Overcoming Supply Chain Management Challenges in a Very High Mix, Low Volume and Volatile Demand Manufacturing Environment

Applying Lean Manufacturing Principles to
Optimize the Supply Chain

Case Study:
Dr. Harpal Gill, PhD.
Mark Lopus
Kevin Camelon

Synopsis

Supply chain management challenges are unique in very high mix, low volume and volatile demand manufacturing environments compared to very high volume and low mix environments. More and more, manufacturers are confronted with this problem today.

Traditionally, lean manufacturing practices are believed to be more suited for high volume, low mix manufacturing. This is a myth. This papers shows that lean manufacturing practices have many benefits to offer in all manufacturing environments, regardless of the product mix and volume.

The lack of proper education and training in an organization has been shown to be the biggest barrier to a successful lean manufacturing implementation. Lead time in different areas of the supply chain is a main cause of inefficiencies. Through proper training, encouragement and participation at all levels, excellent results in supply chain optimization in high-mix, low-volume manufacturing environments can be attained. Value stream mapping has proven to be a very simple but extremely effective tool for identifying issues affecting the key metrics of a supply chain.

This paper compares the supply chain challenges using two cases of manufacturing environments. It describes how the supply chain was optimized in terms of performance metrics with special emphasis on excess and obsolete (E/O) inventory and Lead Time (LT) reduction in the optical industry. The improvements in each of the metrics are shown to have a direct effect on the organization's Ship to Commit (STC) performance.

The paper also describes the special tools developed to optimize different parts of the Supply Chain process and how some Lean manufacturing components – particularly six sigma and Kaizen – were deployed to optimize the Supply Chain metrics for a high-mix, low-volume manufacturing environment. The results of each practice are included.

High Volume / Low Mix vs. Low Volume / High Mix: The Supply Chain Challenge

All companies share the same end goals of on-demand order fulfillment and lower costs of goods sold. But the ability to realize gains from supply chain optimization is not the same among companies with different product mix and volume ratios.

A high volume / low mix manufacturer producing consumer electronics for a broad global market has different leverage points within the supply chain than does a low volume / high mix manufacturer who builds specialized technology products for a narrower market. When comparing supply chain metrics between these two types of manufacturing companies a huge contrast becomes readily evident as shown in Figure 1. Each metric is defined and measured on a scale of 1 to 5 in a metrics scorecard where rating of 5 is the optimal score relative to the industry. The criterion for the ratings is listed below in Table 1.

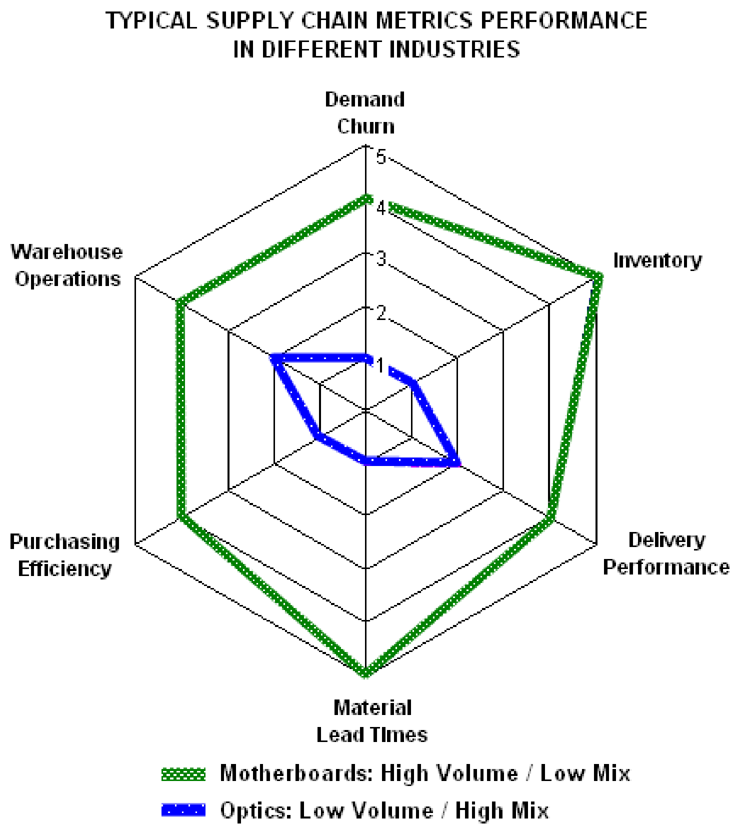

Figure 1: Optics Supply Chain performance pales by comparison to that of an established consumer based industry like PC motherboards. Achieving comparable levels of excellence requires innovative implementations of lean principles.

A high volume / low mix manufacturer producing standard PC motherboards, for example, can be expected to have relatively stable and predictable end-product demand. It will have a smaller supply base providing many standard ship-to-stock components and materials. High volumes can be leveraged to reduce the ordering frequency and subsequently run a more efficient supply chain operation with high inventory turns and little exposure to excess and obsolete inventory.

In contrast to the generally robust supply chain performance in the well established high volume / low mix businesses, the same is not true for the fiber optic components and subsystems manufacturers. They operate in a very low volume / very high mix environment, facing constant demand volatility as product forecasts oscillate. This type of manufacturer relies on a large supplier base, each providing unique components for specialized products making the supply base and internal operations management unwieldy and exposure to excess and obsolete inventory a big challenge.

For the low volume / high mix manufacturer, supply chain optimization requires innovative approaches to match the performance demonstrated in high volume / low mix environments.

Supply Chain Performance Metrics Scorecard	
Demand Churn	
Score	**Criteria**
5	Demand is steady with no churn within a long term fixed planning horizon
4	Demand fluctuates within the short term fixed planning horizon but is only committed to the Master Demand Schedule when there are no negative impacts to inventory, manufacturing capacity or delivery capability.

3	A short term fixed planning horizon is defined where churn should not occur. Tools are available to measure the impact of demand churn within the horizon. Churn is reduced and impact is assessed before being committed to the Master Schedule
2	Visibility of forecast churn and sales order cancellation and reschedules exists. Churn still occurs in the Master Demand Schedule without control.
1	No visibility of demand churn in the Master Demand Schedule exists. No impact of schedule changes can be assessed. Sales orders and forecasts are cancelled and rescheduled with no regard to delivery capability or inventory impact.
Inventory	
Score	**Criteria**
5	There are little or no excess and obsolete inventories or shortages. Inventory turns are best in class for the industry.
4	Excess and Obsolete inventory is clearly predicted. Few shortages occur and they are well known in advance. Inventory turns are acceptable relative to the industry.
3	Excess and Obsolete inventory is regularly predicted and proactive actions to mitigate are taken. Material shortages are recognized and mitigated in advance. Inventory turns are marginal but improving relative to the industry.
2	Tools providing visibility of excess and obsolete inventory are in place. Visibility of upcoming shortages is available. E/O inventory and shortages still occur. Inventory turns are low.
1	There is no visibility of excess and obsolete inventory. Shortages occur frequently without warning and seriously impact Ship to Commit. Inventory turns are very low.
Delivery Performance	
Score	**Criteria**
5	Ship to commit is 100%
4	Planners make accurate delivery commitments. Missed commitments are rare. Ship to Commit performance is good (less than 90% - 95 %.) Delivery performance scores at the customers are approaching and meeting their required targets.
3	Tools are available to make better, more accurate delivery commitments. Potential missed commitments are predicted in advance. Ship to Commit performance is good (less than 80% - 90 %.) Delivery performance scores at the customer are good but still need improvement.
2	Ship to Commit performance is not good (60% - 80 %.) Commitments are often missed with no advance warning. Delivery performance scores at the customer are poor.
1	Ship to Commit performance is very poor (less than 60 %.) Commitments are rarely met. Delivery performance scores at the customer are unsatisfactory.
Material Lead Times	
Score	**Criteria**
5	All materials' lead time is within the demand requirements.
4	Lead Time reduction strategies have been applied to all of A, B and C class items and they are available within 4 weeks.
3	Lead Time reduction strategies for A and B class items are defined. Many items' lead times are reduced but some are still only available at a lead time greater than 4 weeks.
2	Materials have been classified into ABC categories and strategies have been applied to C class items to reduce their lead time to less than 4 weeks.

1	Many materials have very long lead times. No strategies exist to reduce the lead times.
Purchasing Efficiency	
Score	**Criteria**
5	The supply base is optimized. The procurement systems are fully automated and all suppliers manage there own orders through online systems; buyer involvement in order maintenance is minimum.
4	Fewer buyers can easily manage more purchased items. Some suppliers are managing their own orders online.
3	Buyers have the tools to help them manage their orders more effectively. Strategies have been applied to reduce the number of orders to issue and maintain.
2	The supply base is reduced through various strategies. Buyers still have to place and maintain many purchase orders.
1	There are too many purchased components from too many different suppliers. Buyers have difficulty scheduling and maintaining all the orders. Tools for them to manage the orders are ineffective or nonexistent.
Warehouse Operations	
Score	**Criteria**
5	All inventory moves through Receiving and IQA into available stock within 2 hours of delivery. Kitting requests are scheduled in advance and staged for availability on demand. Transactional data entry fully automated.
4	Materials pass through Receiving and IQA to available stock on the same shift. Kitting requests are completed within 3 hours and data entry is real-time.
3	Materials pass through Receiving and IQA to available stock on the same day. Kitting requests and data entry are completed within the same shift.
2	Measurement of Receiving, IQA and kitting cycle times are in place. Strategies are defined to reduce the cycle times.
1	It takes a very long time for materials to pass through receiving and IQA to available stock; there is no measurement of these processes in place. Material kitting for production and data entry of inventory transactions are slow.

Table 1: Supply Chain Metrics Scorecard

Fabrinet: Reasons for the changes

Fabrinet serves an industry characterized by very high-mix, low volume production. It is a global engineering and manufacturing services provider of complex optical and electro-mechanical components, modules and bulk optics. The company serves data communications, telecommunications, networking, medical and automotive markets worldwide. It has over 20 different end customers and each has unique requirements affecting the supply chain and manufacturing model. Each customer has its own factory within a factory at Fabrinet

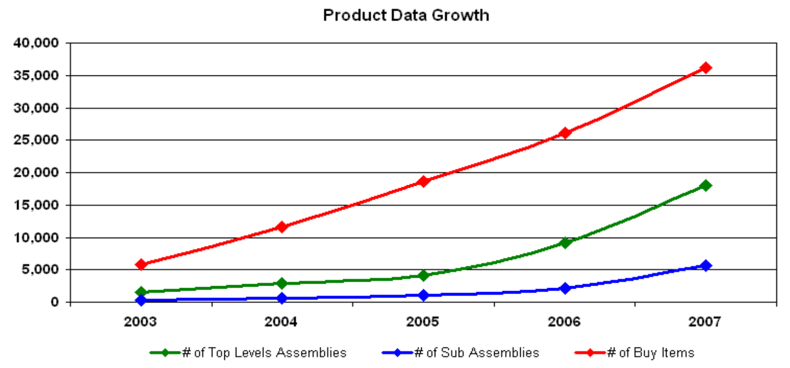

Figure 2: Fabrinet maintains a steadily growing base of active products. With complex bills of material and unpredictable product life cycles, supply chains must be primed and geared for flexibility.

to safeguard its intellectual property.

Supply Chain Management is among the greatest challenges Fabrinet faces. Close to 90% of the product cost is made up of material used to manufacture the products. The company's growing product portfolio encompasses more than 23,000 top levels and subassemblies using over 36,000 components (Figure 2) purchased from over a thousand suppliers located in different parts of the world (Figure 3.) Many of the suppliers in the burgeoning optics industry are small with limitations in quality systems, reliability and overall maturity.

Technology in the optics industry evolves at a rapid rate. As OEMs develop new product designs, component and subsystem manufacturers compete to be the first in getting them to market. A supplier who wins the business must stay at pace with a program's demand shifts throughout its life cycle or risk losing the business to competitors who are ready to deliver at the first opportunity. In this race to deliver, short term production schedules swing up and down dramatically (Figure 4.) Referred to as "Demand Churn," this schedule volatility stresses the supply chain to its extents. Drop-In demand – short term upside spikes when customers have immediate new needs with "fill-or-kill" orders – need to be responded to with commitments instantly. Demand is also regularly Pulled-Out, or removed from the short term delivery window leaving materials potentially exposed in the pipeline. In both cases, an immediate realization of the changes, response and appropriate actions are very critical.

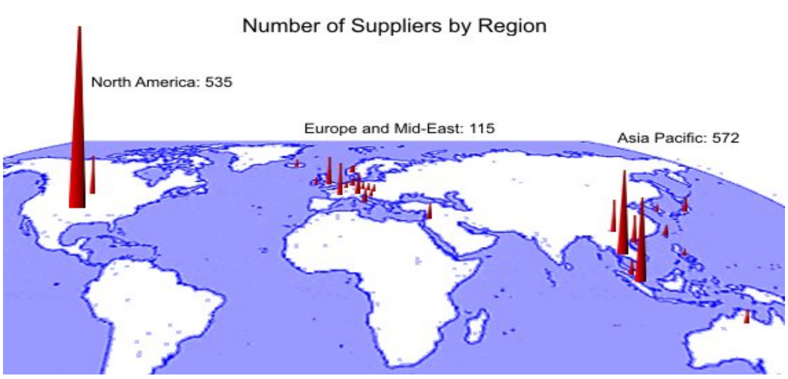

Figure 3: Fabrinet's supply base consists of a broad range of suppliers scattered over a wide geographic area.

A key metric for measuring success at Fabrinet is Ship-To-Commit (STC.) Despite the long lead times of many materials and components used in optical technologies, customers continually demand that their orders are filled in ever shorter lead times. To accomplish this, Fabrinet requires a highly flexible supply chain management system. It must be able to deal with demand changes on the fly and ensure an uninterrupted, scalable supply of materials with continuous cost reduction. It is necessary to close the lead time gap between customer demand and supplier delivery without exposing the company or the customer to high levels of excess and obsolete (E/O) inventory.

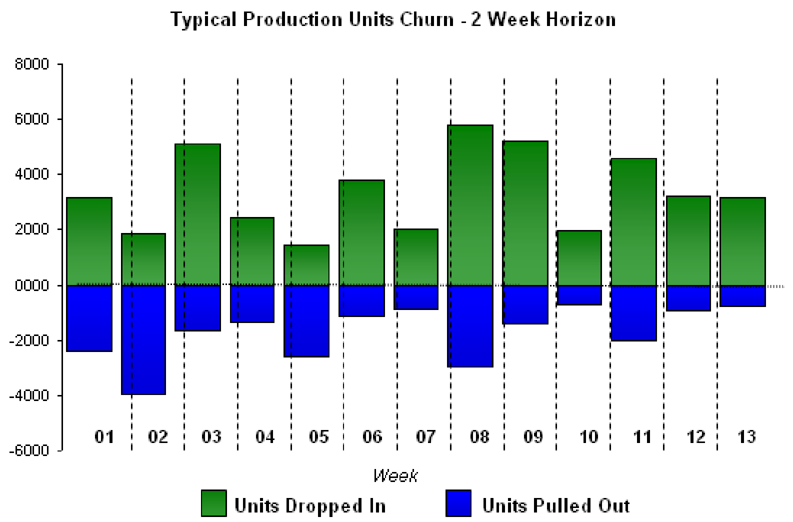

Figure 4: Rapidly advancing technology and intense competition in the optics industry means product configurations and market requirements change constantly; manufacturers must adapt to new designs and revisions in-line and on demand.

The answer to these challenges lies in applying the principles of Lean Manufacturing to the supply chain. Combined with new IT tools for intelligence and productivity, Lean Manufacturing concepts are transforming Fabrinet's supply chain from the bottom up. By value stream mapping the supply chain processes, we identify opportunities where Kaizen and Six Sigma projects, processes and tools will enable staff to address the base objectives. These lean practices add value by driving a second tier of objectives, which in turn lead to improved performance for the customer and an ultimate increase in business wins for Fabrinet (Figure 5.)

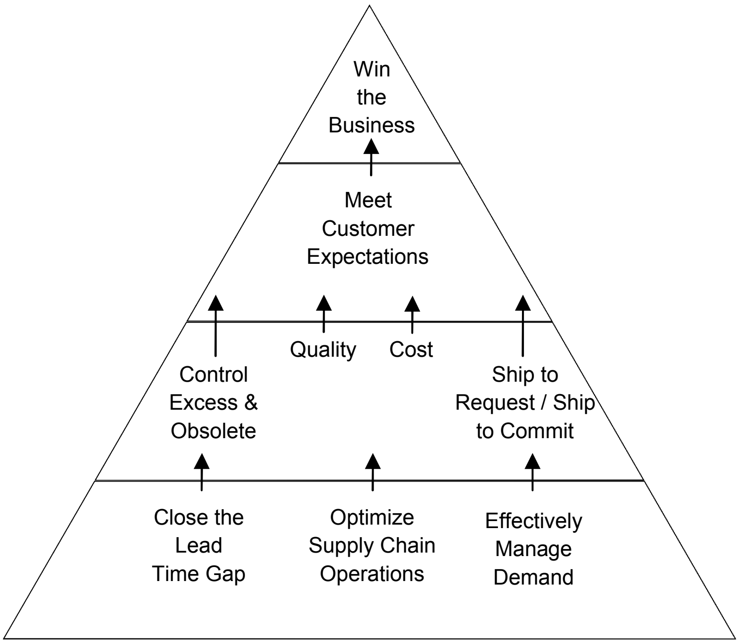

Figure 5: By focusing lean projects on base objectives, we see improvements in other key metrics that lead to greater customer satisfaction, cost and Quality.

Lean Manufacturing: Getting Started

One of the biggest challenges in implementing Lean Manufacturing (LM) is convincing both management and staff at all different levels of the power of Lean Manufacturing tools. Many of the staff at Fabrinet envisioned lean concepts as very complicated mathematical modeling of the process using complex math equations to find the optimal conditions and solutions for lowest cost, best quality and best STC. Others viewed lean manufacturing to be more applicable for optimizing manufacturing shop processes. The problems in supply chain were seen to be insurmountable and beyond the scope of lean manufacturing practices.

We had to get past the initial cynicism and notion that lean concepts were very complicated and only suitable for high volume products, required special skill sets and were outside the scope of rank and file.

A series of classes including staff from all levels of the supply chain staff were held. Class material was designed without involving any mathematics to demonstrate that the overall concepts are simple and easy to understand. Different components of lean manufacturing were reviewed and each component was explained in the simplest terms to ensure everybody understood the basics. The training and education initiative was also intended to show that not all of the LM tools are always applicable in all cases and that many are not always necessary.

To ensure everyone was on board, several small working groups were set up during working hours to encourage interactive discussion, ask questions and debate the pros and cons of the LM practices. The primary goal was to create team work, improve the confidence level of each individual and demonstrate that everyone can contribute to continuous process improvements.

As soon as employees realized Lean stands for waste reduction and not for eliminating people and jobs, Fabrinet accomplished a major milestone toward accepting and adopting Lean Manufacturing practices throughout the Supply Chain organization. With practice, Fabrinet employees realized that Lean Manufacturing was about cost and cycle time reduction and was a means toward providing the best value proposition to customers.

The Value Stream Process Map: Identifying the Problems

At Fabrinet, the supply chain (SC) optimization was divided into two separate efforts. First we had to address the common features of SC for all of the customers and then optimize the supply chain for specific customers as shown in the case study in the latter sections.

To define the overall SC project and identify the problems, the team constructed a complete supply chain process map from the point of communication of demand from the customers through delivery of product. From a high level perspective, the supply chain process was divided into three discrete areas, namely, demand management, strategic supply chain, and logistics (Figure 6.) The problems and their magnitude in each SC process area were identified together with a specific team of staff responsible for the improvements. Lead time was identified as the fundamental parameter for baseline measurement and improvement across the board. Low hanging fruit was targeted for immediate improvement while higher goals were slated for broader scope projects.

	Process Step	***L/T***	***Problem Statement***	***Measure***
Demand Management	Receive Demand (PO and Forecast)	1-2	Demand Management is lacking analytical tools and standardized demand processing rules. Planners take days to analyze and process customer demand before transforming them to delivery commits and a master demand schedule. The lack of tools not only slows the demand analysis process, but also results in inaccurate commitments and unoptimized production schedules.	$\bar{X}$ = 5.75 σ = .707
	Analyze Demand	2		
	Load MDS	1		
	Validate MDS	1-2		
Strategic Supply Chain	Execute MRP	2	Procurement lead times are too long. With so many purchased parts and suppliers, buyers can't process and schedule all the orders on time within the MRP cycle. A substantial reduction in material lead times is a must in order to meet the aggressive ship to commit requirement.	$\bar{X}$ = 58.14 σ = 34.42
	Process Purchase Orders	2-3		
	Receive Supply Commits	2-3		
	Material Delivery	28-182		
Logistics	Receive Material	2	Moving material through receiving, IQA, warehouse and out to production takes too long. IQA needs to process inspections faster. Kitting materials for production is slow and often results in delays in getting materials to the production floor.	$\bar{X}$ = 7.88 σ = 1.45
	Incoming Quality Inspection	2-4		
	Store Material	1		
	Kit and Issue to Jobs	2-3		
	WIP → Pack → Ship			

Figure 6: Value stream map of the existing process together with the problems identified in each area.

The x-bar and sigma values for each processes section were computed. In demand management and logistics, the actual lead time of the processes were measured over a 26 week period. The data for the strategic supply chain was based on the total fixed lead times of all purchased components.

The average lead time for the total SC process was identified to be 71.7 days with a standard deviation of 34.5 days making both the commitments and deliveries to customers very unpredictable. The following sections describe how the average and standard deviation was reduced to improve the overall STC.

Opportunities for improvements in each of the three main areas were divided into a series of Kaizen and Six Sigma projects. Six sigma projects were identified as "high hanging fruit" due to their complexity and the duration. These projects required innovation, development, and validation before they could be implemented. They could take anywhere from 4 weeks to 6 months for full implementation. Kaizen projects, on the other hand, were designated as "low hanging fruit" and quick wins. These projects were considered much simpler and quicker to complete, taking anywhere from 1 week to 4 weeks for full implementation.

Demand Management: Problems and opportunities for improvement

To tackle the problems in demand management, the focus team looked at the detailed process and tools used in handling, analyzing and responding to customer demand. They found that demand churn in the 2 week planning horizon was out of control and invisible. This was driving shortages, excesses and missed commitments. There was no way to quickly and accurately measure the effect of demand spikes. Recognizing that we needed to be flexible to support churn demand, it was decided to standardize the demand management process and develop analytical tools that would help them recognize, analyze and respond to demand churn before it was processed through MRP.

Projects to Improve Demand Management			
Project Name	**Type**	**Project Scope**	**Results**
Churn Analysis	Six Sigma	A statistical measurement and reduction of demand churn in the 2 week planning horizon. Supported by other projects and tools, planners would reduce the volatility and increase the accuracy of production schedules by eliminating the unnecessary churn.	• It took 4 weeks to develop/validate and implement tools and metrics. • Able to see and control the churn data real time and analyze capability and impact. • It took 15 weeks to bring the negative churn to within control limits.
WHATIF MRP	Kaizen	Develop on-demand MRP run and analysis reports that planners can use to analyze demand fulfill scenarios before running the scheduled MRP.	• It took 2 weeks to set process, test/validate and implement • Time to commit for drop in (Upside) demand was reduced from 7 days to 1 day; no longer had to wait for the scheduled MRP run.
Max-Kits	Six sigma	Develop spreadsheet based macro that automatically calculates maximum available kits on the fly for a prioritized list of top level assemblies as well as analyzing exposure to E&O.	• It took 30 days to implement and execute. • Improved the lead time to commit delivery of high-priority upsides from one week to a few hours.
12-Week Shortage Analysis	Six Sigma	Develop a long term, early-warning tool providing clear visibility of potential material shortages in the 12 week planning horizon.	• 6 weeks to develop the analysis report. • Once the analysis report was completed and verified, shortage escalation teams addressed shortages before they impacted production schedules. • Material shortages in production were reduced from "frequent' to 'rare'.

Table 2: List of projects identified to improve the demand management cycle.

Churn Analysis
The Churn Analysis project was a key step in improving the demand management process. The team realized that while some churn is inevitable (and even welcome in the case of doable upsides) other churn was unnecessary and could be controlled in the master production plan to avoid inventory problems or create unnecessary, non value added work downstream in the planning process. The goal was to identify the unnecessary churn. The churn analysis turned out to be a far more powerful tool than first anticipated. The senior management of the customers started using it for monitoring their own product life cycle management and marketing forecasts. Previously, senior management focused more on the overall revenue numbers but not the churn mix which was the major cause of E/O inventory.

WHATIF MRP
The WHATIF MRP was an easy-win process development. Before this process was available, planners in various production business units had to wait for a single, weekly MRP run to see the total picture of their customers' new demand and materials position. While waiting, many would attempt to manually calculate materials availability in order to commit to the customer, resulting in inaccurate commitments and materials shortages. After implementation, a planner could run a full MRP on-demand as a simulated production scenario, then identify availability and constraints, and feed back to the customer with accurate commitments. It allowed the planners to load the weekly scheduled MRP with a realistic demand plan avoiding lot of errors and cancellations.

Max Kits Analysis
The Max Kits tool was a software development with multiple analytical uses. Primarily designed as a real-time Available-To-Promise engine, it also functions as means to identify finished assemblies that can be built with available E/O inventory. Prior to this tool, all assessment was based on time consuming, manual data crunching and estimations. Now, planners have an automated tool that provides an exact assessment for the total number of full kits and additional material required to build out the required demand or to eliminate total exposure to E/O.

12-Week Shortage Analysis
The 12-Week Rolling Shortage Analysis was a key early warning tool that addressed frequent material shortages. Prior to this tool, planners had no way to accurately predict when material shortages would affect production schedules. Designed for ease of use, planners could run the 12-Week Shortage Analysis and quickly identify problematic components. With this data available, business unit planners formed escalation teams with members of the Strategic Supply Chain group. Material shortage issues that could not be solved within the purchasing groups were escalated to management and then executive staff. Material shortages were reduced from frequent to rare.

Overall Results in Demand Management
With these automated, accurate tools for analyzing and responding to customer demand, the baseline lead time metric for demand processing improved from an average of 5.75 days and a σ of 0.707 days to average of 2.75 days and σ of 0.276 days. This resulted in direct STC improvements, upside opportunities in revenue and reduced E/O inventory. Additional benefits were gained downstream in the supply chain processes. Among them, buyers had more accurate and reliable schedules to manage and stores had steadier throughput. Overall improvements in the SC metrics resulting from this work can be seen in the case study section.

Strategic Supply Chain: Problems and opportunities for improvement

Two teams were formed to identify and implement a series of actions (Table 3) to reduce the lead time for all material components to less then 4 weeks. Before this effort, lead times ranged anywhere from a few days to 28 weeks.

At Fabrinet, each customer has its own factory with a dedicated support infrastructure. The strategic supply chain group, however, is centralized and provides services to all customers while each customer business unit has its own dedicated planning and procurement group providing tactical support.

The Strategic Supply Chain team saw the supplier lead times to be the biggest opportunity for overall lead time reduction. They divided all purchased components into discrete commodities and the associated suppliers within each commodity. Meanwhile, a team of tactical planning and purchasing staff worked on tools to increase efficiency in order processing.

Projects to Improve the Strategic Supply Chain			
Project Name	**Project Type**	**Project Scope**	**Results**
Current Lead Times Map	Six Sigma	Map current lead time status of all purchased parts by commodity and identify issue causing long lead times > then 4 weeks.	All components with lead times > 4 were segregated into weekly lead time buckets. Corrective actions to reduce these lead times were identified for each item.
Vertical Integration	Six Sigma	Identify all the parts that could be manufactured in-house. Decide if vertical integration was economically viable and would enable significant lead time reduction.	381 parts were moved from buy to make status. Lead times were reduced to less than 4 week as well as inventory, WIP, and E/O for these parts.
VMI Implementation	Six Sigma	Review the complete SC base and identify additional parts that can be moved to existing VMI hubs on site at Fabrinet.	1760 parts were added to existing VMI. Reduced LT dramatically, eliminated E/O for these parts, enabled pull to demand and consolidation of suppliers.
Long Term Contracts	Kaizen	Formalize business relationships with key vendors	Suppliers to buy material to Forecast, and build to PO. 36 suppliers supported this project reducing the lead times significantly.
Vendor Consolidation	Six Sigma	Review supply base for similar parts and identify consolidation opportunities to key strategic suppliers.	Number of suppliers reduced from 1200 to 840. Enabled price and lead time leverage, helped build strategic partnerships.
Fixed Days Supply	Kaizen	Optimize A, B, C class components classifications and define a standardized procurement strategy for each type of component.	This resulted in reduced number of shipments/week, freight costs, fewer receipts and inspections at IQA as well as reducing workload for buyers.
Supplier Localization	Six Sigma	Identify all components that can be moved locally. Move all overseas vendors where possible to local suppliers.	Reduced lead times by 80%, cost by 30%+, improved supplier communication.
Buyer Productivity Tools	Kaizen	Augment standard ERP functionality to provide business unit buyers with tools that help them efficiently process purchase orders.	Reduced the time required to process purchase orders by 30%.

Table 3: List of projects and problems identified for improvements in the Strategic Supply Chain

Current Lead Time Mapping:

The lead times for each component are stored in the ERP system database. This was the lead time base line used for this exercise.

In the first step of the mapping process, all the parts that had lead times of less than 4 weeks were segregated into one bucket. Most of these parts were already part of our existing VMI hubs and fixed supply programs.

- **VMI:** Vendor Managed Inventories are on-site hubs where vendors have established 4-6 weeks inventory on site at Fabrinet. Fabrinet pulls inventory from these hubs based on the kitting requirements for production. The vendors replenish the inventory based on the consumption and the 26 week forward rolling forecast provided by Fabrinet on a weekly basis.

- **Fixed Supply:** The fixed days supply program was designed to manage the 'C' Class items which represent 80% of the purchase parts and 5% of the purchase dollars for a predefined period (usually one quarter.) Each 'C' Class item is purchased using a dynamic 60 day supply rule. This allows the ERP system to manage the demand and the buyers only have to place purchase orders twice per quarter.

After filtering out the items that are managed through VMI and Fixed Days supply, we were left with 35% of the total components that had a lead time of 6 to 28 weeks. A number of possible solutions were explored for each item after understanding each customer's requirements and flexibility for change.

Solutions for the remaining components fell into six different categories:

1. Standardize procurement process
2. Vertical Integration
3. Localization
4. VMI (Vendor Managed Inventory)
5. Long Term Contracts
6. Vendor consolidation

Standardized procurement process
The mapping process revealed that the procurement rules were inconsistent amongst the different groups. Some business units scheduled C class parts weekly versus others who scheduled in 60 day increments. The result was a domino effect throughout the system; buyers had heavier work loads, shortages occurred, and IQA had too many receiving lots to process. When clear and concise procurement rules were applied across all business units, the problems subsided.

Vertical Integration
381 components with lead times greater than 6 weeks were identified. It was determined that these could be built in-house by Fabrinet. In addition to reducing the lead time, vertically integrating these items provided the customer with lower costs by removing packaging and transportation costs. Additionally, total control over potential E/O material was realized by building these components to final product demand.

Localization
The geographical location of several suppliers was making communications and logistics difficult to manage. This was the root cause of long lead times in some components. Components that could be moved to qualified local sources without any design changes or major re-qualification of the final product were transitioned. 1507 components were moved to local suppliers resulting in substantial cost savings, lead time reductions and improvements in logistics.

VMI
The original VMI program was established for the common, off the shelf electronic components. While the program worked well with these parts, it did not address the unique or the semi-custom components. Analysis showed that some of these components should be incorporated into this program. Subsequently, 1760 parts were added to the existing list of VMI parts thereby reducing their lead times to zero, reducing inventory levels, and increasing availability for response to upside demand.

Long Term Contracts
Many of our suppliers were inherited from customers and no formal business agreements between them and Fabrinet existed. Some of these suppliers were reluctant to make investments or take other steps to improve lead times. Negotiating contractual agreements to engage in long term business relationships was in some cases all that was required to make dramatic improvements. Lead times for items supported by the 36 suppliers who participated in the program were improved to less then 4 weeks using this strategy.

Vendor Consolidation
The largest opportunity for vendor consolidation was in the common hardware and electronic parts. Since these items are largely interchangeable, Fabrinet narrowed down the supply base to two suppliers for hardware and eight for common electronics. This allowed consolidation of demand volumes and gave the key suppliers a greater sense of strategic partnership with Fabrinet. All these suppliers provided significant price reduction and participated in our VMI program.

Buyer Productivity Tools
Looking at the purchasing administration process, planning and purchasing staff found that much time was lost in managing a large number of purchase orders. They needed tools that helped them identify exceptional situations, process large amounts of data, and identify opportunities for savings. Working with the ERP support team, they developed a suite of tools to augment their standard ERP functionalities. Some of those tools are:

- *The Auto Reschedule Interface* allowed buyers to upload supplier commitments from a spreadsheet based template to the ERP system en-masse and saved significant time and manpower in maintaining the orders.
- *The Alternate Action Report* employed custom logic to provide different order rescheduling and cancellation suggestions than the standard ERP system provides. This helps buyers more effectively manage their orders.
- *Custom Warnings and Notifications* are customizations the ERP system that help buyers identify exceptions like non-cancellable, non-returnable parts or alternate parts that are available as substitutes for the part they are buying. These warnings help the buyer identify exceptional situations where they should focus their time.
- *The Excess On Order Analysis* is a custom intelligence tool that dynamically shows buyers where an open order might result in excess inventory.

Overall Results in Strategic Supply Chain
After implementation of the improvement programs, we reduced the average lead times to 3.60 weeks and standard deviation to 5.19 days compared to initial average lead time of 58 days and standard deviation of 34 days. We were very successful in reducing the standard deviation and thereby provided much better predictability. The final average component lead times fell short of the set goals. The primary reason for this was due to parts that were single sourced with very little leverage or flexibility for change. This accounted for 4.3% of the total components requiring a modest investment in buffer stocks to bridge the gap to achieve the goals. This is discussed in more details in the case study section.

In addition to the lead time reductions, all the supply chain metrics showed significant improvements as shown in latter sections.

Logistics (Warehouse and Incoming Quality Assurance): Problems and opportunities for improvement

The second largest opportunity for lead time reduction identified through the process mapping was in the activities associated with the logistics process. A detailed study of the receiving, IQA, storage and kitting processes revealed several non-value added and inefficient activities. To understand the cycle times and potential for improvements, staff from different areas of the logistics team was enlisted to bring forward ideas for improvements. These would be both simple and more complex projects to drive significant optimizations in throughput, storage space and overall costs.

Projects to Optimize the Logistics and IQA			
Project Name	**Project Type**	**Project Scope**	**Results**
Standard Storage Box	Six Sigma	Eliminate all cardboard boxes and standardize box size to optimize storage space	Project took 3 months to complete. A standard, off the shelf plastic box was selected allowing bar code implementation
Warehouse Racking	Kaizen	Optimize distance between shelves to align with standard box size.	This project took 2 weeks; Increased warehouse capacity by 40%.

Freight Consolidation	Six Sigma	Reduce Number of inbound shipments at a controlled rate.	Reduced freight and staff costs.
Box Locator Label	Kaizen	Develop a label that is easily readable and can be used as location identification in the ERP system.	Label was developed in 2 weeks and allowed for automatic traceability.
Smart Bins for Hardware	Six Sigma	Move the hardware stores to the production line, for auto replenishment of stock by supplier.	Eliminated kitting of small piece parts. Provide consumption PO to Supplier weekly. Supplier manages Min/Max
Barcode Label	Six Sigma	Develop an electronic bar code label for all material that will enable full lot control functionality in ERP system.	Eliminated manual, hand written receipt transaction label and data entry errors.
Consignment Process	Six Sigma	Develop a process allowing material to be pulled on demand from VMI and consignment and reconcile consumptions into a weekly PO	4000+ parts now follow this process, real time transactions avoiding delays and buyer inefficiencies.
Optics Skip Lot	Six Sigma	Eliminate unnecessary inspection at IQA. Implement skip lots.	1415 parts were moved into this program increasing throughput at IQA and minimizing administrative work.
RLC Skip Lots	Six Sigma	Eliminate unnecessary inspection at IQA. Implement skip lot	35% upside in IQA throughput and shortened time to stores.
Mechanical Dock to Stock	Six Sigma	Move the IQA function to the suppliers, Fabrinet to spot check critical dimensions and criteria.	Eliminated 65% of inspection in IQA for Mechanical Parts
Combine IQA/Receiving Label	Six Sigma	Combine 2 Labels into 1 Label	Increased efficiency, reduced 1 process step, combined all data on one label for ease of data tracking

Table 4: List of projects and problems identified for improvements in the Logistics area of Supply Chain

Smart Bins for Hardware

Studies demonstrated that the time to kit small quantities of hardware (nuts, bolts and washers) was unnecessarily lengthening the kitting cycle time. A local supplier was engaged to setup a “smart bin” system within the manufacturing areas. This supplier maintains inventory in the smart bins based on a min/max quantity of each hardware item. This allowed the operators to have easier access to the hardware items on the line with a guaranteed supply; 74% of all hardware items have been migrated to this program.

Consignment Process

In the past, consuming materials from consigned or VMI inventories required buyers to issue a new purchase order each time production required the materials to be moved from consignment or VMI for kitting. This caused delays to the kitting process and disrupted the overall purchasing organization’s daily work load. A new workflow was developed in Fabrinet’s ERP system that allowed for material to be pulled from consignment or VMI inventories while the quantity was automatically captured and accumulated by the system. This accumulated quantity of goods consumed from consigned or VMI inventories was automatically released against a predefined blanket agreement and communicated to the supplier weekly for invoicing. The new process eliminated significant non-value added activity for the purchasing group and made the consigned / VMI inventory management process fast and transparent to inventory control and production staff.

Freight Consolidation

The frequent demand fluctuations in the MRP system were driving a large number of shipments from the suppliers which incurred excessive clearance charges at customs. A focus team was put together to optimize the complete freight process. The team determined that specific freight consolidation points should be established in strategically selected geographic zones. These consolidation points would be the "ship to" points for the suppliers and shipments would be dispatched from the consolidation points three times per week to Fabrinet. Having greater control of the number of shipments and timing of shipments allowed for greater optimization of the receiving and IQA departments while also reducing the freight charges and associated clearance costs.

Bar Code Label
Our warehouse process involved many manual data entries throughout the material handling process. A warehouse focus team was created and tasked to identify solutions to eliminate the manual data entries. The solution proposed was to migrate to a barcode label system with real-time transaction processing via handheld mobile devices. Suppliers were required to affix a bar code label embedded with specific data points to each shipment. Upon arrival at Fabrinet, receiving staff scans the label with the handheld device and process the transaction in the ERP system real-time. During the kitting process, the label would again be scanned and quantities entered in the handheld, and the system would update the location of the material automatically. Significant efficiencies were realized with the implementation of this process as well as greater data accuracy.

Skip Lots
Fabrinet's Incoming Quality Inspection department was required to inspect each component lot at IQA before delivery to the warehouse. A team reviewed eight quarters of IQA data by commodity to determine which suppliers were shipping consistently good quality. The Supplier Quality Engineering (SQE) organization worked closely with the suppliers to implement the skip lot inspection programs avoiding the unnecessary inspection at the IQA. Optical and electronic RLC components were the first commodities to be transitioned to skip lot, followed by mechanical and active electronics. This transition increased IQA capacity by more than 150% allowing IQA/SQE teams to place greater focus on problematic suppliers and first article qualifications.

Overall Results in Logistics
Optimizations in the Logistics processes yielded improvements in lead time, capacity, head count and other costs:

- The measured process lead time of 5-9 days was optimized to a 1-2 day process.
- Storage capacity in warehouse increased by 40% within the existing facility.
- Kitting lead time was cut to single digit hours.
- Head count costs dropped by 22% in the warehouse and IQA.
- Over Time costs dropped by 40% in IQA and the warehouse.

With all the optimizations in buyer efficiencies, reductions in freight costs, controls in scheduling of incoming material, and greater warehouse throughput, Fabrinet was able to reduce the logistics process time by 80%.

Customer Specific SC Optimization: Case Study

To demonstrate and validate the effectiveness of applying lean manufacturing concepts at Fabrinet, we selected a single customer's business unit and applied the lean tools to their specific case. This customer is referred to as "Customer C" throughout this case study. Fabrinet had very low Ship-to-Commit performance with Customer C. Pursuing improvements in the three target areas (demand, strategic SC, and logistics operations) created the net effect of greatly improving STC.

Historically, Customer C had exceptionally high demand churn rates. It was discovered that a lot of

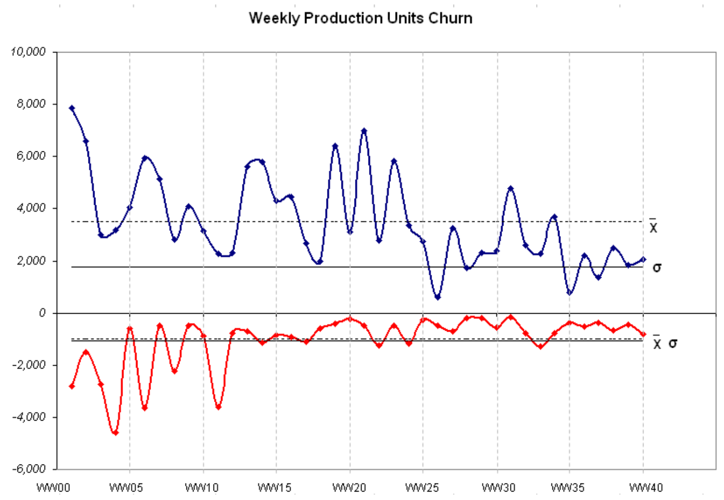

Figure 7: Applying Lean demand management tools helped control the demand churn for the case business unit.

demand was loaded only to drive material expediting activities. By applying the lean analytical tools to this case, planners were able to scrutinize the demand intelligently and adjust it appropriately before loading it to the master demand schedule. The trend in the demand churn before and after can be seen in Figure 7 where a dramatic improvement is clearly evident.

The Strategic Supply Chain team analyzed this customer's 2300 active material components. After netting out the 'C' Class items that were already on the VMI program, the value stream mapping activity revealed 370 items that required lead time optimization through the lean projects.

The team prepared the initial list of target items and shared it with the customer to facilitate discussions on the current status and the potential solutions for each item. After detailed negotiations at the item level with respect to timelines, requirements for qualification and long term reliability testing, the final solution road map was agreed and 354 of the target items' lead times were effectively reduced to less than 4 weeks.

There were 16 items for which Fabrinet and the customer agreed the best industry lead time had been achieved. However, these 16 items did not meet the 4 week lead time requirements. Based on due diligence done through the value stream mapping activities, the customer agreed that the remaining 16 items would be part of a safety stock program to achieve the final goal and conclude the activity.

As the project moved through the various phases of implementation, the optimizations that would be gained through the reduced lead time began to take effect:

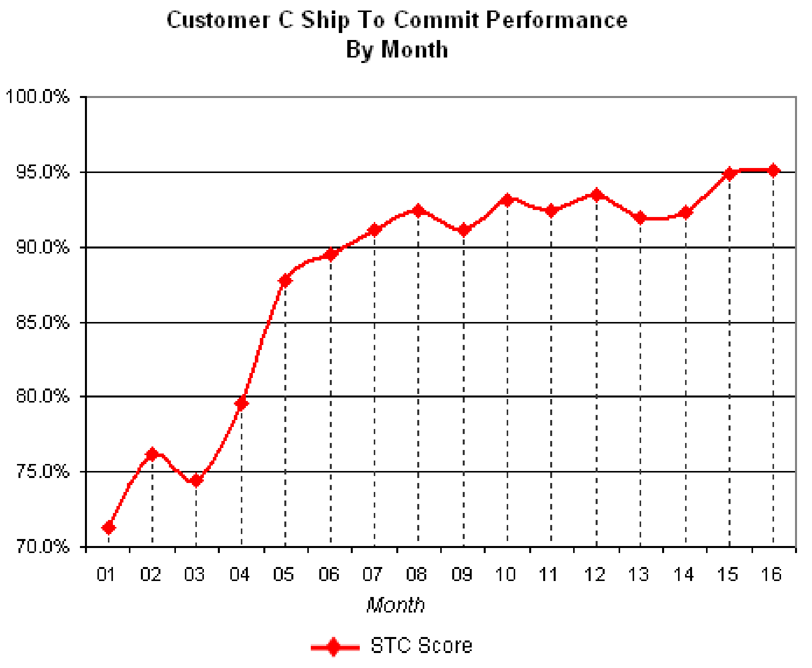

Figure 8: Ship-To-Commit performance improvement resulting from applying lean manufacturing principles.

- Component demand was steadier requiring less order maintenance. This resulted in a 40% reduction in the day to day communication and administrative activities for the tactical purchasing team.
- Fabrinet's tactical purchasing team was able to focus their activities managing the high-level 'A' category items, NPI Products and upside demand opportunities.

Upon completion of all the activities associated with this project, the final max lead time for the items was reduced from 8.78 weeks to 3.78 weeks meeting the set goals of max lead time of 4 weeks for any individual component.

With new products being introduced on a regular basis, the principles and achievement of the lean projects is continued on a weekly basis. The weekly activity ensures that any new items introduced into the planning and procurement cycle are validated and optimized to be at 4 weeks or less lead time before being released to an "active" status.

The focus on reducing material lead time was the primary factor in achieving major improvements in Fabrinet's Ship To Commit scores for this Customer C (Figure 8.)

Overall Gains from Lean Implementation at Fabrinet

As lean projects were carried out across the supply chain, overall performance metrics improved across the board. Fabrinet's high mix / low volume supply chain was transformed. After lean implementation, the supply chain performance – previously typical for a high mix / low volume industry – changed. Metrics scores more closely resembled those of low mix / high volume industries (Figure 9):

- Demand churn, order cancellations and reschedules were brought into full visibility allowing appropriate decisions.
- As material lead times were reduced, they became more predictable.
- The number of suppliers and purchase orders issued each week went down and buyers became more efficient.
- IQA and warehouse throughputs improved.
- Overall inventory turns went up.
- Excess and Obsolete inventory decreased while Ship-To-Commit performance improved to target levels.

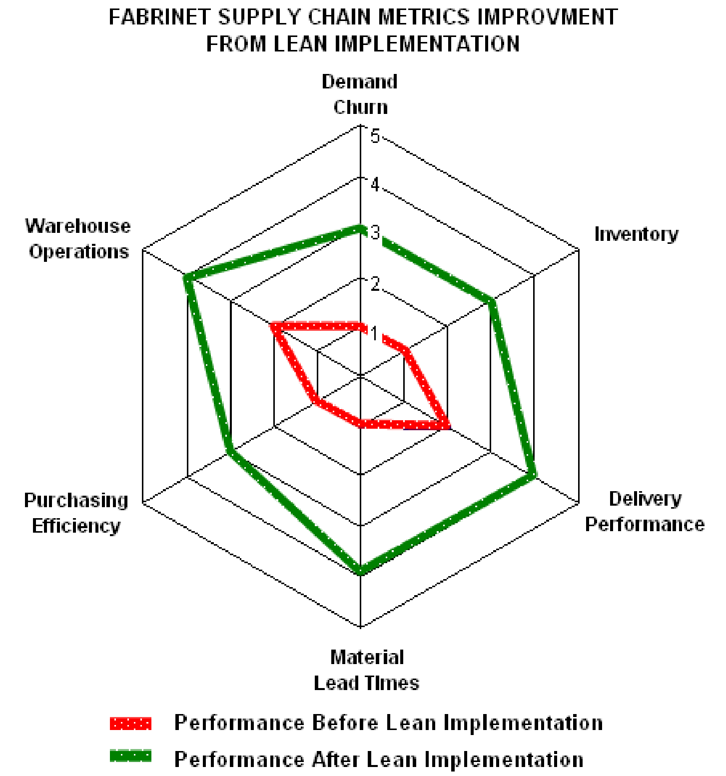

Figure 9: Fabrinet's supply chain performance was transformed by Lean Manufacturing Principles

Conclusion

Realizing benefits of lean manufacturing practices is not as complex or as involved as many may believe. It does not require extensive training programs or in-depth understanding of statistics. Staff at all levels can contribute with very little training as many of the LM concepts are based on common sense. The key to successful implementation is to get started with a positive attitude.

Value stream mapping is an excellent tool for identifying waste and opportunity for optimization. Its very simple yet extremely effective if applied without any bias. Staff at all levels can understand this tool and its application very quickly. Using value stream mapping, we were able to quickly identify broad issues then drill down to smaller ones, enabling us to optimize the complete supply chain with excellent results in all metrics.

Six Sigma and Kaizen projects are easily identified during value stream mapping. Once the projects are identified, having the right teams with the required skill sets is critical to the success of the project and the overall optimization.

Lean thinking and value stream mapping must remain as an integral parts of the continuous improvement process in order to keep the supply chain process optimized.

About the Authors

Dr. Harpal Gill, Executive Vice President, Operations
Dr. Gill has served as Executive Vice President, Operations of Fabrinet USA, Inc. and Fabrinet Co., Ltd. since May 2005. Prior to joining Fabrinet, from July 2003 to January 2005, Dr. Gill served as the senior vice president of engineering for Maxtor Corporation, a disk drive manufacturer. From January 1999 to July 2003, Dr. Gill served as the vice president of engineering for Read Rite Corporation, a supplier of magnetic recording heads for data storage devices, in Bangkok, Thailand. From June 1996 to October 1998, Dr. Gill served as the managing director of JTS Corp., a disk drive manufacturer, in Chennai (Madras), India. Dr. Gill has also held senior management positions in Reliability, QA, and Process Development with Seagate Technology. Dr. Gill earned a Bachelor of Science degree in mechanical engineering from Brunel University in the United Kingdom and a doctor of philosophy degree in Manufacturing Processes optimization using forward forecasting techniques from the University of Bradford in the United Kingdom.

Kevin Camelon, Senior Director of Supply Chain
Mr. Camelon joined Fabrinet in February 2004 as Manager, Electrical Supply Chain. Over the past 3 years his responsibilities have increased. His current position is Senior Director with overall responsibility for Supply Chain, Logistics and Supplier Quality. He has worked in Thailand since 2001. Prior to moving to Thailand he was employed for 17 years by Future Electronics, a world leader in electronic component distribution. Within Future Electronics he held various management positions in Canada, Europe and Singapore and was a key contributor to Future Electronics' Global Expansion from 1988-1999.

Mark Lopus, Director of Business Systems
Mr. Lopus joined Fabrinet in 2006 as the Director of Business Systems. He is responsible for business process and ERP system development. He has worked in Thailand since 1997 in various materials management and supply chain positions with companies including Cypress Semiconductor and Innovex, Inc. Before joining Fabrinet, Mr. Lopus, who is also a certified ERP consultant, worked on multiple ERP and business process implementation projects in Thailand and other Asian countries.