Supplier Development Programme within collaborative customer-supplier relationships. * Net Good Assets register. * <i>Current supplier database - costs, qualified components' characteristics, capabilities and performance.</i> 	<p align="center">SET10</p> <ul style="list-style-type: none"> * Supplier managed quality adherence. * Supplier quality review.
Delivery	<p align="center">SET 3</p> <ul style="list-style-type: none"> * Analysis of past performance. * Supplier's Risk Management Audits. * Supplier capability assessment – effectiveness and efficiency. * Supply Chain Mapping – inventory, process capacities/capabilities, lead-times (intra/inter-process/organisation) and lead-time flexibility. 	<p align="center">SET7</p> <ul style="list-style-type: none"> * Lessons Learned feedback process and corporate knowledge database. * Process innovation. * Supplier Development within collaborative customer-supplier relationships. * Lean manufacturing techniques, to benefit from improved process integration and proactive mitigation of process risks. * De-conflict with critical path. * Temporary inventory, capacity and capability process buffers to create management space. * <i>Current supplier database - costs, qualified components' characteristics, capabilities and performance.</i> 	<p align="center">SET 11</p> <ul style="list-style-type: none"> * Inventory, capacity and capability process buffers. * Project plan, including milestones. * Critical Path Analysis. * Risk Register informed by supplier KPIs and reviews. * Root Cause Analysis * Appreciate Frozen Horizons. * Process innovation. * Formal project risk processes, eg Prime Contractor' LCM process. * <i>Shared supply chain management data</i> * <i>Continuous staff training to maintain effectiveness of current tools.</i>
Relationships	<p align="center">SET 4</p> <ul style="list-style-type: none"> * Supply Chain Mapping – relationships and influences. * Process relationship analysis 	<p align="center">SET8</p> <ul style="list-style-type: none"> * Lessons Learned feedback and corporate knowledge bank. * Collaborative customer-supplier relationships. * <i>Current supplier database - costs, qualified components' characteristics, capabilities and performance.</i> * Process relationship analysis 	<p align="center">SET 12</p> <ul style="list-style-type: none"> * Categorise suppliers using Pareto Analysis and manage differently. * Collaborative customer-supplier relationships. * Use knowledge from network relationship mapping to resolve supplier commitment difficulties indirectly.

Key: Techniques currently in use. *Techniques recognised as desirable but not yet in use.*
 Modifications/additional techniques identified during the validation process

Figure 2 - Summary of Tools and Techniques

if implemented correctly. The secondly was widespread confusion over terminology. It quickly became clear that interviewees interpreted the term 'supply chain' in a number of different ways. The third issue was visibility.

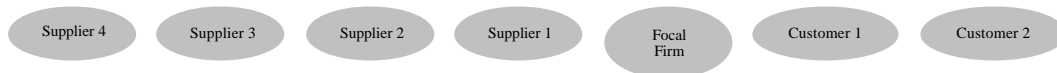


Figure 3. – Simplified Supply Chain Model

The research revealed that there was absence of a common understanding of the scope or extent of supply chain risk management, much of it relating to confusing and contradictory interpretations of 'supply chain': These included:

- An organisation's internal logistics network of customer/supplier relationships.
- An organisation's Tier 1 suppliers, deliberately excluding the implications of any indirect relationships with suppliers in Tier 2 or beyond.
- An organisation's Tier 1 suppliers and, where the organisation had a responsibility to provide demand information, management of internal departments as if they were Tier 2 suppliers.
- Organisations upstream in the supply chain that concentrated their attention on their customer chains rather than their supplier chains.

Once a common definition was established, using the diagram in Figure 3 as a basis for comparison, all interviewees agreed that end-to-end management of an organisation's complex and unstable supply chain network, (particularly up-stream into the supplier base), would be an improbable if not impossible task. The difficulty of the challenge faced by supply chain managers was likened to navigating across a featureless terrain in a "confusing fog" of sometimes useful and sometimes useless, misleading, contradictory or partial information. Interviewees representing every tier in the supplier chain indicated that they choose to look for risks only as far as their respective Tier 1 suppliers. A small proportion of interviewees believed they could see sources of risk as far as their Tier 2 suppliers. In further discussions, it became clear that this was not the case. They based their response on the *expectation* that their Tier 1 suppliers would be feeding through relevant information from Tier 2. The assumption was that if Tier 2 identified a risk or event that it could not deal with, it would issue an alert message to its customer.

When invited to consider whether the limited upstream and downstream reach of their risk management techniques was sufficient, interviewees responded unanimously that it was. Having proclaimed themselves to be satisfied with the reach of their existing supply chain management tools, the practitioners initially failed to accept the need to improve the reach of their risk management techniques. They reconsidered only when presented with a definition of supply chain risk management as *'the identification and management of risks within the supply chain and risks external to it through a co-ordinated approach amongst supply chain members to reduce supply chain vulnerability as a whole'*, which emphasised the need to consider risk management from a total supply chain view. Some

of the additional risk management tools/techniques identified by interviewees as desirable, but not known to be in use, (Figure 2, italic text), reflect a requirement for tools/techniques to be applied with a wider, multiple-organisation supply chain perspective in mind.

OPTIONS FOR IMPROVED IMPLEMENTATION

Three possible approaches designed to improve visibility, and thereby risk management within the supply chains, were put forward to interviewees and subjected to focus group review. All three options were inspired by literature reviews and by earlier interviewee responses.

Method 1, a 'go it alone' option was motivated by the possibility of achieving competitive advantage over rival organisations through exclusive or advanced identification of sources of risk. For example, if the consequences of an anticipated event were expected to disrupt others in the same industry sector, an organisation might gain advantage by simply improving its tolerance relative to its competitors. Alternatively, if the risk was a perennial concern or one that extended beyond the firm's immediate sector, the organisation could market the skills it acquired to deal with the risk, potentially developing a new revenue stream.

In the context of aerospace manufacturing this option was deemed to be impractical. The complexity of the networks as well as issues of power and influence limited the viability of such an approach. Moreover, the interviewees also stressed the problem of selection - which of their many thousands of supply chains should they interrogate, when, how far into it and which supply chain branches to follow? Pareto Analysis is widely and effectively used to target management resources economically in other circumstances, but the complex and expensive nature of aerospace products dictates that applying it in this scenario would be problematic.

The second method tabled was a more limited audit encompassing the focal firm, its immediate customers and suppliers. The method involves organisations acting collaboratively, in interlocking risk management relationships to produce overlapping information flows all along the supply chains. Such an approach would allow organisations to identify relevant sources of risk within their locus of control or immediate supply chain vicinity and enjoy the confidence that others were doing the same. The approach represented a formalisation of what was supposed by some to be already occurring. It was supported in principle, but practitioners believed that it would require industry-wide acceptance to be effective in practice.

Aerospace is already a heavily regulated sector and a number of interviewees identified currently accepted quality standards, such as ISO 9001, the Total Quality Management process standard, or its European equivalent, EFQM, as cost-effective vehicles for confidence-building risk management measures. The Society of British Aerospace Companies' (SBAC) 'Supply Chain Relationships In Action' (SCRIA) code of conduct already promotes the benefits of accepting more widely recognised and trusted manufacturing quality standards amongst its member organisations. The SCRIA code of

conduct could also be used to promote the benefits of adopting widely accepted and trusted supply chain vulnerability management tools and techniques.

Method 3 was an extension of Method 2, based on interviewees' suggestions that the effectiveness of their current management tools would be improved by the introduction of a shared data environment. It was felt that this would significantly reduce the commercial risks attached to sub-optimal supply chain performance. The majority of interviewees considered Method 3 to be sound in principle. It reflected the frequently expressed view that improved sharing of data would lead to consequential improvements in profitability and facilitate the continuous improvement practices that contribute to longer term supply chain health. Furthermore, a successful precedent had been created in the defence sector. The establishment of a shared data environment for organisations involved with a single shipbuilding project had achieved significant benefits.

Whilst there was clearly support for the method in terms of its proven potential for reducing demand-related and process performance risk, there were equally clear indications that organisations would be unwilling to share data relating to other sources of risk. In short, they expected good risk management news to be retained in an organisation to enable a competitive advantage. Bad risk management news would also be retained within the organisation for fear of competitive disadvantage.

CONCLUSIONS

The case study identified the sources of risk as the practitioners saw and understood them. Interestingly, their principal concerns were not with the direct risks that characterise the preoccupations of insurers, crisis managers and businesses continuity planners (e.g. impacts of fire, flood, protests or terrorism on facilities or other assets). References to these 'external' forces were few. The managers focussed instead on the risks to their own areas of responsibility, in this instance on the consequential risks to supply chain performance arising from other managerial practices and industry trends. In particular they emphasised those trends that were believed to be undermining efforts to optimise supply chain processes. The risks they identified and the 'in context' examples provided highlighted tensions between individual process performance measures, the impact of strategic business decisions, constraints imposed by the complex safety-critical nature of the products and by industry or supply chain structures. In fact counteracting complexity was a recurrent theme. The demands of the marketplace, constant changes in product specifications, together with other continuous improvement initiatives within the organisations and the wider industry as a whole meant that the supply chains never actually reached a stable 'steady state'.

Furthermore, product and supply chain complexity meant that although interviewees were implicitly or explicitly adopting a process-based view of risk in their supply chains, this was certainly not an 'end-to-end' supply chain perspective. Though there was no commonly accepted definition of the term supply chain (and thus 'supply chain' risk or vulnerability) within the industry, it was clear that extant managerial practices reinforced a much-truncated view of the supply chain. None of the organisations concerned routinely monitored beyond their immediate customers or suppliers.

The audit of risk management tools and techniques currently in use within the supply chain/networks revealed a host of well know process reengineering and control tools. They further underlined the prevailing process management-based view of supply chain risk, and one that was largely single organisation, internally-focused. Concerns expressed by some that the available tools and techniques were not being applied in a consistent and coherent manner across the networks also proved to be well founded. As a result, three possible methods for extending or improving implementation were explored. The third method, involving a truncated (but as yet undetermined) interlocking and commonly accepted approach, supported by a common data environment, emerged as the favoured way forward.

The evidence from this study suggests that inter-organisational cooperation to reduce demand related forecasting and inventory management risk would be significantly improved by more wide-spread collaboration, so perhaps would event management capabilities, allowing mitigating action to be taken to deal with supply-side disruptions. However it was very clear that competitive commercial interests were likely to deter organisations and individuals from sharing other forms of risk management data. In addition this would not overcome problems arising from a disconnection between supply chain management objectives and changes in business strategy.

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