Implementing Internal Supply Chain Improvements

by
Michael E. Carnette

Submitted to the Departments of
Mechanical Engineering and Management
in Partial Fulfillment of the Requirements for the Degrees of

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Abstract

This thesis describes the implementation of specific improvements to the material and information flow between a supplier and customer. The guidelines were developed based on the implementation of a pilot program with an internal supply chain of an electro-mechanical product manufacturer (the supplier and customer were separate divisions of the same company). Results of the pilot program included:

- Combined supplier customer inventory turns went from 2 turns/ year to 4 turns/year
- Employee effort in managing supply chain reduced by 13 hours/week (650 hours/ year)
- Customer satisfaction improved

Underlying principles of production system design (pull systems vs. push systems) and inventory management are discussed with respect to supply chain performance. The kaizen principle of eliminating all unnecessary work is also utilized. These principles must be well understood by any company attempting to redesign its supply chain.

Detailed instructions for designing, evaluating, and implementing a supply chain improvement program similar to the pilot program are given. The instructions are based on the underlying supply chain principles and the author's real-life experiences at the company. Detailed worksheet/checklists are provided to aide the reader in designing and starting a similar program.

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1. Introduction

Many companies and industries have begun to view supply chain management and logistics as new strategic weapons. They realize that proper design of material and information flows can add customer value and reduce production costs to create a competitive advantage. However, while companies want to improve their supply chain performance, they have had only moderate success. One reason is that the research literature advocating new techniques is not well suited to the industrial customers. Common complaints are that the literature is too academic (long, complex, and idealized) and that there are not enough practical guidelines to aid in implementation.

This thesis focuses on the author's experiences in implementing a supply chain improvement program at a manufacturing company. The improvements involved principles of inventory management, production system design (pull vs. push production), and kaizen (waste reduction). This paper's purpose is to provide:

1. a description of the pilot program and the results it achieved;
2. a practical discussion of production system design and inventory management in a supply chain to help the reader determine if improvement processes similar to the pilot program may be valuable in her own situation; and
3. easy-to-follow instructions to aid in design and implementation of a system similar to the pilot program (if the reader decides to pursue such a program).

1.1 Motivation

This thesis is based on a pilot program designed and implemented between supplier and customer divisions of a single company: an "internal supply chain". Frequent complaints (from the supplier and customer) about the original relationship included:

- High inventory
- Wrong inventory (shortages of some item, and simultaneous surpluses of others)
- Poor delivery performance (deliveries not on schedule)
- Low customer satisfaction

- Long lead times ("advance warning" customer must provide to get parts on a given day)
- High costs (in time) for managing the relationship
- No quality plan for customer found defects

The research internship goal was to have a working pilot which successfully attacks these problems. This goal implies performance requirements:

- Improved inventory performance (less total inventory)
- Improved delivery performance (fewer stockouts)
- Shorter lead times for getting parts from the supplier
- Increased overall company profitability from lower total system costs (reduced costs for managing supplier/ customer relationship)
- Improved quality (less defects found by customers)

The pilot program described in this paper was developed as an attempt to achieve these goals.

1.2 Scope

As stated above, the pilot program dealt with part of an internal supply chain: the supplier and customer involved were part of one company. Significant improvements in overall supply chain performance (cost reduction and improved customer satisfaction) were obtained by redesigning the processes linking these internal departments. Most logistics and supply chain management work has focused on interactions between independent companies. The principles applied in the internal pilot can be directly applied with external suppliers and customers if a cooperative relationship exists.

The pilot program and this thesis deal with analysis and redesign of the processes that link the supplier and the customer (information and material flow between the two). Redesign of the supplier's and customer's internal processes was beyond the scope of the research. These internal processes are very important, but several factors made work in these areas impractical for the research internship. Even greater overall system improvement can be expected if both linkage processes and internal processes are considered for redesign.

1.3 Thesis Overview

Chapter 2 describes the original situation before the pilot program. It gives an overview of the entire company, then describes the specific supplier and customer involved in the pilot. This chapter is included to provide an example and a means of comparison for readers: if the relationship described looks familiar, there may be opportunities to apply some of the principles from this thesis.

Chapter 3 shows the new supplier-customer relationship of the pilot program. This chapter also gives the specific qualitative and quantitative results obtained. A comparison of chapters 2 and 3 shows that relatively minor changes in the supply chain can produce significant performance improvements. The final section of chapter 3 briefly describes the basic theories applied in designing the pilot program. These are production system design (pull vs. push systems), supply chain inventory management, and kaizen (waste elimination). Understanding these principles is essential to successfully implementing a supply chain redesign.

Chapter 4 covers the implementation process. Understanding the basic principles is necessary, but that is useless without action. This chapter gives a set of guidelines to aid in implementation of a program similar to the one implemented as part of the research internship. It tells how to design a new system, determine probable results of the redesign (to determine if it will be worth doing), and get the system up and running. Appendices A and B are detailed "implementation checklists" which covers the material in chapter 4 and may be used to assist the reader in implementation.

Chapter 5 covers key accomplishments and learnings from the research internship. It also includes suggestions for further improvements to the program described in this thesis.

2. Original Situation

This chapter briefly describes the entire company, the specific supplier and customer involved in the pilot project, and the original processes they used to interact with each other.

2.1 Company, Customer, and Supplier

Relevant parts of the company structure are shown in Figure 2-1. The company produces a wide variety of electro-mechanical products. There are 9 Lines Of Business (LOBs). LOBs are product-based manufacturing business units. Different LOBs make finished products such as photocopiers, health imaging equipment (CAT scans, etc.), photo developing equipment, and digital imaging equipment.

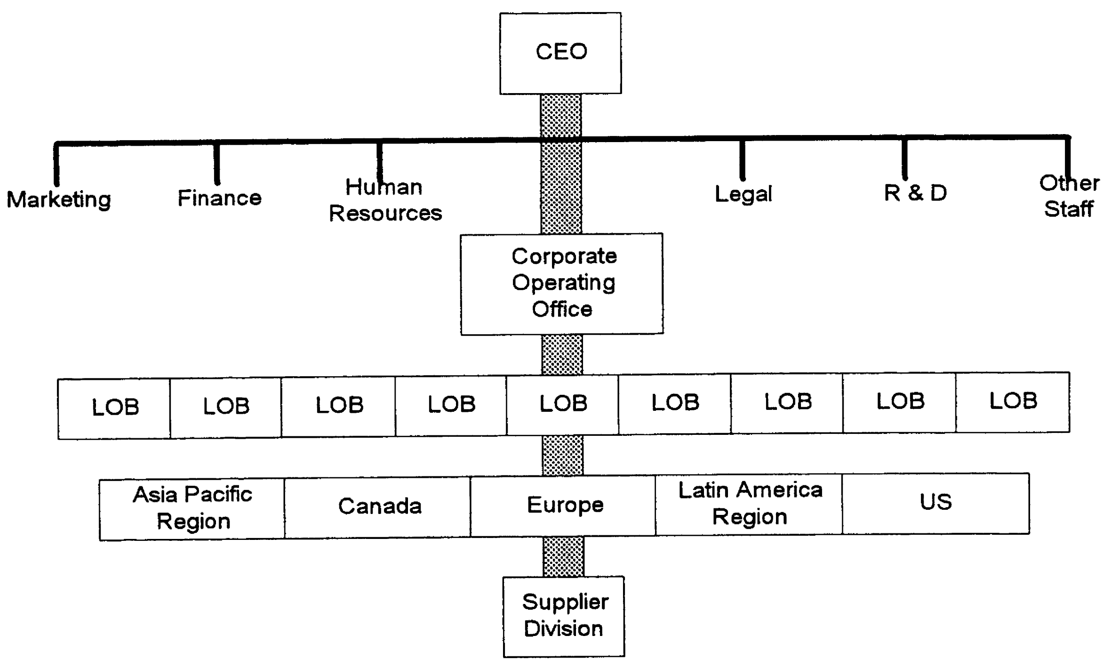


Figure 2-1 Organization chart for the entire company

The LOBs obtain many of their subassemblies from an internal supplier division. The supplier division is a cost center that sells mechanical, electrical, and optical assemblies to the LOBs at cost.

The department of the supplier division that participated in the pilot program builds circuit boards for the different LOBs. From this supplier's viewpoint there are about 50 customers (several customers in each LOB). The supplier is responsible for building the boards and repairing any defective boards that the customers find during final product assembly (100% supplier testing has been determined to be too expensive). This is a high mix/low volume job shop. There are about 250 active part numbers which vary greatly in size (from 15 in.^{2} to over 200 in.^{2}), complexity (from about 10 components to more than 1000 components), and volume (from 10 boards/year to 9,000 boards/year). Total annual volume is 60,000 boards/year.

Set-up times to run different circuit boards are significant (1-2 hours), so the supplier runs boards in average lot sizes of at least 100. Cycle time (time from start of a job to when it is ready to ship) for a job is around 12 days. The supplier works two 8 hour shifts 5 days per week. Saturday overtime is common.

The specific customer involved in the pilot makes high-end electronic devices. They make about 15 different types total, but use only 5 different circuit boards from the supplier. Volumes for the different boards range from 1000 to 3000 boards/year (average usage is 20 to 60 boards/week). These 5 boards account for about 10% of the supplier's total business. Each board costs roughly $1000. The customer generally builds devices in batches of 10. Cycle time for a batch of 10 is 2 to 3 days. The customer works one 8 hour shift, 5 days per week with extensive overtime. The customer and supplier are located in the same complex. They are a 10 minute walk (less than 5 minutes by cart) from each other.

The customer's assembly operations are mostly manual. It is very easy to change production from one device (and one type of board) to another. As a result, customer demand for a specific board is volatile and unpredictable. For example, if a part shortage prevents production of one model, the customer can shift production to a different model instantly, completely changing their short term circuit board needs. Engineering design changes are also a common occurrence. When board designs are changed all of the current boards are sent back to the supplier to be updated.

2.2 Original Interaction Processes

Supplier and customer interactions can be grouped into two major functions: board production and delivery, and return and repair of customer-found defective boards. These are described below.

2.2.1 Board production and delivery

Figure 2-2 is a simplified schematic of the board production and delivery process. The numbers in the following explanation correspond to the figure.

The marketing department uses information from the end users to create demand forecasts (1) for the various final products. These item level forecasts are collected by a master scheduler and aggregated into monthly buckets in a master production schedule (2). The master planner breaks this production schedule down into a weekly shop floor production plan (3) that will meet the forecasted needs. This production plan is input into the customer's MRP system. The master planner also creates the work orders which control production (4). The material flow analyst (essentially a buyer) uses the MRP system to monitor the production plan and the inventory level. When needed, the material flow analyst creates production purchase orders (POs) to get more materials from the suppliers. Production POs are cut for the standard supplier lot sizes and must be cut more than 250 days in advance because of the supplier's long lead time (time from receiving an order to when the order is delivered). The supplier's lead times are so long because purchasing electrical components from its suppliers can take more than 200 days.

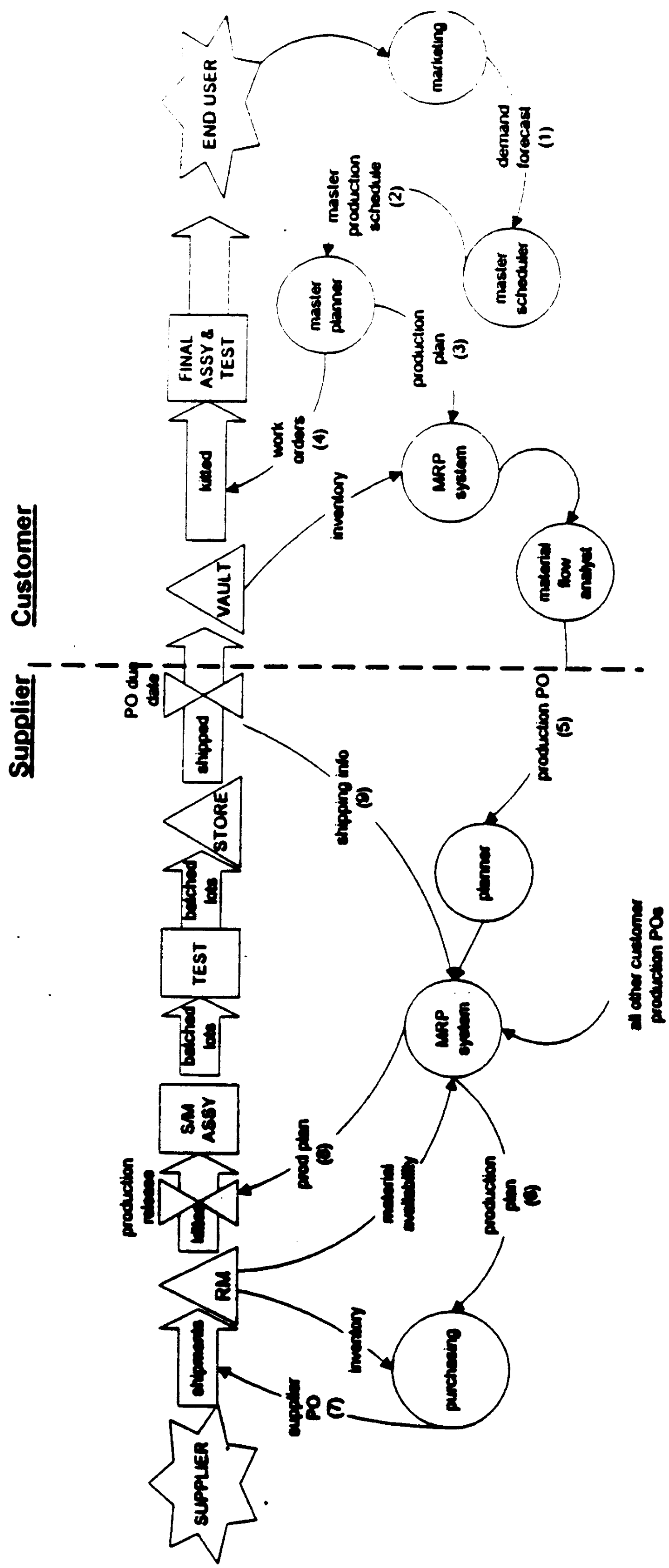


Figure 2-2 Original Board Production and Delivery Process

The paper PO is mailed to the supplier via internal mail (5). Here the supplier's planner enters the PO into the supplier's MRP system (the customer's and supplier's systems do not communicate automatically). The MRP system aggregates all of the individual customer POs into a production plan (6). If there is not enough raw material to meet the production plan requirements over the procurement lead time, the purchasing department issues POs for shipments from suppliers (7). The MRP system controls the supplier's production, also. Given that material is available, the system uses the production plan to coordinate the release of work to the floor(8).

This entire planning and re-planning cycle is performed weekly. Every week the customer develops a new production plan based on new market information and last week's production performance. The material flow analyst and supplier planner meet weekly to determine if the customer's new plan affects the supplier's plan. Changes to the supplier's plan for the next 3 months are supposedly not allowed. However the customer often needs to get more parts sooner than it suspected. "Heroic efforts" by the planner to circumvent the system and expedite orders to satisfy the customer are undertaken. These are sometimes successful, but they are expensive, frustrate the supplier and the customer, and usually result in the supplier missing a delivery to another customer. Whenever the customer realizes it does not need the parts it initially ordered, the schedules do not change. The customer lets the supplier make and ship the parts early, producing excess inventory.

Figure 2-2 also shows the actual material flow. The MRP system uses the production plan to coordinate releases of jobs to production. Once a job is released, it is kitted, assembled, tested, and packed. Boards are batched between each of these steps (e.g. all boards are assembled before any are tested). Average cycle time from release of a job to completion (storage) is around 12 days.

As a rule, the supplier attempts to store minimal finished goods inventory. Boards are only stored until a day or two before the PO due date, then the entire PO quantity is shipped to the customer. Boards often go straight from test to shipping because they are completed on or even after the PO due date. Since the delivery date and quantity were determined 6 months ago when the PO was created, renegotiations to pull in or push out delivery dates are common. The supplier can not generally meet these unexpected changes because it does not hold inventory of finished boards.

Shipping signifies a change of board ownership. The supplier removes the boards from its inventory in the MRP system (9). The customer receives the boards and inputs them into its MRP system with a status of "available for production". After the customer receives the boards, they are stored in a vault. This is the primary circuit board storage location. Boards stay here until a work order to assemble the final product is released. Then vault workers kit all components for the build (work orders are usually in quantities of 10 or 20) and release the kit to assembly. Assemblers build and test the final product. Once the entire order is completed, it is shipped to a distribution center and finally to the end user.

2.2.2 Repair of defective boards

Defective boards are routinely found at the customer site (roughly 1-5% of shipments are defective). Figure 2-3 shows the material and information flow that occur during the return and repair of these boards. The numbering in the figure corresponds to the numbers in the following explanation.

Assemblers at the customer site are usually the ones to first identify a suspected defective circuit board. If their initial diagnostics show that the board appears to be at fault, the assemblers disassemble the final product, create an electronic problem report describing the failure in the customer's quality tracking system (10), return the suspected defective board to the vault (11), get a new board, and return to work. Material handlers in the vault change the board's status to "awaiting engineering disposition" in the MRP system (12). They then hold the suspect boards pending evaluation by a design engineer in the customer's organization.

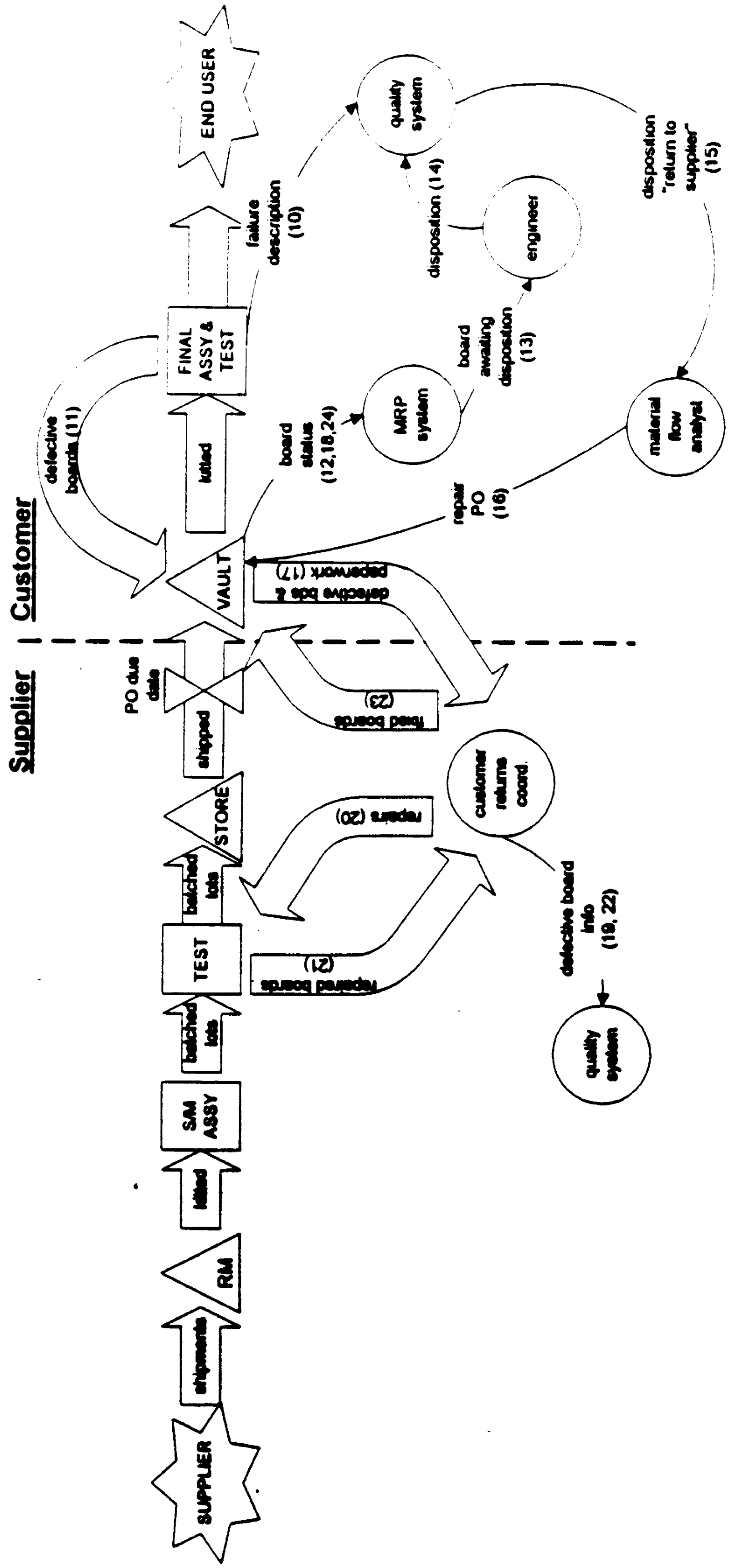


Figure 2-3 Original Board Return and Repair Process

Once the engineer sees the electronic problem report in the system (13), she goes to the vault, evaluates the board, and adds a disposition to the electronic record (14). The board can be dispositioned to be used as-is, repaired by the customer, scrapped, or returned to the supplier for evaluation and repair. Over 95% of the boards are dispositioned to be returned to the supplier. When the material flow analyst sees the disposition for return to the supplier (15), he creates a repair PO (16). The repair PO specifies the quantity of boards to be returned to the supplier and the date when they are expected to be repaired and delivered back to the customer (usually 2 weeks later). The paper repair PO is given to the vault workers who pack and ship the board, the PO, and a print out of the electronic problem report to the supplier (17). The vault worker also changes the board's status from "available" to "unavailable- being repaired by customer" in the MRP system (18). The boards remain part of the customer's inventory, but they are not available for production.

The supplier has a customer returns coordinator who handles the defective boards. She logs the boards into the supplier's quality tracking system (19). The customer's and supplier's quality systems do not communicate. Information such as quantity, part number, and date received are entered, but specific information about the customer found defect is not. The boards are not added to the supplier's MRP system because they are still owned by the customer. Returned boards are tested with the same production tests as first run boards (20). The returns coordinator works with the production testing department to schedule the boards in for testing. If the tests pinpoint the defect, the boards are repaired (and retested to make sure that they are fixed). Boards which do not fail the production tests are called "cannot repeats" or CNRs. Repaired boards and first-time CNRs are returned to the customer returns coordinator (21) who inputs the defect data (component specific failure or CNR) into the quality tracking system (22). Second-time CNRs (boards which were returned previously , were CNRs, went back to the customer, and were returned again) are routed to technicians for more in-depth analysis. Second-time CNRs are not shown in Figure 2-3. Repaired boards are packed and returned to the customer's vault (23). The vault workers change the board's status back to available (24) and store the boards until they are needed. If boards can not be repaired by the PO due date, the customer returns coordinator and the material flow analyst renegotiate due dates.

Engineering changes and field returns are two other product flows that have not been explicitly included in Figure 2-3. When the customer redesigns a board, they send all of their inventory back to the supplier to be updated. Boards from any field failures are also returned to the board supplier for analysis. Both engineering changes and field returns follow the same procedure described above except there may be an additional procurement step if parts must be purchased to complete the update.

2.3 Improvement Opportunities

The customer and supplier both saw opportunities to improve the current system. The major areas of current dissatisfaction are identified below.

Supplier production responsiveness. Because of long procurement times for electronic components, the supplier needs purchase orders to be cut at least 6 months before the delivery date. However, the customer's needs can change significantly over one month. It is difficult for the supplier to meet those quickly changing needs. Sudden changes in customer needs often caused the customer to be starved or the supplier to perform heroic efforts to meet the customer demand. Long procurement lead times for components are a fact of life, but both parties wondered if there was still any way to improve responsiveness.

Inventory. Both customer and supplier felt that finished board inventory levels were too high. But while the overall inventory was high, there were still instances of shortages for specific items. One of the largest costs for the high inventory was updating to new engineering changes. Often this is the only time the supplier learns how much inventory the customer holds. This leaves them asking "why did we make so many of those boards just to have them sitting around and then have to come back for updates?"

Effort to manage current system. The customer and supplier both want the same thing: a cheap, easy way to make sure that the customer has the right circuit boards at the right time to fill its orders. They felt the current system was not meeting those goals. The current system required a great deal of effort to manage metrics that did not affect the goal of supplying the right boards at the right time.

Board repair cycle time. The entire board repair process from identification of a defective board to return of the repaired board to the customer often took over one month to complete. During this time the defective boards are in the customer's MRP system but unavailable for production. This caused planning problems for the customer, believing they had enough inventory when they actually did not. There was a great deal of frustration and dissatisfaction with the long cycle times for repairs. Both supplier and customer wondered if it had to be so long.

Board quality improvement plans. The customer and supplier felt there was no quality plan for eliminating defects. The information collected in the board repair process was not being used effectively to prioritize quality issues and attack the biggest problems.

Corporate improvement goals. Like the rest of the company, the supplier and customer have a mandate from the CEO mandate for "10x improvements" in total cost, quality, and cycle time every 3 years. For example, if a board now has 5% defects, costs $1000, and has a 15 day cycle time, in 3 years the board should have 0.5% defects, cost $100, and have a 1.5 day cycle time. The customer and supplier know that they will have to completely change their current way of doing business if they are to meet these aggressive goals.

3. Pilot Project

The pilot project was developed with the opportunities for improvement of the original processes in mind (see section 2.3 for shortcomings of the original processes). The supplier and customer wanted to increase the supplier's responsiveness and flexibility to the customer's needs. At the same time they wanted to decrease the total amount of inventory in the system and decrease the effort required to make the system work. The board repair process was another source of frustration because of the long time needed to repair a board and the lack of good information flow for corrective actions. This chapter describes the mechanics of the pilot project, the results it achieved relative to some of the opportunities for improvement, and the principles or philosophy used to design the pilot.

This chapter has three sections. The first section of this chapter describes the new processes and compares them to the original ones. Some aspects of the material and information flows are unchanged from the original as described in chapter 2; these parts will not be described in detail again in this chapter. The next section of this chapter describes results obtained by the pilot by December 1995 (the pilot was in place and running by October 1995). The last section covers the basic principles or philosophy which the pilot embodied. This section discusses the motivation for implementing the new processes as a way to address the opportunities for improvement which were identified above. It is important to understand these principles when designing a similar system.

3.1 New Interaction Processes

The new processes for board production and delivery and for board return and repair are described in the sub-sections below. Three major changes were implemented. These are briefly discussed below before the processes are described in more depth.

1. The supplier knows the finished board inventory and uses it to plan its own production. Instead of getting POs, which tell the supplier exactly how much it must ship and when with no regard to current inventory levels, the supplier gets a forecast of the customer's needs. A target amount of buffer inventory above the customer's

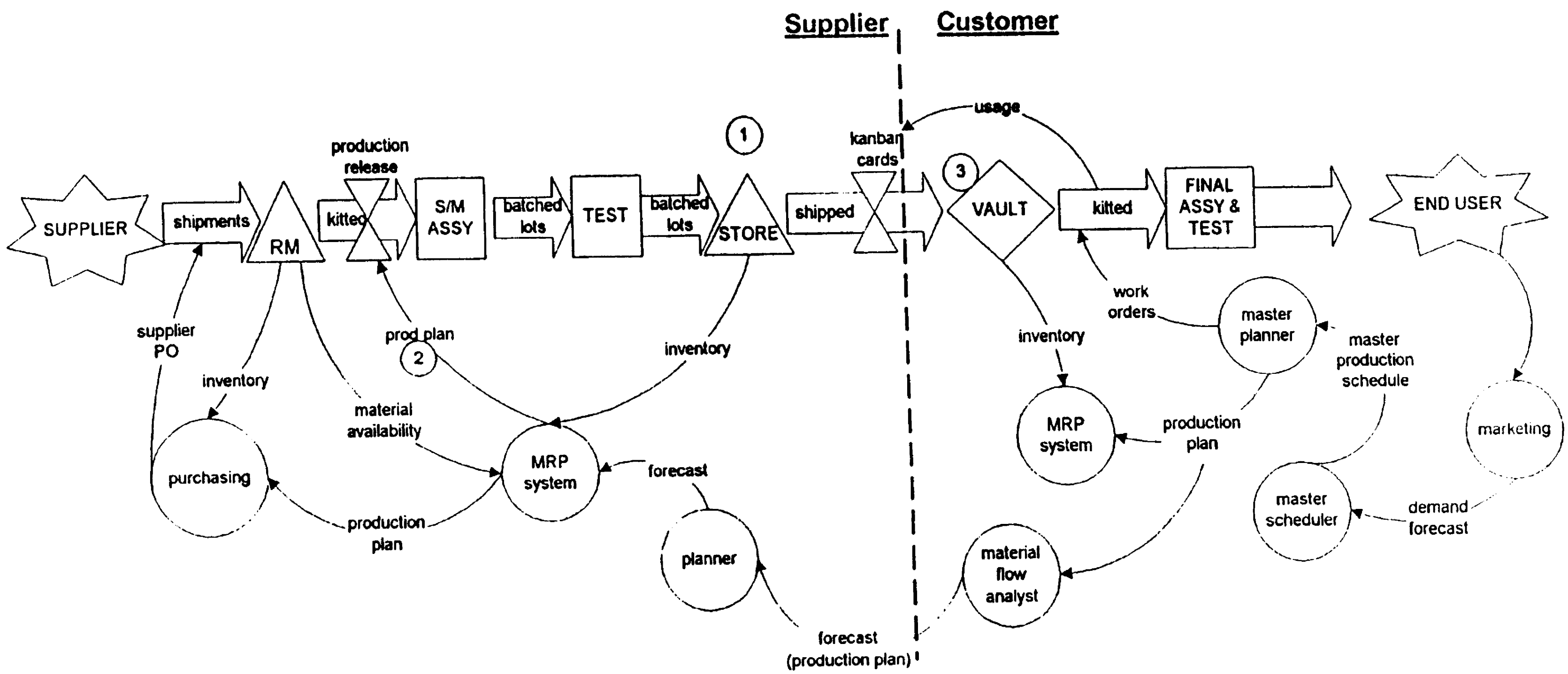
forecasted needs is calculated and held to compensate for errors in the forecast. The supplier uses the customer forecast, the current amount of inventory in the system, and the desired buffer above the forecast to plan its production as it sees fit. Essentially, the supplier's production plan is the customer forecast (customer's production plan) plus the difference between the actual buffer inventory and the target buffer inventory. The extra inventory allows the supplier to be more responsive to the customer's changing needs (especially when the customer needs more parts). But because the supplier now knows the finished board inventory, has a target inventory level, and considers the inventory when planning production, inventory is better controlled and total amount of inventory in the system has decreased.

2. The supplier delivers boards to the customer on a kanban system. Instead of shipping on a PO due date, the supplier ships to the customer daily. The amount shipped is only as much as the customer used the day before. This kanban system limits the customer's inventory to a known quantity, a Standardized Work In Process (SWIP) level, in the vault. This allows the supplier to know how much inventory is in the customer system and to better plan its production.
3. The supplier performs a "1 for 1" swap of good boards for customer-found defective boards. When the customer finds a defect, the supplier provides them with a good board to replace the bad one in a matter of days (originally the board was bad and in the customer's inventory for a month or longer). With this system the customer's inventory of defective boards is eliminated, and the supplier gets defective boards back quicker. This faster feedback should assist in defect identification, and ultimately in defect prevention.

3.1.1 Board production and delivery

Figure 3-1 shows the new material and information flow for board production and delivery. Marketing, the master scheduler, and the master planner still perform the same functions, but the customer material flow analyst now transfers the production plan directly to the supplier's planner as a forecast of future needs. Discrete production POs authorizing shipments for a given quantity on a given date have been deleted. A "blanket PO" authorizing shipment of any amount for the entire year has been instituted. The production plan forecast always has a horizon of at least one year. Currently the forecast is transferred on paper and input into the supplier MRP system manually, but work is underway to install an automatic EDI feed to link the two systems.

The supplier's MRP system now creates a production plan based on the unfiltered customer needs and the supplier's current finished goods inventory level. (Originally the supplier system aggregated all incoming customer POs to make a production plan.) The



Notes:

(1) Target buffer quantity in supplier store is based on historical data of error in forecasts.

(2) Supplier production plan ~ customer forecast + (target buffer size - on hand inventory)

(3) Customer inventory is controlled as Standardized Work In Process (SWIP)

Figure 3-1 New Board Production and Delivery Process bulk of the circuit board inventory is now stored with the supplier so that it can be considered when making the production plan. (There was no way for the supplier's MRP system to know the board inventory in the customer's MRP system.) The customer and supplier use historical data to determine a target amount of buffer inventory that should be held above and beyond the customer's forecasted needs. This target amount is used to compensate for forecast error. (See the end of this chapter for a discussion of inventory policy. See chapter 4 for how to calculate the target buffer size.) The supplier MRP system sets a production plan that will meet the expected customer needs and maintain the target buffer size. Purchasing uses the aggregate production plan and current raw material inventory level to create supplier POs just as in the original system.

The supplier's internal assembly, test, and storage functions are unchanged. However, a kanban delivery system now determines shipments instead of the PO due date. As mentioned above, the supplier's site is now the primary circuit board storage location (so that the inventory can be considered in production planning). Boards are delivered to the customer daily; kanban cards are used to physically show the supplier how many boards to ship. The kanban cards allow shipments based on actual customer usage (a "pull system") instead of the outdated POs. They also act to control inventory at the customer site. See section 3.3 for discussions on pull systems and why controlling the customer inventory is important.

Figure 3-2 shows the kanban delivery process in more detail. Every day a shipper checks his kanban delivery board for cards (1), removes the correct number of boxes of boards (2) (each kanban card means 10 circuit boards) and attaches a kanban card to each box (3), and performs the MRP shipping functions to remove the boards from the supplier inventory (4). He then delivers the boxes of boards with the kanban cards attached to the customer's vault (5). While at the vault the shipper picks up any loose kanban cards on the customer's bulletin board (6) and takes them back to the supplier bulletin board. These cards will determine the delivery quantity tomorrow (7).

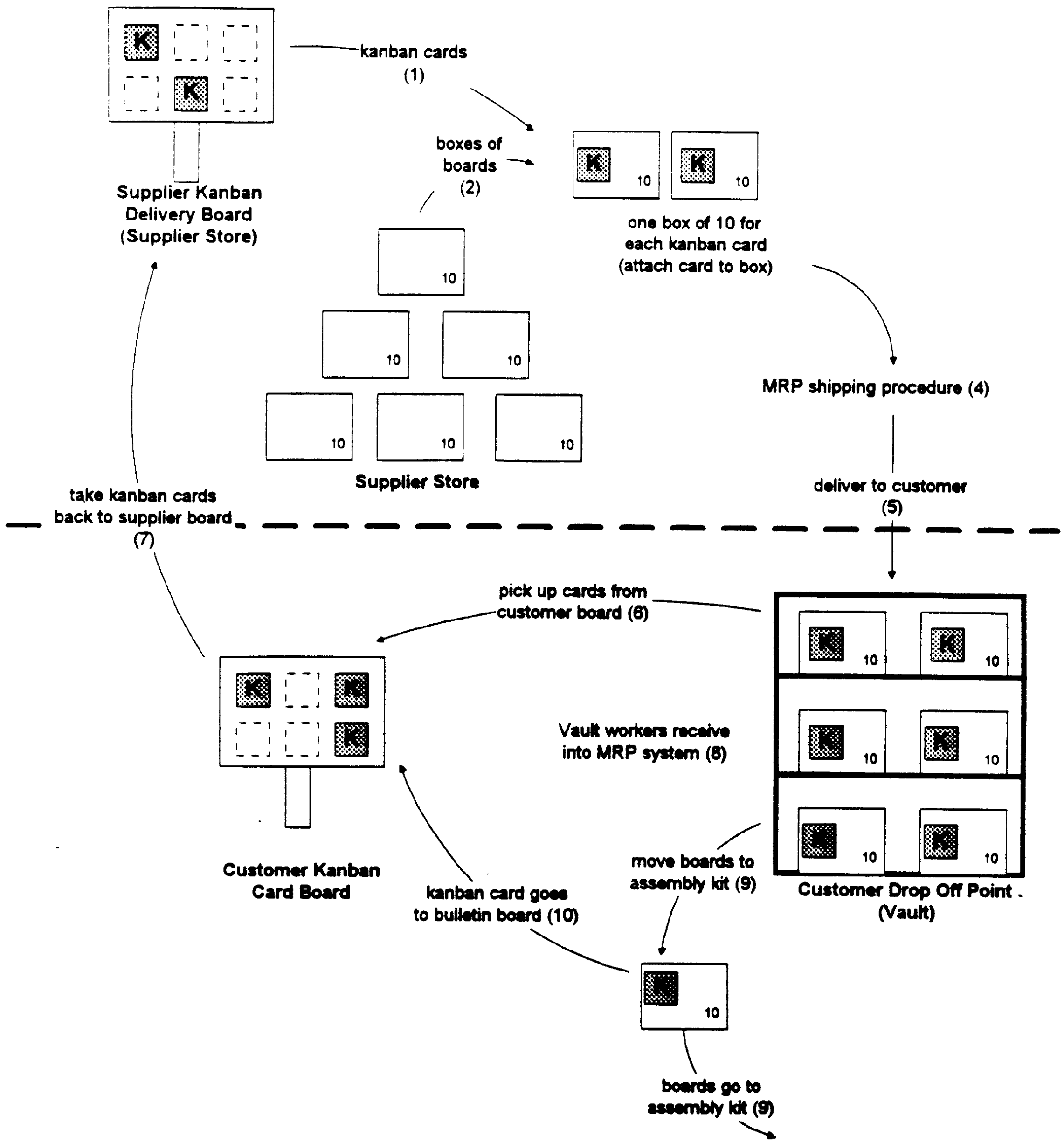


Figure 3-2 Detail of Kanban Delivery Process

The vault workers receive the boards and input them into the customer's MRP system to complete the ownership change (8). The boxes of boards are stored at the delivery drop off point with the kanban cards still attached. When the boards in a box are kitted to a work order (9), the kanban card is removed and placed on the customer's bulletin board (10) for pick up by the delivery person. Boxes of 10 boards are convenient because most work orders are in multiples of 10. One box is allowed to have less than 10 circuit boards. This "partial box" is clearly marked, and it is used for odd-sized work orders. When the partial box is empty, a normal box of 10 becomes the partial box, and that box's kanban card goes on the bulletin board.

The kitted boards go to assembly and test and to the end user in the same manner as described in chapter 2.

3.1.2 Return and repair of defective boards

The new repair procedure is shown in Figure 3-3. An exchange location in the customer assembly area is used to facilitate the return of defective boards. This exchange location includes a small buffer of good replacement boards (which are owned and maintained by the customer) and a spot for boards which are found defective. When an assembler finds a defective board, she creates an electronic problem report the same way as before (1), but then she places the bad board and a print out of the problem report in the defective spot (2). She then takes a good replacement board and returns to work (3). The exchange location for the pilot was a file cabinet by the assembly cells. The cabinet had separate boxes for each part number, and each box had one side for good replacement boards and another for defects. See Figure 3-4 for an example of the boxes used for the exchange locations.

The supplier delivery person who delivers the boards on the kanban system also checks the exchange location. Whenever there are defective boards, the delivery person makes a note of the quantity and part number. During the next delivery (the next day), the delivery person brings good boards from the supplier store (4) to replace the defective boards. The delivery person makes a "1 for 1" swap of good replacement boards for the defective boards (5). If there are more defectives than good ones to swap, the delivery person leaves the extra defective ones to be swapped in the next delivery.

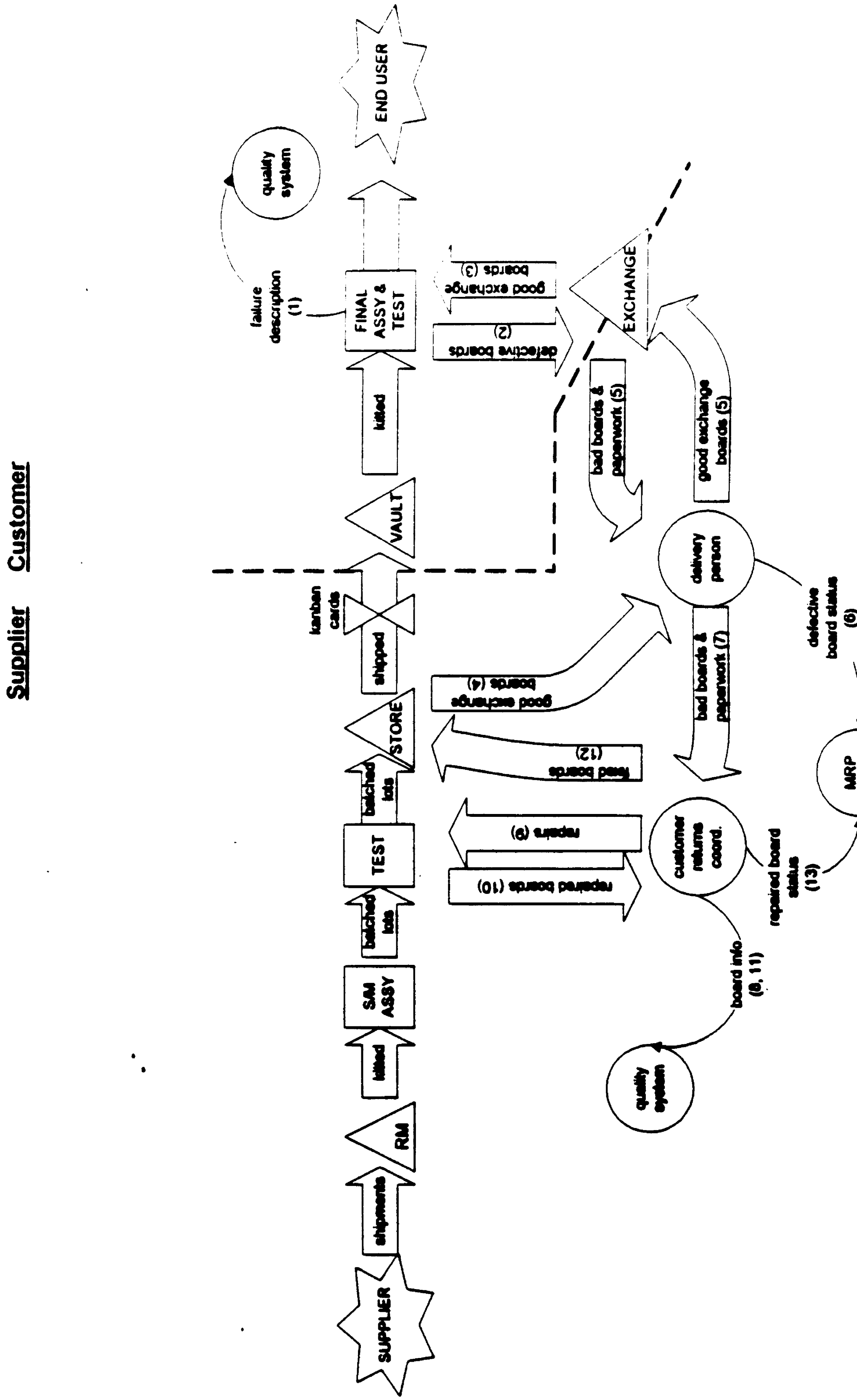


Figure 3-3 New Board Return and Repair Process

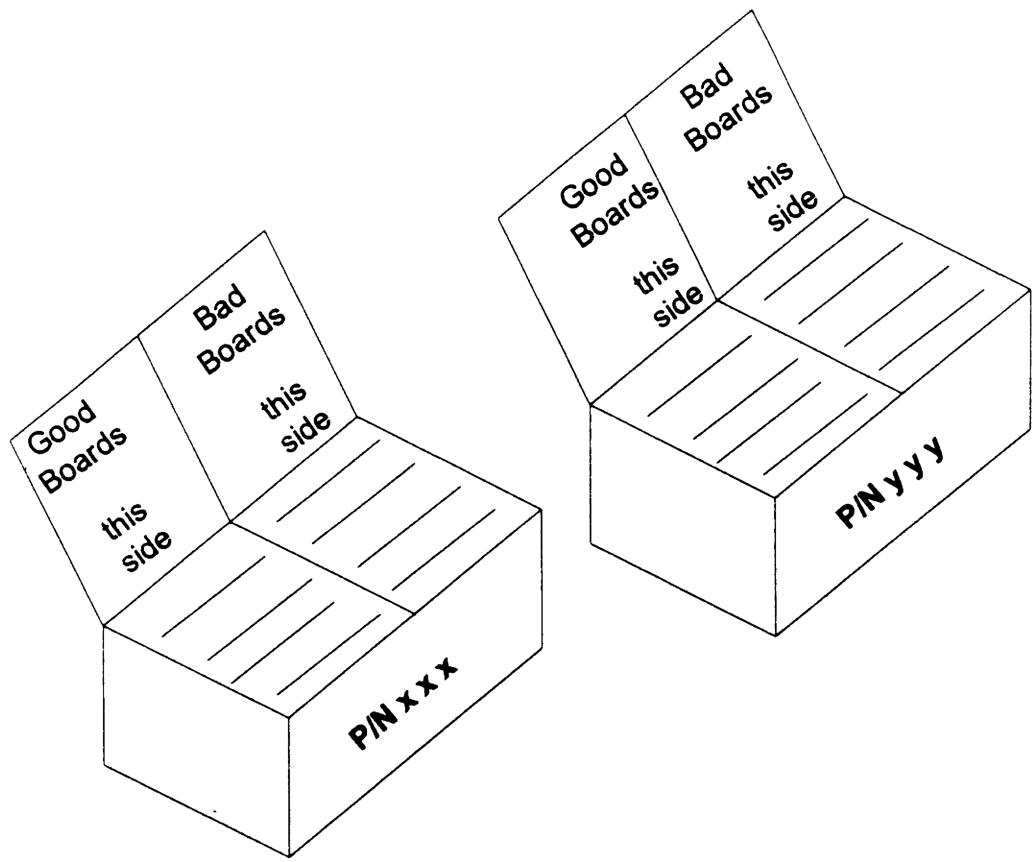


Figure 3-4 Examples of Exchange Location for New Return Process

Then the delivery person returns to the supplier with the defective boards and the print out of the problem report. He changes the status of the boards in the supplier MRP system. The boards are transferred from "available for shipments" to "on hold for repair" (6). This is because now the defective boards are owned by the supplier. The customer has received good replacements for the defects. Essentially, the customer's inventory is always good boards available for production.

After changing the boards' inventory status, the delivery person gives the boards to the customer returns coordinator (7). The original repair process as described in chapter 2 is followed: the board information is logged into the quality system (8), the boards are tested and repaired (9,10), and the repair information is input into the quality system (11). Once the repairs are completed, though, the boards are returned to the supplier store (12), and their status is returned to "available" (13). These boards may be shipped to the customer as part of the kanban deliveries or as replacements for customer found defects.

3.2 Results

Implementation of the pilot program started in August and was complete by October. By December some significant results had already been achieved.

3.2.1 Inventory reductions

Figure 3-5 shows inventory turns and total inventory (number of boards) for the internal supply chain. Inventory turns are calculated as an average of the previous month of shipments to the end customer converted to a yearly rate and divided by the combined supplier and customer inventory. Inventory data for August is incomplete (actual inventory was higher, meaning turns would be less), but the figure still shows an increase in inventory turns.

Figure 3-6 gives a more detailed look at supply chain inventory and shipments. Inventory is divided into 3 groups: supplier (assembly, test, and storage), customer vault, and customer WIP (assembly and test). Inventory data for the supplier and customer WIP in August were unavailable (but were non-zero). Shipments are average weekly shipments to end users over the last 4 weeks. This figure illustrates the program's effect in limiting the customer inventory in the vault. Also, total inventory has decreased while shipments have increased.

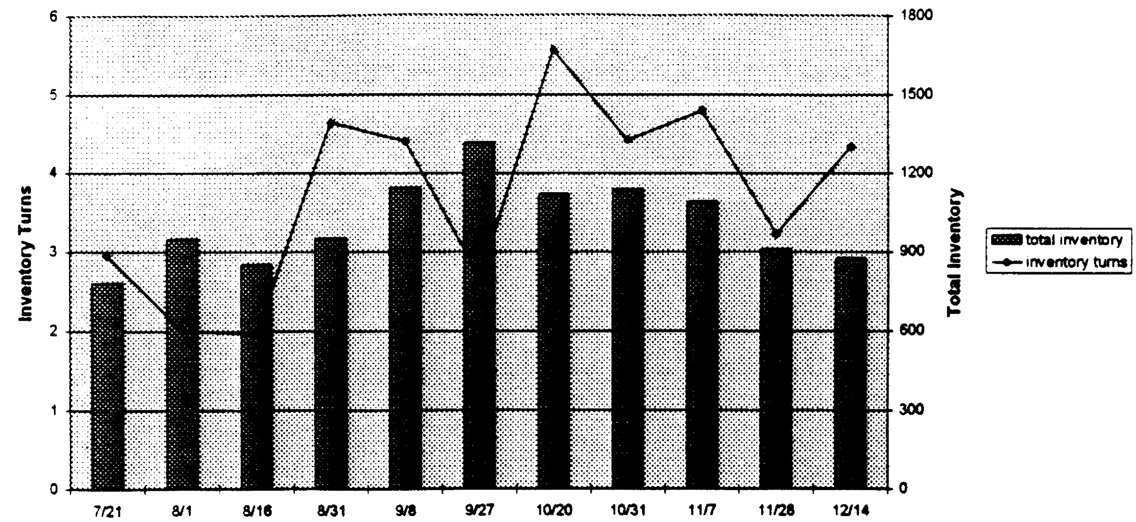


Figure 3-5 Pilot Program Total Inventory and Inventory Turns

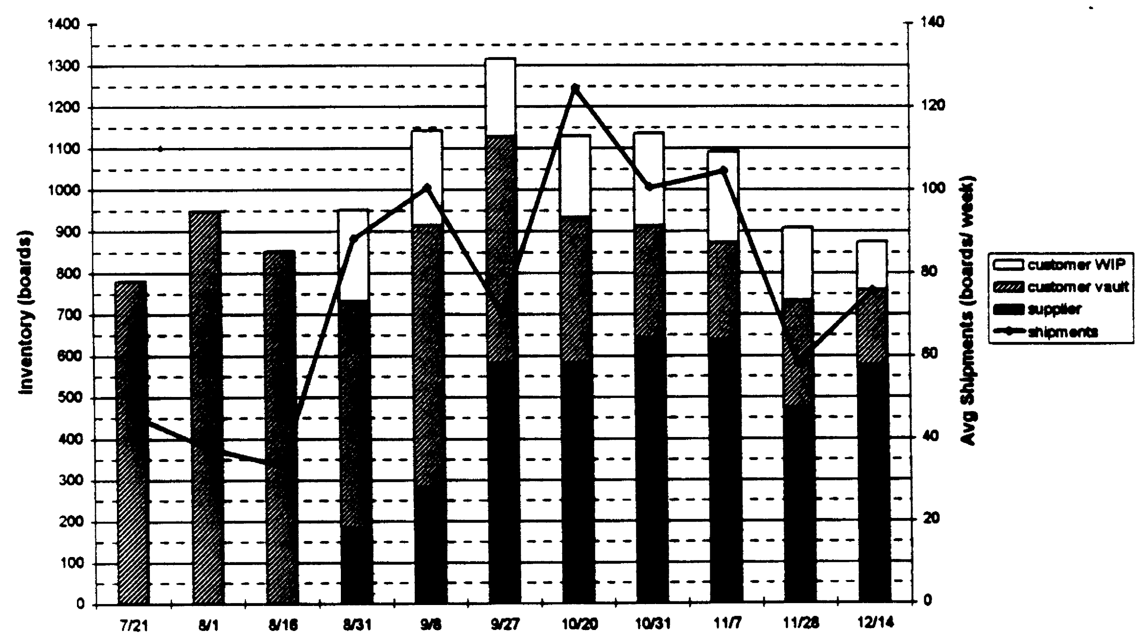


Figure 3-6 Pilot Program Inventory and Average Shipments

These results illustrate the effect of the supplier store target inventory level and the kanban delivery system. Both of these processes allow inventory to be controlled and specified by the supplier and customer. Without these controls, as shipments increased, inventory would have also increased. As other internal processes are improved (specifically customer forecast accuracy and supplier manufacturing cycle time) the supplier's target inventory can be reduced to produce even more inventory savings.

3.2.2 Cost and time savings

The workers responsible for the interaction processes (board delivery and return and repair) were interviewed in December, 2 months after the pilot started. They estimated actual decreases in the time required (a substitute measure for effort) to perform their functions as shown in Figure 3-7. The figure shows that elimination of production and repair POs, engineering disposition, renegotiations, and other non-value-adding activities reduced total workload 13 hours per week. Although less effort is being used for the processes, both customer and supplier indicate that service has improved. Boards have always been available when the customer needed them.

Using a burdened labor rate of $40/hour, the time savings translates into a savings of $26,000/year just for the pilot program (about 10% of the total supplier volume).

customer	time savings (hours/week)	who?	why?
	2:30	vault workers	eliminate all activities for defective board return and repair
	6:00	engineer	eliminate all activities for defective board return and repair
	8:00	mat'l flow analyst	eliminate all POs and negotiating delivery dates
	16:30	Time savings for customer	

supplier	time savings (hours/week)	who?	why?
	3:00	planner	eliminate negotiating delivery schedules
	(4:00)	planner	managing MRP system with daily deliveries
	:30	shipping	eliminate current shipping responsibilities
	(2:30)	delivery person	daily kanban deliveries
	(3:30)	Time additions for supplier	
	13:00	**Net time savings**	

Figure 3-7 Time savings realized by pilot program as reported by employees performing functions

3.2.3 Improved customer satisfaction

The customer is very pleased with the pilot program because it addresses many of the problems with the original system (see section 2.3). Several factors in addition to the above inventory and cost savings helped to improve customer (and supplier) satisfaction.

Improved responsiveness. The pilot program allows the supplier to be much more responsive to the customer's needs. Originally it took heroic efforts to have supplier shipments vary from the schedule planned 6 months earlier. With the pilot program whatever boards the customer needs are always in stock and available. There are limits to board availability based on the target buffer inventory, but the system was designed with the probability of a shortage explicitly calculated and accepted by both parties. So far, no stock-outs have occurred in the pilot.

Better service with less effort. Boards have always been available for the customer when needed. Some of the most skeptical people now trust that they can "just go to the vault and the boards are there."

Eliminated defective customer inventory. Using the exchange location has eliminated defective inventory in the customer's MRP system. This eliminated a source of great customer frustration (thinking boards were available when they were actually being repaired).

Closer supplier/ customer relationship. The daily contact between the supplier delivery person and the customer vault and assembly workers has helped to improve the two department's relationship. The customer feels that they are having better, more personal attention paid to them. Additionally, the supplier is now openly sharing its quality data with the customer in regular meetings where quality problems are prioritized.

Supplier benefits, too. The program does not just shift the burden on to the supplier. The supplier now gets more control over its own operations and can plan production more freely to optimize its own operations. The exchange location lets the supplier get defective boards back in one day instead of two weeks. This faster feedback aids in board repair and also in identifying quality problems sooner.

The additional supplier responsibilities (more inventory and additional effort for daily deliveries) is acknowledged in writing by the customer. Customer and supplier must both agree that the program is better for the entire supply chain.

3.3 Basic Principles

The pilot project was designed based on several basic operations principles. Understanding these is necessary for design and implementation of similar processes at another site. The system designer must understand what she is trying to accomplish and how these processes may help. She will then be much more successful.

3.3.1 Production Planning: Pull vs. Push

Production planning can be divided into two types of systems. If a production department makes parts according to its internal schedule and ships them out without considering the customer's current needs, the department is using a "push" system. It is pushing parts through production to the customer. In a "pull" system the customer is more involved. The production department makes and ships parts only when the customer says they need them. The customer is pulling parts to itself through the supplier's production. Pull and push systems each have strengths and weaknesses and work better in different environments.

Pull systems usually have minimal inventory and produce all of the savings associated with reduced inventory. Well designed pull systems also create better customer satisfaction because the customer gets exactly what it needs when it needs it. So pull systems offer the greatest benefits when inventory is expensive and customer demand is unpredictable.

Several factors are important for a pull system to work well. The supplier must be able to meet the customer's demand in a timely fashion. If the supplier waits and doesn't produce until the customer says what he needs, then the supplier must be able to produce the needed part very quickly. The supplier must have short production lead times and flexible production processes that can allow it quickly to switch from one product to another.

Push systems are necessary when pull systems are not feasible. For example, if a supplier has long lead times and inflexible production processes, they can't wait for the customer to say what they currently need. It would take the supplier too long to satisfy the need, so they must build to forecasts. A push system produces more inventory and added costs, but in many cases, especially if inventory is cheap and customer demand is steady, a push system may be a better option.

The supplier in the pilot program was in a difficult but common situation. Their production processes were inflexible and had long lead times (suggesting a push system), but the customer's needs were very unstable and inventory was expensive (suggesting a pull system). An additional complication was the supplier's large number of different products and customers.

In this environment the supplier was using a strict push system. Customers wrote the supplier POs far in advance, the POs were put into an MRP system, and the MRP system controlled production so that those POs were filled. Filled POs were shipped to the customer, and the supplier's job was done. The supplier's delivery performance is based on whether the PO was fulfilled on schedule This system was not working well, though (see Section 2.3). There are two reasons:

First, build priorities are set based on the PO due date because the supplier does not have any better information on the customer needs. So the supplier may be building parts that are not needed while slipping on more critical ones. This leads to late PO shipments, bad on time delivery (performance measure), lots of renegotiations (time and effort), and a poor supplier/ customer relationship.

Secondly, the system and the incentives shaped behaviors that hurt overall supply chain performance. The customer was measured on its inventory, and the supplier was measured on its inventory. Supplier delivery performance was measured against the planned schedule (push system). This forced the build up of excess inventory. The customer's thinking was: "even if we have high inventory, we will catch up sooner or later, so let's get boards in now since we're on the schedule", and the supplier thought "we're going to meet our promise dates no matter what, that's how we're measured". This lead to the situation in July (before the pilot started) where the customer had enough of one of the pilot boards to build production for the rest of the year. Then the boards all had to be returned for an engineering update.

The pilot program used both push and pull systems decoupled by the supplier inventory buffer. The supplier's raw material procurement and circuit board production were still a push system. A forecast is used to make a production plan and parts are made according to the plan. Procurement and manufacturing lead times were too long for pull system to be feasible. But circuit boards are delivered to the customer in a pull system. Boards stayed with the supplier, visible to its production planning, until the customer actually needed them, regardless of what the forecast predicted. This addressed the high volatility of customer needs, improving the supplier's ability to control inventory while helping to prevent shortages.

3.3.2 Inventory Management in a Supply Chain

Inventory has a very important purpose. It allows upstream production to continue despite downstream problems. It also provides flexibility to cover for uncertainties about the future. It is not wise to unilaterally eliminate inventory without understanding the reasons why it is there. If inventory is cut without paying attention to those underlying causes then the supplier's ability to meet customer needs may be hurt. Companies should attempt to understand the underlying reasons for the inventory and explicitly calculate the trade-offs between inventory costs (including holding costs, costs to manage the inventory, and risk of obsolescence) and customer service. Companies should also put in place processes that will allow it to control inventory while attacking the causes of the inventory. As the problems are resolved, inventory can be reduced while maintaining high service levels. The pilot program attempts to control (and reduce) the supply chain inventory so that as underlying problems are solved, even more reductions can be achieved.

Using a single inventory location in a supply chain makes inventory control simpler. From that location, parts should move non-stop through the manufacturing processes to the end user. The first question is where that single inventory location should be. It is best to hold inventory as far back in the supply chain as possible, given that the time to process the inventory from that point to the customer is acceptable. This provides more flexibility for the supply chain (if the inventory may be used for different final products) and is less expensive because less value has been added to parts. But service times must also be considered. It cannot take too long for the inventory to be processed to the point where it is needed.

After the inventory location is chosen, the amount of inventory must be chosen and there must be mechanisms to control (or limit) the inventory to the desired amount. When determining the inventory level the tradeoffs between inventory costs and benefits must be weighed. Kanban is an excellent way to control inventory level. When done correctly, the number of kanban cards determines the maximum amount of inventory in the system. Kanban also provides a simple way to decrease inventory as problems are solved: just remove a card from the system.

Inventory ownership is a major challenge when an inventory policy like above is undertaken. Inevitably some member of the supply chain will have to hold more inventory than they currently do. Resistance from that member is natural because almost all companies measure individual inventory, not supply chain inventory. To make this system work and improve supply chain performance, the supply chain inventory should be the important inventory measure. For instance, in this case the supplier was forced to hold more inventory. The supplier accepted this burden because it and the customer were part of the same company. The supplier's management accepted the local inventory increase under the expectation that the total combined inventory would decrease significantly. When the supply chain consists of separate companies, work must be done to create a cooperative and trusting relationship so that all parts of the chain are working to optimize the entire supply chain and not their own operations. For example it may be necessary to enter into risk sharing agreements covering a supplier's inventory.

3.3.3 ***Kaizen, Waste Elimination***

Any production processes that are not transforming material toward its final state are additional unnecessary costs, or waste. It is important for production operations to realize this and minimize all efforts that are not directly transforming material. Of course other activities must be performed (quality, etc.), but the effort to do them should be minimized by automating them or eliminating the need to perform them. With quality, for example, testing could be automated or variation could be eliminated, reducing the need for quality inspections.

There were many sources of waste in the supplier/ customer interactions. They will be discussed briefly below.

Inventory. Unnecessary costs are incurred for storing, handling, and tracking the inventory. Also, there is the possibility that inventory will become obsolete or need to be updated. Then the entire production effort of that inventory was an unnecessary cost.

Tracking parts. A lot of time and effort was devoted to finding a certain part that was not where it was supposed to be or counting parts to make sure that the MRP systems were correct. The processes should be so well controlled that the occurrences of lost parts or incorrect inventories is eliminated. Also, for tracking lost parts, the cost of the part should be weighed against the cost to track it. Both the supplier and customer realized that it would be unwise to spend $5000 worth of employee effort to track and recover a $1000 part, however this scenario was a possibility. (This is an illustration only; it is not based on actual observances).

Duplication of effort. Often both the customer and supplier perform the same functions. This is extra cost that could easily be eliminated by more open communication. For example, both the supplier and customer had quality systems to record and analyze defect data, but they were not connected. This resulted in double entry of defect information and no complete record of board quality problems (the customer didn't record the supplier fix, and the supplier didn't record the specific customer failure). A more effective quality system could be achieved at a lower cost by having one of the two share information but only enter it into one system.

Paperwork. First, wastes that cause paperwork(tracking, etc.) should be eliminated. Then other paperwork should also be eliminated. EDI is one option.

4. Design and Implementation

This chapter presents the steps the author used for design and implementation of the specific pilot program described in chapter 3. If the reader determines that a system similar to that pilot program may be worth investigating, this chapter may provide useful guidelines for setting up, evaluating the benefits of, and starting a similar system.

Figure 4-1 provides an overview of the design and implementation process. There are five phases: initiation, design, evaluation, implementation, and maintenance. The initiation phase is where the prospective partners (supplier and buyer) get together and agree that this type of program is worth investigating. In the design phase the actual program parameters are determined from current supply chain metrics. During the evaluation phase the parties decide if the program as designed is worth pursuing. If it is, they proceed to the implementation phase. If the parties do not agree, redesign may be possible, or else the program may not be suitable for the current situation. Finally, the maintenance phase provides structured methods to measure the project performance as compared to the expectations.

The rest of this chapter describes each phase in more depth. Detailed checklist/ worksheets covering this entire procedure are provided in Appendices A and B. Appendix A covers the steps in the entire design and implementation process and may help actual system designers manage the process. The numbering in Appendix A follows the pattern in Figure 4-1. Appendix B is a summary worksheet of the results of the design process. This may be a simple way to present the design results to others who were not directly involved, and may be particularly useful in the evaluation phase.

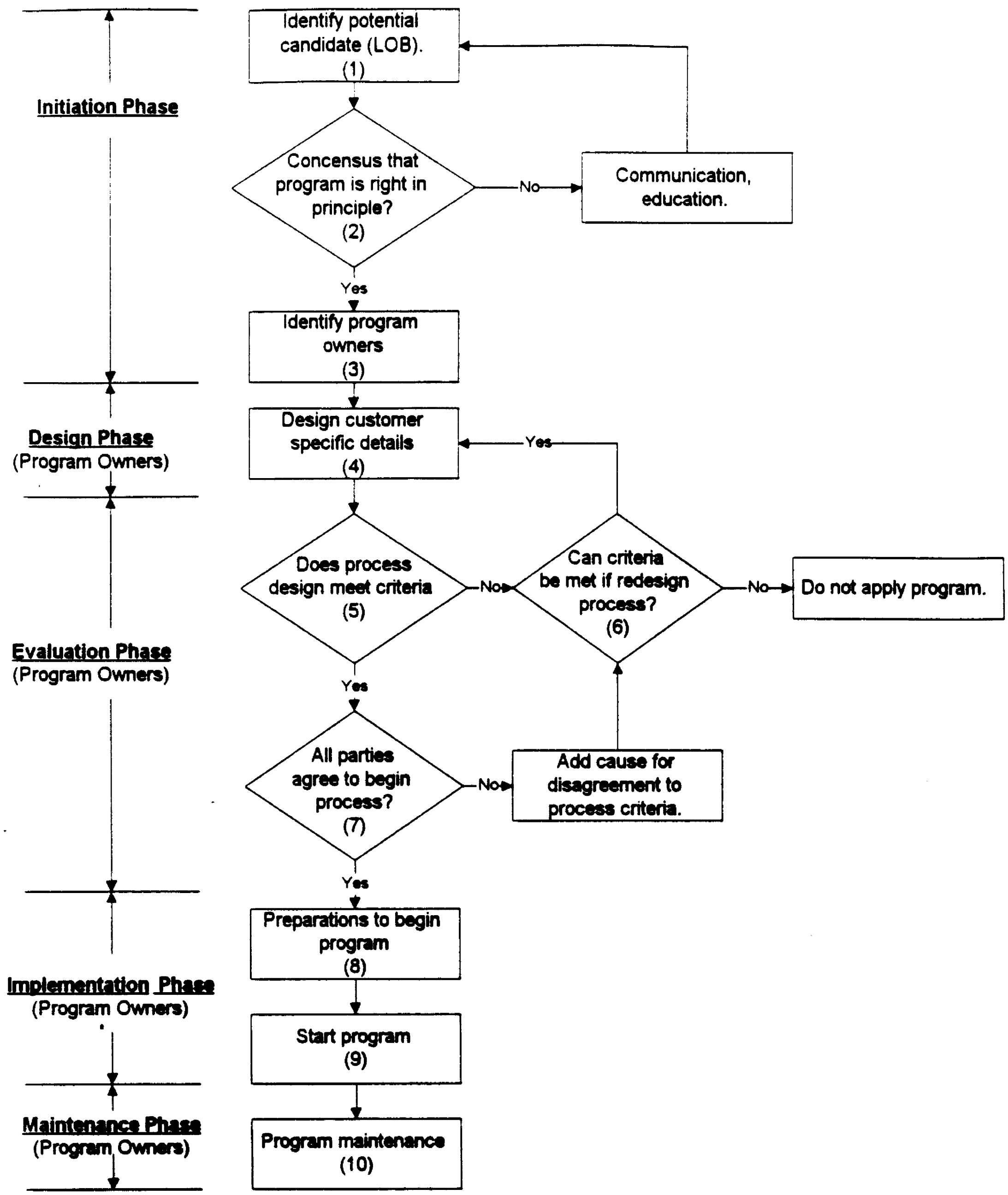


Figure 4-1 Flowchart of Design and Implementation Process

4.1 Initiation Phase

4.1.1 Identify potential candidate

The first thing that a party (supplier or customer) must do is identify a potential partner. The only requirements are that the two potential partners have an open relationship and are interested in improving supply chain performance (increasing customer satisfaction, reducing inventory and other costs, reducing cycle times and lead times, etc.).

4.1.2 Reach consensus on principles

Once a potential partner is identified, the two parties need to come to consensus on the *principles* of the program. These principles are described in the last section of the previous chapter. A meeting with all functional managers from both organizations is suggested. Before the meeting, all invitees should get an agenda describing the underlying principles, the processes in general, and (if possible) some estimate of expected benefits and costs. It should be very clear that the purpose of the meeting is to agree that the principles are valid and that the program should be investigated further. Specific details of how the program will be structured will be worked out later.

If consensus is reached on the validity of the principles, the parties should proceed to the next step, identifying program owners, during the same meeting. If the supplier and customer can not reach agreement, they can not continue at the present time.

4.1.3 Identify program owners

Once the parties have decided to proceed, each party should identify a program owner. The two owners will be responsible for driving the rest of the design and implementation. The owners are extremely important to the success of the project. They should have a detailed understanding of the current processes linking the supplier and the customer, and they should also be committed to seeing the new program adopted. For example, the program owners for the pilot program were the supplier planner and the customer material flow analyst. These two were chosen because they had in-depth knowledge of the current system and processes and they knew what information flows were important to include in a new system.

4.2 Design Phase

The design phase is where the specific details of the new processes are worked out. The two program owners are responsible for completing this phase, but they should get input and information from other functions as needed. The owners also should solicit concerns from all affected areas at the very beginning of the design so that they can be incorporated proactively.

The specifics that must be designed can be grouped into three categories:

1. supplier target buffer inventory (inventory above forecast)
2. kanban delivery system
3. return and repair system

These categories are not completely independent; iterations may be necessary to ensure that the entire system works smoothly.

4.2.1 Supplier target buffer inventory

The primary inventory location should be with the supplier so that the inventory can be visible for the supplier's production planning. The inventory location within the supplier (raw material, semi-finished goods, or finished goods) depends on the supplier's manufacturing processes and the customer's needs. The time to process the product from the inventory location to shipment to the customer must be short enough that the customer is never starved. In general this will mean the inventory should be kept as finished goods at the supplier site.

The target buffer inventory is inventory above the customer's forecasted needs and depends on the supplier's manufacturing practices and the customer's forecast accuracy. The supplier must determine the average lead time required (including procurement, scheduling, and manufacturing) to process product to the inventory location. The customer forecast error over that lead time should be calculated by looking at historical data. Appendix A shows how to calculate this historical forecast error as a standard deviation. The owners' decision of service level (probability that the inventory will cover the forecast error so there will be no stock out) will determine how many standard deviations are required. The target buffer inventory is then the chosen number of standard deviations of forecast error over the lead time. (Target buffer inventory should also consider inventory to cover for the repair process, see section 4.2.3)

The supplier must plan its production to keep the buffer at the target size and meet customer demand forecasts.

4.2.2 Kanban delivery system

One of the most important parts of a kanban system is the "usage signal". This is the action that tells the supplier that the parts have been used and more are required. This is important because once the parts have been "used" they are not part of the controlled inventory. The usage signal should be as close to assembly into the final product as possible. In the pilot project kitting to the specific work order was the usage signal.

It would be ideal to get usage information instantaneously (e.g. automatic message when part is assembled), then deliveries could exactly match usage. This was too complicated for this case, it was much simpler to have a delivery person make normal periodic rounds (e.g. daily or every Tuesday and Thursday) to check to see if more parts are needed. Delivery frequency is important: if the deliveries are more frequent, less inventory is needed, but more effort is required by the delivery person. Whoever is performing the deliveries must decide the maximum frequency by their available resources: how much time can they devote to the deliveries?

The actual delivery frequency and the kanban inventory should be designed concurrently. If the kanban delivery is like the pilot where a delivery person comes once to pick up cards and replenishes that amount in the next delivery (see Figure 3-2), there must be enough kanban cards to cover usage for two delivery periods. This is because the delivery person has a one period review time of the inventory (she checks the inventory once in a period) and a one period lead time to replenish the inventory (she takes one period to bring new parts to replace the ones that were used). The inventory in the system must cover the inventory review time plus the inventory replenishment time, or two periods.

Another way to see why "2 period usage" must be considered is by walking through the example shown in Figure 4-2. Assume the delivery frequency is daily and the supplier delivers at 9 AM. Figure 4-2 shows the number of kanbans on the supplier board, in the customer inventory, and on the customer board for part of a week. According to the figure, before 9 AM Tuesday, there was one card on the supplier board, four cards on the customer's inventory, and two cards on the customer board. At the 9 AM Tuesday delivery, the supplier delivered one kanban card to the customer inventory, increasing it to five, and brought back the two cards from the supplier board. During the day the customer used three kanban cards, so right before the 9 AM Wednesday delivery there were two cards on the supplier board (from the Tuesday delivery), two cards with customer inventory, and three cards on the customer board. The rest of the figure follows the same logic. Looking at the three cards used after 9 AM Tuesday illustrates why "2 period usage" is important for determining kanban inventory. In the worst case the three cards are used at 9:15 AM Tuesday. Following the figure, those cards do not make it back to the supplier until 9 AM Thursday (when they are added to the two cards already there). Cards used one day (e.g. Tuesday) do not return until two days later (Thursday), so there must be enough kanban cards to cover 2 days' usage.

	Tue 9 AM		Wed 9 AM		Thu 9 AM	
Supplier Kanban Board	1	2	2	3	3	2
Customer Inventory	4	5	2	4	2	5
Customer Kanban Board	2	0	3	0	2	0

Figure 4-2 Example of kanban delivery

Delivery frequency should roughly match customer usage history. If usage generally happens daily, hourly deliveries may be too frequent (many deliveries of zero boards: lots of wasted time), but weekly deliveries may be too infrequent (excessive inventory at customer site).

To determine the amount of kanban inventory, historical usage data must be examined again. Historical usage should be aggregated into buckets of the new delivery frequency. Each bucket should be added to its adjacent bucket to get "2 period usage". The average and standard deviation of this 2 period usage must be calculated (see Appendix A). Minimum kanban inventory is the average 2 period usage plus a chosen number of standard deviations. The number of standard deviations determines the probability that there will be inventory available at the customer site (avoiding a stock out).

Usually each kanban card represents more than one part. The actual number of kanban cards and the number of parts per card depends on the specific situation. In the case of the pilot, 10 parts per card were used because it made the customer's kitting function easier. The most important requirement is that the total kanban inventory (cards times parts per card) is greater than the minimum kanban inventory calculated using the "2 period usage". Also, fewer parts per card is preferred so that later inventory reductions (by removing a kanban card from use) are simpler.

4.2.3 Return and repair system

The major design changes to the original return and repair system were on the return process; the supplier's repair procedure is essentially unchanged. For the return process, the owners need to determine how much floor stock should be available to cover for any defects found during assembly. And the supplier may want to increase the target buffer size to account for boards that may be in repair.

Depending on the value of the parts, floor stock may not be an issue. If the customer wants to minimize floor stock, though, they can calculate it in a manner similar to calculating the supplier's buffer inventory. The same person who does the kanban deliveries should exchange boards in the return and repair system. So the frequency of the two processes should be the same. The owners can convert historical data of defects found by the customer into a 2 period defect count (number of defects found every 2 periods). The floor stock is the average 2 period defect count plus the chosen number of standard deviations to give the desired coverage.

An additional amount of boards may be needed as part of the supplier's buffer to cover for boards in the repair process. This amount can be estimated by converting the 2 period defect count found above into number of defects found per day and then multiplying that by the supplier's average repair time. The result should be added to the target inventory calculated in section 4.2.1. above.

4.3 Evaluation Phase

Once the process is designed, the owners must evaluate the design on performance criteria (inventory in system, cycle times, delivery performance, time and effort required) and reach agreement from all affected parties (the same ones who got the program started, see section 4.1.2) that the design is worth implementing. Implementation should not continue until agreement from all parties is obtained. If the parties do not agree, redesigns will be needed. Once all parties do agree, they should choose a start date to help drive the implementation phase. Drafting and signing a contract describing the agreement is also an option (see an example in Appendix C)

The design summary in Appendix B is a tool to help organize and present the relevant design parameters. This can help in presenting the design to the other parties that must agree to it. The summary should be modified to include any additional concerns that surface. If the parties create a contract, the design summary is a good supporting document for it. The summary has three sections:

1. process parameters
2. expected benefits
3. supporting environment

4.3.1 Process parameters

All process parameters from the design phase should be presented. These include:

- Parts to be part of the program
- Delivery frequency and time frame
- Number of kanban cards and number of parts per card
- Supplier target buffer inventory
- Customer floor stock
- Planning issues: customer forecast specifics and change limits, part lead time in customer MRP system, use of blanket PO
- Process specifics: inventory locations, employees who will perform activities, employee responsibilities

4.3.2 Expected benefits

The owners should attempt to quantify the expected benefits from the program. Areas that may be considered are:

- Time and effort required to perform delivery and repair functions
- Supply chain inventory (straight inventory, inventory turns, days of supply, etc.)
- Service (number of shortages)
- Cycle time for part repair
- Customer satisfaction (bad parts in inventory)

For these and any other expected benefits, the owners should record the current value, the expected value with the new processes, and the reason why the new processes will produce the expected results.

4.3.3 Supporting environment

The supporting environment section highlights some other issues that must be addressed if the program is to be successful. The most important of these are:

- The program will increase the supplier's inventory level. This increase must be acceptable to the supplier and its management.

- Training of all involved employees is essential. The employees must understand the reasons for the new processes and their roles in making it work.
- Contingency plans should be in place. The customer and supplier should expect mishaps at the beginning, and they should be planned for.
- Both parties should be committed to continuous improvement. Information about board quality and the program performance should be shared openly and used to further improve.
- Engineering changes were a serious issue in the pilot program. The customer and supplier must communicate very well to coordinate engineering changes so that updates of old revisions are minimized.

4.4 Implementation Phase

Once the design has been approved and a start date has been chosen, the owners have a large amount of work to do to prepare for start up. Much of this work will depend on the specific program design, but some of the general categories include:

1. Physical preparations including: inventory locations, inventories (building buffer, deplete customer stock), making kanban cards and kanban bulletin boards
2. Training employees on the program as a whole and their responsibilities (ensure back-ups are trained, too)
3. Planning changes: open customer blanket POs, alter supplier production planning

After all of the preparations have been completed the program can be started. The owners should expect a few glitches at the beginning; it is a good idea to walk through the process with delivery person first few times. For the pilot program the delivery person initially felt overwhelmed by the new responsibilities. However, after about 2 weeks he had no more problems. It just required practice and time to learn.

4.5 Maintenance Phase

Once the program is up and running, the owners are responsible for fine tuning the program and making sure that it is providing the expected benefits. The best way to do this at the beginning is to have periodic review meetings. Initially these meetings should be frequent, perhaps monthly. As the situation becomes more settled, the meetings can be scheduled less frequently. At a minimum the program review meetings should cover:

1. Actual performance vs. expected benefits

2. Process problems (actual workers performing the processes should be invited to the meetings)

Part quality was a major concern for the pilot program, so regular meetings among the supplier and customer engineering and quality groups were also established. Defect information collected by the supplier was shared at these meetings and used to prioritize engineering efforts.

Lastly, the supplier and customer owners should promote additional improvements to the system. These include internal manufacturing improvements, cycle time reductions, and EDI to electronically link the different systems.

5. Conclusions and Recommendations

Supply chain reengineering can provide great benefits to a company and can be a source of strategic advantage. The pilot program described in this thesis addressed some specific problems that one manufacturer was having in part of its internal supply chain. These problems included:

- high total inventory levels
- a high occurrence of parts shortages while other items had surpluses
- high costs and a high amount of effort to manage the supplier/ customer relationship
- low customer satisfaction

The pilot program used a combination of a push system for the supplier's board production process and a pull system to deliver the parts from the supplier to the customer. The two systems were decoupled by an inventory buffer. Analysis of the return and repair process showed that cost savings could be achieved by eliminating unnecessary activities. The pilot program produced encouraging results, including:

- an increase in combined supplier and customer inventory turns from 2 turns/ year to 4 turns/ year
- a reduction in time needed to manage the supplier/ customer relationship of 13 hours/ week
- improved customer satisfaction

The remainder of this chapter is divided into three sections. First, key learnings from the pilot program design and implementation are discussed. These are, in the author's opinion, the major reasons for the pilot's successful results. While the pilot did produce positive results, there are issues concerning its applicability and implementation which require further attention. These issues concerning application of the pilot program are described in the next section. The last section of this chapter addresses the supplier's internal manufacturing practices. These could not be the focus of the thesis because of time and resource constraints, but improving them will provide even greater benefits to overall performance.

5.1 Key Learnings from Pilot Program

Visibility of true customer needs and current inventory is important. Two of the most important features of the pilot were that it allowed the supplier to have visibility of the finished board inventory and to have a better estimate of the customer's true material requirements. In the original push system the supplier had no idea of the existing inventory of finished boards. This led to unnecessary inventory build-ups and extra costs. Also, the POs from the original system did not portray the customer's true production requirements. The major reasons for this were that 1) the POs were created far in advance, 2) the POs were batched into supplier production lot sizes, and 3) the customer was prone to overstate its needs to make sure that shortages were prevented. Providing the customer's own internal production schedule to the supplier as a forecast provides the supplier with much better information. Using that information along with knowledge of the current inventory of finished boards allowed better use of the supplier's production capacity and reduced over-all inventory.

Hybrid systems that combine push and pull production may perform better in certain environments. Pull systems have become very popular, and with good reason. They offer important benefits such as inventory reduction, reduced cost, and better customer satisfaction. But pull systems are not always possible because they require manufacturing operations to be very fast and flexible. In situations where pull systems are not feasible, it may still be possible to design a system that combines parts of pull and push systems. In the case of the pilot program, the supplier's manufacturing operations were still a push system, but delivery of circuit boards to the supplier was a pull system. The two systems were decoupled by a buffer inventory. (This does not mean that slow inflexible manufacturing should be tolerated, though. See the last section of this chapter.)

Inventory control requires in-depth analysis of operations. Inventory serves useful functions, and supply chain performance may deteriorate if inventory is reduced capriciously. Companies must analyze their operations to understand the underlying problems that are making inventory necessary. Conscious calculations should be made to trade off the costs of holding the inventory against the benefit that the inventory provides. Once the inventory location and level have been chosen, mechanisms such as kanban should be used to control the inventory and limit it to the prescribed level.

Culture is important. The most important reason for the pilot's success was the cooperative atmosphere and the supplier's and the customer's willingness to accept change. The pilot created new responsibilities for the supplier, and posed risks for the customer (the customer now trusts the supplier to plan correctly and not stock-out of parts). Both departments accepted the changes because they understood the potential benefits for the combined system outweighed any extra burden on themselves.

5.2 Pilot Program Issues that Require Further Investigation

How to move from a pilot to a full system? The pilot program provided good results, but it only affected about 10% of the supplier's production. The difficult next step is determining when, if, and how to expand the pilot. Because the pilot program is an exception to the standard procedures, it requires the supplier and customer to know two ways of doing the same process. Boards that go to customer A must be handled one way while boards that go to customer B are handled differently. How important is standardization of procedures? If every one of the 50 customers required a different process, the complexity would probably overwhelm the supplier, but it may not be possible for a single system to satisfy all of the different customer's needs. If the pilot were to be expanded, other complications that would have to be addressed are:

1. Inventory. If the supplier used this type of program for all 250 of its parts, it would need to create a separate warehouse. Also, the supplier may not be willing to hold that much excess inventory.
2. Exceptions. Some of the parts that the supplier makes may not be good candidates for this type of program because of their low volume, their poor quality, or some other

reason. How would these boards be handled? Chaos would result if every different board had its own process.

Application of the program to other situations requires careful analysis. It is important to understand that while the pilot program worked well in the specific situation described here, it may not work as well in other situations. Each case must be closely examined on an individual basis to determine if a program similar to the pilot is the best approach to improving system performance. Appendix B may help after a preliminary design is completed. If some dimension of the design is found to be unacceptable (e.g. amount of inventory needed in the supplier buffer), that may be an indicator that some other aspect of the supplier or customer operations should be addressed first. A thorough understanding of the underlying principles is perhaps the best tool for determining whether this type of program is worth pursuing.

How to develop the necessary atmosphere? The previous section mentioned how a cooperative atmosphere is important to the success of a project like this which attempts to improve performance across organizational boundaries. Some parties may have to accept new challenges for the benefit of the entire system. If this type of relationship doesn't exist, how can it be created? This question is very relevant for supply chain issues. Often supply chains are composed of different companies. How does one company create the atmosphere where other companies will be willing to take risks for the benefit of the entire process? The supplier had this difficulty with its external suppliers. The supplier wanted to create the same type of system as the pilot program where the external suppliers would hold more inventory and deliver it as needed. This effort failed, though, because the external suppliers did not want to increase their local inventory even if it would mean improving over-all supply chain performance.

5.3 Discussion of Supplier Internal Operations

The pilot program only addressed the interactions between the supplier and the customer. Even greater benefits may be obtained from analysis of their internal operations. Figure 3-

6 shows that the supplier is carrying about 550 boards costing $1000 each when board shipments average roughly 70 boards per week! This is better than the original system, but there is still room for much improvement. Efficient lean production techniques could conservatively reduce buffer inventory to two weeks, or about 150 boards. This would be a savings of roughly $400,000 in inventory for this single customer (10% of the supplier's business). Areas which must be considered to approach faster, more flexible, leaner manufacturing in the supplier area are discussed below. Each area may provide benefits independently, but the greatest impact would come from new manufacturing processes which addressed all of these issues.

Manufacturing cycle time improvements. Current manufacturing cycle time is about 12 days. One of the biggest opportunities for reducing manufacturing cycle time is eliminating kitting. Components and boards are kitted at several steps during manufacturing. Raw material is kitted before actual assembly starts; boards are kitted during assembly (one side is assembled for the entire production run before the other side is started); and boards are kitted during testing. All of this kitting is time that the boards are sitting and not being worked on. This adds to the cycle time. Areas to investigate to reduce kitting are:

1. a more extensive use of on line components (instead of storing components in a vault),
2. use of two sided circuit board arrays (An array is a sheet of identical bare circuit boards. Electrical components are placed on the boards in arrays, and the arrays are divided into individual boards at the end of the assembly process.) to eliminate batching between assembly of top and bottom sides of circuit boards, and
3. moving the test area to the end of the assembly line to facilitate in-line testing.

There are other areas to investigate to reduce manufacturing cycle time. These include eliminating current manual operations and manual in-line quality checks. Analysis of the current manufacturing layout to identify bottleneck operations may also provide ways to reduce cycle time.

Improving manufacturing flexibility. It currently takes 1 to 2 hours for the supplier to change-over production from one type of board to another. Analysis of current set-up procedures could reduce change over time to 20 minutes. Faster change-overs would not only provide the supplier with free capacity, but it will also allow smaller lot sizes and therefore less inventory. Flexibility may be improved even more be utilizing some form of group technology approach to production. Group technology would entail classifying the boards into a few similar classes. Flexibility to change-over production between boards of the same class should be great (perhaps zero set-up time). This approach would also provide greater manufacturing flexibility and thus better customer responsiveness and lower inventory. Classifications that may be investigated for a group technology approach may be common components or common array size.

The current stencil operation for applying solder paste (one of the first steps in circuit board assembly) is a barrier to flexibility. New, more flexible technology for applying solder paste is available and should be investigated.

Board quality improvements. Board quality is in the 5% defect range. This is not good enough. Work must be done to identify and eliminate root causes of defects. The quality information sharing process incorporated in the pilot program is a good start, but it is up to the employees using the process to make sure that it helps identify root causes. Uncontrolled manual operations in the supplier assembly process also contributes to the defect rate. Manual operations should be minimized, and wherever they are required, they should be standardized.

Product line rationalization. The supplier is building a very wide range of products, as described in section 2.1. This greatly complicates the supplier's operations and contributes to long manufacturing times and low customer satisfaction. A detailed analysis to determine the total cost of producing the different boards should be performed. The author suspects that such an analysis would indicate that redesigning or outsourcing a few troublesome board types could greatly improve overall performance.

Product design for assembly. The most effective way to produce quality parts easily is to consider their manufacture during the design phase. Guidelines for board layout, common components, and board testability should be developed and used in costing boards for customers. The use of standard array sizes to reduce change-over times should also be studied.

Appendix A: Implementation Checklist/ Worksheet

Initiation Phase

1. Identify potential candidate.

- See opportunities to improve customer satisfaction with customer returns, reduce inventory.

2. Get consensus that program is right in principle

☐ Identify representatives for all concerned parties:

☐ supplier:

manufacturing:____________________
test:____________________
shipping:____________________
management:____________________
planning:____________________
buying:____________________
quality:____________________
other(s):____________________

☐ Customer:

planning:____________________
buying:____________________
operations:____________________
material handling/vault:____________________
quality:____________________
management:____________________
other(s):____________________

☐ Set up meeting to introduce concept to all parties.

☐ Invite all concerned parties (supplier and customer).

☐ Be sure invitees know goals before the meeting: to get consensus on principles and identify owners.

☐ In meeting present:

- Principles
    - One buffer is better than two
    - Inventory should be visible to supplier so it can be used to plan production
    - Pull system is better than push system
    - Need to minimize non-value-added work and duplicated work
- Basic process and responsibilities
- Rough estimate of benefits (based on existing programs?)

☐ During meeting, get consensus that program makes sense and should be pursued.

- Don't need agreement on details, concerns on these can be worked out later.
- If no consensus, can not continue, work with customer over time on alternate solutions.
- If consensus is reached, go directly to step 3 during the meeting.

3. Identify program owners (1 for supplier, 1 for customer)

☐ Describe owner characteristics:

- Must see the value in program
- Must have stake in success
- Must understand details involved in current process (NOT department manager)

☐ Describe owners' responsibilities:

- Design process details, getting input as needed (steps 4-6).
- Get agreement from all parties on process (step 7).
- Implementation (steps 8-10). (Responsible to make sure all steps are completed)
- Maintenance once program starts (step 11). (Responsible to make sure all steps are completed)

☐ Select supplier owner:____________________

☐ Select customer owner: ____________________

<u>Design Phase</u> (Responsible: supplier owner and customer owner)

4. Design customer specific details

NOTE: This section assumes that forecast error and actual part usage are normally distributed random variables. This assumption is used whenever a standard deviation is calculated. If the owners know a better way to estimate the parameters they should use it. For normally distributed random variables, standard deviations translate into the following percentages:

standard deviations	% covered		standard deviations	% covered
0.5	68%		2.0	97.7%
1.0	84%		2.5	99.4%
1.5	93%		3.0	99.9%

Use this chart for choosing inventory coverage for the target buffer inventory, minimum kanban inventory, and good floor stock at exchange location.

☐ Solicit questions/ concerns from all parties. Record (use separate sheet if necessary):

- ______________________________
  ____
- ______________________________
  ____

☐ Review all questions/ concerns. Use to revise or add to the program summary referenced in step 5.

- Keep all of the criteria in mind during process design. This will reduce redesigns.

☐ Identify part numbers to be part of program:______________________________

____

4.1 Design target buffer inventory

☐ Buffer location: ______________________________

Time to process parts from buffer to customer: ______________________________

- This is maximum time it will ever take to fill a customer need. This must be short compared to customer need. This should be part lead time in customer MRP system.

Design Phase (cont.)

☐ Use actual demand history to determine forecast error over minimum lead time (This step must be repeated for each part):

☐ Part number:______________________________

☐ Minimum lead time (procurement, planning, and manufacturing): ____________________

- Compare what customer forecasted they would need on specific date to what the actually needed on that date (forecast date should be minimum lead time before ship date). Use at least 10 entries, and more is better.

Forecast Date	Forecast Qty (1)	Ship Date	Ship Qty (2)	Delta = (1) - (2)	Delta^2

Sum of Delta^2:______________

$$\text{Standard.Deviation.of.Forecast.Error} = \sqrt{\frac{\text{Sum.Of.Delta\^{}2}}{\text{Number.of.Entries} - 1}} = \_\_\_\_\_\_\_\_\_\_$$

☐ Choose number of standard deviations for percent of time buffer would cover forecast error: standard deviations:_______________=___________% of time forecast error is covered

☐ Calculate target buffer size (the above table and forecast error calculation must be done for each part individually):

Part	Forecast Error Standard Deviation	X	Number of Standard Deviations	=	Target Buffer Size
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	
		X		=	

☐ Determine customer forecast horizon and bucket size (daily/weekly/ monthly buckets, and for how far out?). Also, any limits to customer forecast changes :______________________________

____

____

<u>Design Phase</u> (cont.)

4.2 Design kanban delivery system

☐ Choose usage signal:____

- Usage signal is customer action that means parts were consumed. The closer it is to assembly into final product, the better.

4.2.1 Calculate frequencyof deliveries by delivery person and minimum kanban inventory

- Frequency is limited by amount of time supplier shipping can devote to deliveries. At a minimum this is time shipping is currently devoting to customer.

$$\text{Maximum. frequency} = \frac{\text{time. shipping. can. devote. to. customer}}{\text{time. for. one. delivery. \&. exchange}}$$

☐ Maximum frequency = $\dfrac{\_\_\_\_\_\_\text{hrs/week}}{\_\_\_\_\_\_\text{hrs/delivery}} = \_\_\_\_\_\_ \dfrac{\text{deliveries}}{\text{week}}$

- Minimum kanban inventory will be calculated in this section by:
  1. Getting historical data of part usage.
  2. Finding "2 period usage" by adding usage in 2 consecutive periods. 2 period usage is required because customer usage in one period is not replaced until the period after next. (Example: if daily delivery usage on Tuesday is not replaced until Thursday, so kanban inventory must cover usage on Tuesday and Wednesday)
  3. Averaging the "2 period usage" for the usage history
  4. Finding the standard deviation of "2 period usage"
  5. Minimum kanban inventory is average 2 period usage plus a number of standard deviations.

- NOTE: This inventory calculation assumes usage is a normally distributed random variable. If the owners can work out a way to make usage more stable or predictable there may be opportunities to decrease the kanban inventory. Two examples:
  1. Customer agrees to not kit anything more than 1 day in advance, making usage smoother (eliminates lumpy, random batch kitting),or
  2. Customer agrees to kit all jobs for the week on Monday and Tuesday. supplier can come after Tuesday just to pick up cards, then deliver on Friday. This eliminates the need for the kanban inventory to cover 2 periods. Normal usage for one period can be examined instead of "2 period usage".

If no special arrangement has been reached, proceed with next check box below. IF some type of arrangement has been reached so that usage is not random, record it below with what the inventory should be and why. Then skip down to "Record delivery frequency" at end of this section.

1. The agreement:____

____

____

2. What kanban inventory should be: ____________________________________

____

3. WHY the agreement allows the stated kanban inventory (include consideration of demand forecast): ____

____

<u>Design Phase</u> (cont.)

☐ Calculate 2 period usage from part usage history (Suggest use at least 3 months of history, expand table if necessary):

Part: ______________________ Frequency: ______________

Period	Dates (from - to)	Total Period Usage	2 Period Usage (current period + last period)
1			N/A
2			
3			
4			
5			
6			
7			
8			
9			

Total: ______________________

$$Average.Usage = \frac{Total}{Number.of.Entries} = \underline{\hspace{6cm}}$$

☐ Calculate standard deviation (easiest with a table):

Entries (N)	(1) 2 Period Usage (from table above)	(2) Average Usage (same for all entries)	Delta =(1)-(2)	Delta^2
1				
2				
3				
4				
5				
6				
7				
8				
9				

Sum of Delta^2: __________

$$Standard.Deviation.of.Usage = \sqrt{\frac{Sum.of.Delta^{\wedge}2}{Number.of.Entries - 1}} = \underline{\hspace{4cm}}$$

- **Average and standard deviation calculations must be repeated for every part and every possible delivery frequency**

☐ **Determine number of standard deviations used to calculate minimum kanban inventory:________= ________% of time kanban inventory will cover customer usage (no stock-outs)**

Design Phase (cont.)

☐ Calculate minimum kanban inventory for each possible frequency as average 2 period usage plus chosen number of standard deviations:

Delivery frequency:

Part	Average Usage	+	Number of Std. Dev.'s	X	Stand. Dev. of Usage	=	Minimum Kanban Inventory
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	

Delivery frequency:

Part	Average Usage	+	Number of Std. Dev.'s	X	Stand. Dev. of Usage	=	Minimum Kanban Inventory
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	

☐ Choose kanban delivery frequency and minimum kanban inventory under the following constraints:

- One frequency for all parts. Frequency is also for part exchanges.
- Frequency must be less often than maximum frequency calculated above.
- Should minimize kanban inventory.

☐ Record delivery frequency:____

☐ Record minimum kanban inventory (for chosen frequency):

Part	Min kanban inventory (K)		Part	Min kanban inventory (K)

<u>Design Phase</u> (cont.)

4.2.2 Determine number of parts per kanban card and number of kanban cards.

- The number of kanban cards must be greater than the minimum kanban inventory divided by the parts per card:

$$Number.of.kanban.cards \geq \frac{Min.kanban.inv.(K)}{Number.of.parts.per.card}$$

- There are several guidelines for choosing the number of kanban cards and number of parts per card:
  - Total kanban inventory should be close to (but greater than) minimum kanban inventory calculated above.
  - Total kanban inventory must be less than target buffer size calculated above, to guarantee inventory will be available.
  - Must have at least 2 kanban cards for each assembly number.
  - Parts per kanban card may be dictated by customer practices. (For example if customer kits in sets of 10, can use kanban size of 10 and kit a container at a time, eliminating single part picking)

☐ Record chosen kanban parameters:

Part	Number of parts/ card	x	Number of kanban cards	=	Total kanban inventory
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	

☐ Determine DEDICATED kanban delivery locations:

Customer site:____

Supplier store:____

☐ Determine contingency plans

If customer stocks out:__________________________________

____

Other:____

____

Design Phase (cont.)

4.3 Design return and repair system

☐ Exchange frequency:______________________________

- This should be same as kanban delivery frequency

4.3.1 Determine number of good parts needed on floor in exchange location

- Examine customer quality system to get part defect history
- Find the average and standard deviation of part defect rates over 2 periods. (over 2 periods because 2 periods pass before parts are replaced)

☐ Calculate 2 period defect count from part defect history (Suggest use at least 3 months of history, expand table if necessary):

Part:_______________________

Period	Dates (from - to)	Total Period Defects	2 Period Defects (current period + last period)
1			N/A
2			
3			
4			
5			
6			
7			
8			
9			

Total:______________________

$$Average.Defects = \frac{Total}{Number.of.Entries} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

☐ Calculate standard deviation (easiest with a table):

Entries (N)	(1) 2 Period Defects (from table above)	(2) Average Defects (same for all entries)	Delta =(1)-(2)	Delta^2
1				
2				
3				
4				
5				
6				
7				
8				
9				

Sum of Delta^2:__________

$$Standard.Deviation.of.Defects = \sqrt{\frac{Sum.of.Delta^{\wedge}2}{Number.of.Entries - 1}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

- Average and standard deviation calculations must be repeated for every part

<u>Design Phase</u> (cont.)

☐ Determine number of standard deviations used to calculate minimum floor stock:________ = ________% of time floor stock will cover customer found defects (no stock-outs)

☐ Calculate minimum floor stock as average 2 period usage plus chosen number of standard deviations:

Delivery frequency:

Part	Average Defects	+	Number of Std. Dev.'s	X	Std. Dev. of Defects	=	Minimum Floor Stock in Exchange Box
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	
		+		X		=	

4.3.2 Calculate inventory supplier needs to hold to cover repair cycle time

☐ Get data on average repair cycle time from when defective parts are returned to supplier until they are repaired and returned to customer.

Part	Avg Repair Time (days)		Part	Avg Repair Time (days)

☐ Convert average defects in 2 periods (step 4.3.1) to returns per day by dividing by number of days in 2 periods.

Part	Average Defects	÷	days in 2 periods	=	Returns per day
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	
		÷		=	

☐ Multiply returns per day times repair cycle time to get needed extra parts in supplier

Part	Returns per day	x	Avg Repair Time	=	Parts needed in supplier
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	
		x		=	

<u>Design Phase</u> (cont.)

☐ Determine locations at customer site for defective parts and good exchange parts: ___________

____

____

☐ Determine contingency plans

If run out of good exchange parts: ____

____

____

others:____

____

____

<u>Evaluation Phase</u> (Responsible: supplier owner and customer owner)

5. Evaluate process design

☐ Complete Summary of Program Design. It is should be attached (or in Appendix B)

- Modify the summary to include additional concerns discovered in beginning of step 4.

☐ Obtain approval of summary from all concerned parties. Concerned parties are listed in step 2.

- Talk to experts to get correct information. This will ensure approval from concerned parties
- If do not pass all criteria go to step 6.
- If pass all criteria go to step 7

6. If summary is not approved, determine if system redesign is possible.

☐ Identify which criteria were not met.

☐ If the problem can be designed out, go back to step 4 and do it.

- Areas to look at for the redesign may be:
  - Frequency of deliveries
  - Assembly numbers on program
  - Limits to customer schedule changes

☐ If problem can't be designed out then it's not feasible to do the program.

- Example: Not enough part volume and value to justify effort

7. Agreement to begin process

☐ Pick a start date. Date must allow enough time for steps 8 and 9 to be completed.

☐ Complete a written agreement (optional). Include:

- Calculations on benefits
- Completed criteria checklist

☐ Obtain signatures (optional) from all concerned parties on written agreement

- If a party won't sign:
  - Find out why they don't agree with the program
  - Add the reason for disagreement to the criteria
  - See if can design can be changed to meet the new list of criteria (go back to step 6)

<u>Implementation Phase</u> (Responsible: supplier owner and customer owner)

8. Preparations to begin program

8.1 Customer owner is responsible for:

- ☐ Giving all involved parties (assemblers, material handling, engineering, planners, buyers, etc.) an overview of the entire process and why it is being done.
- ☐ Training assembly operators in part exchange process:
  - When filling out problem reports include: ASSY #, S/N(s), QTY, date, operator who found problem, description of failure
  - They are responsible for floor stock quantity: must leave defective part when take exchange part. (What do they do if not right number?)
  - Exchange is for production parts only. Not for updates or old stuff from who knows where.
  - supplier shipper can only perform 1 for 1 exchanges. If the shipper doesn't have a good part, he can not take the defective part until the next delivery.
  - If CNR parts are found to fail again, call customer engineering.
- ☐ Training material handling (vault) on kanban delivery process:
  - Receive parts into system same day as they are delivered.
  - Receive parts before use them
  - NEVER remove kanban cards from boxes until parts have been "used"
- ☐ Training engineering:
  - Responsible for letting assembly know if they take parts from floor stock. (floor stock count is assembler's responsibility)
  - If bad parts aren't in box when shipper comes, parts will not be exchanged until next trip.
- ☐ Training planning/buying:
  - Procedure to get production schedule to supplier
  - No safety stock level in customer system (supplier can supply needs).
  - Important delivery performance measure is line outs, not delivery to schedule.
- ☐ Setting up locations for good exchange parts and defects
- ☐ Setting up kanban delivery location and customer kanban bulletin board
- ☐ Making sure current inventory of parts gets depleted
- ☐ Purging current inventory of all out-of date ECNs
- ☐ Loading parts as blanket orders in purchasing

8.2 supplier owner is responsible for:

- ☐ Giving all involved parties (assemblers, material handling, engineering, planners, buyers, etc.) an overview of the entire process and why it is being done.
- ☐ Training shipping
  - Procedure
  - Deliver repaired parts back to customer as soon as possible
  - Very important to deliver on schedule consistently. There must be reliable back-ups.
  - Verify problem report information before exchange.
  - Exchange must always be 1 for 1.
- ☐ Training customer returns
  - Procedure
  - Identify (tag) CNR parts before the go to supplier store
  - Pack parts so that they are ready to ship.
  - (Put failure into comments section??)
- ☐ Training planning
  - Procedure
  - Manage customer orders so that there are no past due orders and there is always an open order to ship to.
- ☐ Making dedicated storage location for buffer in supplier area
- ☐ Making kanban cards
- ☐ Setting up supplier bulletin board (adds to current bulletin board)

<u>Implementation Phase</u> (cont.)

9. Start program

- The owners may want to walk through with the operators for the first week

<u>Maintenance Phase</u> (Responsible: supplier owner and customer owner)

10. Program maintenance

10.1 Customer owner is responsible for:

☐ Program meetings

Frequency: once a month for first few months, then at least once every 3 months

Topics:

- Actual performance vs. expected for agreed upon metrics:

Metric	Responsible to present

- Any process problems. Get input from people actually performing process (shipping, vault, assemblers)
- Any issues regarding the number of kanban cards: schedule changes, stock outs, excess inventory

☐ Quality meeting

Frequency: 1 or 2 times a month

☐ supplier provides:

- histogram of defects on returns in last 2 months
- histogram of defects on returns in last year
- return cycle time (into quality system until out of quality system)

☐ Customer provides:

- histogram of failures in last 2 months
- histogram of failures in last year

☐ supplier and customer develop action plans for most important defects and failures.

-

10.2 Supplier and customer owners are responsible for:

☐ Promoting internal changes to improve linkage, examples:

- EDI
- cycle time reductions

☐ Designing the process for new parts to be added to the existing program

☐ Determining:

- Target buffer size
- Number of kanban cards
- Number of parts per card
- Floor stock of good parts

☐ Amending the written agreement to include the new parts

Appendix B: Summary of Program Design

Before starting the new program, the supplier owner and the customer owner must make sure that:

1) The process parameters are defined.
2) Expected benefits are stated.
3) Necessary supporting environment is present.

1. The process parameters are defined

☐ Parts to be part of program (step 4 of Implementation Worksheet):______________________

____

☐ Delivery frequency (step 4.2.1):______________________(e.g. every Mon, Wed, Fri)

☐ Delivery time range:______________(e.g. between noon and 2PM)

☐ Kanban parameters are agreed upon (step 4.2.2):

Part	# of kanbans (exc. partial)	kanban size (parts/card)		Part	# of kanbans (exc. partial)	kanban size (parts/card)

- One additional "partial" kanban is needed for each assembly number to cover odd sized lots.

☐ Target buffer sizes (inventory above customer forecast) are agreed upon:

- This includes target buffer from error forecast (step 4.1) AND inventory to cover repair cycle time (step 4.3.2)

Part	Target Buffer Size		Part	Target Buffer Size

☐ Customer sets floor stock quantities (step 4.3.1):

Part	Floor Stock		Part	Floor Stock

Planning procedure

☐ Supplier plans its own production, guarantees customer that parts will be available when needed.

☐ Customer uses a blanket purchase order (PO) instead of discrete PO's to buy the parts.

☐ Customer gives supplier a production forecast of its future needs

☐ Any limits to forecast changes (step 4.1): ______________________________

____

☐ Customer forecast horizon and bucket size (weekly, monthly) (step 4.1):______________

____

____

1. The process parameters are defined (cont.)

Major process specifics

☐ There are dedicated, clearly labeled locations for:

  ☐ Supplier's inventory buffer

  ☐ Delivery of production parts at the customer site

  ☐ Customer found defects and good parts for exchange.

☐ Defect documentation is a standard form that includes: ASSY #, S/N, QTY, description of failure (e.g. failed test xxx) , cause (if known), and operator who found problem.

☐ Customer owns all parts in exchange location on assembly floor and manages how its assembly workers exchange defective parts for replacements.

☐ Customer will never remove kanban cards from parts until they have been used according to the usage signal. Usage signal:____

☐ Supplier will always perform a 1 for 1 exchange of defective parts for good parts from supplier.

2. Expected benefits

Effort reduction/ productivity gain.

☐ Make a detailed estimate of the effect that running the program on the selected assembly numbers would have on customer and supplier employee workload in man-hours per week.

  Estimated workload change for customer:______________________

  Estimated workload change for supplier:_______________________

Combined supplier/ customer inventory reduction.

☐ Calculate inventory before the program is started. (suggest use inventory turns or a ratio of inventory to forward looking demand such as "days of supply")

  ☐ Include ALL inventory "buckets" where parts may be stored in the supply chain.

  Pre-program inventory:___________________________

☐ Make detailed estimates of the effect the program would have on the inventory measure.

  Post-program inventory estimate:__________________________

Service and customer satisfaction

how to estimate? line outs?

Decrease in customer defective inventory.

☐ Record the defective part inventory on the customer's books on a date before the program starts:

  Date:__________ Defective Inventory($):_________________________

☐ Calculate the expected average defective inventory after the program takes effect:

avg defective inventory ($) = cost ($/part) * returns/day (part/day) * avg time defective (weeks)

- Returns per day is historical rate of defects returned from customer (step 4.3.2).
- "Avg time defective" is time defective part is on "unavailable" status in the customer's tracking system. This may become zero.

part	cost ($/part)	return rate (parts/wk)	avg time defective (weeks)	avg defective inv

TOTAL:

2. Expected benefits (cont.)

The program provides faster feedback of quality issues.

☐ Estimate the current time between when a defect is found and when it is returned to supplier.
Feedback time before program:______________________

☐ Calculate the expected effect the program will have on the time it takes supplier to receive a defective part. In most cases, this will be 2 times the delivery period. (e.g. 2 days if deliver is daily).
Estimated feedback time after program:____________________

Other benefits

____
____
____
____
____

3. Necessary supporting processes are in place

Inventory level needed in supplier is acceptable.

☐ Calculate required supplier inventory as:

inventory ≅ target buffer size + 0.5* manufacturing lot size

Part	target buffer	+	half of a manuafcturing lot	=	supplier inventory

TOTAL:______________

Engineering change orders (ECOs) and assembly number changes are coordinated.

☐ Customer will assign new assembly numbers to redesigned parts which are not interchangeable with current parts in terms of form, fit, and function.

☐ Customer will accept old ECNs which were built before the latest ECN was activated or will pay to update the parts to the new ECN.

☐ At the end of the product life, customer will buy any remaining supplier inventory.

☐ Supplier will plan its production to minimize its inventory of old ECNs.

Contingency plans are in place

☐ If customer runs out of parts:_______________________________________
____
____

☐ If there are no good exchange parts to replace defective parts:__________________
____
____

☐ others:____
____

3. Necessary supporting processes are in place (cont.)

Plan is in place to train all personnel

☐ All involved personnel understand their functions completely and have an overview of the entire process

☐ Supplier Shipping
☐ Supplier Customer Returns
☐ Supplier Planning
☐ Supplier Program Engineering
☐ Supplier Management

☐ Customer Receiving
☐ Customer Assembly
☐ Customer Buyer
☐ Customer Planner
☐ Customer Engineering
☐ Customer Management

Established process for sharing quality information (step 11.2)

☐ Customer is responsible for holding meetings to review part defects and corrective action plans
☐ supplier is responsible to have appropriate quality personnel at meetings.
☐ Meetings are monthly or more frequent.

Periodic program review (step 11.2)

☐ Program owners are responsible to hold meetings to review the program with all involved parties.
- See training list above for involved parties.

  ☐ Show program performance compared to the benefits in the written agreement.
  ☐ Any suggested improvements.

☐ Meetings are every 6 months or more frequent.
☐ Program owners will analyze performance and suggest improvements if possible:
- Reduce target buffer size if supplier inventory has been consistently more than needed
- Reduce number of kanban cards if customer kanban inventory has been consistently more than needed

Additional concerns

- Any additional concerns from supplier or the customer should be listed here:

☐ ____
____
____

☐ ____
____
____

Appendix C: Sample Optional Supplier/ Customer Agreement

Agreement
(supplier) and (customer) agree to use follow the program described below to define the procedures for delivery of production parts and handling of customer-found defects. This agreement is for the following part numbers:

Process
(supplier) will plan its own production using based on (customer)'s forecast of production needs. (supplier) will hold a buffer inventory of parts, and ship to (customer) as needed using a kanban pull system. (customer) will hold only hold the small amount of inventory specified by the kanban system.

(supplier) will deliver production parts to a dedicated (customer) location (delivery frequency)(delivery time range). The delivery quantity will be determined by the kanban system.

(supplier) will replace defective parts found by (customer) during normal production. (customer) will store the defective parts in a designated area. (delivery frequency) between (delivery time range) (supplier) will replace the defects found the previous (delivery period) with good exchange parts. Repaired parts may be delivered to (customer) as exchanges for defectives or as normal production parts.

Benefits
(supplier) and (customer) acknowledge that the Program will:

Reduce combined (supplier) and (customer) inventory from a baseline of (inventory measure)* to an estimated (inventory measure)* by (time goal). (*see attached inventory analysis)

Eliminate on average (time savings) hours/week* of work associated with the traditional part delivery and repair processes, saving the company an estimated (dollar savings)/ year*. This time savings can be used productively. (*see attached time analysis)

Reduce the time between when a part is found defective and when it is returned to (supplier) from a current baseline of XX weeks to an estimated XX days. This faster feedback on part quality will be used to reduce repair cycle times and drive effective corrective action programs.

Responsibilities
Both (customer) and (supplier) agree to:

- Identify program owners who will be responsible for program performance and maintenance.
- Work together to minimize the effect of engineering changes on inventory and production.
- Continuously improve their internal processes to move toward Just In Time production.
- Openly share quality information and work together to identify and eliminate root causes of defects.
- Establish a continuing review process to measure Program's impact and determine whether to continue.

(Cust) Manager Date	(Cust) Owner Date	(Cust) Assy Suprv Date	(Cust) MMO Date
(Sup) Manager Date	(Sup) Owner Date	(Sup) Supply Chain Date	(Sup) Test Suprv Date