Tipping the balance of power: the case of Large Scale Systems Integrators and their supply chains

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Abstract: The Large Scale Systems Integrator (LSSI) model of supply chain organisation and management is gaining in popularity as Original Equipment Manufacturers (OEMs) seek gains from distributed innovation and leveraged supplier R&D, all the while maintaining economies of scale at the assembly stage. The LSSI model requires a change in the roles and responsibilities of both OEM and its suppliers. Ultimately, staffing patterns at all levels of the supply chain will need to adapt to changing roles for engineering, design, purchasing, and manufacturing. The success of the LSSI model is based on comprehensive and shared knowledge management responsibilities, coupled with deep technical, customer, and market knowledge that are distributed across the extended enterprise. This disrupts the balance of power in the traditional OEM-led supply chain model, offering opportunities for Tiers 2 and 3 suppliers to gain influence.

Keywords: coordination and collaboration; influence; innovation; knowledge management; manufacturing; power; roadmapping; supply chain.

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1 Introduction

Boeing engineers often comment that an airplane is really a collection of components flying in formation. For the 737, the number of parts that need to come together approaches nearly three million parts, and for the 777, the number is closer to six million. Most of the Boeing fleet has been made under a supply chain model which stressed Boeing's pre-eminence. However, with its announcement of the 7E7 (later named the 787), Boeing proclaimed itself a systems integrator in much the same way that Dell Computer has established its market niche. This will forever change the way that Boeing selects and interacts with many of its suppliers. But the transition is not without challenges for Boeing (Tatge, 2006) and any other Original Equipment Manufacturer (OEM) seeking to go the systems integrator route.

Boeing is spending more than $7 billion US to build the world's first composite fuselage airplane, but its suppliers are also investing R&D and resources to bring the vision to reality. Boeing is outsourcing more than half of the structure of the plane's pieces which will be manufactured in far flung parts of the world, and also it is treating the 132 global build sites as partners, not suppliers in the strict sense of the word. Boeing suppliers will design and build many of the critical and structural components of the new airplane (SpeedNews, 2006), with Boeing assuming responsibility for final assembly (Gates, 2005; Holmes, 2005; Cecere, 2006).

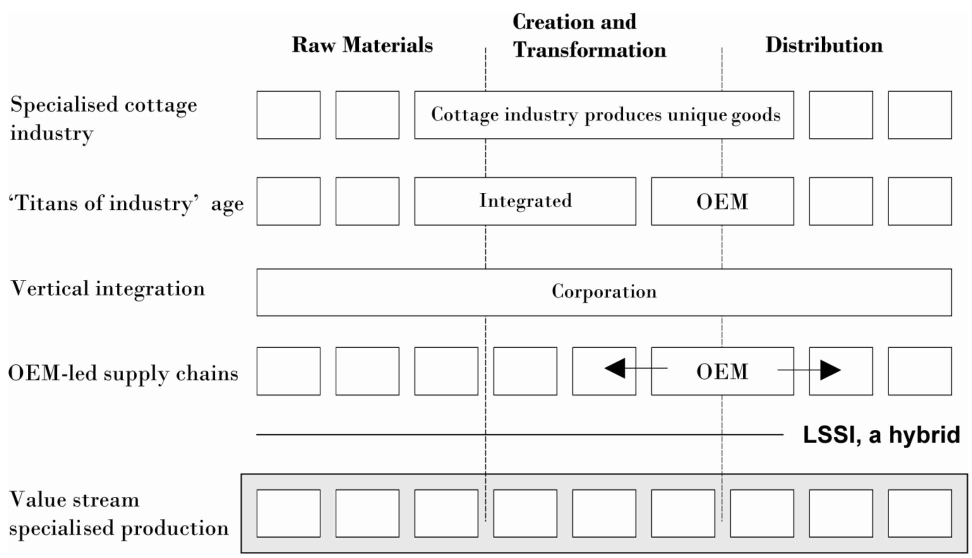
The growing trend for OEMs to act as Large Scale Systems Integrators (LSSIs) creates a critical challenge to both the OEM and its suppliers. Traditional balances of power within the supply chain garnered through economies of scale, economies of scope, and sources of innovation cannot be maintained. Nowhere is this more evident than in those industrial sectors that have competed on the basis of economies of scale and whose OEMs have focused on core competencies while outsourcing non-core production.

This paper begins with a history of production and manufacturing in whose roots lie many of the current supply chain organisational structures and motivations. From this, a generalised model of the supply chain emerges which highlights the location of innovation power and economic power based on an in-depth analysis of four industrial sectors.The LSSI production model is then detailed with particular attention to innovation sources within this framework. Here, the emphasis is placed on the changing relative contribution of firms participating in the supply chain, and the requisite changes required for coordination and collaboration among firms. The changing roles imply changes in the balance of power in traditional supply chains, and have implications for policies and procedures, staffing patterns, and knowledge management for both LSSI and participants in its supply chain.

2 The evolution of manufacturing enterprises

When considering the evolution of organisations involved in the production of goods and materials, historical context is useful. Figure 1 highlights this historical perspective, beginning with specialised cottage industries which reflected skilled sets of individual workers or firms which were combined with equally unique access to customers and technologies. These cottage industries arose through two developments. First, the availability of capital in urban markets encouraged demand. This emerging demand was then fuelled by a growing international market for goods. Also accompanying this stage was an increasingly well-developed entrepreneurial class (Mendels, 1972). Eventually, cottage industries gave way to what might be called the 'Titans of Industry' age. The primary driver of this transition was the Industrial Revolution. At this time, specialised skills, customers or technologies ineffectively competed against firms that combined machines, inanimate sources of power, and available raw materials into a factory system (Landes, 1998). Schmenner (2001) notes that these industries were (and some continue to be) driven by swift, even flow, where the key competitive advantage was in the rapid flow of materials through the manufacturing process. Because of the fixed investments in machinery, throughput and efficiency became critical dimensions of competitive advantage, encouraging firms to focus on volume and securing access to the raw materials needed to maintain full production.

Figure 1 Evolution of production and manufacturing models



Chandler (1992) notes that the firms spawned during the Industrial Revolution were capital intensive, and able to exploit both economies of scale and scope that were made possible by the new technologies. The Titans of Industry were the firms that emerged through the three-pronged investment in manufacturing, marketing, and management necessary to fully exploit these economies. Typically, these firms included those that focused on the transformation of raw materials into products or into the assembly of these products into more complex offerings in the market. This led to the concept of an OEM that still exists today.

Firms in this age grew through forward integration into market distribution and/or backward integration to control access to raw materials. Ultimately, this resulted in the development of vertically integrated corporations that spanned all of the traditional routines of the firm including the well specified technical routines for producing things, procedures for hiring and firing, ordering new inventory, research and development, advertising, and business strategies aimed at product and geographical diversification (Nelson and Winter, 1982).

In recent decades, many corporations that once spanned the traditional routines of the firm have been replaced by supply chains where some or nearly all of the production of goods and services is done by other firms. In 2006, for example, worldwide estimates for this outsourcing tops $6 trillion US, with a 30% annual growth rate expected (CBC News Online, 2006). This trend has intensified due to several factors, including an emphasis on firm core competences; modularisation of design; the emergence of specialised, complementary firms; and increased global goods and services production capacity. The belief that firms should focus their efforts on those activities at which they excel to achieve competitive advantage (Prahalad and Hamel, 1990) encouraged the vertically integrated corporations to target their resources to core technologies, processes and skills, and to begin outsourcing non-core aspects of production. As firms began to specialise in technologies, product components or manufacturing processes, a natural distinction could be made between those companies that produced a component or subassembly, and those companies that assembled these into product configurations to meet the demands of the end customer. Manufacturing capabilities began to reside within the supply base. The automotive industry's OEM and tiered supplier relationship is a good example of this.

Modularisation in design heightened the ability of an OEM to determine the product architecture with firms in the supplying tiers responding to an OEM architecture and product feature set specifications. Here, OEMs retained responsibility for product design and engineering, coupled with a focus on assembly and process automation. The relative importance of individual supplier firms was directly related to the value of their contribution to the end product in terms of customer perception.

Novak and Eppinger (2001) suggest that the modularisation of product components and the complexity of the end product both influence the structure of the supply chain. In their argument, product complexity is a proxy for transaction costs within the supply chain. As product complexity increases coordination costs increase.

A second factor that supported the transition from vertically integrated corporations to an OEM-led supply chain is the emergence of firms specialising in management or other administration functions that were complementary to the manufacturing enterprise. These firms encouraged corporations to further outsource non-core business operations for activities ranging from logistics to human resource management to accounting, among others. In doing so, OEM administrative practices were perpetuated through many suppliers by virtue of these intermediaries who were coordinating shipments or payments, for example (Ramachandran and Tiwari, 2001), sometimes even transparently to the supplier (Morgan, 2002).

The third key factor that encouraged corporations to divest non-core production and administrative activities is the availability of geographically dispersed capabilities. The geographical dispersion of capability combined with a lower wage rate, gives firms in developing countries a competitive advantage over more traditional suppliers located in developed countries and has encouraged the practice of offshoring. Such has been the rise of the information sector and supporting services in India and the manufacturing sector in China, both of which have emerged as the result of geographic capability dispersion and lower wage rates (Friedman, 2005). Today the 'China price' is frequently the baseline for make vs. buy and supplier sourcing decisions.

More recently, an OEM-led supply chain model is being challenged by networks of firms competing in a coordinated and collaborative fashion (Christopher, 2000; Sherer, 2003; Yusuf, Gunasekaran, Adeleye and Sivayoganathan, 2004). Each of these firms adds value in such a specialised production network. The value stream model emphasises participation through distinctive capabilities where collaboration and coordination are achieved, in part, through common goals. In the value stream specialised production model, a single firm does not control the activities of the network as is the case in an OEM-led model. Often shared goals are enabled by information technology and its ability to replace routine or redundant functions, anticipate communication needs, support collaborative planning and design activities, and forecast combined demand and consequent product flow needs across firms (Lancioni, Smith and Schau, 2003).

The focus of this paper is the LSSI model which possesses attributes of both an OEM-led and the value stream specialised production models. In the LSSI model, an OEM assumes the role of an integrator of subassemblies that are produced elsewhere. As part of this, the LSSI de-emphasises its own manufacturing role, sometimes completely abandoning it, and instead emphasises its ability to conceive of a product vision and to work collaboratively with suppliers to achieve it.

It might be assumed that the LSSI model should exhibit hybrid vigour, combining the best features of the two parent models. Such is the goal of those companies adopting this model. Early observations suggest, however, that the systematic changes needed to achieve this vigour are slow in coming, making the transitions to the LSSI model a difficult one. Some of the reasons for this difficulty can be found in how power is distributed in an OEM-led supply chain, a typical precursor to the LSSI model. Understanding the balance of power in the supply chain is critical to realistically assess implementation strategies (Maloni and Benton, 2000).

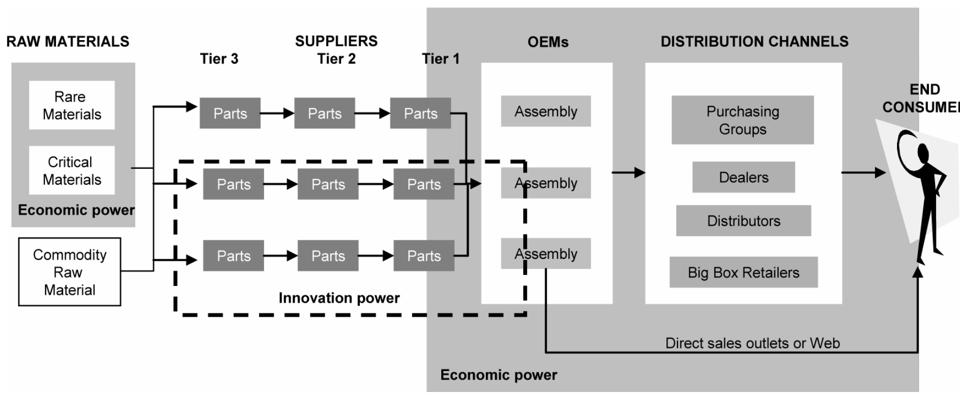
3 Balance of power in traditional OEM-led supply chains

Power and influence in a supply chain rests with the firm or firms that can direct innovation, determine cost targets, and/or enforce production schedules or impose administrative or management processes on other players in the chain. Porter (1980, 1998) has long espoused the importance of sectoral competitive dynamics in shaping the relative influence of buyers and suppliers. For example, in industries where the end consumer is price sensitive, there is a downward pressure across the supply chain to reduce the price/performance ratio over time. On the other hand, when customers are price insensitive to an industry's product, then the buyers and sellers within those supply chains face the challenge to innovate without the expectation that costs must decline. Petrick, Purdam and Young (2004) recently studied four industrial sectors to identify patterns of economic and innovation power: aerospace, automotive, building materials, and medical devices. This work found that the automotive industry, with a few notable exceptions such as Toyota and Honda, focuses almost entirely on economies of scale. Modular design in this sector has forced suppliers to meet product configuration needs that are established by an OEM, and downward price pressure dominates nearly all the suppliers within this sector.

The medical devices industry focuses on innovation in its production activities and economies of scope in its distribution activities. The building materials industry focuses on economies of scale in both the production and delivery activities, and also effectively competes with economies of scope in delivery channels. In the aerospace industry where products typically have a life of 30 years or more, the emphasis is on economies of scale in production, punctuated with intensive innovation for new platforms.

Based on this in-depth analysis, a generalised model of the supply chain was developed which highlights the location of economic and innovation power (see Figure 2). In this generalised example, multiple supply chains are presented that transform raw materials into components (Tiers 2 and 3) to subassemblies (Tier 1) and assemblies (OEMs) which then reach the end consumer through one or more distribution channels including purchasing groups, dealers, distributors, and big-box retailers. More recently, web-based sales directly to the end consumer have become an important distribution channel that is likely to grow in importance in the future.

Figure 2 Traditional balance of power in a generalised supply chain framework



In this generalised view, economic power is concentrated at either end of most supply chains. On the one end, suppliers that possess critical or rare raw materials can influence the cost and availability of an important-to-the-end-product material (as compared to the relatively low influence on cost or availability for commodity raw material suppliers). On the other end of the supply chain, OEMs that determine product architecture and the distribution channel factors that control access to the end customer act as gateways to the marketplace for those suppliers trapped in the middle. The top handful of OEMs and/or distributors (typically, fewer than 5–10 players) significantly influences others in the industrial sector. In the middle, some Tier 1 and most Tiers 2 and 3 (or n, in some cases) suppliers are often squeezed. OEMs through economies of scale can also exert downward pressure on suppliers, chipping away at supplier margins over time.

Innovation power, on the other hand, typically lies with firms that have inimitable skills, manufacturing capabilities or intellectual property (Collis and Montgomery, 1995). These firms can influence the supply chain through their uniqueness, and often represent highly desirable partners for others in the supply chain. Firms that compete in specialised product areas have greater control over their destiny than those producing commodity types of products. Supply chain coordination and collaboration practices that emphasise codevelopment and joint R&D favour the firms with innovation power.

Interestingly, only a small number of firms actually exert both economic and innovation power. Such firms are more likely to possess economies of scale benefits and unique intellectual property positions. An example of this rare breed is Intel which has brand recognition for the end consumer, large scale manufacturing benefits, and unique chipset designs and manufacturing capabilities.

Only occasionally does the end consumer exert economic power. Typically, this occurs when the consumer chooses among distribution channels and directly or indirectly influences price points. Consumer power may grow with the pervasiveness of the internet and can already be seen as eroding the power of traditional distribution channels. More likely, however, it is the distribution channel that sits between an OEM and the end consumer that may be able to influence other participants. Even with the rise of the internet, channels to the market remain important economic power brokers, and these channels can be expected to exert growing pressure on the remaining supply chain participants in terms of the information content that accompanies their components, subassemblies, and assemblies.

4 Firm positioning to achieve power

Achieving power in the traditional OEM-led supply chain or in the newer networked value stream specialised production requires firms to identify the ways that power is conferred within their industrial sector given the competitive dynamics. These firms must then develop innovation, production, coordination, and collaboration mechanisms that fit the competitive dynamics of the industrial sector. Table 1 highlights the relationship between the sources of power and the role that a firm might adopt to achieve power or improve its position in its supply chain. Knowledge gathering and creation capabilities (Petrick and Mailtand, 2005) combined with an understanding of the critical-to-customer features helps suppliers achieve innovation power. Collaboration mechanisms to share product feature needs and customer insight with suppliers (Van Aken and Weggeman, 2000; Welty and Becerra-Fernandez, 2001) and deep background knowledge about non-core technologies which are produced by supplier firms (Granstrand, Patel and Pavitt, 1997) are essential for an assembly firm (OEM) to achieve innovation power. The deep background knowledge helps an OEM to establish product architectures that incorporate emerging technologies in the supplier base to create product features which are compelling in the marketplace.

Table 1 Strategic fit of firm role and sources of power in the generalised supply chain model

	Source of Power	
Role	*Innovation*	*Economic*
Supplier	Unique access to technical knowledge drives product feature innovation	Emphasis on low cost production combined with just in time coordination metrics promotes high through-put
Assembler	Concentration on core capabilities combined with background knowledge of non-core technologies and collaborative design processes increases market relevance of end-product	Emphasis on process innovation, assembly automation, and logistics coordination of the supplier base reduces the price/performance ratio over time

To achieve economic power, suppliers must rely on low cost production methods to drive cost out of the end-product. For the assembler (OEM), the emphasis must be placed on process innovation and automated assembly. Coordination mechanisms between the supplier and assemblers that emphasise just-in-time manufacturing and inventory management promote the high throughputs necessary to achieve economic power.

5 How the Large Scale Systems Integrator model differs from OEM-led supply chain model

The concept of large scale systems integration (also known as LSSI) is typically associated with software or enterprises (Markus, 2000; Mendoza, Peréz and Grimán, 2006), but has also been used with respect to manufacturing (Sage and Lynch, 1998; Hobday, Davies and Prencipe, 2005). LSSI implies that a system exists in which individual subsystems act, and that the action of these subsystems reflects the goals of the overall system. In general, to achieve subsystem point solutions that optimise the system's performance requires coordination (Mejabi, 1994). In the manufacturing and product development world, this coordination must be extended through collaboration due to the complex nature of technologies and the product complexity that results.

The key difference between the LSSI model and an OEM-led supply chain model can be seen in the types of coordination and collaboration that are required for success, and in the way that innovation is conceived of and produced by the multiple actors in the supply chain. In essence, LSSI is an OEM-based model on steroids where both coordination requirements and collaboration opportunities are heightened.

It is important to make a distinction between coordination and collaboration in a way that is not typically done in the supply chain literature which tends to use the terms somewhat interchangeably (Holweg et al., 2005). In this paper, coordination embodies formal, repeatable routines, many of which are supported by information technology, and intended to bring action in the supplier firm into line with expectation of the 'customer' – which may be either a downstream supplier or OEM. Coordination might be reflected in shared databases or software for logistics, in the contractual arrangements for the purchase and provision of goods or services, and for example, in the flow of information to reflect scheduling across the supply chain. These types of activities are generally more mechanistic than the organic nature (Burns and Stalker, 1961) of collaborative mechanisms. For example, collaboration mechanisms might be reflected in working groups or memoranda of understanding. Here, collaboration mechanisms refer to more loosely structured opportunities for discussion and trading of information which may or may not be supported by information technology. Collaboration should yield benefit to all parties involved and, as distinct from coordination, it is voluntary and tends not to be imposed on one node of the supply chain by another.

OEM-based supply chains tend to rely heavily on coordination mechanisms and follow a continuum of collaboration practices and mechanisms, depending upon the type of supplier. Laseter and Ramdas (2002) have developed a taxonomy that combines degrees of differentiation (to the end product) with the cost and complexity of the subsystem relative to the end product to assess the relative contribution of suppliers. Table 2 uses this classification scheme to identify types of suppliers in the LSSI model.

Not surprisingly, *commodity suppliers* who provide low cost and complexity components that do not differentiate the end product exert little influence. They respond to the demands of others in the supply chain by providing components that are produced in quantities needed with little or no modification to the component for any one use. Commodity suppliers would likely be found in Tier 3 (or n, depending upon the sector).

Table 2 Supplier roles in the LSSI model

	Cost and complexity	
End product impact	*Low*	*High*
Non-differentiating to end product	Commodity supplier (low influence)	Strategic supplier (moderate influence)
Differentiating to end product	Value added supplier; information source for technology evolution (moderate influence)	Key collaborator (high influence)

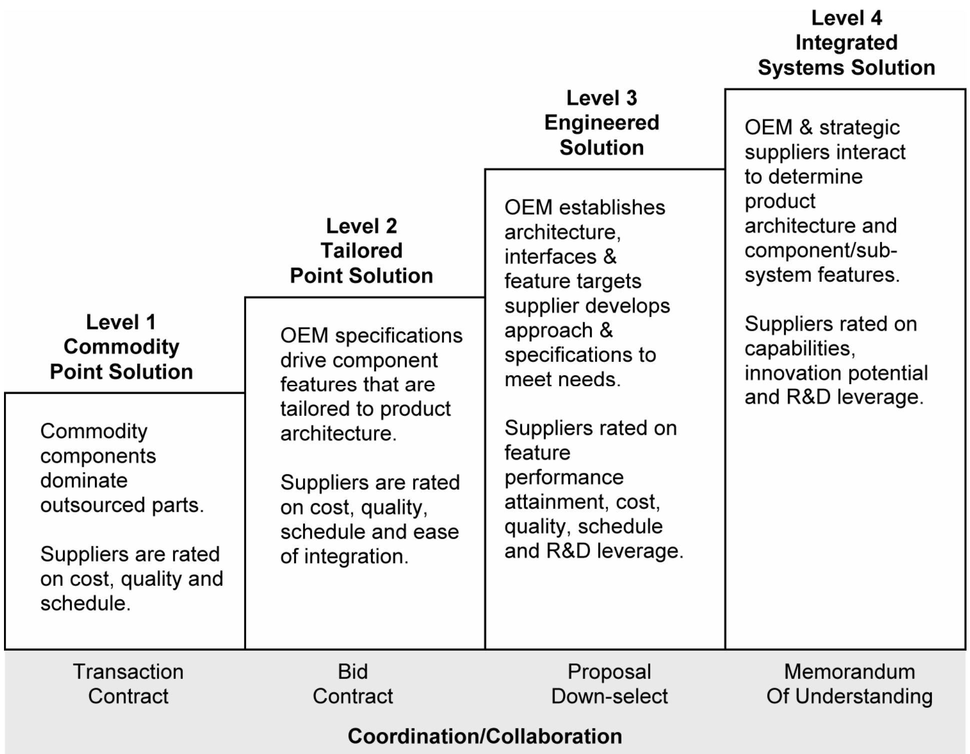
Value added suppliers produce components that are low in cost and complexity, but which help to differentiate the end product in the market-place. Here, the supplier adds value to the end product, and also to the LSSI through its technical knowledge and advanced warning of emerging or competing solution opportunities. If this supplier chooses to inform the LSSI, it can increase its value to the LSSI, thus increasing its influence. Value added suppliers would be found in Tiers 2 or 3 depending upon the component.

Strategic suppliers are those that provide high cost or highly complex subassemblies needed by the LSSI. These subassemblies are not necessarily differentiating in the marketplace, e.g. the end customer cannot recognise one supplier's product over another's, but the relative cost or complexity of these subassemblies does affect the end product's price. Here, the strategic supplier has moderate influence simply by virtue of its impact on the end price. Strategic suppliers would be found in Tiers 2 or 3 with a higher preponderance in Tier 2 due to the complexity of the subassemblies.

The most critical supplier to the LSSI is the *key collaborator*, so named to stress the different nature of this LSSI-supplier relationship. Typically, a Tier 1 firm, the key collaborator exerts high influence in the LSSI model, since it is this firm that codevelops product features and architectures with the LSSI. Often this key collaborator is the LSSI's link to other suppliers in the chain as the key collaborator role often includes management and coordination of specialised production or directed innovation and R&D. Choosing a key collaborator in the LSSI model is as much about choosing the capabilities of the key collaborating firm as it is about selecting the key collaborator's network of suppliers. To be innovative, the key collaborator's supplier base must include innovative capabilities as well.

Many studies have identified asset visibility as a competitive advantage in supply chains (Forrester, 1961; Lee, Padmanabhan and Whang, 1997; Chen, Drezner and Simichi-Levi, 2000; Holweg et al., 2005), and examples of this abound in the literature (see for example, Cigolini, Cozzi and Perona, 2004). In this case, LSSI and OEM-led models are similar, and asset visibility will remain an important source of competitive advantage. However, the key to successful transition to the LSSI model is for the OEM to determine the types of coordination and collaboration practices that best fit the various activities of the supplier base. Figure 3 addresses the coordination needs based on the type of solution provided to the LSSI. Here, it is important to make a distinction between the supplier type and solution type. It is not uncommon for a single supplier to provide more than one type of solution. This complicates LSSI coordination with its supplier, since a one-size-fits-all coordination mechanism with any single supplier may not be appropriate.

Figure 3 Coordination and collaboration requirements to support the LSSI model



Teece (1986) identified contracting as an effective way for suppliers to gain access to complementary assets. In the LSSI model, the type of contract and the depth of interaction between firms needed to achieve it must be considered. The suggested coordination and collaboration mechanisms in Figure 3 reflect the continuum from open market pricing and negotiation through cooperation where successively higher levels of integration, joint planning, and technology are required by participating firms (Speckman, Kamuaff and Myhr, 1998).

At the simplest solution level, the commodity point solution, the LSSI or another in its supply chain establishes a desired quantity and delivery date. In this case, the supplier is rated based on cost, quality, and schedule, coordinated through a transaction contract. At Level 2, the supplier is responding to the LSSI's specifications where the supplier has to engineer the solution to fit these specifications. Coordination is best accomplished by a bid process that rates suppliers on cost, quality, and schedule, given the specifications needed. Suppliers build into their quotes any engineering time needed to achieve the desired feature.

At Level 3, suppliers must develop engineered solutions to meet a set of product features that are established by the LSSI. Here, the LSSI establishes the interface needs for the solution so that it is consistent with the context in which the subassembly will be embodied in the LSSI's product configuration. the LSSI then tasks the supplier to develop a solution that provides the product features that are consistent with the interface. Coordination mechanisms at this level should emphasise proposal development and down-select leading to an eventual contract. Since an engineered solution typically requires R&D, suppliers at this level should be rated based on their ability to propose a solution that meets the feature set needed, the cost, quality, and schedule, as well as on the amount of R&D that the LSSI will leverage as part of the engineered solution.

At Level 4, the supplier collaborates with the LSSI to determine product architectures and features. This supplier provides deep process and material knowledge to LSSI, helping to inform product architecture alternatives. At this stage, the coordination mechanism between the LSSI and the supplier must focus on mutual benefit through a Memorandum of Understanding (MoU). It is here that the LSSI model often hits the proverbial brick wall. For truly compelling innovations to reach the end product, intellectual property often must be shared, jointly owned, or jointly developed. Contract and case law have not kept pace with the realities of this level of collaborative development. Level 4 interactions cannot be contracted at the outset through normal Level 1 or 2 coordination mechanisms. And the need to jointly develop or share intellectual property often makes the proposal route less attractive to the supplier firm. Unfortunately, an MoU can be sufficiently vague so as to in fact, limit the innovation that takes place as the result. Even in cases where the MoU successfully leads to a proposal, the transition to contract is often tedious and time intensive. This occurs in part because the collaboration is happening between designers and engineers of differing firms, while contracting happens between purchasing departments of those firms. The disconnection between action and decision is a hurdle that few LSSIs have successfully or consistently cleared.

6 Implications for supplier and OEM roles in the LSSI model

6.1 OEM as LSSI

A firm seeking to adopt an LSSI role must have robust coordination and collaboration policies established that can be perpetuated through its supply chain to ensure that supplier decisions and investments compliment the LSSI's overall goals. Herein lies the challenge. Though heuristics and benchmarking methods have been suggested to reach consensus on supplier selection and collaboration (Handfield et al., 1999; Simatupang and Sridharan, 2004, 2005), in practice the metrics used to judge suppliers in the OEM-led model tend to focus on the three general aspects of cost, schedule, and quality. A supplier that delivers at cost, on time, and within the target level of quality is more highly valued than one who does not, often earning the status of *preferred supplier*. Preferred suppliers are those that the OEM would choose to go back to for additional goods or services. In this manifestation, supplier history is valued.

As a comparison, in the LSSI model manufacturing expertise is transitioned to the supply base and suppliers in the LSSI model are the primary sources of invention or the transition of invention to innovation through the product component and engineered solutions that are produced by the supplier. In this model, a key value of a supplier should be its ability to innovate, its unique capabilities, and its match with emerging product technology, manufacturing, and component needs. Note that this is not necessarily a historical perspective. Metrics to assess capabilities or to compare suppliers on those capabilities are generally qualitative when they exist at all. A second problem is that existing preferred suppliers have earned that status by virtue of their ability to meet current needs. For the LSSI whose new products are substantially different from its existing offerings, preferred suppliers may actually not be the best fit for the new product platform. Thus, the LSSI must carefully triage its supplier needs and match its purchasing processes and approaches with the solution type. Centralised supplier management departments in LSSIs find such triage difficult.

As OEMs transitions to LSSIs, the tendency is to reduce the manufacturing footprint, which in turn results in a loss of manufacturing knowledge. The footprint reduction is a positive aspect of the transition, freeing up capital and other resources. The loss of manufacturing knowledge is a long-term danger, however, and the LSSI must selectively maintain that knowledge to be able to judge supplier capability. Similarly, this knowledge must be used during engineering and design to fully exploit the innovation potential of a process or a material/process combination. Boeing engineers working on the configuration of a new airplane, for example, consider three factors: possible design configurations, technology solutions (including materials), and structural manufacturing issues. According to one Boeing engineer leading new product development, effective new airplane design must balance this three legged stool while considering cost, weight, and certifications.

In organising for product development, the LSSI must maintain a core of knowledge relevant to the product domain. It must also assume a leading role in anticipating market needs and driving market desires. In-depth customer knowledge must be translated into a compelling vision for end product features. This need should encourage LSSIs to invest time and effort into activities that produce deep customer understanding, projecting well beyond the feature sets of existing products.

From a knowledge management perspective, the LSSI must create a framework in which diverse information can be gathered and organised to replicate across its supply chain the knowledge sharing that Nonaka (1994) associated with the vertically integrated model. Strategic roadmapping is being used successfully by many companies (Petrick and Echols, 2004; Phaal, Farrukh and Probert, 2004; Petrick and Provance, 2005), but its contribution to competitive advantage is extremely important in the LSSI model where knowledge is distributed throughout the supply chain.

Iansiti (1998) distinguishes between domain-specific knowledge and context-specific system knowledge in technology integration. In the LSSI model, the OEM and its key collaborators possess the context-specific knowledge about the product and its feature needs. Value added and key suppliers might be expected to possess the domain specific knowledge arising from deep technical knowledge in specialised fields. A robust roadmapping practice combined with formalised supplier and customer input is thus essential. To achieve this, a level of trust must be developed that encourages information sharing in a bidirectional mode (Ring and Van de Ven, 1994; Gulati, 1995, 1998).

6.2 The supplier base

There is little that a *commodity supplier* can do to increase its influence within the supply chain, but a strong emphasis on production efficiency and on automated order and inventory management can help one commodity supplier compete against another in the LSSI model. For example, joint demand forecasting of end product compared to commodity volume requirements can yield value to the LSSI and can help in production scheduling and management for the commodity supplier.

The *value added supplier* in the LSSI model is the technical engine of the supply chain, often being closest to the emerging technology opportunities. Forecasting the development and timing of emerging technologies enables the LSSI and its key collaborators to develop more compelling product features, and advanced knowledge helps LSSI lead the market rather than follow its competition. Here, the value added supplier can facilitate technology roadmapping by using its deep technical knowledge to assess the likely emergence of various technology alternatives. Within its own planning, the value added supplier needs to maintain a core of technical experts and to charge them with the responsibility of scanning the technical landscape. This requires a complementary investment in travel to conferences and other research or technical sites combined with other activities that enable the technical experts to remain current in their fields. It may also encourage a linkage with universities or other research labs focused on the value added supplier's core technical competence.

The *strategic supplier* may have deep technical knowledge, but this must be combined with design and engineering expertise to anticipate ways to improve modularity, plug and play, and interface interoperability. Since the strategic supplier may be providing product to multiple OEMs or LSSIs, it is in the strategic supplier's interest to develop a deep appreciation for the interface requirements. This suggests that designers with a specialisation in systems engineering would be a key resource to the strategic supplier to both manage its internal product development and to work with OEMs and LSSIs to anticipate or refine their own product's interface requirements. Since the cost of the strategic supplier's product directly impacts the end-product's price, the strategic supplier needs to focus on ways to control its own costs. This might be accomplished through policies of technology reuse to reduce the R&D and testing costs. The strategic supplier can use roadmapping of customer needs to anticipate the opportunities for technology reuse.

Key collaborators will be chosen by the LSSI based on their innovation capability and their unique combinations of product, process, and/or material. It behoves key collaborators to invest heavily in deep process and material knowledge and to protect this knowledge through patents when possible, or trade secret when more appropriate. The key collaborator should enhance its own staff with domain experts from the markets and fields into which LSSI places products. Roadmapping can help to identify future end product and market trends for the LSSI, and can help the key collaborator to anticipate gaps in its own expertise and correct them. Corning, for example, actively uses roadmapping to consider human resource capability gaps and needs. Joint roadmapping and planning between the key collaborator and LSSI also helps to keep technology off of the critical path, thus reducing time to market.

7 Conclusions: tipping the balance of power

OEMs generally expect to establish a leadership role in the supply chain either through economies of scale or scope, or through access to the end customer. It is also expected to be both the driver of costs and innovation. As an OEM firm makes a transition to the LSSI model, it is expected to see that power will be shared more equitably with suppliers. Tier 1 suppliers who already exert power in the supply chain by virtue of their linkages to an OEM and due to the complexity of many of their product offerings will continue to wield influence. The real change in the LSSI model comes in the opportunity of Tiers 2 and 3 suppliers to become more powerful and more highly valued. To successfully compete in the LSSI model and to enhance their own power, Tiers 2 and 3 suppliers will have to invest in their own innovation capabilities and provide downstream visibility to this knowledge.

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