

AN INVESTIGATION INTO THE MANAGEMENT OF SUPPLY CHAIN VULNERABILITY IN UK AEROSPACE MANUFACTURING

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ABSTRACT

This paper reports on the findings of a single-in depth exploratory case study into the drivers of risk and the management of supply chain vulnerability in aerospace manufacturing. It examines the problem from a multiple-organisation perspective, using an assembler of military aircraft, the Prime Contractor, as its point of embarkation. The paper examines managers' perceptions of supply chain risk, presented here with reference to the industry context. It goes on to provide a summary of supply chain risk management tools and mitigation techniques, identified by the managers concerned as currently in use plus others that were believed to be beneficial. Finally, it identifies the limitations of existing tools and techniques and puts forward suggestions for improved implementation.

Keywords: Supply Chain Networks, Risk, Vulnerability

INTRODUCTION

Supply chain vulnerability is an ever-present fact of business life. In recent years a number of managerial trends including JIT delivery, supplier rationalisation programmes and the widespread outsourcing of non-core activities have all served to increase the efficiency of supply networks. In some quarters however, there are concerns that these measures appear to have increased supply chain vulnerability (McGillivray 2000; Svensson 2000).

Supply chain risk management is defined 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*" (Christopher et al 2002). For the purpose of this study, we define the term 'vulnerability' in accordance with the dictionary-derived definition of its relationship to 'risk' - to mean where the supply chain/network is '*at risk*': *vulnerable; likely to be lost or damaged*'. Earlier research undertaken by Cranfield School of Management confirmed that supply chain risk is inadequately understood. It also identified a requirement for a generally applicable tool kit, to assist organisations in the management of supply chain risk. 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.

METHODOLOGY

In line with best practice case study research, the single case study presented here represents 'a unique, extreme or revelatory situation' (Yin 1989). It examines the phenomena in commercial

supply chains engaged in the manufacture of high performance military aircraft - an extreme risk environment. It is an industry context where supply chain risk has not yet been widely investigated. An extensive literature search undertaken early in the summer of 2002, revealed a total of 62 articles on supply chain risk/vulnerability (Haywood 2002). Only one dealt with aspects of aerospace manufacturing, focusing on how the burden of risk within the industry is being passed on to smaller weaker suppliers (Cook 2001).

Primary data collection was through semi-structured interviews with 47 managers drawn from different aircraft programmes and from five levels of the supply chain – i.e. from end customer through three tiers of suppliers, plus two industry bodies representing SMEs active in the higher reaches of the supply chains. Each manager was asked to reveal what they considered to be the vulnerabilities within their supply chains, the sources of risk and the tools or techniques currently used to mitigate those risks. Interviewees were also invited to comment on alternative techniques and suggest others that might be considered appropriate. Finally they were canvassed for suggestions as to how implementation of existing approaches might be improved along the whole supply chain. Earlier research indicated that supply chain risk and vulnerability is a highly sensitive issue, consequently interviews were conducted on a one-to-one basis with assurances given that the anonymity of all respondents, departments and organisations would be protected. Data analysis was completed following thematic coding of interviewee responses and validated through a return to the literature, academic peer review, and group practitioner review with other experienced aerospace manufacturing supply chain managers.

FINDINGS: SOURCES OF RISK

The case study identified the sources of risk as the practitioners saw and understood them. Interestingly, their principal concerns were not with the risks from fire, flood, protests or terrorism. 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 compromising efforts to optimise supply chain processes.

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. However, the risks identified and the 'in context' examples provided, indicate tensions between process performance measures. They also highlight the impacts of strategic business decisions, constraints imposed by the complex safety-critical nature of the products and by industry or supply chain structures as contributing risk factors.

For example, evidence that suppliers were being selected on the basis of price only was seen to be increasing the risks to delivery schedules for the customers concerned, and presumably those downstream. Interviewee 12 (Regional Industry Organisation) provided the following example

relating to overseas sourcing: *'One of my last jobs was as a quality director and I had to look at a potential source in central Europe. It was a typical facility for the area, much of it old, some of it getting new investment. Two other aerospace manufacturers were out there as well getting parts manufactured - but one of them had a permanent team there and talking in the evening it became clear from their technical team, who were out there manufacturing some quite simple compressor blades, that it wasn't going well. They said to me, ' we thought we'd have been out of here months ago but they can't seem to grasp the simplest things'.*

Another cost-related example was consortium bids (CONBID), a procurement strategy where consortium manufacturers will aggregate their Europe-wide demands for metallic raw materials and then place a single demand upon the mills qualified to supply it, in order to leverage an improved price. *'Typical aluminium price per kilo will range between £3.50-£4.00. The mills, which charge £4.00 have very good processes and systems and even during the difficulties of 2001 were maintaining their deliveries, even if the lead-times extended a little. The cheapest mill is possessed of staff who that utterly and absolutely arrogant and the most disinterested and incompetent bunch of people I have ever come across. But CONBID is still placing over 50% of their demand with them because they are a few pence a kilo cheaper, which is baffling when you consider even for commercial airliners only 4% of cost is in its airframe and only 2% of a military aircraft's costs are... so why you would be willing to take risks on that percentage of costs baffles me entirely.'* [Interviewee 20 - Tier 1]

The industry is also characterised by high fixed costs for suppliers and high switching costs for their customers, this had led to industry consolidation, which is reinforced by quality accreditation requirements: *'It's not the wide network you might expect; for example there are only 2 undercarriage suppliers to speak of. In the 1990s a lot of new companies set up with all of the capabilities and capacities you could think of, but without the quality approvals they were unable to break into the market. So we have an industry that is quite narrow. For example, for a new aircraft, we could almost write down now the suppliers that will support it. It's important to realise that if you had a problem with one of those suppliers establishing an alternative source of supply wouldn't just be an overnight job'* [Interviewee 3 - Tier 1].

Military aircraft require the application of leading edge technologies to differentiate them from currently available alternatives. Pressure to maintain competitive advantages by bringing these leading edge technologies into production ahead of competitors can be a source of risk when development of immature sub-systems and assemblies must be integrated into equally immature airframes. *'We design in anticipated technologies perhaps 10 years out, because we must be leading edge for as long as possible - it's no good using mature technology now because although it's less risky it doesn't produce the performance improvement military applications demand. Obviously that brings a development risk, for example, now we have some aircraft avionics equipment that isn't tolerating the temperature changes it should withstand and certain functionality isn't there yet, the same is true with other aspects of aircraft equipment. The impact has been slippage in a variety of delivery schedules.'* [Interviewee 22 - Prime Contractor]

In parts of the aerospace manufacturing supply chain process capacity, rather than raw material or component availability has produced a risk to delivery schedule adherence. For infrequent or low volume requirements customers consequently have to choose between the cost of reserving

future capacity or the risk of waiting for fulfilment for extended periods. In extreme cases, where there is only one source globally, the total fulfilment lead-time could be 12 months (Interviewee 4, Tier 2). *'Capacity limits are also a risk for us, because you find the majority of lead times in the industry are queue times. We find the better customers will manage that by investing in capacity time ahead of their confirmed demand, so that if a late change occurs they have an opportunity to get ahead of the queue.'* [Interviewee 3 -Tier 1]

Suppliers are increasingly expected to provide design advice for their customer's process and a total management solution for their product. Some suppliers, both large and small, are unwilling to accept this wider role or accept it without the capabilities required to successfully achieve it. Interviewee 7 (Prime Contractor) illustrated how this could impact on the delivery schedule:

'Sometimes you're too much for a suppliers' business - we're demanding they become more involved in our processes and, particularly for smaller suppliers, they don't necessarily have the skills we expect but they accept the task because they are so reliant upon us and can't afford to lose the business. Of course it's a problem for us because if they fail it's left to us to sort out the mess while we try to keep the programme on schedule. I think we could do more here, not just sorting out the business with the supplier once a problem happens, but also understanding beforehand where you fit in the pecking order, what they are really capable of and do you want to modify that by expanding into the relationship or retreating away from it.'

'Offset' is a sales and marketing technique used extensively, but not exclusively, in the arms and aerospace manufacturing industries (Davis 2002). It is a form of counter trade involving a series of commercial mechanisms employed when export sales are dependent on other compensatory factors such as: the financing of trade; compensation of indigenous industry, development of industrial base. Interviewees indicated that, in practice, Offset also means their final customers had a greater than usual influence upon the prime contractor's supply chain design decisions. Offset risks could also be compounded by the complexity of aerospace manufacturing relationships: *To compensate the customer's indigenous industry or develop its industrial base, prime contractors may be obliged to incorporate customer specified sources of supply into their supply chains. This can expose additional sources of risk. For example, incorporating suppliers from a potential customer's country into an existing supply chain may increase the geographical length of the supply chain, thus impacting lead-times and possibly increasing transport costs if faster modes of transport are used to maintain the same lead-times. Alternatively, existing suppliers may be replaced with less effective or unreliable suppliers, resulting in higher costs from management responses such as additional buffer stocks of inventory, higher levels of supplier liaison or higher levels of supplier development. The highly competitive and price conscious nature of the over-supplied international aircraft sales market also means these potential additional costs must be tolerated within thin profit margins.* [Interviewee 8 – Tier 1]

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 (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 AVAILABLE 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. 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. 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, TQM 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. 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. However, Figure 2 provides further evidence of contradictory requirements within the supply chain. 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

SUPPLY CHAIN MANAGEMENT ACTIVITIES

SUPPLY CHAIN RISKS

	Supply Chain Planning	Supply Chain Change Management	Supply Chain Management
Cost	<p>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>SET 5</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>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>SET 2</p> <ul style="list-style-type: none"> * Supplier Quality Audits. 	<p>SET 6</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>SET 10</p> <ul style="list-style-type: none"> * Supplier managed quality adherence. * Supplier quality review.
Delivery	<p>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>SET 7</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>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>SET 4</p> <ul style="list-style-type: none"> * Supply Chain Mapping – relationships and influences. * Process relationship analysis 	<p>SET 8</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>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

regular or temporary basis to mitigate delivery or schedule adherence problems (Set 7 and 11).

IMPROVING REACH AND EFFECTIVENESS

Three key issues were identified as barriers to effective implementation of a supply chain vulnerability toolkit. The first was staff training, there was quite a widespread recognition that existing tools could be much more effective 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 research revealed that there was absence of a common understanding of the scope or extent of supply chain risk management. These included: an organisation's internal logistics network; its Tier 1 suppliers only; Tier 1 plus internal departments involved in data sharing; organisations upstream of the focal firm that were taking a customer-orientated view of the supply chain. The third issue was visibility.

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. When initially invited to consider whether the limited upstream and downstream reach of their risk management techniques was sufficient, interviewees responded unanimously that it was. They reconsidered only when presented with a definition of supply chain risk management that 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.

Three possible methods for improving the reach of the existing tools were subsequently tabled by the researchers for consideration by interviewees and focus group members. One of these methods, involving a truncated (but as yet undetermined) interlocking and commonly accepted approach, encompassing the focal firm, its immediate customers and suppliers, emerged as the favoured way forward. 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. To ensure widespread application, it was suggested that it be annexed to one of several existing industry-wide performance accreditation schemes. The effectiveness of the toolkit could be improved further by the introduction of a shared data environment. A successful precedent had been created in the defence sector with the establishment of a shared data environment for organisations involved with a single shipbuilding project. It was felt that this would significantly reduce the commercial risks attached to sub-optimal supply chain performance and lead to consequential improvements in profitability and longer-term supply chain health.

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 the organisations would be unwilling to share data relating to other sources of risk. There were also some risks, e.g. those associated with Offset, that the supply chain managers were unable to manage. These emerged as a result of strategic business decisions taken elsewhere in their own organisations or in those of customers or suppliers.

SUMMARY AND CONCLUSIONS

The risks readily identified by aerospace supply chain managers were the consequential risks to supply chain performance arising from other managerial practices and industry trends. In particular managers emphasised those trends that were believed to be undermining efforts to optimise supply chain processes. 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 adopting a process-based view of risk within their supply chains, this was certainly not an 'end-to-end' supply chain or network-wide perspective. 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-known process reengineering and control tools. 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. 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 and formalised collaboration, preferably involving a shared data environment. This would facilitate improved 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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