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# Moving Beyond the Dyad: Multi-Tier Supply Chain Integration in the Aerospace Industry

Andrew White

Zaher Mohdzain

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Dr Andrew White[1], Dr Zaher Mohdzain[2]
Centre for Logistics and Supply Chain Management[1] and Information System Research Centre[2]
Cranfield School of Management
Cranfield University
Cranfield
Bedford
MK43 OAL
United Kingdom

**Abstract:** This paper presents a case study on how multi-tier supply chain integration is being achieved via the use of information systems in the aerospace industry. It is based on interviews conducted with three organizations across the supply chain and an IT vendor who supplied the technology. The study finds that by using a new set of technological standards, namely Web Services, data can be taken from the systems of three disparate organizational systems and then used to help an integrated product team from three organizations manage the supply chain. In order to capture the benefits of this technology, the development of a supply chain mindset, integration of marketing and logistics activities and observing demarcation of what issues can and cannot be discussed via the multilateral relationships need to be addressed. The contribution of the paper is that emergent information systems can be used in a multi-tier context to address the problem of the Forrester effect, a phenomenon that has plagued supply chains for decades.

**Keywords:** SCM, E-logistics

## I. Introduction

The global aerospace industry is currently enjoying a period of substantial growth, following the slump in sales that resulted from passengers' reluctance to fly after the tragic events of September the 11th. Aerospace is a sector that contributes a significant proportion of national wealth to countries such as the USA, UK and France, and it consists of four key sectors: civil aircraft, military aircraft, missiles and space. The aerospace industry consists of a supply chain that starts with prime contractors such as Boeing and Airbus, then has systems and major equipment suppliers, sub-system and major component suppliers come next, which is followed by component suppliers. This supply chain is supported by a miscellaneous range of other suppliers in areas such as information systems and manufacturing equipment. The industry can be characterized in the following terms: high levels of technological and scientific intensity; high cost and high-risk programs; long development and payback cycles; low volume, high value products; civil-military linkages; international collaboration in design and development; central role of Government as sponsor, customer, regulatory and market gatekeeper; high barriers to entry; highly safety critical; long service life (AIGT, 2003). As with any industry, aerospace is in a continual state of change. Recent developments in the aerospace supply chain include: an increased use of supplier development activities to improve their capabilities (Reed and Walsh, 2002); an increased level of outsourcing, which has had the negative consequence of a reduction in the level of control over information for changes in supply and demand (Bales et al. 2004); an increased focus on large-scale integration of systems and platform assembly by those higher up the supply chain, and the optimization of manufacturing and supply chain operations through the adoption of lean principles (Williams et al., 2002); continual challenges in seeking appropriate, markets vs. hierarchies, supply chain relationships (Rossetti and Choi, 2005); the integral role of people and information technology management as a source of competitive advantage (Russell and Hoag, 2004).

This paper will present and analyse a case study conducted on an aerospace Original Equipment Manufacturer (OEM), which serves customers comprising of more than 500 airlines, 4,000 corporate and utility aircraft and helicopter operators, 160 armed forces and 2,000 marine based organisations. Their annual sales total approx. $9 billion, of which 55 per cent are services revenues. The paper will start by reviewing the literature concerning supply chain management and the use of information systems as a means to improve performance in this area. It will present the rationale for the methodology that was employed and how this was operationalized. The results of the study will then be presented, including: how the technology that integrates multiple tiers in the supply chain works; the motivational antecedents that were responsible for it being developed and deployed; and the factors that were seen as being responsible for enabling the benefits attributed to the system being realised; and the benefits attributed to it.

## II. Supply Chain Management

Supply chain management is a concept that is emerging in recognition that buyer-supplier relationships need to be managed beyond logistics and procurement functions

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(Lambert *et al.*, 1998; Cooper *et al.*, 1997). In the literature, supply chain management has been defined as a "*connected series of activities that are concerned with planning, coordinating and controlling of materials, parts and finished goods from suppliers to customers*" (Stevens, 1989), or "*the management of upstream and downstream relationships, with suppliers and customers, to deliver superior customer value at less cost to the supply chain as a whole*" (Christopher, 1998). As supply chains often involve more than a dyadic relationship, Mentzer *et al.*, (2001) defined it as "*a set of three or more entities (organizations or individuals) who are directly involved in the upstream and downstream flows of one or more of products, finances and/or information, from a source to a customer*".

Research in supply chain management encompasses a number of evolving factors in relation to how organizations cooperate and compete. These factors include the use of virtual teams (Bal *et al.*, 1999), sharing risks and rewards (Cooper and Ellram, 1993), integration of business processes (Stevens, 1989; Christopher, 2000), improved information sharing (Mason-Jones and Towill, 1999; Morash, 2001), and developing long-term relationships with key suppliers (Cousins, 1999; Schonsleben, 2000). Managing a single organization within a larger collaborative environment also requires a different set of competencies, such as in managing interorganizational processes (Garcia-Dastugue and Lambert, 2003) and exploiting information systems and technology to facilitate multi-tier integration (White and Daniel, 2003).

Within the management of supply chains, two paradoxes are present, which create a level of uncertainty as to what strategy supply chain managers should employ. This can be articulated in a number of ways. For example, should an organization seek to make its operations and supply chain more "lean" (Womack and Jones, 1994; Karlsson and Par, 1996) through the removal of waste (minimising inventories, reducing process inefficiencies and minimising obsolete stock) or more "agile" (Christopher, 2000) (where excess capacity is required to respond to sudden changes in factors such as demand)? Secondly, should an organisation adopt a competitive position in its relationships with suppliers (Lewis and Yildirim, 2002), and thus create a high rate of turnover of suppliers, or should it invest in longer-term collaborative relationships with suppliers (Cousins, 1999; Schonsleben, 2000)?

## III. Information Systems In The Supply Chain

The use of interorganizational systems to link up different actors within a supply chain is not a new concept that originated with the advent of the Internet. These systems have been utilized by organizations for a number of years, combined with the medium of EDI (electronic data interchange), to facilitate electronic trading (Cunningham and Tynan, 1993). Whilst EDI systems brought benefits to trading partners, it's use was limited due to high costs and limited content (Frohlich, 2002) and low levels of flexibility in it's implementation and operation (Nurmilaakso *et al.*, 2002). Nevertheless, researchers in interorganizational systems can learn much from EDI implementations, for example, in understanding the role of dominant buyers (Webster, 1995), due to the similarities between these two technologies (Soliman and Janz, 2004).

Interorganizational systems built upon the foundation of an organization's internal information systems, often referred to as ERP (Enterprise Resource Planning), are increasingly being used to manage processes that interface or integrate with customers and suppliers (Shaw, 2000). These ERP systems integrate information and information-based processes within and across functional areas, and employ reference models or process templates that claim to embody good practices within an industry (Kumar and Hillegersberg, 2000). As the importance of extending the orientation of the management of business processes, from within the organization, to between organizations (Clark and Stoddard, 1996), the evolution of information systems designed to manage supply chains occurred (Stefansson, 2002; Nedede-Amadi, 2004). These are defined as information systems that: facilitate demand and manuf-cturing planning and communication between trading partners, synchronize activities within the supply chain and maintain the provision of timely information (Tarn *et al.*, 2002); provide the capability to transfer more accurate and timely information that results in higher levels of visibility of demand and inventory in a supply chain (Patterson *et al.*, 2003); facilitate market mechanisms (a means to conduct a business transaction) and coordination flows (the sharing of information to coordinate the flow of products) (Garcia-Dastugue and Lambert, 2003); and are not confined to a single organizations processes, programs, data repositories but are able to interoperate with other systems that manage links in the supply chain (Yang and Papazoglou, 2000)

The important roles that information systems and technology play in the operations and management of supply chains have repeatedly been highlighted in the literature. However, much of this research is conceptual in nature (see Manthou *et al.*, 2004, Lin and Lin, 2004, Swaminathan and Tayur, 2003; Strader *et al.*, 1998 as examples), and thus a paucity of empirical papers exists. Previous research has indicated, for example, the impact of information systems and technology in increasing the performance of supply chains (Frohlich, 2002; Goutsos and Karacapilidis, 2004; Jayaram, *et al.*, 2000; Alkadi *et al.*, 2003), the alignment between supply chain strategy and business strategy (Williams *et al.*, 1997), and overall growth and profitability (Kotha and Swamidass, 2000; Byrd and Davidson, 2003). On a more operational level, the adoption of information systems and technology has been linked to an increase in product offerings and customer service levels (Kincade *et al.*, 2001), quality and timeliness of production information (Brandyberry *et al.*, 1999), lowering the total cost of supply and increasing the order fulfilment rate (Lin *et al.*, 2002). Even the perception about trading partners' technology adoption, according to previous research, could improve the supply chain relationship between both parties (Kent and Mentzer, 2003).

A paradox also exists in the effect that information systems have on interorganizational relationships, which bears similarities to ones observed in interorganizational relationships in general. In their "move to the market" hypothesis, Malone *et al*., (1987), suggest that increased use of interorganizational information systems will enable a greater use of markets relative to hierarchies. In contrast, in their "move to the middle" hypothesis, Clemons *et al*., (1993) assert that due to the existence of relationship specific investments, this move to the market will not occur, rather that "*the firm will rely on fewer suppliers than before, with whom the firm will have close and long-term relationships and with whom the firm will cooperate and coordinate closely*". In recent studies on the impact of Internet-based electronic marketplaces on buyer-supplier relationships, it was found that these entities are having an impact on the characteristics of interorganizational relationships (White and Daniel, 2004; White, *et al*., (2004).

This review of the literature has demonstrated the increasing importance of supply chain management to contemporary organizations, and the pivotal role that information systems undertake in enabling high levels of operational performance in this area. However, both the practice of supply chain management and the use of information technologies in this domain are in a state of evolution. Therefore, there is a continual possibility of innovative practices emerging through the syntheses of developments in these two areas.

## IV. Methodology

The objective of this study was to explore the potential role of emergent information systems and technologies in enabling innovative models that would increase the level of supply chain performance. The study seeks to explore a new domain for the purpose of theory generation. Such strategy would require the use of inductive, qualitative methods rather than deductive, quantitative research methods which, in contrast, is more appropriate for theory testing (Hussey and Hussey, 1997; Locke, 2001). As inductive methods are more frequently operationalized through case studies (Eisenhardt, 1989; Yin, 1989), this approach was therefore adopted. The value of the case study approach, according to Hoskisson (1999), also lies in its ability to consider theory in the context of the rich picture of the organisation studied, including its unique idiosyncrasies.

The OEM was selected because it was undertaking activities that aimed at integrating multiple tiers in its supply chain. This was something that in the experience of the authors was a very uncommon practice in how contemporary supply chains operate, and which a review of the literature substantiated. Given that problems which characterise supply chains, such as demand amplification (Forrester, 1961; Lee, et.al. 1997), span multiple tiers in the chain, it is fair to assume that technological interventions that span these tiers should warrant academic study. Therefore, the study adopted the following research question: to investigate the phenomenon of multi-tier integration systems (MTIS) and to examine the technical and managerial competencies needed to operate in this mode.

The supply chain under investigation involves a highly specialised manufacturing process for which there are only a very small number of suppliers globally. Moreover, the manufacturing process utilizes high quality specialist alloys, for which global demand is constrained and shortages frequently occur. The process, which is presented as Figure 1, shows how customer demand is received by the Final Build operation in the OEM. This is then communicated to the Module Build manufacturing cell, again within the OEM. From here the demand signal is passed on to a tier 1 supplier, who in this case is a producer of highly engineered metal components. They in turn pass on the signal to a tier 2 supplier of specialist materials. Inventory is positioned all along this supply chain and moves as a consequence of demand information signals.

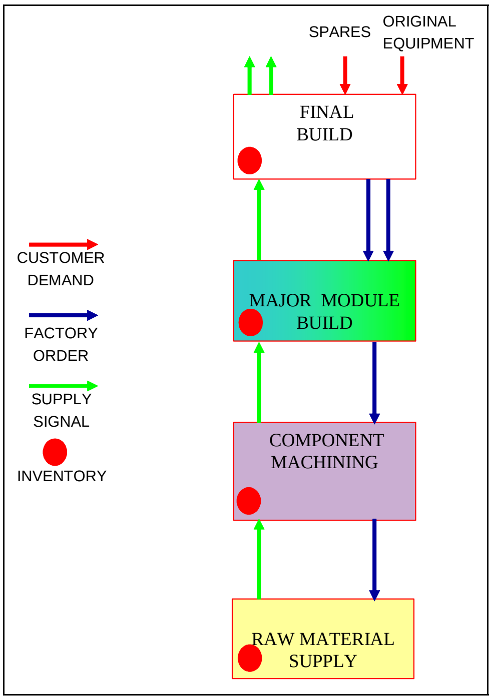


FIGURE 1 – THE OEM'S SUPPLY CHAIN

In order to investigate the use of the OEM's multi-tier integration eleven interviews were undertaken, in both the UK and in the US, with each actor in this process (see Table 1 for details). Each interview lasted between one and two hours and was tape-recorded and transcribed. The interview findings were supplemented by supporting documentation from the OEM, its suppliers and the technology vendor and from external commentators.

| Organisation | OEM | Tier 1 Supplier | Tier 2 Supplier | IT Vendor |
|---|---|---|---|---|
| **Industry Sector** | Aerospace | Industrial Manufacturing | Material | IT |
| **Supply Chain Staff Interviewed** | 4 | 4 | 1 | 1 |
| **Location of Interviews** | UK | US | US | UK |

TABLE 1 – INTERVIEWS CONDUCTED

# V. Results

## V. 1 Motivational Antecedents

The motivational antecedents that were responsible for the development and deployment of the information system that integrated multiple tiers in the supply chain stemmed from a need to reduce the demand amplification that was occurring across the supply chain. This supply chain can be characterized by the following phenomena: it plays a crucial role in the building of the OEM's core product, the current build time is 120 days and has a target to be reduced to 40; demand information frequently fails to cascade down the supply chain, thus leaving suppliers working with incorrect or out of date forecast information; the consequence of this is either shortages or excesses of inventory, both of which incur financial consequences; to date there has been no means to enable visibility of demand, supply and inventory across the supply chain; due to the volatility of supply and demand signals there is a low level of reliance on the interorganizational processes that are currently in place.

The demand amplification in the supply chain was being caused, from an external perspective, by a post 9/11 growth in sales and shortages of supply for materials such as titanium. However, internal factors were also responsible. The consequence of this was a supply chain that was under performing, with the consequential impact on costs and revenue. It was described in the following terms by one supply chain manager from the OEM:

*"In simplistic terms I would say that 50% of the noise [schedule variation] is generated internally from our organization and 50% by the supply chain not being able to support our delivery dates."*

This demand variation appears to of been exacerbated by the adoption of "lean thinking" in the aerospace industry (Womack and Jones, 1994). Low levels of inventory, coupled with deficient processes can lead to a under performing supply chain, as described by a manager from the OEM:

*"The elimination of waste and all of that type of activity is absolutely right for any organization, I agree with that. However, I believe that lean and systematic removal of waste from a process, or from any manufacturing process, can only be achieved providing you've got stability [in demand] and you've got capable processes. The problem as I see it is that our internal manufacturing facilities and suppliers have responded with the systematic removal of inventory. The problem with removing inventory without improving your processes is that it makes you very exposed."*

When looking across the supply chain, this phenomenon is exacerbated by the fact that the OEM, hitherto, has had no direct communication channel with the tier two supplier. It is this supplier who is the first to witness shortages of material, which have a consequential impact on the poor performance of the supply chain.

*"The situation is that all our problems don't lie with the first tier suppliers. The first tiers often put their hands up and say it's not my fault, it's the material supplier. The problem is he [the material supplier] does not have direct communication with the OEM."*

There would appear to be certain circumstances, under which multi-tier integration is appropriate, in other words, an emergent "design science" (van Aken, 2004). So what are these circumstances? Firstly, from a commercial perspective, that the number of alternative suppliers must be relatively low and the value of the transactions undertaken with them relatively high. Secondly, from an operational perspective, that the production time must be greater than the customer lead time. And finally, from a technical (and product safety) perspective, that the product must have a high impact on safety and possess a high level of technical risk.

## V. 2 The Multi-Tier Information System

The MTIS works by taking data from the OEM, the tier 1 supplier and the tier 2 supplier and presenting it in a common format. The data is accessed via a website, which all three parties have access to, and regular teleconferences are held to discuss the content. This process is presented as Figure 2, which shows how the information system enables an integrated product team across the supply chain.

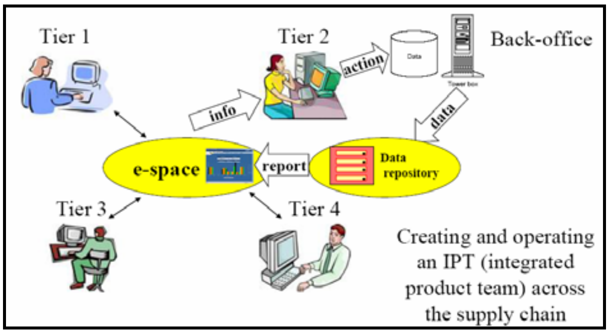


FIGURE 2 – THE INFORMATION SYSTEMS ENABLED MULTI-TIER INTEGRATED PRODUCT TEAM

The types of data which the information system manages are: inventory, its location and status (e.g. work in progress); the forecasts for future demand; and customer orders. The system uses Web Services as an underpinning technology and is based on the J2EE standard. The benefit of this type of technology was suggested to be twofold and is described as:

*"The system has got 2 layers to it. It's got a data transport layer, which means you can transport data without having to redefine it, and the process and application layer. So the application which visualises the data has been designed with the data in mind. So these 2 things sit together, so you've got a transport system and an application bolted together. And that's important because the transport system allows everybody to feed in their data without redefining the process."*

*"The one thing that I didn't want to do was to work outside of the core ERP system, and the benefit that the multi-tier system had was that it was using direct data that could be readily updated from our ERP system. That was absolutely pivotal. I didn't want to create another ERP system within the supply chain, going all the way down and all the way back up."*

### V. 3 Managerial Challenges and Implications

The use of the MTIS required a number of non-technological changes to take place in order for the potential benefits to be captured. These changes covered factors such as the emergence of a supply chain mindset, the integration of marketing and logistics functions and understanding the boundaries concerning what could be discussed and communicated via the multi-tier relationship.

### V. 4 A Supply Chain Mindset

The adoption of information technology often brings with it a subsequent need for a new mindset within the organisation (Stevens, 1989; Orlikowski, 1992). The use of a MTIS was no different in this respect. What enabled this change was the ability of the information system to share data across multiple functions and organizations, and use this data to coordinate a unified response.

*"What the IT does is that it enables people beyond the first tier supplier to have weekly or bi-weekly meetings given a set of data that is not open for debate. Everybody's got the same data and will start planning around issues that might hit us if we don't do something in 6 – 7 months time."*

This in turn gave a new perspective to operators concerning the consequences of decisions they made and constraints that the parts of the supply chain, that they hitherto had no visibility over, were under.

*The value of getting the people from [the OEM] to be able to start understanding that there isn't an infinite capacity out there."*

### V. 5 Marketing / Logistics Integration

The separation of the marketing and logistics functions of an organization is increasingly being seen as a major inhibitor to a high performing supply chain. Hence the emergence of the concept and practice of demand chain management. This case illustrates this point, in that the use of the MTIS brought these two departments together to work in a much more coordinated manner:

*"The purchasing people in the first tier supplier would normally not have any visibility of the interaction between us and the customer facing department. The use of multi-tier integration meant they saw the 2 year horizon that we were giving their commercial people. This enabled them to work with the commercial people and to be able to conduct a lot better planning of their procurement activity."*

*Funny enough it provided clear transparency for the first tier suppliers as well, so the purchasing organisation at long last started to understand what sales people were doing, and the planning people could plan around that in the mill [tier 2]. This also enabled the sales people and the planning people within the tier one organization to work around a common set of data, and these people could be all together in the same virtual room or whatever you want to call it. This ensured everybody understood the key issues.*

### V. 6 Multi-Tier Relationship Boundaries

Operating multi-tier relationships, rather then just dyadic relationships, requires a realization of what the norms are that should cover these new types of relationships. These types of relationships challenge the normal dyadic structure of relationships: OEM to tier one, and then tier one to tier two. The whole point of such an exercise is that some factors are no longer solved on a bi-lateral basis, rather a multi-lateral one. The following insight from a supplier shows one aspect of the demarcation that needs to take place:

*"You certainly have to be more open with the three way relationship. However, there are still things that are out of bounds. Pricing is one of them. But as far as working out issues such as quality and schedules, that makes perfect sense."*

### V. 7 Realized Benefits

The major benefit of the multi-tier information system was the moving from a reactive management of the supply chain to a proactive one. The situation prior to the use of the MTIS was that *"nobody knew there was a problem till there was a problem. Then you were in a highly reactive mode"*. With the MTIS *"because we take a 12-month view, we're always looking ahead to see where the shortfall is because we actually ask them [the supplier] to give us the view of their output for 12 months in support of our product. Now what this shows is that we can look ahead and can see if they are planning to produce less then what we need. Now we are able to say OK, well, that's what you've got planned for the next 12 months and you won't have any major cause to change that pattern unless we do something."*

This has enabled the performance of the supply chain to improve from schedule adherence rates of around 25 – 50% before the MTIS, to 100% when it was implemented. This improved performance has been enabled by an increased level of operational responsiveness within the suppliers business. This improved responsiveness in the tier two supplier is described in the following terms:

*"What they say now is look, we're prepared, on a basis of what we're seeing, to create raw material in bulk form at*

*a rate per month. We're not going to wait for your orders, we're going to plan to actually smelt and process at a set rate. So effectively they're saying that they've got confidence now because they can see through our signal without having to second guess what the tier one supplier is saying to them."*

The consequence of this was that the lead times for the product that this supply chain produces has fallen from 6 or 7 months to 3 months. This is a very clear indication of an improvement in a supply chain's agility and its ability to be customer responsive. Moreover this has been achieved without any stock outs and a cost reduction has been negotiated as recognition of the reduced operational and inventory holding costs in the supply chain.

## VI. Conclusions

This paper has presented a case study on a groundbreaking supply chain management information system in the aerospace sector. It has shown how multi-tier integration, between three tiers in the supply chain, can occur via the use of new technological standards, namely Web Services. This technology allows data to be taken from disparate systems across a supply chain, consolidated in a web-based information system and then the results of these data feeds presented to parties from all three tiers. This data, namely supply, demand and inventory, can then be analysed and a collective decision made regarding how the supply chain should operate. These standards allow for the manipulation of what can be regarded as supply chain processes, without interfering with the underpinning systems and the complexity that this would involve. Our study shows that the evolution to this type of planning requires a supply chain mindset to be present. This is where variables across the supply chain are considered, not just those within the operators own organization. Moreover, to fully exploit the potential of this technology, attention should be paid to the integration of the marketing and logistics functions in the tier one organisation, as communication between these two entities is pivotal to this approach. We also noted an adherence to a set of rules or principles of behaviour when operating in this environment e.g. conversations between the OEM and the tier 2 supplier must not cover issues of prices. That was considered a proprietary discussion between the tier 1 and the tier 2 organization.

Significant organisational benefits attributed to this information system were observed. These include a shift from a reactive to a proactive supply chain management approach; improved levels of schedule adherence and an improved level of operational responsiveness, which is leading to a significant reduction in the supply chains lead time.

In summary, this paper has shown that going beyond dyadic supply chain relationships is being enabled by breakthroughs in new technologies, which in turn are enabling new levels of agility to be delivered and levels of customer responsiveness achieved.

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