Case study

The making of a lean aerospace supply chain

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Abstract

Presents the details of an initiative launched in 1995 to transform an aerospace machined parts supply chain comprised of many small businesses from high cost mass production to lower cost lean production. It presents the overall conditions as they existed at the onset of the initiative, strategies and tactics that were used to bring about the desired changes, and an analysis of the business practices, cultural, and behavioural factors that contributed to successes and failures. Recommendations are given to help others in their quest to develop lean supply chains. The lessons learned are most applicable to supply chains containing a large number of small, privately held, businesses making inexpensive parts. However, many of the recommendations will also apply to supply chains containing larger publicly held companies producing more expensive parts or assemblies.

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Introduction

The objective of this case study is to share important experiences that others can benefit from in their efforts to create lean supply chains. It describes the conditions that existed between a large customer and many smaller suppliers in a time of great change in the marketplace, and integrates technical, cultural, and behavioural factors. A central theme is the actions and responses of the people involved in the initiative and how legacy behaviours rooted in mass production (Ansari *et al.*, 1997) affected efforts to rapidly introduce major change. In particular, the lean supply chain initiative deployed by Large Aerospace Company (LAC)[1] threatened traditional business practices and the long-standing, well-understood, relationships between various stakeholders. The changes implied by the initiative upset the status quo and tested the technical (Robinson, 1990) and emotional (Goleman, 1995) competencies of both LAC and the machined parts supply chain. This case study seeks to link these attributes in a holistic framework to demonstrate the importance of understanding the perspectives of multiple stakeholders when introducing broad-based change in supply chain management practices.

Background

Large Aerospace Company Inc. assembled a team of energetic, qualified, and well-educated change agents in 1995 to lead a multi-year activity to create a lean supply chain for machined parts that was patterned after Honda's supply chain practices (Nelson *et al.*, 1998). The implementation leaders were a cross-functional group of mid-level managers with adequate internal and external resources to drive the transformation. Key functions – purchasing, engineering, quality, finance, human resources, continuous improvement, materials management, and MIS – were
co-located to facilitate communication and co-ordination and thus help achieve the goals. The managers had diverse backgrounds with different levels of knowledge of lean production, and the employees reporting to each manager had narrower backgrounds and an even wider variation in their understanding of lean production. All of the managers had a

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functional responsibility in addition to supporting the lean supply chain initiative.

The supply chain selected for this initiative produced machined parts from bar stock, castings, and forgings. The first-tier machining suppliers specialized in machining and typically outsourced all other operations such as electroplating, non-destructive inspection, heat treating, welding, brazing, plasma spraying, etc. The LAC supply management team maintained close business relationships with the first-tier machining suppliers because of the purchase order contract that joined them together. LAC supply management also had strong informal relationships with many key Tier 2 and Tier 3 suppliers which were utilized primarily to expedite parts. The bulk of the day-to-day interaction was between LAC managers and individual buyers and the owner or operations manager.

The relationship between customer and supplier is normally complex and involves many parameters that extend across technical, functional, business, and human dimensions. The following six headings summarise the key conditions, as they existed in 1995, to aid in developing a more complete understanding of the context of this case study.

Machining supplier data

- Suppliers were small family-owned businesses with 25-60 employees.
- Suppliers had £3-10 million per year in total sales.
- Most had been doing business with LAC for 20-40 years.
- The owners were typically the child or grandchild of the founder.
- The owners were usually strong entrepreneurs tolerant of certain types of risk.
- Most owners were not interested in change.
- Other members of the family often worked in the business.
- All produced parts using batch and queue mass production systems.
- Most produced a wide variety of product configurations.
- Most had modern machines (due to their belief that technology improved productivity).
- Information systems were being upgraded.
- Suppliers interfaced with 10-15 buyers from LAC.
- Part prices were based on "economical lot sizes".
- There was little long-term business planning.

Product data

- There were few design standards for machined parts.
- Less than 1 per cent of the parts were in computer file format.
- The commodity spanned several engineering teams across all product platforms.
- LAC's engineers rarely worked with machining suppliers in the design stage and were largely unavailable once the part was in production because inexpensive machined parts were "low on the priority list".
- There was a backlog of over 200 engineering changes related to blueprint errors or manufacturing process improvement waiting to be processed.
- Simple configuration changes took an average of 11 weeks to complete.
- Of configuration changes 25 per cent resulted in cost reduction, 65 per cent had no change in price, and 10 per cent resulted in cost increases.
- The machined parts are typically less than 50cm in diameter.
- Primary manufacturing processes are milling, turning, drilling, and grinding.
- Parts were designed to close tolerances and are of medium to high complexity.
- Parts are made from bar stock (60 per cent), forgings (20 per cent), and castings (20 per cent).
- Parts are made from a variety of standard and custom alloys: stainless steel/nickel (60 per cent), titanium alloys (35 per cent), and aluminum/magnesium (5 per cent).
- Over 200 sub-tier suppliers support the machining suppliers by providing raw materials and performing a variety of services such as welding, brazing, heat treat, X-ray, coatings, and chemical and metallurgical testing. All sub-tier products, processes, and services are controlled by LAC's quality organisation.

Cost performance

- Of the parts 90 per cent had a unit cost of <£600, 80 per cent had a unit cost <£300.
- Annual quantities ranged from hundreds to a few thousand pieces.

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- There were no long-term agreements with machining suppliers. All parts were quoted competitively every 6-18 months.
- Twelve machining suppliers produced 80 per cent of the purchased volume.
- LAC typically represented 30-80 per cent of a supplier's annual sales.
- Machining suppliers did not have pricing agreements with their suppliers (nor did LAC have pricing agreements with the sub-tier suppliers).
- Sub-tier suppliers generally raised their prices 5-10 per cent every year, which the machining supplier either partially adsorbed or passed through to LAC in its entirety.
- The cost of this commodity increased an average of 5 per cent each year.

Delivery performance

- The machined parts commodity consisted of about 5,000 part numbers; 2500 part numbers had delivery requirements within the next 18-24 months.
- Of the machining suppliers 95 per cent were located within 150km of LAC.
- Each machining supplier was responsible for about 200 part numbers, and typically had 50-75 part numbers in process.
- Parts typically require two-five outside processes.
- The supply chain had well-established social and business relationships, supply lines, materials management, and logistics systems.
- On average, there were 350 overdue part numbers every day (~20 per cent of LAC's total overdue).
- On-time delivery performance was about 70 per cent.
- The average lead-time was about eight months.
- The machining suppliers were learning to use LAC's new just-in-time materials management system.

Quality performance

- All machining suppliers had a documented quality system in accordance with LAC requirements.
- Annual quality system audits showed that 30 per cent of the machining suppliers received "A" ratings (best), 55 per cent "B" ratings, 10 per cent "C" ratings, 5 per cent "F" ratings (worst).
- A handful of machining suppliers were ISO 9002 certified.
- There were 10-15 reportable quality problems per month.
- Sub-tier suppliers were responsible for many of the quality problems.
- There were three-four significant quality problems per year.
- Root cause analysis and corrective action plans were generally weak.

Continuous improvement

- Suppliers were skilled at optimizing their mass production system.
- Machining suppliers achieved productivity improvements 2-4 per cent per year, which were used primarily to partially absorb sub-tier supplier cost increases or improve margins.
- Over the last ten years, set-up time was reduced from 10-20 hours to 2-4 hours per operation (Note: there may be five-ten machining operations required to produce a part).
- The average lot size decreased from ~400 pieces to ~100 pieces over an eight year period.
- None of the suppliers had formal continuous improvement programmes in place.
- None of the suppliers posted metrics.
- Shops ranged from very clean to dirty.
- A few suppliers had formal employee training programmes in place.

It should be apparent from the summary points presented that the machined parts suppliers had not been previously challenged by LAC or other major customers to significantly improve their overall business performance. Machined parts was one of the last commodities to be managed tactically, in part due to the lack of attention normally received by less expensive parts. This was unfortunate because end-use customer expectations and requirements were rapidly moving towards the same level of performance as that which was expected from larger publicly held companies – especially cost reduction. In addition, the aerospace industry was recovering from a major downturn and would require much higher volumes and faster response times to accommodate anticipated demand starting in 1995 and lasting through 1998.

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LAC supply management

LAC had initiated large-scale continuous improvement programmes within its own manufacturing shops during the low point of the business cycle in the early 1990s. The initiative focused on internally manufactured products, which accounted for 35 per cent of product cost, and was patterned after the Toyota Production System (Ohno, 1988; Shingo, 1988). LAC utilized experienced consultants to facilitate change. There were dramatic (50-90 per cent) reductions in lead-time, cycle time, walking distance, part travel, scrap, floor space, etc., all of which helped reduce product costs. By 1995, senior management had witnessed first-hand the impressive results that can be achieved using the methods developed by Toyota and other lean producers (Womack *et al.*, 1990; Womack and Jones, 1996).

Attention turned to the 65 per cent of cost that was produced by external supply chains by mid-1996. LAC senior management was late in addressing this component of product cost because:

- "Purchasing" was not viewed as a strategic function.
- The people in "purchasing" were viewed as having a low skill level compared to engineering, manufacturing, finance, legal, MIS, quality, and even human resources.
- Supplier relationships were historically limited to the first-tier.
- LAC decided to develop lean production competencies internally, prior to seeking the participation of external suppliers.
- LAC believed that it did not have enough resources to develop lean suppliers.
- Multiple workforce reductions pre-occupied executives, managers, and employees.

There was tremendous pressure to reduce cost, reduce lead-time, improve delivery performance, improve quality, and demonstrate large gains from continuous improvement. Time was quickly running out for the machined parts supply chain, which was considerably less knowledgeable on how to improve performance compared to larger aerospace suppliers. They lacked the skills, resources, mindset, market awareness, sense of mutual dependence, and customer focus needed to introduce significant change. For example, machining suppliers were unable to compete against larger companies for more knowledgeable people that might have recognized the need for change sooner because the latter offered better salaries and benefits. In addition, entrepreneurial-minded small business owners rarely shared or relinquished control to those who would challenge practices that were known to have been successful in the past. Lastly, LAC's supplier initiatives were invariably reserved for major suppliers with serious cost or delivery performance problems, or where a historical relationship had been established due to their exclusive position in the industry or where the spend was highest. The machined parts suppliers did not warrant attention; that is until LAC's financial performance became a bigger issue to external investors.

Despite these barriers, which were truly known only to lower level "purchasing" people – because access to senior management was limited – LAC's senior management was "raising the bar" faster than the machined parts supply chain could respond. Indeed, even LAC's lean supply chain team had difficulty precipitating the necessary changes in the supply chain because they were not yet aware of the totality of the dynamics that were operating between multiple stakeholders. They did not fully understand the history of LAC's relationships with first-tier suppliers nor how deeply the culture and paradigms that guided people's behaviours were rooted.

The procurement people that managed machined parts in 1995 had survived many layoffs in the previous eight years. As a result, the buyer workforce was reduced by about 75 per cent so that one person typically did the work of four people just a few years earlier. Each buyer thus procured an average of about 1,000 part numbers, which was two-three times the amount of parts that can be effectively managed. Unfortunately, LAC's purchasing information systems and procedures had not changed significantly or rapidly enough during 1988-1995, a period of immense market upheaval where orders fell by 50 per cent.

It was difficult to find buyers because the machined parts commodity was viewed as a purchasing "backwater" where the least capable people ended up. This, of course, was not completely true; the buyers worked very

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hard and took their responsibilities seriously. However, their strength was in traditional purchasing practices which LAC management correctly determined to be an outdated and a high cost way of doing business. Buyers were physically separated, often by several kilometers, from their internal customer and important functions such as engineering, materials management, and finance. In addition, problems with low cost parts were seen as low priority by just about everyone except the buyers and their internal and external customers. As a result, their calls for help were rarely answered, and so the buyers largely gave up asking for help. This generated a lot of hostility that would affect the future integration and functionality of co-located cross-functional teams.

The machined parts purchasing group did respond to some of senior management's initiatives in the 1988-1995 time frame, such as cost reduction and supplier reduction. The cost of purchased parts fell during the depth of the downturn due to oversupply of capacity and the traditional use of verbal threats; buyers would stop quoting unco-operative suppliers or cancel purchase orders if they did not quickly comply with the needed cost reduction. For years LAC and other aerospace customers regularly "beat-up" the machining suppliers to achieve cost reduction and never acknowledged the cost inputs from sub-tier suppliers. As might be expected, LAC's customers were using the same tactics to force cost reduction and other performance improvements.

The number of suppliers was successfully reduced from 80-50 over an eight-year period. However, quality and delivery performance remained inconsistent. LAC and its machining suppliers had little experience with effective root cause problem solving, so cost, delivery, and quality problems remained systemic obstacles to end-use customer satisfaction. This cultural weakness would threaten LAC's ability to win new business when production volumes started to return in the last half of 1996.

LAC introduced cross-functional product development teams in the early 1990s to overcome the ingrained habit of throwing the blueprint "over the wall" to manufacturing. The concept worked reasonably well for high cost parts, but was not effective for lower cost machined parts that crossed multiple engineering groups and product platforms. So the machined parts commodity continued to be managed tactically – i.e. "place and chase" – through 1995. A new organisation was then created that was designed to move from tactical "purchasing" to strategic "supply management". Managers and staff from all relevant functions were co-located to improve tactical response and achieve strategic business goals. The strategic goals were:

- Reduce the machining supply base by 20 per cent.
- Teach continuous improvement to machining suppliers.
- Source parts in product or process families.
- Reduce unit cost by 5-10 per cent.
- Improve quality by 50 per cent.
- Improve on-time delivery performance by 25 per cent.
- Reduce lead-times by 30 per cent.
- Stabilize prices by establishing long-term agreements.

Most of the functions integrated well with the buyers except for engineering and continuous improvement, which were seen as outsiders. Engineering staff were, at first, slow and unresponsive to the demands of the production environment; they lacked a sense of urgency. It took over one year to correct this deficiency, partly because the pool of engineers to draw from was small. Very few engineers were willing to: leave their functional "home"; work in manufacturing; work on low-prestige machined parts; work with suppliers that were judged to be subordinate in intellect; and risk their career for unknown learnings or rewards. In fact, the first engineers to participate in this new organisational structure found their experience in manufacturing to be personally fulfilling. However, on returning to engineering after completion of the rotational assignment, they were initially shunned by their peers and were not adequately rewarded by their management for the personal risks and challenges that they engaged in. Nor were they recognized for the vast improvement in technical, business, and interpersonal skills that most engineers acquired.

Manufacturing engineers from internal shop operations that had recently learned the various improvement tools staffed the continuous improvement team. Buyers regarded the manufacturing engineers as the people most capable of ruining their

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supplier's delivery performance by instituting product or process cells. The buyers were very sensitive to this because it was their name that appeared on parts shortage reports; not the manufacturing engineer, not the supply manager, and not the supply management team. Indeed, some early attempts to install product cells had mixed results, which reinforced the buyers' perceptions that continuous improvement was not effective and that suppliers, using traditional batch and queue methods, knew best how to manufacture parts.

In addition, buyers viewed lean production as the latest "fad" that would not last. Successes were not communicated well, and early failures tended to dominate the buyers' opinions, their current conversations, and near-term future actions. Word soon spread throughout the machining supply base (primarily by LAC's buyers and field quality personnel) that LAC's "help" had actually hurt the machining suppliers that participated in the continuous improvement events. It was not until much later, after additional successes and more suppliers began to embrace continuous improvement, that buyers began to partially support the lean supply chain initiative. Buyer support was a critical achievement because suppliers listen very closely to buyers; if individual buyers sincerely support an initiative, then suppliers will eventually follow suit. In small businesses, the owner is the key person that has to be convinced.

The establishment of long-term purchasing agreements (LTAs) was an integral part of the lean supply chain initiative. However, buyers were reluctant to support this strategy because they believed that LTAs would result in the loss of their job. Their fears were not unfounded, since they witnessed other purchasing organisations that had suffered this very fate. So the buyers overtly undermined the initiative and its leadership by keeping the machining suppliers focused on tactical delivery and cost issues. In addition, executives in the supply management organisation had a poor understanding of lean production and did not know how to support the initiative. Thus, they tacitly undermined the initiative as well. This reinforced
suppliers' and buyers' assumptions that continuous improvement would be a passing fad. The machining suppliers shunned LTAs since a few of LAC's recent fixed price contacts with suppliers in a related commodity contributed to very poor financial results. In addition, LAC was slow to respond to suppliers' requests for price adjustments due to significant increases in raw material prices.

An integral part of the LTA strategy was to source products via part or process families, which would lower product cost by reducing set-up times, scrap, lead-times, etc. The initial work focused on establishing part families. LAC's manufacturing engineers sorted hundreds of blueprints into logical groups and presented their results to selected machining suppliers. Supplier feedback showed that LAC's understanding of part families differed from how machining suppliers would group parts. In the next iteration, LAC's supply management team sought input from machining suppliers on how best to establish part families based on primary manufacturing processes. The owners of the machining suppliers balked when they saw the results because they assumed that they would lose their most profitable parts to other suppliers and gain potentially less profitable parts that they had not previously made. Also, most of the machining suppliers were unwilling to specialize in the production of a narrow group of parts, preferring instead to maintain a broad range of machining capabilities.

So, the initial attempts at sourcing part families was not very successful. It was clear that the lean supply chain team did not fully understand what constitutes risk in the eyes of the machining suppliers. In addition, volumes were ramping up starting in mid-1996, and LAC's lean supply chain team drifted back towards tactical "purchasing" and away from strategic "supply management". Efforts to establish LTAs were inadvertently put on hold.

Supplier perspective

The machining suppliers were a hard working and very dedicated group of people. Most of them were dependent on LAC for 50 per cent or more of their sales. However, they lacked a uniform understanding of the marketplace and the speed with which the business model was changing. They were far removed from the end-use customer, and LAC management was not successful in convincing suppliers that they needed to make major changes in

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their production system. Senior management would hold annual conferences where attendance was always limited to first-tier suppliers with spend greater than £6 million.

That threshold excluded most of the machining suppliers. Executives would show chart after chart depicting changing business conditions, and the suppliers were told many times what they had to do in order to keep doing business with LAC. Not surprisingly, the meetings were interpreted as one-sided and confrontational. The content and tone of the meeting rapidly spread from the few machining suppliers in attendance to the many smaller first-tier machining suppliers. The feedback was almost always negative, which reinforced the machining supplier's view that LAC did not understand their business. The lack of credibility stemmed from the fact that LAC's senior management had never addressed systemic complaints from its suppliers. The primary complaints were:

- High schedule variation.
- Lack of engineering support.
- Suppliers not involved in design.
- Business was a "one-way street".
- Price increases from Tier 2/3 suppliers.
- LAC behaved inconsistently.

It is clear that the machining suppliers had for years operated under conditions of high uncertainty and low trust which negatively influenced their thoughts and actions. Real or implied threats resulted in an impulsive desire to fight back (Nicholson, 1998), albeit usually in subtle ways that were generally very effective at slowing change initiatives.

The machining supplier's concept of customer focus was limited to the tactical demands of cost, delivery, and quality. The daily conversations between buyers and suppliers rarely included discussion of broader strategic issues affecting the machined parts supply chain. They apparently saw no need to educate suppliers on market-driven issues that could affect their future existence. There were vast quantities of information readily available to individual buyers from internal and external sources that showed a major shift was happening right before their eyes. But the buyers effectively ignored this data. Perhaps this was because LAC senior management lacked credibility with its employees, and therefore the ability to effectively influence them. It is very important to note that continuous improvement was not yet a part of the buyer's vocabulary, even though it was rapidly becoming the common language of people in LAC's internal shop operations. The machining suppliers reasoned that if the buyers were not supporting lean production, then they did not have to support it either. In addition, buyers continued to receive rewards from management for sporadic successes in tactical purchasing that were most often related to heroic efforts to meet delivery requirements.

For years the first-tier machining suppliers were told, often explicitly by the buyers and purchasing managers, to avoid specialization. LAC, like most other aerospace companies, valued suppliers with a broad range of machining skills to help them get out of never-ending part shortages. The machining supplier, in turn, learned from previous downturns that having a wide range of skills would help ensure survival of their business. LAC was no different, having also learned that a wide range of skills helped them better manage large fluctuations in business volume. So there was good alignment in business strategy, which worked well as long as LAC could tell its customers what products they wanted and the price that they should pay. But the alignment crumbled in about 1988, when customers started telling LAC what they wanted and at what price they were willing to pay.

LAC began to deploy manufacturing engineers into the machining supply base in 1995 to train them on the continuous improvement tools developed by successful lean producers. Most of the suppliers resisted LAC's help because they had seen many previous initiatives come and go with little or no results. Common complaints about the lean supply chain initiative included:

- "It's just the latest fad."
- "We don't make car parts!"
- "We're not in Japan."
- "Your manufacturing engineers don't know how to make these kinds of parts."
- "It won't work [because production is low volume, high diversity]."
- "I don't want to share information with my employees."
- "I don't want to specialize."

The concept of lean production was a major shift in thinking for the machining suppliers and constituted a significant amount of risk in

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their eyes – especially since their other customers were not yet asking for this capability. The magnitude of the shift was at first underestimated by the lean supply chain initiative team, and it was very difficult to concisely explain to LAC senior management why the machined parts commodity continued to perform poorly on cost, delivery, and quality. Senior management had little patience and had planned on many "quick wins" that would immediately flow to the bottom line.

Because most the machining suppliers were slow to buy-in to lean production, the lean supply chain initiative team did not rely on them to deliver the lean production message to their sub-tier suppliers. Nor did the lean initiative team assume that the benefits of lean production were self-evident. So, significant effort was made using a variety of methods to consistently communicate the many benefits simultaneously to Tier 1/2/3 suppliers. The benefits included improvement in:

- cash flow,
- profit,
- inventory turns,
- customer satisfaction,
- delivery performance,
- new product introduction,
- workplace safety,
- shop and office cleanliness,
- employee involvement,
- equipment up-time,
- morale,
- speed,
- capacity,

and reduction in:

- scrap,
- inventory,
- non-conformances,
- set-up time,
- cost,
- work-in-process,
- walking distance,
- part travel,
- cycle time,
- capital expense,
- mistakes,
- variation,
- re-work.

Continuous improvement events were a primary approach for introducing lean production concepts to machining suppliers. Machining suppliers would learn the tools and techniques of continuous improvement by direct experience, and facilitated by an LAC expert or outside consultant. LAC thought that the week-long continuous improvement event format that it used internally would also be applicable to machined parts suppliers. A few suppliers were eager to participate, but most resisted, citing a lack of resources. The suppliers said they were not able to devote 10-25 per cent of their workforce to participate in a continuous improvement event for several days and still maintain on-time delivery performance.

LAC's lean supply chain initiative team suffered a short-term loss of credibility by not recognizing the resource constraints of the machining suppliers and the magnitude of the paradigm shift that lean production was to them. After many unsuccessful attempts to overcome the resource obstacle, LAC recognized that the continuous improvement event format would have to be flexible in order to meet the needs of the suppliers. So a menu of continuous improvement events was developed that focused on the basic tools such as 5S, reducing part travel, reducing walking distance, set-up reduction, and mistake proofing (Robinson, 1990). Some continuous improvement events were as short as one-half day, which resulted in greater participation among a wider group of machining suppliers.

LAC did not charge suppliers any money for the help it provided. Instead, the initial approach was to simply exchange training in continuous improvement for reduced part cost, reduced lead-time, and improved quality. The contract was verbal. Improvements in quality were passed directly to LAC with no qualification. However, commitments to reduce lead-times were not easily obtained because the raw materials were single-sourced or because most of the parts had secondary operations performed by outside suppliers. The machining suppliers were not in control of these businesses whose performance was often erratic. So the machining suppliers would usually hold in reserve most improvements in lead-time as a safeguard against future unknown problems. This was not acceptable to LAC since its customers were demanding significant reductions in lead-time. It was clear that prior neglect of sub-tier suppliers by LAC would become a major barrier to implementing a lean supply chain for machined parts.

LAC told the machining suppliers that "in return for our help, we want to split cost

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reductions 50-50". Most suppliers were very reluctant to share in any cost reduction for three primary reasons. First, about half of the part cost came from sub-tier suppliers that had a history of annual price increases. The machining suppliers had fixed price purchase orders and thus had to absorb these increases. Second, high schedule variation forced the machining suppliers to regularly split lots to meet LAC's delivery demands. This required them to pay high minimum lot size charges that were not normally passed along to LAC. Third, machining suppliers saw an opportunity to improve their margins after having endured several years with little or no profit. Thus, LAC's business practices coupled with sub-tier supplier non-performance created opportunistic behaviour patterns among the machining suppliers.

Lastly, complete buy-in was difficult to obtain because the suppliers were small, privately held companies that had a strong sense of independence. The very reason why they were in business for themselves was to be independent of the hierarchy normally found in larger publicly-held companies. In addition, the inability of LAC to respond to systemic complaints strengthened the belief that they were alone and independent. LAC's talk of "teamwork" and "partnering" rang hollow because their input was consistently ignored. This, in effect, provided a strong disincentive to participate in the transformation to lean production.

Conclusions

This case study illustrates the many factors involved in the deployment of lean production in an aerospace machined parts supply chain. LAC's culture and business practices are typical of that exhibited by many large mature companies because their behaviours are rooted in the teachings of mass production (Ansari *et al.*, 1997). The legacy of past practices impaired LAC's ability to drive needed change within its own operations as well in the machined parts supply chain. Successful transition from mass production to lean production requires a deep understanding of the differences in cultural and behavioural attributes, as well as the elimination of contradictions that create uncertainty and confusion (Argyris, 1998). Some of LAC's difficulties stemmed from the fact that it did not fully understand the concept of how to eliminate waste in production (Womack and Jones, 1996). Nor did it recognize the parallel challenge of how to eliminate wasteful human behaviours.

It is apparent that there were a large number of complex and interdependent issues that affected LAC's strategy, planning, implementation, and results. Despite many obstacles, the lean supply chain team was able to achieve a moderate level of success in a relatively short period of time – about three years. Factors judged to be the greatest obstacles were: (1) LAC's past business practices; (2) poor alignment within LAC; (3) confusion over roles and responsibilities; (4) the independent mindset of the owners of the machining suppliers; and (5) the batch and queue system that had previously delivered personal and financial success to the business owners in the machined parts supply chain. In general, LAC underestimated the strength of existing paradigms, the depth of operating norms between people within the machining supply chain, and the complex interrelationship between tacit and explicit knowledge when implementing a major change programme.

The sub-tier suppliers remain a significant source of opportunity for performance improvement. LAC has discovered, just as Toyota did 35 years ago, that the mindset and performance of the sub-tier suppliers limits first-tier supplier performance. LAC is continuing its quest to develop lean supply chains, with additional emphasis on the sub-tier suppliers. The following is a concise summary of the successes and key lessons learned from LAC's lean supply chain initiative.

Successes

- LAC improved its credibility by responding to many supplier complaints.
- LAC's lean supply initiative team developed a consistent message and communicated it to suppliers every day. They played an interpretive role in explaining why this initiative was needed, how it responded to both local and global interests, and how it could be a sustaining source of competitive advantage for decades to come.
- The internal competencies that LAC gained in lean production, coupled with widespread dissemination of success

stories, eliminated the ability of suppliers to say that it could not be done in the aerospace business.
- Continuous improvement event formats and content were changed to better meet the needs of small businesses and resulted in greater participation.
- After three years, about 30 per cent of LAC's machining suppliers cognitively understood lean production or were on the path of implementation. Less than 10 per cent of the sub-tier suppliers were implementing lean production.

Improvement opportunities
- Ensure that all of the people that interact with suppliers – executives, managers, buyers, field quality personnel, engineers, etc. – have a shared understanding of lean production. Suggest classroom training, followed by site visits to successful lean producers, followed by classroom dialogue, followed by additional site visits to lean producers, etc.
- Understand what you are doing from the perspective of multiple stakeholders.
- Resolve systemic supply chain complaints prior to launching a lean initiative.
- Have a clear understanding of how the sub-tier suppliers operate.
- Deploy lean production with Tier 2/3 suppliers, slightly ahead of Tier 1 suppliers.
- Require suppliers to share in cost reductions – or be prepared to reduce order backlog.
- Customers must see suppliers as people that they can learn from.

Recommendations
- Centralize commodity management to reduce the number of buyer interfaces and avoid sending confusing signals to the supply chain.
- Commodity management should include the entire supply chain and related industries that affect their performance.
- Visit many Tier 1/2/3 suppliers to better understand dependencies and constraints, and to help plan the initiative.
- Reduce schedule variation.
- Aerospace supply management executives should join together and co-author letter of joint expectations for lean production to their supply chains. They should publish this letter often in various trade journals.
- Understand risk in the eyes of small businesses. Distinguish between acceptable stretch goals and unrealistic goals that generate negativity and cynicism.
- Structure continuous improvement activities to the realities of small businesses.
- Assign people to work on the project full-time and establish regular dialogue meetings.
- Always co-locate cross-functional lean supply chain teams.
- Be patient – lean production is not a "quick win" initiative. Major changes in mindset and skills take time: at least one-two years for basic understanding, another three-four years for training and implementation, and two-four more years to achieve sustaining skills and behaviours.

Note

1 LAC is a supplier of engineered components to both small and large airplane manufacturers, with a turnover in excess of £1 billion. The names used in this case study have been changed to ensure confidentiality.

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