Improving Lead Time of Semiconductor Processing Equipment

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ABSTRACT

The purpose of this study is to develop and implement a plan for improving manufacturing lead time. Company XYZ produces semiconductor processing equipment. The equipment is used in the integrated circuit manufacturing process. The equipment is marketed and sold, installed and serviced to companies located throughout the world. A majority of Company XYZ's customer base is located in major semiconductor manufacturing regions including Asia, Europe, Japan and the United States. World wide equipment competition, as well as customers delaying their capital investments has resulted in Company XYZ receiving less visibility to their commercial planning window. This has caused the manufacturing schedule and corresponding resources to be more difficult to manage. The delay has caused Company XYZ's customers to adjust their manufacturing planning processes and require shorter

equipment lead times. This paper provides the process used by Company XYZ to improve their manufactured equipment lead time.

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Chapter I: Introduction

Company XYZ designs, manufactures, installs and provides on site service of semiconductor processing equipment. Semiconductor manufacturing is a global industry. The greatest majority of semiconductor manufacturing is performed in Asia, Europe, Japan and the United States. The products the company produces are sold and used by the major semiconductor manufacturers located in these regions and throughout the world. The manufacturing of semiconductors is an extremely competitive business. Semiconductor manufacturers are continuously focused on using lean manufacturing principles to reduce costs, minimize manufacturing cycle time and maximize manufacturing yield.

Company XYZ's customer's planned equipment purchasing cycle is beginning to decrease. This decrease is the result of shorter planning cycles by Company XYZ's customers. This change will require Company XYZ to modify their equipment manufacturing and planning processes. In an effort to support its customers and maintain its competitiveness Company XYZ desires to reduce the lead time of the equipment it manufactures.

The Company's semiconductor processing equipment manufacturing lead time ranges from 2 months to 6 months depending on the product family. The manufacturing lead time is a result of a design to order business model. The design to order business model is used as a result of the need to meet customer specifications. Specifications vary from customer to customer resulting in low volume highly engineered custom features which are not included in the standard equipment design. These custom features result from specifications provided by the customer to meet their manufacturing process specifications. A lack of component overlap results in equipment which is highly configurable.

Company XYZ uses standardization in the design process. Equipment standardization of mechanical, electrical and control system components is common practice. The shared components between each tool order accounts for a large majority of the parts required to meet a customer's tool specifications. The customer specific components present procurement and manufacturing challenges. The procurement of components, tool assembly and tool final test have been identified as areas of opportunity which need to be investigated.

Company XYZ has a need to define an equipment manufacturing process and plan which will allow manufacturing flexibility. This flexibility includes reducing tool procurement and manufacturing cycle times as well as the ability to quickly convert manufacturing work in process (WIP) from one customer to another. The study will be piloted using one of the flagship product lines produced by company. This study is aimed at the fundamental goals of any organization to insure that standardization is maximized and lead time of their product is minimized. The standardization and reduction in lead time will result in a high level of customer satisfaction by providing the right product at the right time and quality level with the right price for both the customer and Company XYZ.

Statement of the Problem

Lead times for Company XYZ need to be reduced to satisfy customer demand and maintain strategic market supplier preference.

Purpose of the Study

The purpose of this study is to determine activities and a process to reduce manufacturing lead times and maximize the use of component standardization. Reducing lead time allows the company to retain existing customers as well as provide an opportunity to expand the existing customer base. A secondary benefit of the study provides an opportunity to increase facility throughput and increase current manufacturing capacity. A review of the current standardization model, procurement processes, manufacturing planning and manufacturing processes will be used to identify areas for improvement and to resolve complementary problems.

Assumptions and Limitations of the Study

1. Results of the study apply only to Company XYZ - the focus of the research.
2. The data gathered is reliable and accurate.
3. The research is limited to one product family.
4. The results of the study may require changes in Company XYZ's traditional, manufacturing, purchasing and inventory philosophies.
5. The executive management team will provide necessary support to implement suggested changes.
6. The pilot process to be used represents a significant dollar and time investment by Company XYZ.

Definition of Terms

Component: A purchased or manufactured part, sub assembly or final assembly.

Cycle Time: The time which elapses from the beginning of a process or operation until its completion.

Design to order: A business philosophy in which product designs are specifically completed based on specifications provided by the customer during the ordering process.

Equipment Purchasing Cycle: The planning cycle for purchasing Company XYZ's equipment

JIT(Just in Time): A production paradigm which insures the right product in the right quantity at the right time to the customer.

Lead time: The time required to produce a product beginning with procurement of raw materials and ending with finished goods.

Lead time offset: Manufacturing time used in the production planning process to balance the release of production orders to the assembly floor labor. Normally measured in days.

Low Volume: Products which are produced in small volumes and batches. In some cases the company may forecast the usage or production period.

Non value added activity: A business or manufacturing process step which provides no benefit to the customer.

Process of Record: Equipment specific manufacturing processes used by Company XYZ customers to manufacture integrated circuits.

Procurement: The purchasing process of ordering components to be received on the date needed to support manufacturing cycle time.

Standardization: The design for manufacturing philosophy of using components which have a cost, lead time, function or quality advantages.

Standardized work: Standardized procedures concentrating on the most efficient human movements and work sequence for each process.

Supply Chain: The system of organizations, people, technology, activities, information and resources involved in moving a product or service from suppliers to customers. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer.

Tool: A piece of semiconductor processing equipment built by Company XYZ.

Total Replenishment Lead Time: The time required to procure and consume a component used in the tool assembly and shipment process. The time consists of the component procurement lead time, manufacturing lead time and goods receipt time.

Work in Process (WIP): Unfinished product that is in queue for additional processing.

Further Limitations of the Study

This study was intended to provide a process and means to reduce tool lead time for Company XYZ. The study was focused only on one product family. Similar product families were available to be considered but are not included due to resource and time constraints. The procurement processes required to be successful in reducing lead time were included in the study. The processes included expediting of parts for various supplier and company reasons as well as qualifying new suppliers and engineering change order requirements. This study did not include an evaluation of additional lean methodologies which could be used to reduce lead time. The study did not consider the cost savings provided by delaying the purchase of components between configurations. Efforts were made to record and provide data based on the details and ignoring the exceptions. This was done to provide a good picture of the overall manufacturing and procurement processes and ignoring differences which could prevent significant process improvement.

Research Methodology

The research method for this field problem included a review of literature and focus on the procurement and manufacturing strategies which have been identified to reduce equipment manufacturing lead time. The strategies included:

1. Standardization Opportunities
2. Manufacturing Routing Evaluation
3. Manufacturing Lead Time Evaluation
4. Assembly Bills of Material Changes
5. Procurement Changes
6. Product Forecasting Changes

The current state of these strategies was analyzed and potential improvements areas were identified.

Recommended changes in these strategies were implemented. The recommended changes were presented to plant floor employees, design and manufacturing engineering, operations management, product management, commercial teams and executive management. Changes were implemented based on employee input and approval from the executive management team.

The feedback and strategy changes were applied to determine impact on the manufacturing lead time.

Chapter II: Literature Review

The purpose of this study is to provide a process which will reduce lead times of semiconductor processing equipment. The literature review provides an overview of the history of lead time reduction, definition of lead time, and the importance of lead time reduction. The review also includes lead time reduction techniques.

Origin of Lead Time Reduction

In industry, lean manufacturing is a key competitive initiative. The history of lean dates back to 1940 when a German worker produced 3 times as much as a Japanese worker and an American worker produced three times as much as a German worker (Ohno, 1998). This provided a production ratio of 9 to 1 between American and Japanese work forces. The Japanese leader Toyoda Kiichiro proposed to reduce the gap with America resulting in the birth of lean manufacturing. Eiji Toyoda and Taiichi Ohno at the Toyota Motor Company in Japan pioneered the concept of lean production (Womack, Jones, Roos, 1991). Lean manufacturing strives to attain perfection through declining costs, striving for zero defects, reducing inventories and providing for endless product varieties which are a continuous quest. Lead time reduction has become one of the major tactics which enables lean manufacturing.

Definition of Lead time

Lead time reduction is one of the most important objectives in running today's businesses. It is especially true for highly competitive industries, such as the semiconductor industry. Reducing lead time is the most important factor in achieving world-class operations. In the 1960s and 70s, manufacturers competed on the basis of cost efficiency. In the 1980s, quality was the rage and Zero Defects and Six Sigma came into vogue. Cost and quality are still crucial to world-class operations, but today, the focus is squarely on speed. Nearly all manufacturers today are under pressure from customers to cut lead times.

Customer lead time refers to the time span between customer ordering and customer receipt. Manufacturing lead time refers to the time the supplier receives an order to the moment it ships in the absence of finished goods or intermediate work in progress (WIP) inventory. It is the time it takes to actually manufacture the order when there is no component inventory other than raw materials or supply parts. Lead time also includes the time it takes for a company to process and have the part ready for manufacturing once it has been received. The time it takes a company to unload a product from a truck, inspect it, and move it into storage is non-trivial. It is important for the supply chain to know their internal process cycle times when tight manufacturing constraints or just in time manufacturing is used.

In many manufacturing plants less than 10% of the total manufacturing lead time is spent actually manufacturing the product and less than 5% of total customer lead time is spent in the production process. (Smith, 2004). The cumulative cycle times of the processes in the value stream are the theoretical limit to how much we can reduce lead times, without investing in different equipment. Clearly, there is ample opportunity to reduce lead times in most organizations.

Lead time in the Semiconductor Industry

The semiconductor industry is characterized by high value added, high technology and high usage. This makes lead time reduction one of the most important objectives for wafer fabrication manufacturers. Wafer fabrication is one of the most complex modern manufacturing processes. In this complex manufacturing environment a typical wafer fabrication process flow may contain 300-500 operational steps over 30-45 days to complete. (Chia, Nan Wang, 2007). The lead time is due to the sequence of operations, where there are multiple similar steps repeated, and none can be skipped. If the fabrication of a central processing unit(CPU) requires 35 exposure masks, that translates approximately into 35 times completing photo resist coating, exposure, development, main process step (such as etching or diffusion), photo resist stripping and/or polishing plus other steps. There may be additional steps before and after all other processing. There are wait times associated with scheduling a product into production. Wait times result from product lines being busy producing other products or a production run which produces scrap. The scrap can result from poor equipment set up or processing issues. This results in tooling and alignment changes which take time to complete. There are possible wait times for batches being processed during the production run. Machinery works at different speeds and maintenance steps or tool changes may be required between production runs. Physically transporting the silicon wafers from one piece of processing equipment to another is also a common occurrence.

Semiconductor manufacturers strive to reduce the lead time by simplifying the manufacturing process and design, by improving the production control mechanisms for effective scheduling, better dispatching and improved line balancing. Increasing tool availability and reliability, improving the floor layout for effective material handling, and batch size changes to reduce queuing times and decrease setups are some other measures that are taken. Wafer processing lead time consists of queuing time for the equipment, waiting time due to preventive/breakdown maintenance or engineering hold, processing time, inspection time, and transportation time. (Akalt, Nemoto, and Uzhoy, 2001)

Lead Time in the Semiconductor Processing Equipment Sector

Much like wafer fabrication, semiconductor processing equipment manufacturing is characterized as high value added and high volume. This can be traced to complex component manufacturing processes, high equipment uptime requirements and a large variety of manufacturing processes. The equipment industry is viewed as a high mix low volume model. This is the result of the small manufacturing quantities as well as customer requirements for special features and tool options. The special features and tool options are required to provide customers with specific product processing capabilities. The high mix low volume business nature results in assembly work being scheduled on the floor in terms of customer priorities and dates.

A demand driven manufacturing schedule indicates which job should be completed in which order. The length of the lead time is a result of a combination of procurement activity and manufacturing activity performed. The long procurement lead time is the result of raw materials and fabricated components which have long supplier lead times due to engineering specifications or complex manufacturing processes. The manufacturing lead time is the result of the need to assemble modules, integrate them together, complete equipment functional verification and wrap, crate and ship the equipment.

There are many tools available to improve lead times. Some of the more common tools are:

1. Multi- functional employees – Employees trained to handle several different machines and operations that constitute a cell in lean production methods

2. Supplier relations – Leveraging the supply chain to help reduce lead times. Supplier actions which can help reduce lead time are consignment inventory, safety stocking and sharing long term forecasts. Lead time improvement can directly provide opportunities to attain perfection. Costanza (1996) states that "Its (Lean Manufacturing) primary objective is to build a high-quality product in the shortest production time and at the lowest possible cost". The supply chain is where lean manufacturing can be implemented to its greatest extent. This implies that the supply chain can have significant impact on lead time reduction.

3. Plant/Facility Layout: Setting up the assembly floor to enhance flow, simplify management, and reduce material handling. It can involve rearranging an area, installing U shaped cells or undertaking a complete layout change. A layout change enables a change from functional management to managing by value streams.

4. Standardized operations (work): Determine the one best way to complete assembly tasks and train all production employees to perform the work following the same process steps in the correct order. Standardized work includes the use of documented procedures, work instructions and drawings

5. Standardized components/subassemblies (Standardization): A manufacturing and supply chain approach for increasing commonality of part, process, product or procurement. Such change will enable delayed making of manufacturing or procurement decisions, thus reducing variability found in having many non-standard components.

6. Simplification: Breaking work down into the simplest steps to allow multi functional employee assembly.

7. Problem Solving/Prevention: Use problem solving techniques as well as corrective and preventative action processes to minimize future lead time impact.

The lead time of both the procurement and manufacturing processes have been identified as strategic areas of focus based on historical research and data, executive management experience and investigation into the recent causes of extended lead times. Focusing on both manufacturing and procurement processes provides a dual pronged approach which leverage each other to reduce lead times.

Reducing lead time results in eliminating manufacturing constraints, reduced overhead costs, reduced work in process inventory, reduced floor space, increased on time deliveries, higher product quality, less employee turn over and lower product cost. (Dossenbach, 2000).

Chapter III : Methodology

The objective of this study is to provide a process which will reduce lead times of semiconductor processing equipment. Lead time reduction involves the rapid fulfillment of customer orders and the rapid transformation of raw materials into quality products in the shortest amount of time possible. Company XYZ's lead time includes the purchasing time of components and the manufacturing time to build the tool. The manufacturing time consists of module sub assembly, module assembly, module integration and checkout, mechanical functional test, tool disassembly and final quality checks. The last steps of the process are the package, crate and ship activities.

Both supply chain and manufacturing processes will be evaluated to identify areas of potential improvement to reduce lead times. Information will be gathered using the company's ERP system, cycle time reduction team process activities as well as observations on the assembly floor. The data collected will be analyzed to determine the contribution to reduction of tool lead time. Further analysis will be completed and recommendations will be made to reduce the lead time from the current standard to less than 60 days.

The study is focused solely on the spray processing product line. The spray processing product line produces the highest volume manufactured product. The product represents approximately 60% of the planned equipment sales revenue for the coming year. The product line margins are high and the product line is expected to contribute significant profits in the future. A significant reduction in lead time is required to support anticipated customer demand and meet strategic corporate targets. A lean manufacturing business model has traditionally resulted in Company XYZ manufacturing spray processing equipment in a single batch of one. The equipment is manufactured based on identified customer needs or forecast provided by the commercial team.

The first step of the project required employees of Company XYZ to attend a project planning meeting and brainstorming session. This session helped determine the processes of focus and provided training to employees from different departments of the company. After completion of training employees toured the production floor to learn the spray processor manufacturing process. Information regarding the production and procurement processes was gathered. The information gathered included current spray processor lead time, manufacturing lead time, manufacturing routing times, product procurement profile, sales order memo documents and component costs. The assembly lead time for the spray processor product line is represented by Table A.

Spray Processor Lead Time Summary

Process	Assembly	Checkout	Presource inspection	24 Hour Burn- In	Tool Disassembly	Wrap, Crate and Ship
Leadtime	39 days	20 days	2 days	5 days	3 days	2 days
	783 hours	200 hours	0 hours	0 hours	24 hours	16 hours

Lead times in shop calendar (work) days
All modules can be assembled in parellel

Table A

The first step in the current production method is completion of the annual tool sales forecast. Once completed, a manufacturing schedule with tool ship dates is completed to support the tool sales forecast. The manufacturing schedule is load balanced to maximize assembly resources, minimize the need to add production employees and support a level procurement plan. Components required to meet the manufacturing schedule are loaded into the ERP system. Production control reviews the manufacturing schedule and identifies work order release dates. Procurement reviews the manufacturing schedule and determines actions required to procure components to meet the work order release dates. The supply chain team begins purchasing components. Production control releases the work orders to the production floor. Manufacturing scheduling and planning are discussed between sales and operations teams on a weekly basis. It is common for tool configurations to change during the procurement and manufacturing process. The configuration changes are the result of company XYZ customers adjusting their tool purchasing plans.

The release of work orders signals the beginning of the assembly process. The first step of the assembly process is completion of module electrical and mechanical sub assembly components. Sub assembly completion is followed by the installation of the sub assemblies into modules, additional assembly, and installation of mechanical and electrical components of the modules. Once all assembly processes are completed the modules are integrated together. The integrated modules are connected to de-ionized water, clean dry air, vacuum and nitrogen supplies for tool checkout and full functional test. A complete mechanical, electrical and control system functional check is completed. This functional check is designed to simulate how a customer would exercise the tool upon purchase and installation. The checkout process is followed by in internal quality inspection performed by a member of the service/installation team. Upon successful completion of the inspection full functional cycling of the tool is completed for a specified period. Full functional cycling without mechanical, electrical or control system failure for the specified period is required for successful completion. Once the full functional cycling is completed, the tool is disconnected from the facility supplies, purged to remove the water in the tool, disassembled to the module level, quality checked, wrapped, crated, and shipped.

Strategies and Instrumentation

The strategies to reduce lead time fall into two broad categories. Manufacturing strategies and supply chain strategies. The instrument used to understand the procurement and manufacturing lead times for a tool is the Tool Procurement Profile. The procurement profile identifies the component procurement sequence and planned assembly time in a spreadsheet and graphical form. This data provided areas on which to focus improvement. This resulted in focusing on the following strategies:

Manufacturing strategies which were used to investigate and reduce lead time were:

A. Assembly routing review and modifications

B. Assembly lead time review and modifications

C. Common Configurations

D. Tool Reconfiguration

Supply chain strategies which were used to reduce lead time were:

A. Component Lead Time Reduction

Manufacturing Strategies

The method to obtain data for the lead time reduction process was accomplished by retrieving information from Company XYZ's ERP system, production floor observations and discussions with lead time reduction team members. The first step of the data collection process was to establish a baseline tool configuration. Establishing a baseline allowed a reference point for comparison purposes as the manufacturing and supply chain strategies are investigated and actions implemented. A baseline configuration was identified based on past and planned forecasted tool configurations. Forward looking configuration information was provided by the commercial/sales team.

Assembly Routing Review

The first manufacturing strategy reviewed was equipment assembly routing information. An assembly routing is documented for each manufactured assembly. The assembly routing documents manufacturing operation sequence, work centers where the operations are performed, the number of labor hours required to complete the manufacturing sequence and in-process inspection or test requirements. Accurate assembly routings allow the product to be scheduled through the manufacturing floor in the most efficient manner.

Assembly Lead Time Review

Assembly process manufacturing lead times were gathered and evaluated next. The information gathered regarding lead time was the assembly number, bill of material level structure number, assembly offset and the lead time of each assembly in days. When necessary, a lead time offset is used in production scheduling to release assemblies earlier in the assembly process. This allowed some labor leveling of the assembly processes and reduced spikes in work requirements.

Common Configuration Determination

Common components between tool configurations were gathered by review of shipment configuration history over the past twelve months and anticipated tool configurations over the coming twelve months. Historical data was gathered from the ERP system and anticipated configuration data was provided based on sales/commercial team tool forecasts. The data included customer, historical component configuration and quantities of each of the components used. Anticipated configurations were evaluated using John Galt Solutions

Forecast Wizard probability software. The software helped determine the most likely component configurations, quantities and planning buckets to be used in purchasing material to meet planned assembly requirements in the next 12 months based on past and anticipated tool configurations.

Generic Tool Build and Reconfiguration

Past manufacturing history indicated greater than 90% of tools were built and reconfigured during the assembly or checkout process. Reconfiguring a tool after assembly and check out provides an additional manufacturing alternative. Research indicated reconfiguration was caused by a lack of visibility to Company XYZ's customer's long term forecast and the length of Company XYZ tool lead time. The current tool lead time is 161 calendar days. The benefit of building a generic tool and reworking it to a different configuration is being able to ship a tool in an expedited manner versus building a tool from start to finish to meet customer needs. This approach also consumes components which have been purchased or manufactured as quickly as possible compared to procuring and manufacturing additional components. Historically, reconfiguration has happened 3 times to each tool at random times during the tool build and checkout process. The team determined that the most logical time to complete reconfigurations was after checkout completion rather than during the build or checkout process. The team identified the steps in the tool manufacturing process. The team then brainstormed the ideal time to reconfigure the tool which would minimize checkout time.

This alternative requires the ability to have the needed parts in inventory as well as resources available to complete the reconfiguration and checkout when required. It was determined that the availability and number of manufacturing resources to complete the reconfiguration would not be a limiting factor as resources could be planned and scheduled appropriately.

To minimize the inventory outlay and provide the greatest manufacturing flexibility, the team identified a "generic" tool configuration. The generic tool configuration provided a tool which can be completely assembled and checked out. If reconfiguration is required, the generic configuration provided the minimum exertion of time and effort.

Supply Chain Strategies

The team reviewed the part procurement and product forecasting processes to determine if a supply chain strategy could be implemented to help reduce lead time. The tool procurement profile identified a list of all components required to produce a tool. This information gave the team the ability to pursue a reduction in purchased component lead time.

Purchased Component Lead Time Reduction

Product forecasting is completed based on a sales forecast. Sales and operations planning have developed forecasting time fences to help the company determine dates when significant investment in purchased components begins. These time fences help the company understand the inventory investment to build tools and help determine if a forecasted tool slot should be built as scheduled, delayed or cancelled based on actual sales activity. There are two time fences. Time fence one (161 days) represents when the first parts are scheduled to be ordered. Time fence two (127 days) represents a significant jump in component purchasing spend rate. Time fence two also represents the need to have a customer name and configuration defined and driving in MRP.

Purchased component lead time data was gathered through the use of the tool procurement profile. Procurement profile data included component part numbers, quantities, costs, component procurement lead time and the number of days components are required to arrive prior to tool shipment to meet the production schedule and ultimately the tool shipment date. Table B is a graphical representation of the data. The purple line represents the cumulative material investment dollars spent each day as the shipment date approaches. The blue line represents the arrival dates of material and when it is needed on the floor to maintain the production schedule. MRP schedules the arrival of parts to maintain the planned manufacturing schedule.

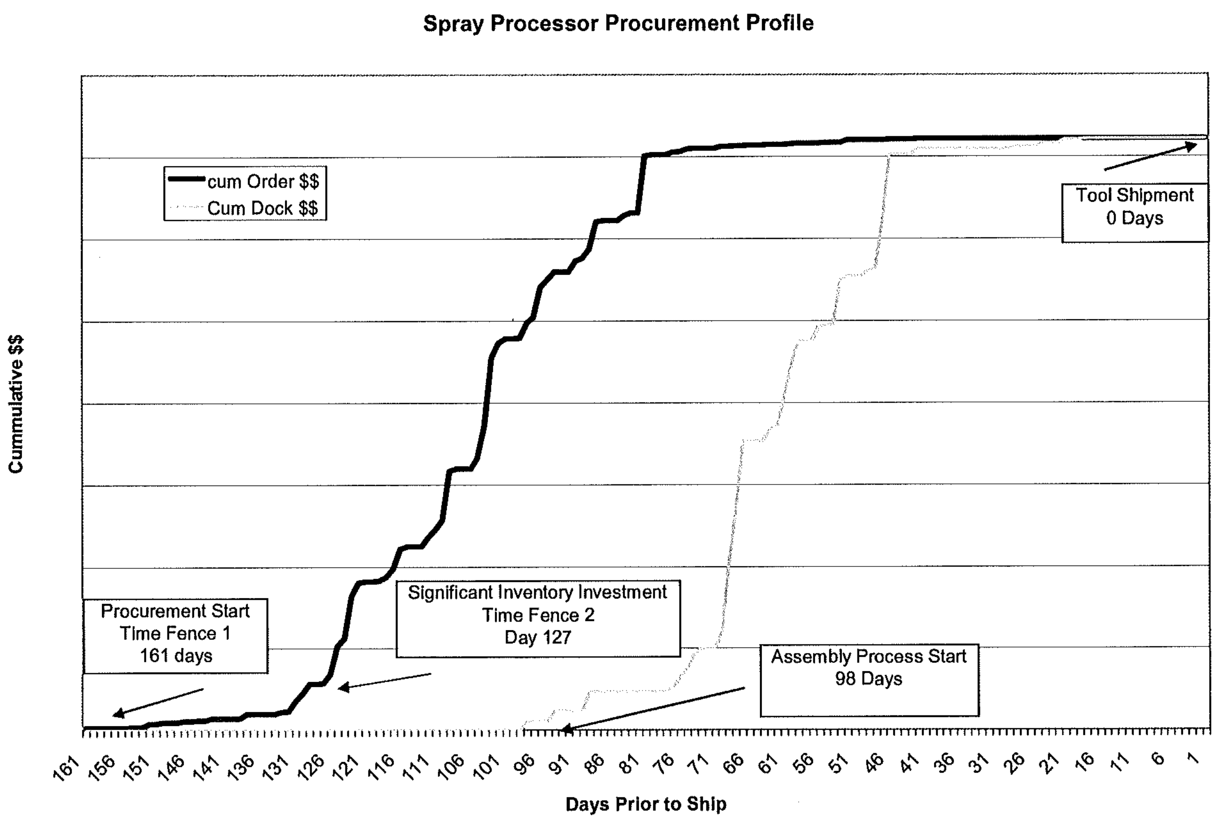

Table B

Analysis of Data

A plan of action and corresponding project schedule was identified for each of the strategies. The team prioritized manufacturing strategies based on logical process steps. A baseline tool configuration was established for comparison purposes to determine the costs and benefits of implementing each of the strategies. Data was captured for each of the five strategies. The data was used to determine the strategies which provide the greatest benefit toward the reduction of tool lead time.

Assembly Routing Review

Assembly routing data was gathered for the baseline tool. The routings were segregated by modules which make up a full tool configuration. The modules included in the evaluation were the Fluid Delivery Module, Process Module, Material Handling Module, Canister Console, and Power Distribution module. The checkout, tool disassembly and wrap, crate and ship routing time evaluation was also included but was completed after the assembly module review. This allowed the team to prioritize their efforts on the tool manufacturing processes which consume the majority of the labor. The evaluation required multiple meetings to review and confirm the data and ultimately complete this task. Individuals representing assembly employees, manufacturing engineering, production coordinators, production scheduling, and production managers met and reviewed the assembly requirements and associated labor hours for each of the 223 manufactured assemblies. The meetings included a documentation review of the component bills of material, assembly drawings, and corresponding work instructions. The manufacturing expertise of the team members and previous assembly history provided the basis for determining adjustments to the individual operation routing times for each assembly. The routings times varied significantly based on the assembly efforts required. Assembly routing times varied from .2 hours

(12 minutes) for simple mechanical assemblies to 44 hours for the most complicated electrical assemblies and 200 hours for the tool checkout process. Tool assembly requires 783 hours of labor and 39 working days. Tool checkout, pre-source inspection and burn-in requires 200 hours of labor and 27 working days. Tool disassembly, final QC check, wrap, crate, and ship requires 40 hours of labor over 6 working days.

Assembly Lead Time Review

Company XYZ schedules product through the production floor based on assembly lead time rather than routing times. A reduction in lead time may have an impact on manufacturing cycle time. A review of assembly lead times was completed at the module level which included the process module, fluid delivery module, and chemical canister console. The lead time reduction team met multiple times to complete the activity.

Determining lead times required an indented bill of materials for each module. An agreement on the scheduling of production processes was also determined. The manufacturing processes can be scheduled with limited or unlimited capacity. Historically, the company has added production headcount when an increase in manufacturing volume was experienced. In addition, there is a strong cross training program in place providing flexibility in operator assignments. Based on this the team chose to schedule based on unlimited capacity.

The determination of lead times began with identifying every manufactured assembly in each of the module indented bills of material. Step two was to determine the order of the assembly processes. If it was determined 2 or more assemblies could be completed at the same time the lead times were documented appropriately. The lead time of each manufactured assembly was determined and tracked by spreadsheet. The minimum lead time assignment for shop floor scheduling purposes was 1 day (8 hours). Components with routing times of less than 8 hours which could be completed simultaneously with other components were noted. When needed, production scheduling used negative manufacturing offsets to load level shop order labor requirements. Negative offsets were used to help simulate assembly shop order releases as closely as possible to assembly routing times. Smoothing the release of production orders to the manufacturing floor is an advantage to using offsets. If offsets were not used shop order releases happened in "waves" every few days rather than when manufacturing capacity was available. Multiple rates of manufacturing efficiency were included in the evaluation to provide an understanding of the role efficiency plays in the scheduling process. The team determined that an efficiency rate of 80% was best suited for this exercise. A high labor efficiency rating was used due to the maturity of the product line, employee training, and manufacturing documentation level. Table C indicates the data gathered to complete the evaluation for the canister console module.

Canister Console Module Lead Time Example

Level	Component	Description	QTY	U/M	Current Lead time	New Lead Time	Work Center	Assembly Hours	Cum. Hours	MRP Planner	Current LT Offset	Revised LT Offset	Build Sequence
0	SCAPZ3-H0104	ZETA 300MM, G3S, V2, CC, TRA	1	EA	2	5	SZ90	16.25	16.25	55	0		
1	923807-601	ASSY,FNL,CAN CNSL,4P,PVC-C,R	1	EA	7	3	PICK	6.07	6.07	62	0		
2	923808-601	ASSY,CSTR CSL,4-P,PVC-C,RH,Z	1	EA	7	5	PICK	13.6	13.6	62	0		
2	924215-001	ASSY,PLUMBING,CAN CNSL,ZFE/B	1	EA	7		CC62	3.06	3.06	62	0		
1	925021-603	ASSY,BOX,3 SMPLNG VLV,PVC-C,	1	EA	3		CC62	4.13	4.13	62	-7	-2	3
2	911900-703	ASSY,VENT,PVDF,MOLDED,ZETA	2	EA	3		SZ10	0.11	0.22	55	0		
1	922170-601	ASSY,COMP RINSE DI BYPASS,PV	1	EA	3		CC62	0.51	0.51	62	-7	-2	1
1	923203-001	ASSY,ASPIRATOR,H2SO4,1/4 , Z	1	EA	3		CC62	0.51	0.51	62	-7	-2	2
1	926741-004	KIT,CANISTER CAP ASSY,50 PSI	4	EA	3		CC62	0.11	0.44	62	-7	-2	6
1	926683-602	ASSY,CNSTR,FNL,3/8T,NO KEY/L	2	EA	3		CC62	1.51	3.02	62	-7	-2	4
2	921738-001	ASSY,VERT/LIFT PRESS REL(3/8	1	EA	7	2	CC62	1.01	1.01	62	0		
1	926683-621	ASSY,DUAL CNSTR,FNL,1/2T,PVC	1	EA	3		CC62	2.01	2.01	62	-7	-2	4
2	921738-002	ASSY,VERT/LIFT PRESS REL(1/2	1	EA	7	2	CC62	1.01	1.01	62	0		
1	926684-003	ASSY,KEY/LABELS,CANISTER,H20	1	EA	3		CC62	0.51	0.51	62	-7	-2	5
1	926684-004	ASSY,KEY/LABELS,CANISTER,H2S	1	EA	3		CC62	0.51	0.51	62	-7	-2	5
1	926684-006	ASSY,KEY/LABELS,CANISTER,NH4	1	EA	3		CC62	0.51	0.51	62	-7	-2	5
1	926684-804	ASSY,KEY/LABELS,CNSTR,H2S04,	1	EA	3		CC62	0.51	0.51	62	-7	-2	5
1	914063-624	KIT,FLTR MTG.BRKT(MILPR 1/2	1	EA	3		CC62	0.76	0.76	62	-7	-2	8
1	914063-625	KIT,FLTR MTG.BRKT(SM MP 3/8	2	EA	3		CC62	0.76	1.52	62	-7	-2	8
1	922264-151	ASSY,CHEM IFACE,1.5NPT,1 CHE	1	EA	3		CC62	0.31	0.31	62	-7	-2	9
1	922264-152	ASSY,CHEM IFACE,1.5NPT,2 CHE	1	EA	3		CC62	0.31	0.31	62	-7	-2	9
1	922264-154	ASSY,CHEM IFACE,1.5NPT,4 CHE	1	EA	3		CC62	0.31	0.31	62	-7	-2	9
1	929244-001	KIT,H202 AUX CANISTER PRESSU	1	EA	3		CC62	0.51	0.51	62	-7	-2	7
						Total Cummulative Hours			57.6				

Table C

Component Lead Time Review

The team determined that tool lead time is made up of two parts - Manufacturing lead times and component lead times. The component lead time is defined as the procurement lead time (PDT) plus the days prior to shipment a part is required to be in stock (dock days) to meet the production shipment schedule. This is known as the total replenishment lead time of a component. Data revealed that 2221 component line items are needed to produce a tool. This included component number, component description, quantity, component cost, and MRP controller/buyer. An evaluation of component total replenishment lead time was completed. Table D represents components with lead times greater than 135 days. The team focused it's evaluation on the total replenishment lead time field for components greater than 135 days. The team evaluated the steps which could be taken to reduce the total replenishment lead time and found opportunity for reduction by:

1. Supplier negotiation- Working with existing suppliers to reduce their lead time
2. Changing suppliers- Finding suppliers who can meet reduced lead time, quality and cost requirements
3. BOM structuring change – Postponing the date material is required in the assembly process or delivered to the assembly floor
4. Component substitution – Replacing an existing component with an equal or more suitable component
5. Safety stock - Keep material stock on hand to meet total replenishment lead time requirements.
6. Replacing the existing custom component with an "off the shelf" component.

Component Lead Time Data

Component	Required Qty	STD Cost	Total STD Cost	PDT	Material description	Dock Days	Order Days
316890-002	4.000	666.50	2,666.00	105	FAN,CENTRIFUGAL,SPCL	56	161
316890-002	1.000	666.50	666.50	105	FAN,CENTRIFUGAL,SPCL	56	161
294133-400	1.000	99.90	99.90	56	ASSYPC-SENSOR SUMMATION BOARD	98	154
313242-001	1.000	575.29	575.29	56	VALVE BLOCK,DEVICE NET,16 3-WAY VALVE	98	154
316523-001	1.000	75.65	75.65	84	TRANSFORMER,208V X 115V	69	153
300201-085	8.000	0.15	1.20	63	SCR,PH SS 6-32 X 2-1/2	89	152
317479-002	3.000	718.00	2,154.00	84	VLV,PNEU,3-WAY,1/2 ORF,1/2 T,S300	68	152
434589-001	1.000	900.06	900.06	63	PANEL,EMI/RFI SHIELDED,ELEC CAB,ZETA-SFP	89	152
434589-001	1.000	900.06	900.06	63	PANEL,EMI/RFI SHIELDED,ELEC CAB,ZETA-SFP	89	152
313242-001	3.000	575.29	1,725.87	56	VALVE BLOCK,DEVICE NET,16 3-WAY VALVE	94	150
307997-001	2.000	840.83	1,681.66	49	VALVE BLOCK,DEVICE NET,16 VALVE	98	147
294059-400	2.000	203.03	406.06	56	ASSY,PC-STACK LIGHT I/F BOARD	89	145
919305-306	1.000	52.10	52.10	56	ASSY,CABLE,THORKOM,FLOWTRANS,W1315	89	145
317479-002	2.000	718.00	1,436.00	84	VLV,PNEU,3-WAY,1/2 ORF,1/2 T,S300	59	143
317479-002	1.000	718.00	718.00	84	VLV,PNEU,3-WAY,1/2 ORF,1/2 T,S300	59	143
917224-003	1.000	172.07	172.07	42	ASSY,CABLE,EXH XDCR,W1089-1&W1090-1	98	140
927775-002	1.000	317.99	317.99	42	KIT,WIRE,PM VLV BLK I/O PNL,2P,Z3G3	98	140
907356-001	1.000	97.17	97.17	63	ASSY,TACH PICKUP	76	139
234752-016	1.000	39.90	39.90	63	CIRCUIT BREAKER,3 POLE,16 AMP	75	138
300252-052	8.000	0.50	4.00	49	SCR,PH SST CR 8-32 X 1 5/8	89	138
300541-001	1.000	3.10	3.10	63	SWITCH,INTERLOCK,SPDT,250VAC,10A	75	138
300893-002	16.000	27.25	436.00	49	COUPLING,8 PORT MALE KYNAR	89	138
300893-002	2.000	27.25	54.50	49	COUPLING,8 PORT MALE KYNAR	89	138
300897-002	16.000	27.25	436.00	49	COUPLING,8 PORT FEMALE KYNAR	89	138
300897-002	2.000	27.25	54.50	49	COUPLING,8 PORT FEMALE KYNAR	89	138
311493-001	1.000	2,985.95	2,985.95	70	RGLTR,TEFLON,1 ORF,SLAVE,3/4 FTF	68	138
311584-204	1.000	569.09	569.09	70	REG,PNEU,PFA,1/4 ORIFICE	68	138
314136-002	1.000	351.00	351.00	49	CONVERTER,POWER,DC TO DC	89	138
423820-012	1.000	14.08	14.08	49	GASKET,EMI/RFI,MODIFIED,23.50,4HOLE	89	138
423820-014	1.000	8.64	8.64	49	GASKET,EMI/RFI,MODIFIED,12.67,2HOLE	89	138
423820-016	2.000	6.72	13.44	49	GASKET,EMI/RFI,MODIFIED,6.63,1HOLE	89	138
922364-001	1.000	40.81	40.81	42	KIT,WIRE,ELEC I/O PNL,BACK,FDM,ZFE/BE	94	136
922767-002	1.000	46.05	46.05	42	KIT,WIRE,ELEC I/O PANEL,LEFT,FDM,ZFE/BE	94	136
923293-001	1.000	46.80	46.80	42	ASSY,CABLE,SIGNAL,W1279-1,ZFE/BE	94	136
923293-002	1.000	47.20	47.20	42	ASSY,CABLE,SIGNAL,W1280-1,ZFE/BE	94	136
923293-003	1.000	46.74	46.74	42	ASSY,CABLE,SIGNAL,W1287-1,ZFE/BE	94	136

Table D

Common Configuration Determination

Common configuration determination began with the commercial team providing a copy of the Internal Order Memo Form (IOMF). The IOMF represents a "shopping list" of the components which make up all the possible combinations of components which represent each customer's tool configuration. The IOMF is a revision controlled document which contains 509 component part numbers. The items on the IOMF represent engineering designed and released components. The

IOMF provides a means to translate customer order requirements into a valid configuration which can be manufactured.

The sales team contacts customers regularly to determine their need for a tool and the tool requirements. The sales team passes on the customer's requirement to the sales order administrator. The sales order administrator confirms the customer's requirements with the sales team. He refers to the IOMF document and the corresponding configuration rules included in the document. The sales order administrator uses the IOMF to identify all the bills of material to manufacture the product and completes the Engineering Change Order (ECO) to release and load the requirements into the business system. The Engineering Change Order releasing the configuration is approved by the sales order administrator and production planner. Upon ECO release the material to be ordered is driven through the material requirements planning (MRP) process.

The team completed an IOMF review to identify significant common and non-common components. Significant non-common components included tool electrical configurations, the wafer handling system and a large number of customer specific features. Electrical configuration differences result from country specific electrical code requirements. The non-standardization of the wafer handling system is the result of the need to handle multiple wafer diameter sizes. The customer specific features are one time or limited-use features and tool options which tend to be customer and process specific.

The second step of the evaluation was to determine the most frequent manufacturing processes customers perform using the tool. Each customer establishes manufacturing processes of record (POR) on Company XYZ equipment. Understanding the processes of record helps to understand tool component standardization possibilities. The customer provides process of record information during the tool ordering process. The team gathered this information through a review of recent customer shipments and by interviewing the commercial and applications engineering teams.

The final step of the evaluation was to gather past tool configuration history and planned future configurations. The data provided a finer level of common components between each tool based on customer process of record and previous tool configurations.

Generic Tool Build and Reconfiguration

The current lead time to build a tool from scratch was calculated to be 161 calendar days. The team used the common configuration data to identify multiple tool configurations which could be used as a generic tool to be built and reconfigured. The goal was to identify a single generic configuration which could be quickly reconfigured, checked out and prepared for shipment. Past tool configuration history indicated three processes of record that were most commonly required by customers. Process A was required 78 percent of the time. Process B was required 6 percent of the time and Process C was required 16 percent of the time. The chemical processing requirements for the tools indicated that a majority of the tools were the three chemical variety (39%) followed by the four and five chemical variety (22% each) and the six chemical variety tool (17%). There were no requirements for seven or eight chemical tools.

The data gathered to determine the configuration which provided the greatest benefit included the bill of materials for all configurations, the initial inventory investment in component parts required to build the generic tool, and the inventory required to support the multiple possible tool reconfiguration requirements. The labor cost and time required to build and reconfigure the generic tool to the customer requirement was also determined.

Historically, reconfiguring a completed tool has required 34 calendar days. This consisted of order processing, procurement, tool rework, functional check, inspection and shipping preparation time. Reducing reconfiguration and re-checkout time allows customer needs to be satisfied as quickly as possible. The team investigated these steps and determined that the reconfiguration time could be reduced based on the amount of reconfiguration needed. Table E below provides the data gathered from the investigation.

Tool Reconfiguration Data Summary

Tool Capability	Process of Record A	Process of Record B	Process of Record C	Baseline Tool
Percentage of Tools	78%	6%	16%	100%
Number of Chemicals	3	5	5	5
Number of Canister Consoles	1	2	2	2
Tool Configuration Cost	$942,070.00	$950,043.00	$965,989.00	$982,082.00
Inventory Required to Support Reconfiguration	$438,731.00	$430,758.00	$414,812.00	$398,729.00
Assembly Hours	760	780	743	783
Assembly Cost	$29,260.00	$30,030.00	$28,605.50	$30,145.50
Customer Configuration to Shipment Days	17 days	21 days	27 days	34 Days
Post Customer Configuration Assy. Rework Hours	41	16	4	0
Post Customer Configuration Assy. Rework Cost	$1,578.50	$616.00	$154.00	$0.00
Post Customer Configuration Re-checkout Hours	32	8	8	0
Post Customer Configuration Re-checkout Cost	$1,232.00	$308.00	$308.00	$0.00
Customer Configuration Change Material Cost	-$40,012.00	$49,026.00	$4,602.00	$0.00
Total Labor Hours	833	804	755	783
Total Labor Cost	$32,070.50	$30,954.00	$29,067.50	$30,145.50
Total Material Cost	$902,058.00	$999,069.00	$970,591.00	$982,082.00

Table E

Chapter IV: Results

Introduction

The objective of this study is to provide a process which will reduce lead times of manufacturing semiconductor processing equipment. Cycle time reduction involves the rapid fulfillment of customer orders and the rapid transformation of raw materials into quality products in the shortest amount of time possible. Reduced lead times will help the company increase throughput, and retain and expand its customer base. This was accomplished by using multiple processes which impact the ability of a company to reduce cycle time. The processes which could have the greatest impact on Company XYZ's ability to reduce tool lead time and satisfy customer needs were identified and evaluated. Manufacturing and supply chain processes as well as combinations of both processes were evaluated to determine improvement in tool lead time. A current process and lead time were identified and used as baseline measurements to determine improvements. The processes included in the evaluation were order fulfillment, procurement and manufacturing processes. The information obtained from the processes helped the management team determine the processes which create the greatest value to the company and its customers. This chapter provides the results of company XYZ's efforts.

Assembly Routing Review

The assembly routing review accomplished a 4% (36 hour) reduction in assembly hours. Based on a fully burdened labor rate of $38.50 per hour this corresponds to a cost reduction of $1400 per tool. Individual module results included an increase in process module assembly hours due to recent engineering change order activity. The remaining modules received assembly reductions resulting from improved manufacturing techniques and training as well as a test process to identify manufacturing scrap at an earlier assembly step. The module checkout and tool disassembly reduction was the result of improved operator knowledge and understanding of checkout processes. A significant improvement in the wrap, crate and ship process resulted from recent interdepartmental employee cross training.

Assembly Routing Results

Module Assembly	**Labor Hours Pre-Review**	**Labor Hours Post Review**
Process Module	276	282
Fluid Delivery Module	163	154
Material Handling Module	130	122
Canister Console #1	77	71
A structure	60	58
C Structure - Ship Along	42	42
E structure - Transformers and A-boxes	35	32
Module checkout	200	196
Tool Disassembly	24	22
Wrap, Crate and Ship	24	16
Assembly Total	**1031**	**995**

Table F

Assembly Lead Time Review

Assembly lead times provide the production scheduling department with the correct scheduling plan for each tool. Company XYZ schedules assembly processes using lead times. A review of assembly lead times was completed at the module level which included the process module, fluid delivery module and chemical canister console. The process module lead time was reduced by 2 days, fluid delivery module by 1 day and the canister console by 1 day. This resulted in a four day lead time reduction.

Component Lead Time Review

The current tool lead time is 161 days based on the longest lead time component. Thirty-six purchased components with greater than 135 days of cumulative lead time (order days) were identified and investigated for actions which could reduce their lead time. The results of the investigations and actions taken were:

1. Nine components required a supplier lead time reduction. Negotiations of all nine components were successful. Negotiating the lead time reductions resulted in the opportunity to reduce lead time to as little as 138 days.
2. Ten components required an assembly release delay. Delaying each of these components by 3 days would reduce the tool lead time from 138 to 135 days. The investigation showed these components were structured properly into bills of materials to support efficient assembly processes. No reduction action was taken on these components.
3. The lead time of eleven components could not be reduced due to sole source requirements, and non negotiable engineering specifications required to meet customer process of record performance. All the components are common to past tool configurations. The company initiated a "safety stock" plan for these components. The plan insured that the components would be available at any time. Establishing the safety stock plan provided a lead time reduction from 161 to 140 days.
4. Engineering requests to identify and implement substitute components in three instances could not be completed due to resource constraints. The greatest lead time of the three components was 140 days.
5. The company approved the spending to initiate a safety stock program to reduce the tool lead time.

Combining the assembly and component lead time is an effective method to reduce tool lead time. The actions taken as a result of the component lead time review reduced tool lead time from 161 days to 140 days. This reduction required an inventory investment of $10,014.The investigation results are documented in Table G below.

Component Lead Time Reduction Results

Component	Required Qty	STD Cost	Total STD Cost	PDT	Material description	Dock Days	Order Days	Investigation results	Company XYZ resulting actions
316890-002	4.000	666.50	2,666.00	105	FAN,CENTRIFUGAL,SPCL	56	161	Engineering specified - no suitable substitutes available.	Safety Stock initiated
316890-002	1.000	666.50	666.50	105	FAN,CENTRIFUGAL,SPCL	56	161	Engineering specified - no suitable substitutes available.	Safety Stock initiated
294133-400	1.000	99.90	99.90	56	ASSYPC-SENSOR SUMMATION BOARD	98	154	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
313242-001	1.000	575.29	575.29	56	VALVE BLOCK,DEVICE NET,16 3-WAY VALVE	98	154	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
316523-001	1.000	75.65	75.65	84	TRANSFORMER,208V X 115V	69	153	Existing supplier reduced lead time from 84 to 63 days	Supplier Lead time Reduction
300201-085	8.000	0.15	1.20	63	SCR,PH SS 6-32 X 2-1/2	89	152	Existing supplier reduced leadtime from 63 to 42 days	Supplier Lead time Reduction
317479-002	3.000	718.00	2,154.00	84	VLV,PNEU,3-WAY,1/2 ORF,1/2 T,S300	68	152	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
434589-001	1.000	900.06	900.06	63	PANEL,EMI/RFI SHIELDED,ELEC CAB,ZETA-SFP	89	152	Existing supplier reduced leadtime from 63 to 49 days	Supplier Lead time Reduction
434589-001	1.000	900.06	900.06	63	PANEL,EMI/RFI SHIELDED,ELEC CAB,ZETA-SFP	89	152	Existing supplier reduced leadtime from 63 to 49 days	Supplier Lead time Reduction
313242-001	3.000	575.29	1,725.87	56	VALVE BLOCK,DEVICE NET,16 3-WAY VALVE	94	150	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
307997-001	2.000	840.83	1,681.66	49	VALVE BLOCK,DEVICE NET,16 VALVE	98	147	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
294059-400	2.000	203.03	406.06	56	ASSY,PC-STACK LIGHT I/F BOARD	89	145	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
919305-306	1.000	52.10	52.10	56	ASSY,CABLE,THORKOM,FLOWTRANS,W1315	89	145	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
317479-002	2.000	718.00	1,436.00	84	VLV,PNEU,3-WAY,1/2 ORF,1/2 T,S300	59	143	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
317479-002	1.000	718.00	718.00	84	VLV,PNEU,3-WAY,1/2 ORF,1/2 T,S300	59	143	Proprietary Company XYZ design - off the shelf replacement not available	Safety Stock initiated
917224-003	1.000	172.07	172.07	42	ASSY,CABLE,EXH XDCR,W1089-1&W1090-1	98	140	Resources not available for 3 months to support alternate source	None
927775-002	1.000	317.99	317.99	42	KIT,WIRE,PM VLV BLK I/O PNL,2P,Z3G3	98	140	Resources not available for 3 months to support alternate source	None
907356-001	1.000	97.17	97.17	63	ASSY,TACH PICKUP	76	139	Sole source Part - Alternate source not available	None
234752-016	1.000	39.90	39.90	63	CIRCUIT BREAKER,3 POLE,16 AMP	75	138	Alternate part not available	None
300252-052	8.000	0.50	4.00	49	SCR,PH SST CR 8-32 X 1 5/8	89	138	Supplier lead time reduced from 49 to 42 days, no assembly delay possible	Supplier Lead time Reduction
300541-001	1.000	3.10	3.10	63	SWITCH,INTERLOCK,SPDT,250VAC,10A	75	138	No assembly delay possible	None
300893-002	16.000	27.25	436.00	49	COUPLING,8 PORT MALE KYNAR	89	138	Supplier lead time reduced from 49 to 42 days, no assembly delay possible	Supplier Lead time Reduction
300893-002	2.000	27.25	54.50	49	COUPLING,8 PORT MALE KYNAR	89	138	Supplier lead time reduced from 49 to 42 days, no assembly delay possible	Supplier Lead time Reduction
300897-002	16.000	27.25	436.00	49	COUPLING,8 PORT FEMALE KYNAR	89	138	Supplier lead time reduced from 49 to 42 days, no assembly delay possible	Supplier Lead time Reduction
300897-002	2.000	27.25	54.50	49	COUPLING,8 PORT FEMALE KYNAR	89	138	Supplier lead time reduced from 49 to 42 days, no assembly delay possible	Supplier Lead time Reduction
311493-001	1.000	2,985.95	2,985.95	70	RGLTR,TEFLON,1 ORF,SLAVE,3/4 FTF	68	138	Engineering specified - no suitable substitutes available.	None
311584-204	1.000	569.09	569.09	70	REG,PNEU,PFA,1/4 ORIFICE	68	138	No assembly delay possible	None
314136-002	1.000	351.00	351.00	49	CONVERTER,POWER,DC TO DC	89	138	Resources not available for 3 months to support alternate source	None
423820-012	1.000	14.08	14.08	49	GASKET,EMI/RFI,MODIFIED,23.50,4HOLE	89	138	No assembly delay possible	None
423820-014	1.000	8.64	8.64	49	GASKET,EMI/RFI,MODIFIED,12.67,2HOLE	89	138	No assembly delay possible	None
423820-016	2.000	6.72	13.44	49	GASKET,EMI/RFI,MODIFIED,6.63,1HOLE	89	138	No assembly delay possible	None
922364-001	1.000	40.81	40.81	42	KIT,WIRE,ELEC I/O PNL,BACK,FDM,ZFE/BE	94	136	No assembly delay possible	None
922767-002	1.000	46.05	46.05	42	KIT,WIRE,ELEC I/O PANEL,LEFT,FDM,ZFE/BE	94	136	No assembly delay possible	None
923293-001	1.000	46.80	46.80	42	ASSY,CABLE,SIGNAL,W1279-1,ZFE/BE	94	136	No assembly delay possible	None
923293-002	1.000	47.20	47.20	42	ASSY,CABLE,SIGNAL,W1280-1,ZFE/BE	94	136	No assembly delay possible	None
923293-003	1.000	46.74	46.74	42	ASSY,CABLE,SIGNAL,W1287-1,ZFE/BE	94	136	No assembly delay possible	None

Table G

Common Configuration Determination

The result of this evaluation was the determination of a common configuration which could be forecasted, assembled, checked out and shipped if a matching customer configuration was identified. If a non matching customer configuration was identified the tool could be quickly reconfigured and prepared for shipment. Common components which were identified as part of the configuration included a process module, fluid delivery module, material handling module and canister consoles which are capable of meeting Company XYZ customer's 300mm processing requirements. This tactic was successful as it provided company XYZ the ability to delay the inventory investment of the configurable items needed to meet individual customer requirements from 136 to 84 days. Delaying the inventory investment provided Company XYZ with the ability to use the cash saved from the delay for other company business needs.

Overall this tactic fell short of providing an improvement in tool lead time but provided Company XYZ with additional time to identify a customer and gather required tool configuration information. The tactic fell short of providing the preferred results because:

1. The ability to invest in inventory required to reconfigure the common configuration to a specific customer configuration was not included.
2. The amount of time to reconfigure and re-checkout a tool was determined to be 34 days. This length of time was longer than desired by the team.

Generic Tool Build and Reconfiguration

Comparison of the baseline tool to the three configuration scenarios provided Company XYZ with three possible generic configurations which were practical to build. The team concluded that using the generic configuration for Process of Record A provided the most benefit to the company. This was based on the data collected and justified due to:

1. The up-front cost of components to build the tool was $942,000 compared to as much as $982,000 for the other three options.
2. The calendar time to reconfigure the tool was 17 days compared to as many as 34 days for the other configurations.
3. The total material cost of $902,000 was the smallest of the configurations which were compared.
4. The final comparison of the process of record configurations to the baseline generic configuration identified the cost/benefits shown in Table H.

Process of Record Configuration Cost Benefits

Process of Record	Change Percentage from Generic Configuration to Process of Record	Generic Configuration Cost Adders	Reconfiguration Time	Configurable Inventory Cost(cummulative)
A	61%	$15,000	17 Days	$33,000
B	33%	$0	33 Days maximum	$283,000
C	6%	$0	33 Days maximum	$333,000

Table H

The data shows the percentage of the time the minimum cost additions, reconfiguration time and the cost to support the reconfiguration to the processes of record. The information indicates a Process of Record A tool configuration was required 61% of the time. Process of Record A configurations also require the least amount of reconfiguration time (17 days) and the smallest amount of configurable inventory investment ($33,000). Based on this a Process of Record A configuration is the best match to improve lead time.

The reduction in reconfiguration time provided by the Process of Record A configuration was determined. The reconfiguration process assumed parts were in Company XYZ inventory or readily available within a day from supplier stock. The results of the investigation indicated that a reduction in reconfiguration time from a baseline of 34 to 17 days was possible. The reductions consisted of reducing ECO processing time from two days to one day, reducing production order processing time from three days to one day, and eliminating planning for customer source inspection in the manufacturing schedule. Customer source inspections are performed on less than 15 percent of the tools. Customer source inspections require the manufacturing schedule to be extended by two days. Based on this data, planning for no customer source inspection became the default process and eliminated two days from the reconfiguration process. The remaining twelve days were the result of a five day reduction in tool reconfiguration time, a six day reduction in re-checkout time and 1 day reduction in tool disassembly time.

Chapter V: Discussion

Conclusion

Reduction of Company XYZ tool lead time cannot be limited to the use of simple traditional manufacturing and procurement lead time techniques. This is evidenced by the evaluation and resulting reduction of routing times. Although a reduction in routing time was realized it did not play a role in reducing company XYZ tool lead time due to shop floor scheduling being done by manufacturing lead time. The routing savings contributed to a reduction in tool cost which dropped directly to the bottom line and improved the selling margin of the tool. Consideration should be given to planning tool manufacturing schedules using lead times. Scheduling the shop floor using lead time provides the ability to use MRP to determine tool shipment schedules with greater accuracy but requires more resource effort to maintain than scheduling by lead time. This is likely insignificant as the results of this study indicate the shop floor scheduling system provides necessary data to evaluate lead time improvements but does not play a vital role in achieving lead time reduction results

It is an advantage for a company to include and leverage its supply chain in cycle reduction processes. Reduction in component part lead time can lead directly to reduction in tool lead time. Control over lead time and throughput is more difficult when products are made of high quantities of components and components are purchased from outsource suppliers. Tool lead time is influenced by many factors. Proprietary engineering designs and specifications can limit lead time reduction activities with out the ability to invest in component inventory.

A significant reduction in tool lead time requires leveraging the supply chain as well as the willingness to invest inventory dollars in component parts to meet customer configuration requirements. The reduction of tool lead time required a generic tool configuration which can be assembled, checked out and quickly changed. A generic configuration which provides the shortest reconfiguration and re-checkout time provided Company XYZ with the greatest ability to reduce tool lead time.

Recommendation

The researcher recommends the results from this study be used to reduce Company XYZ tool lead time for the tool being used as the basis for this study. The researcher also recommends developing additional generic tool build models for other Company XYZ products based on the commercial need and willingness to invest significant inventory dollars to meet customer lead time requirements. The researcher recommends continued pursuit of lead time reduction through other lean initiatives.

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