VALUE STREAM IMPROVEMENTS USING KANBAN FOR THE X-WORKCELL

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Kanban is a system of production control that uses cards to represent the number of parts that are required to fill a production order. Kanban cards act as a visual control ensuring only the required amount of production occurs, thus cutting down on wasteful production. The focus of this research was to examine the Kanban system within X-workcell at Cooper Standard Automotive (Cooper) in Mt. Sterling, Kentucky, to see if a re-designed Kanban system could control variations in production levels within the X cell. Data for this research was collected from shipping and production reports that were generated by the personnel at Cooper, as well as surveys of the employees who work within the X cell. The shipping data was analyzed by means of statistical analysis. Shipping and production data were also analyzed visually by the use of line graphs.

It was concluded as a result of this research that a re-designed Kanban system will only be effective at controlling variations in production levels if the customer is capable of predicting their production needs without large fluctuations. Through the course of this research the customer to whom

the X cell supplied hose and tube assemblies had an extremely high variation in demand levels. This variation made it difficult to successfully implement a Kanban system that would control variations in production levels. Although the re-designed system did level production when first implemented, production levels once again began to show high variations at the end of this research.

Even though the new Kanban system did not level production for the duration of this research, the new system was accepted as an improvement over the old system. This conclusion is a result of the employee survey data that was collected during this research. Of those employees surveyed, the majority felt that the new Kanban system was a more effective means of production control than the previous system. This feedback from the employees shows that the new system, while not completely effective, was an improvement to previous systems.

Accepted by: ____________________, Chair

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I would like to thank the creator for everything, literally, and for giving me the chance and abilities to complete this work.

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Chapter 1

Introduction

Modern manufacturing facilities are complex organizations that have many people working together to produce goods. In order to do this more efficiently many companies have adopted various strategies and systems that are designed to increase productivity, increase efficiency, and reduce cost. The Cooper Company (Cooper) in Mt. Sterling, Kentucky, is one such company that is constantly implementing strategies to improve production. The intent of this thesis is to improve an existing process control system within the X workcell known as a Kanban and make the system work more effectively in order to improve production control within the X workcell.

Statement of Problem

Cooper is a manufacturing facility that is divided into several different production units known as workcells. The X cell is the name of one of these workcells and consists of a group of machines and equipment that is used to produce hose assemblies that are used to manufacture automobiles. The X cell is responsible for producing five of these hose assemblies, which are designated by part number. The X cell contains machines and equipment such as hose trimmers, identification stamping machines, plastic injection presses and aluminum tube bending machines, just to name a few. These machines are arranged within the workcell in such a way as to allow the production to flow from one process to another. This process flow allows parts to be produced as efficiently as possible.

The Kanban system is a system of using cards, which are usually made of plastic, to control the amount of production within a manufacturing workcell. Many different types of Kanban systems exist, but all Kanban systems use some type of card to visually control production. Each Kanban card represents a standard number of parts, which usually is equal to the number of parts that are required to fill one shipping container. In this way a Kanban card represents the number of parts that must be produced in order to fulfill a customer's order. In effect the Kanban cards become a visual means of production control.

As of this research the X cell's original Kanban system is no longer in use. Production control is accomplished by managers telling the team leaders of each workcell what number of parts are to be produced that day. This lack of constant visual control is causing problems such as overproduction in some cases and missed shipments due to underproduction in others. Re-designing and implementing a Kanban system for the X cell is the focus of this thesis.

<u>Purpose of the Study</u>

The purpose of this research is to re-design the Kanban system for production control within the X cell at Cooper. More specifically, this research seeks to analyze the current state of production within the X cell and implement a Kanban system that would improve efficiency and equalize production.

To conduct this research, the following research questions were identified.

1. What problems caused the previous system to fail?
2. Can a re-designed Kanban system improve efficiency and level production within the X cell?

Significance of Study

A re-designed and implemented Kanban system will not only increase productivity of the X-cell, but will also allow for much more efficient material handling. Both of these improvements are critically important for Cooper, since the firm supplies hoses and hose assemblies to several large auto manufacturers who demand a high degree of both quality and service. Currently, the original Kanban system for the X cell has become ineffective. The design of the original Kanban does not fit the needs of the cell and due to its ineffectiveness the workers of the X cell do not utilize the Kanban system. As such, this research will take a thorough look at the current Kanban system and then re-design the system as is necessary to improve it.

Assumptions

The most basic assumption of this thesis is that any manufacturing work cell can increase its productivity by the implementation of a Kanban system. This assumption is based on the number of manufacturing firms that have begun to implement Kanban as part of their quality efforts. Other assumptions of this research are that employees and management of Cooper are familiar with the implementation and use of Kanban systems. This is based on other Kanban systems that are present and in use within the Cooper plant. Hereafter, the term "Just-in-Time production" will also represent Lean manufacturing in order to save confusion. Both ideas have their basis in the idea that a manufacturer should only produce what they need when they need it without creating wasteful inventory.

Limitations

This research had some limitations. First, the duration of the research was conducted from the months of October 2002 through April 2003. Any data before and after this time frame was not included in this research.

A second limitation to this research was that any Kanban system implemented would have to have a similar format as other Kanban systems within the plant. This limitation was a direct result of the management at Cooper wanting all Kanban systems in the plant to be uniform. This uniformity allowed workers from different areas in the plant to work in other areas and understand the Kanban system without the need for special training.

The third and perhaps most critical limitation of the implementation of an improved Kanban system was customer scheduling problems. Currently the customer that buys the parts produced by the X cell has a demand that greatly fluctuates over time, from one week to the next. This makes it difficult to level production so that demand can be met without taking extra steps. As the expression goes, the "customer is always right" and there is no way to predict the accuracy of the customer demand schedule. As a result the implementation of a Kanban system depended on collecting data and generating a close analysis of the needs of the customer at any given time. It is evident that the Kanban system in this situation may not be as accurate as a Kanban system in which the customer demand did not fluctuate greatly.

A fourth limitation is the limited amount of space within the X cell. As the X cell is arranged now, there is very little leftover space that is not being utilized by equipment or machinery. As such care must be taken to place the Kanban system in such a way as to be viewable, yet not impede daily operations.

Definitions

Workcell – A group of machines and equipment physically grouped together which are used to manufacture a product or products that undergo similar operations

Kanban - A method for Just–in–Time production in which consuming ("downstream") operations pull from feeding ("upstream") operations. Feeding operations are authorized to produce only after receiving a Kanban card (or other trigger) from the consuming operation. The word Kanban is a Japanese word that loosely translated means "card".

Kanban Cards - Cards that carry production information to help improve production. The cards can be made of various materials and contain data such as product type, number, what operations are to be performed, etc.

Just–In–Time Manufacturing - Approach to achieving excellence in a manufacturing company based on continuing elimination of waste and consistent improvement in productivity. Waste is then defined as those things that do not add value to the product. Just–In-Time uses production and logistics methods designed to result in minimum inventory by having material arrive at each operation just in time to be used.

Materials Management - An organizational structure which groups all or most of the functions related to the complete cycle of material flow, from the purchase and internal control of production materials to the planning and control of the Work–In–Process to the warehousing, shipping and distribution of the finished product.

Work–In–Process - Product in various stages of completion throughout the plant including raw material that has been released for initial processing and completely processed material awaiting final inspection and acceptance as finished product shipment to a customer.

Value Stream – All the actions, both value added and non-value added, that are currently required to bring a product through the main flow essential to every product.

Value Added – Elements of producing a product that actually transform the product in a way that the customer is willing to pay for. For example, taking a raw material such as plastic pellets and injection molding those pellets into the form of an ashtray.

Non-Value Added – Elements of producing a product that do not actually transform the product in a way that the customer is willing to pay for. For example, the time and effort it takes to pick up a product and move it from the workcell and place it in the warehouse.

Cycle Time – How often a part or product is actually completed by a process, as timed by observation.

Changeover Time – The time needed to switch from producing one product type to another.

Chapter 2

Review of Literature

The implementation of Kanban systems in today's manufacturing companies has come about due mainly to the Japanese philosophies of Just–In-Time manufacturing. The person most responsible for developing these ideas was Taiichi Ohno, an executive of Toyota who first addressed the problems of wasteful production (Womack & Jones, 1996). Ohno developed the principles of Just-In-Time to reduce this waste, or Muda that was rampant throughout Toyota (Womack & Jones, 1996). Ohno's leadership and forward thinking helped to make Toyota one of the few manufacturing firms that is the benchmark of quality and productivity in today's marketplace.

Duncan (1988) defines Just-In-Time as " a philosophy which has as its objective the elimination of waste......waste may appear in many forms, including defective parts, excess inventory, unnecessary material handling, setup and changeover times to name a few" (p.21). Just–In–Time is a manufacturing philosophy of eliminating waste through the total manufacturing process, from purchasing through distribution (Hay, 1988, p.1). This is done using the three basic components of flow, quality, and employee involvement (Hay, 1988, p. 1). These three components are used to reduce the waste that is inherent within a manufacturing process. Waste in this case is not necessarily the same as is used in general terms, but instead is anything that does not add value to the product. Time to move the product, storing the product, and time spent waiting on materials to assemble a product are all examples of waste that can be avoided. As such the Just-In-Time philosophy depends on designing the process so that "absolutely essential to production" (Hay, 1988, p.15). Just-In-Time is, at its simplest, defined as "getting the needed parts to the process when needed and the quantity needed" (Hay, 1988, p.15).

In order to accomplish this streamlining of the Value Stream, products must move quickly and precisely to each stage of production. This means that components and products must have a *flow* in order to reach maximum efficiency in the production world. This idea of product flow, however, goes against most people's idea of production. Many people think of production in terms of batch-and-queue, where parts are produced in mass quantities and then sent to the next assembly stage. Taiichi Ohno blamed this mode of thinking on the shift of civilization from hunters to gatherers (Womack & Jones, 1996). According to Ohno, once this change occurred people "became obsessed with batches (the once-a-year harvest) and inventories (grain depositories)" (Womack & Jones, 1996, p.22). It is precisely this mode of thinking that Just-In-Time moves against. Womack and Jones (1996) give this example to demonstrate the differences between Just-In-Time and Batch-and-Queue production. When a person needs to mail a large group of letters, in most cases the person will first fold all of the letters, then get the envelopes and address them, then place stamps on them, finally taking the letters in a large group to be mailed. This process will result in a lot of wasted movement since each letter is handled three times before the process is complete. If this process were repeated in the Just-In-Time frame of mind each letter would be handled only once, since each letter would be folded, placed in an envelope, then stamped and mailed before the next letter was touched. This would save a great deal of wasted movement and stockpiling of materials (Womack & Jones, 1996).

The Just-In-Time philosophy brings about the need for a system of controlling the process flow or a product through a manufacturing process. This control system must be able to precisely dictate what product needs to be manufactured and in what quantity. In some cases the control system may even need to actually control which processes are performed on a product and in what order. Without this control there is no way to ensure production will be efficient. One such system of control that is widely used by many manufacturing companies is Kanban.

Kanban, loosely translated from Japanese, means "card" or "sign" and that, in many cases, is the basis of the system (Kanban for the Shopfloor, 2002). A Kanban system uses cards and other visual signals to control Just-In-Time production (Dennis, 2002). Kanbans are usually cards that are made of either paper or plastic that contains information critical to the production process, and act as an authorization for production (Dennis, 2002). Other types of Kanban exist, such as boards or electronic systems, but generally when one thinks of a Kanban the traditional card comes to mind (Dennis, 2002). The Kanban card contains information that "serves a work order" such as "what to produce, when to produce, and in what quantity" (Lu, 1986, p.85). Kanban cards are designed to fit the specific needs of a production process and are widely varied from company to company; however, there is some basic information that is usually, but not always, common to Kanban cards. Kanban cards may carry such information as lot number, part type, previous process, and subsequent process (Dennis, 2002).

Kanban cards function by moving with materials through the production process (Lu, 1986). Kanban cards "flow in a controlled cycle or process loop" (McIlvain, 1999, p.11). Generally, production facilities manufacture parts in groups and then send those parts to a production station further down the process. These parts usually come in some form of container such as a bin or a box. In the Kanban system each of these bins would come with a Kanban card that gives information that pertains to the part such as lot number, type of part, etc. as well as information on what should be done with the parts at the particular cell or work station, although this can vary based upon the company.

Kanban systems improve efficiency by representing not only information that is pertinent to the production process, but also as means of process control (Kanban for the Shopfloor, 2002). Kanban systems allow for a relationship to be set up between each work area in which the preceding cell supplies the next cell in the process (Lu, 1986). More importantly the subsequent process only withdraws from the previous process the exact quantity of product needed at the time that it is needed (Lu, 1986). Once a Kanban card has been released in the restocking process the card authorizes or orders inventory replacement (McIlvain, 1999). In a simplified example of this situation when a workstation within a workcell needs parts from the preceding workstation parts are transferred to that cell. A Kanban card is then sent to the preceding cell showing that a group of parts has be taken to the next stage of the process. That cell in turn pulls parts from another preceding cell by sending a Kanban to that cell and the cycle continues. This type of production is known as a pull system of production.

In a pull production system, inventory is withdrawn only as demanded by the using process (Pull Production for the Shopfloor, 2002). Pull systems eliminate the waste that results from the more traditional push system of production, in which parts are mass-produced at one station and then large inventories are moved to the next station (Pull Production for the Shopfloor, 2002). This reduction in production waste can greatly increase efficiency as well as cut costs dramatically (Pull Production for the Shopfloor, 2002). Shown in Figure 1 is a graphical representation comparing a pull system utilizing Kanban with a traditional type of Push (or Batch and Queue) manufacturing (Pull Production for the Shopfloor, 2002).

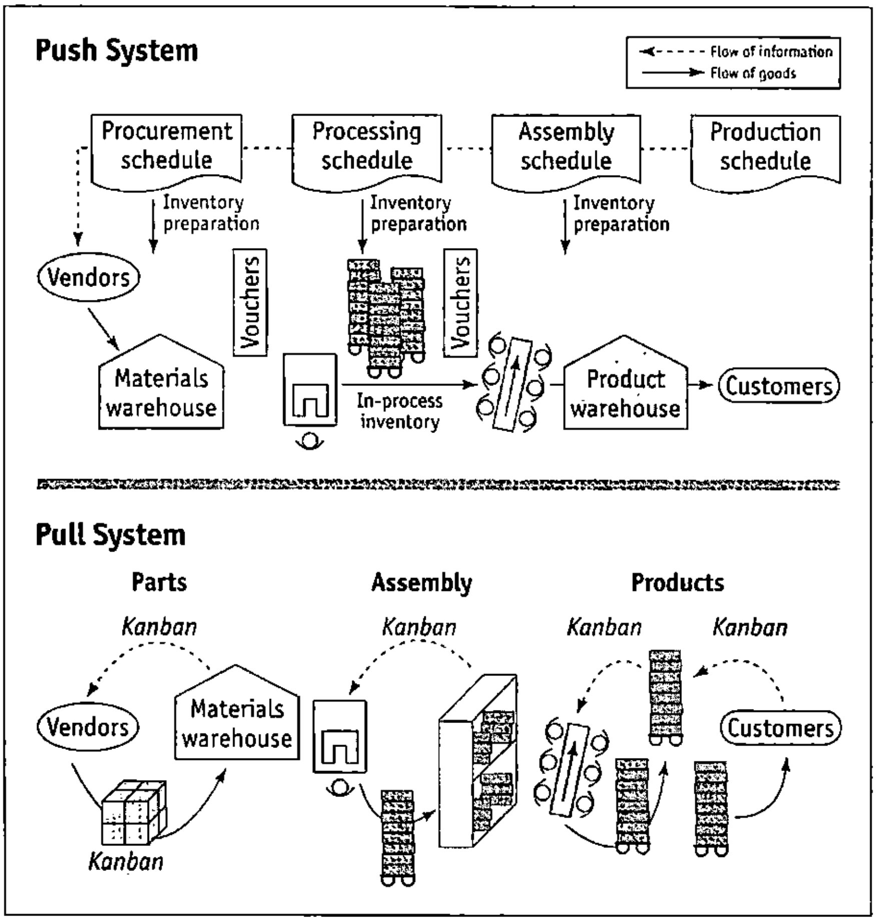

Figure 1. Differences of Push and Pull Systems

Not only does this use of Kanban reduce the waste of overproducing parts, it also allows for close monitoring of material flow through the process. Parts can be tracked by looking at the Kanban, while planning and production scheduling can be refined to make the production process more efficient. Kanban acts as a system of information that integrates the plant and connects all processes to one another (Kanban for the Shopfloor, 2002). This is why

Kanban systems have been labeled the nervous system of lean production (Kanban for the Shopfloor, 2002).

Another key benefit of utilizing a Kanban system is production leveling. The use of Kanban allows a company to distribute the production volume of different parts (Dennis, 2002). Instead of a company building part A all morning and part B all evening, the production would alternate as needed (Dennis). This results in less inventory being created between processes, less strain and unevenness experienced by the operators, and shorter lead time on production which means the company can respond quicker to a customer's needs (Dennis). Production leveling also helps in deciding what will be the equipment, personnel, and material needs for a given product to be produced (Dennis). This allows companies to best utilize their personnel and facilities without placing great strains on them or under-utilizing them (Dennis).

The use of Kanbans is "basically a methodology of delivering and ordering products within a manufacturing facility" (McIlvain, 1999, p.12). There are two major kinds of Kanbans that are widely used in today's companies are production and withdrawal (McIlvain, 1999). The production Kanban sends a signal that more parts are to be produced in order to replace a storage quantity (McIlvain, 1999). The withdrawal Kanban, on the other hand, requests that parts be retrieved from the storage quantity (McIlvain, 1999). Many varieties of these two types exist throughout manufacturing today, as many manufacturers slightly modify or customize the utilization of Kanbans (McIlvain, 1999). Kanbans are generally very simple and can be modified easily to fit the needs of a particular company without much difficulty.

The focus of this research is upon a current variation of the production Kanban in which the Kanban cards will represent a given number of parts. This number will be the total number of parts that can be placed in one shipping container, otherwise known within Cooper as a standard pack of parts. The Kanban cards will be placed upon a board within the cell that will have placards with the five different part numbers. The number of cards that is placed underneath each part numbered placard will then signal the workers within the cell how many parts are to be produced. In this way the Kanban will control the amount of production within the X cell.

<u>Background</u>

Cooper Fluid Division in Mt. Sterling, Kentucky manufactures hose assemblies which are used by many of America's automakers in the manufacturing of vehicles. The Cooper facility has been open for almost ten years and has gained a reputation for quality products. Cooper produces several varieties of rubber hose and aluminum tube assemblies and has recently added a cell that makes extruded plastic hose assemblies. These hose assemblies are then sold to many different automakers such as Ford, Chrysler, and Nissan while new business is coming in all the time. These diverse business associations show that Cooper is a highly competitive and flexible company. This competitiveness comes from being a quality company with a focus on continuous improvement and customer service.

Basic Process of Production at Cooper

The basic process of making hose assemblies at Cooper follows several steps. First, raw rubber is bought and shipped into the facility. This rubber is then run through extrusion machines and cut to produce lengths of hose. These hose lengths are then formed and washed to clean off debris or residue from the forming process. The hoses are then moved to the various workcells, depending upon which assemblies the hoses fit. These workcells take the formed hoses and assemble them to aluminum tube assemblies that are formed within the cell. Workers within these cells perform all the necessary operations to assemble the hose assemblies including gluing clamps onto the hoses, stamping and marking the hoses, and attaching brackets to the hoses. From the workcells the assemblies are taken to shipping and sent to the customer.

This research focuses on one particular workcell that produces five hose assemblies that are designated by numbers. This work cell has been labeled the X-cell and consists of several pieces of equipment that are used for the final assembly. This equipment includes trimming machines, glue pods, clamp attachment stations, endformers, powerbenders, leak testing equipment and final assembly stations. The physical layout of the cell is shown in Figure 2 (Drawings provided by Cooper).

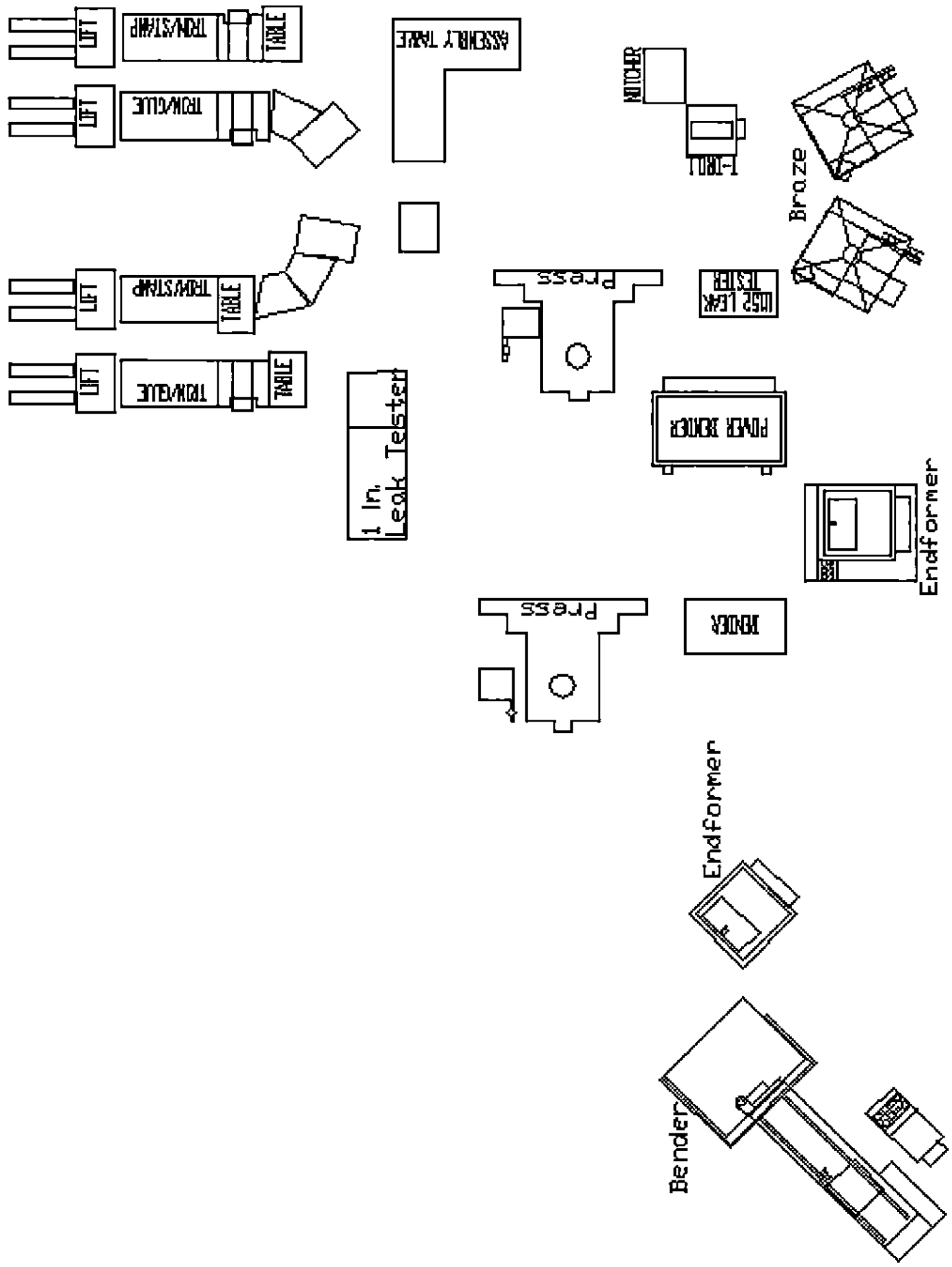

Figure 2. Layout of Equipment within X-cell

Production Processes Within the X cell

The X cell currently produces five separate hose assemblies, which are labeled by part number as 3756, 3806, 3808, 3809, and 4023. Each of these five parts undergoes similar operations within the cell before completion. Each assembly is made up of hose and aluminum tube assemblies which are fitted with components and then fitted together to produce the finished part. The construction of each hose and tube assembly can be divided into two separate groups: hose components and aluminum tube components.

Aluminum tubes arrive at the plant pre-cut to length and are taken to the back left corner of the cell to begin production. The tubes first have to have the ends shaped at an enforming machine at one of two locations depending upon which assembled part the tube will be used for. Once the tube has been endformed it is placed into an automated bender located close to the endformer. After the tube is bent to shape they are taken to a notcher and drilling machine. One set of tubes gets a hole drilled into the side, while the other tube is notched. Then both sets are placed into an automated brazer. Once the tubes have been brazed together they are leak tested and then sent to a press that takes two sets of tubes and applies a plastic bracket to hold both sets together. This tube portion of the assembly is then taken to a station where the hose components are attached. A detailed drawing of the tube assembly area is shown in Figure 3.

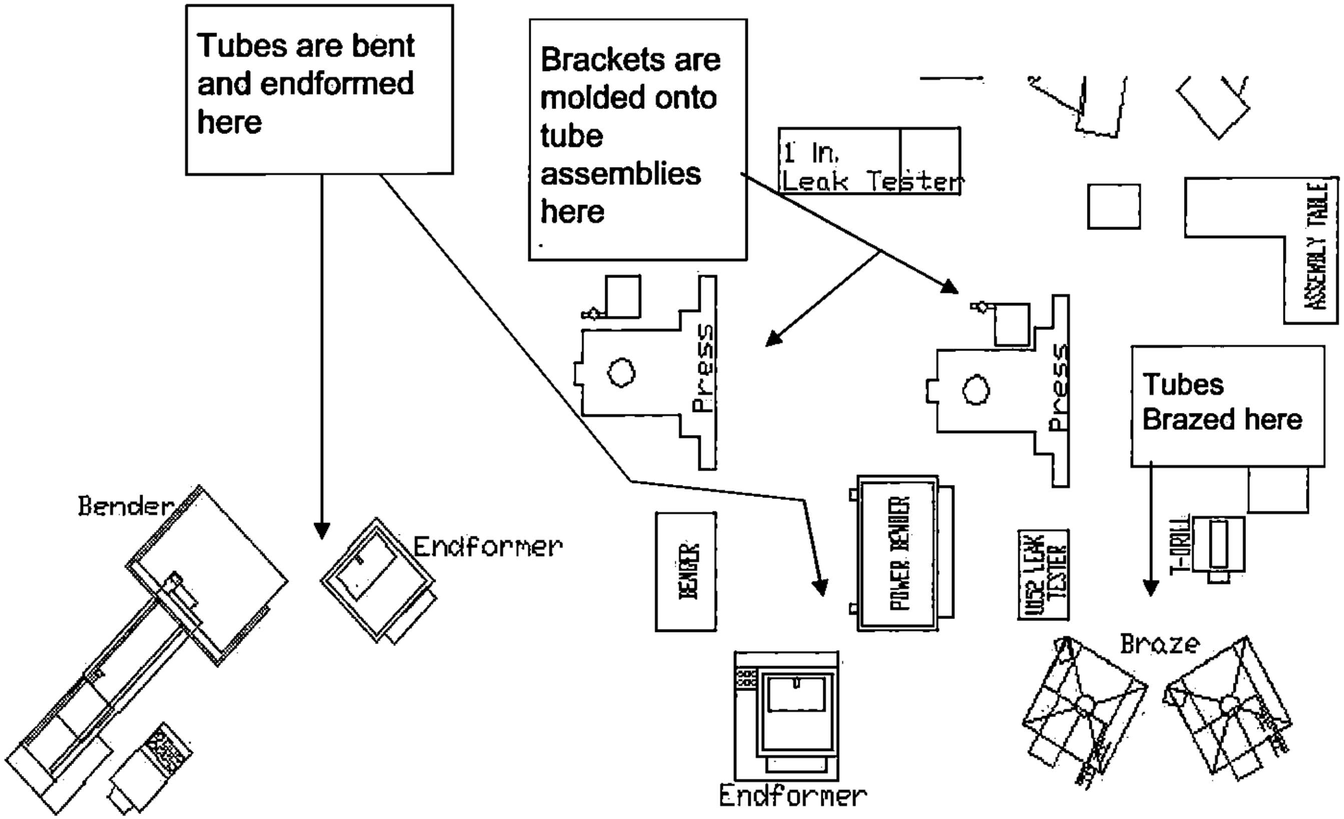

Figure 3. Layout of Tube Assembly Area

The hose portions of the assembly come pre-formed from another area of the plant. The hoses are taken and fitted into a quality check mold that insures correct shape and then trimmed to length. Once the hose has been trimmed it may or may not be stamped, depending on which part it is to be used for. After stamping, the hoses may have sleeves attached depending on what part they are for. Next, clamps are attached to the hoses in one of two ways: glue or air ram and then sent to be assembled with the tube portion. Once the tube and hose portions are assembled they are moved to final assembly where the final components are added before completion. Shown in Figure 4 is the hose area of assembly.

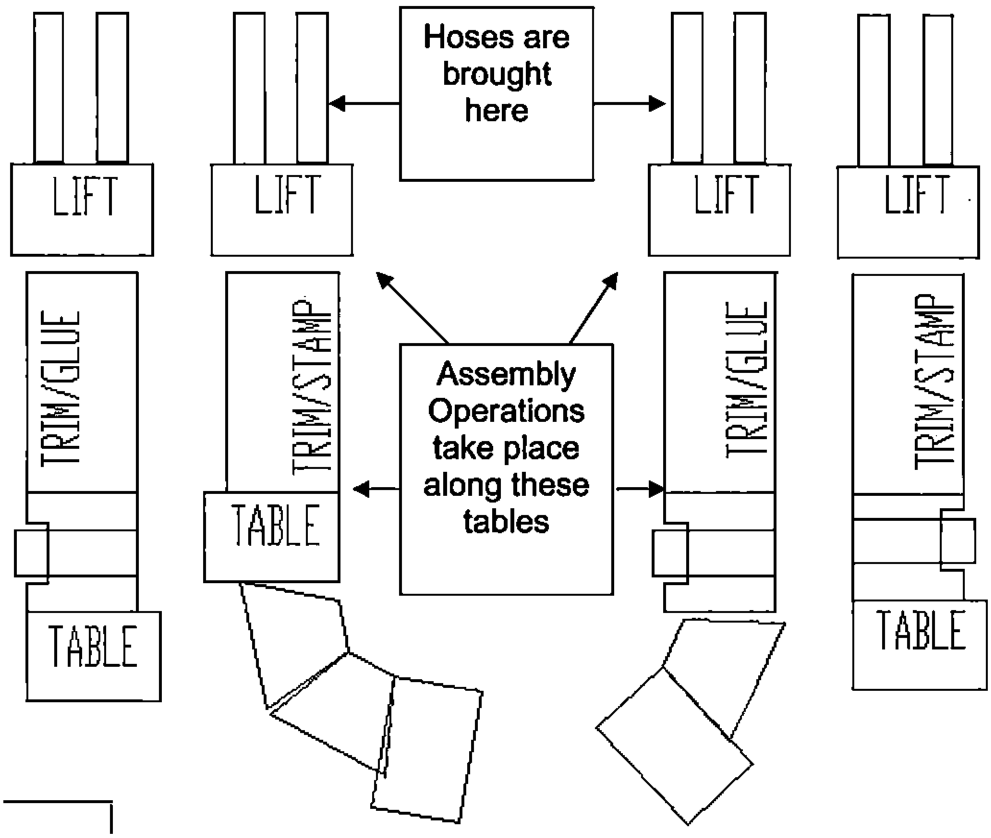

Figure 4. Hose Assembly Area

Final assembly takes place at a table located between the hose assembly and tube assembly section. Once final assembly is complete the parts are placed in cardboard shipping containers and sent to the warehouse for storage until they are shipped.

Chapter 3

Methodology

The bulk of the data collected for the implementation of the Kanban system dealt with the shipping and production numbers of each of the five parts produced within the cell. The numbers were taken from reports that are generated within the facility at Cooper, then entered into the Excel Spreadsheet Software for ease of manipulation, showing both the date and the number of parts that were either shipped, produced, or both on each date. These spreadsheets of the shipping and production data are located in Appendix A of this paper. Not all of the days within a month are represented in the data as the plant is generally closed on weekends and holidays, barring some exceptions when production is required to fulfill orders or equipment failures result in missed production during the week.

Shipping data is recorded on all parts shipped and the data is stored in a database within the shipping department. The shipping data shows what quantities of each part are shipped to the customer, which reflects the actual need of the customer. This data was useful in determining problems with the previous Kanban system since the past demands of the customer were analyzed to give an indication of the production control of the previous system. Since a Kanban system is a type of production control that is set up according to the predicted needs of a customer it is important to understand the customer's previous demands. The more level the shipping data the better the customer is at predicting their needs. If, however, the shipping data has values erratically ranging between low and high values then that can indicate the customer is having difficulty predicting the level of production needed. This in turn makes it difficult to set up a Kanban effectively to control production.

The production data shows what is actually produced within the X cell and when. These reports were recorded after each shift and show which part was produced and in what quantity. This is also important in the devising of a Kanban system since it shows the level of production within the cell. Analysis of the production numbers can determine if the work cell is producing efficiently. If the production numbers show variation, then the production is not as efficient as is possible. Ideally, a Kanban system would control production so that there is little variation, and the amount of production is level. This research utilized analysis of the production numbers in order to determine if efficiency was improved within the X cell, and is given in Chapter Four of this research.

Aside from the shipping and production data that was collected for this research, one other important set of data was collected: the production rate for each part. The production rate is simply the amount of production that can be achieved by the people and equipment within the cell for a particular part. This data was determined by the management of Cooper and is a fixed value on record within work cell. It specifies a limit to the number of parts that can be produced for each of the five parts, and was taken into account when implementing the Kanban system. The rate data for each of the five parts is located in Appendix B of this thesis.

Once all of the data was obtained the shipping data was input into Excel and several descriptive statistical analyses were conducted, namely the mode, mean, median and standard deviation. Line graphs were also constructed for each month to visually clarify trends within the data. This analysis was done to understand why the previous Kanban system was ineffective. Analysis of past trends in customer demand provides a good indication of future needs, but cannot predict the exact numbers needed. The unpredictability of future customer need, in most cases, could be compensated for utilizing the descriptive statistical analysis of standard deviation. The standard deviation value of the shipping data shows at what value data varies above and below the mean. Ordinarily, the re-designed Kanban would have incorporated the mean with the standard deviation added to it to compensate for fluctuations in customer need. However, this was determined to be impractical given the extremely high standard deviation values. As a result the mode and mean values were utilized instead. Since the mode and mean of shipping values of the five parts were very close to one another it was possible to predict the amount of production on average that would be required to fulfill customer requirements using these values. It was with this analysis, based on the mode and mean shipping values along with the production rate data, that the Kanban system for the X cell was devised and implemented. The results of this analysis are shown in Chapter Four of this thesis.

After the shipping data had been analyzed the production data was then input into Excel and line graphs were generated. The graphs were used to determine if production was leveled within the X cell. Level production values indicate production efficiency, whereas non-level production values indicate production is not efficient. Line graphs generated from the production numbers were determined to be the simplest analytical technique to determine if the updated Kanban system increased efficiency. The results of this analysis are shown in Chapter Four of this thesis.

As a final evaluation of the implemented Kanban system, a survey was generated to gather the reactions of the workers within the X workcell. The survey consisted of four yes or no questions designed to evaluate the new Kanban system's effectiveness. The final question was a rated response question allowing those surveyed to express their opinion of the effectiveness of the system on a scale of one to five, with one being not effective and five being very effective. A total of six people voluntarily responded to the survey from a total of twelve workers who work within the X cell. The survey used is located in the Appendix C of this paper, with the results of those employees surveyed summarized in chapter Four of this thesis.

Design of Kanban System

The design portion of the research was not that intensive since Cooper already has Kanban systems in place in other areas of the plant. In an effort to remain standardized the actual physical design of the Kanban system and cards were taken from other areas and utilized within the X cell. This left only the determination of the actual number of cards, creation of cards and boards and installation.

The Kanban cards themselves were made of thin plastic, engraved with the part number and instructions on where to place the card once it was removed from the container of parts to which it was attached after finished production. Metal hooks were used to suspend the cards from the Kanban board located within the cell. The board also had engraved plastic plaques made of the same material as the cards, which were adhesively fixed to the board. One set of plaques had the part numbers and was attached to the right side of the board to show where the cards for each part should go. At the top of the board plaques were attached which labeled one column as Day 1 and the other column as Day 2. Below the hook for each set of cards a placard was attached that gave the maximum amount of cards that could be placed there. This was to ensure that no extra cards were placed there by mistake. In Figure 6 the Kanban board is shown after completion.

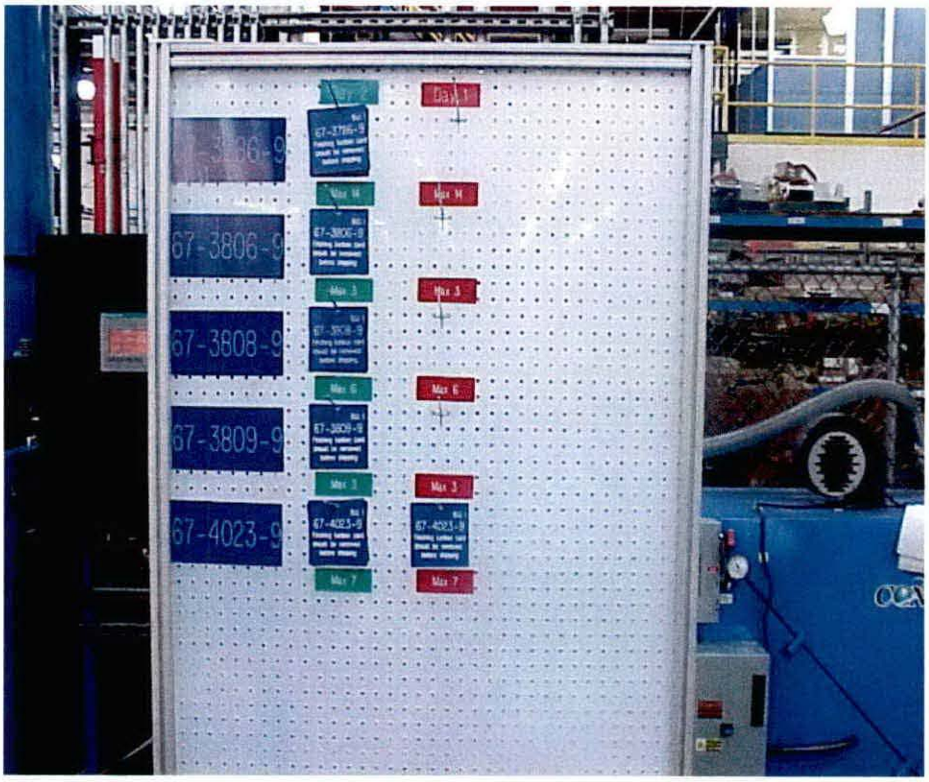

Figure 6. Photo of Implemented Kanban Board

This setup of having two days listed was a common practice at Cooper Standard. Ideally production would already have Day 1 cards removed, meaning the necessary parts were already produced, and production of Day 2 would be under way. Ideally this would mean that production would be two days ahead of schedule at any given time. This practice was instituted in order to ensure that production did not fall behind schedule.

The Kanban board itself was no real change from other systems elsewhere in the Cooper facility. However, through the course of this research an idea developed to add additional boards elsewhere in the X workcell in an effort to ensure better production control. This idea was to provide extra control information in the form of dry erase boards that could list the aluminum tube requirements for that day's production. Essentially these boards would add an extra layer of production control that was specific to the tube assembly area of the X cell and since the boards were erasable more specific values could be entered and erased as needed. The tube Kanban boards allowed for more precise production control of the aluminum tubes within the cell than did the overall Kanban board. Depending upon the part being produced the number of aluminum tubes varied. This variation in number required was not really addressed in the overall Kanban board and as such seemed to cause confusion within the tube assembly area of the X cell. Also those workers who worked producing the tubes were unfamiliar with the overall part numbers since they dealt only with the numerical designations of the tubes. This extra control seemed beneficial in that it showed exact production requirements of the aluminum tube portions as well as clarified part numbers for the workers.

The setup of the tube Kanban board was somewhat different than that of the overall Kanban board. On the left were plaques with numerical designations of each of the tubes that were manufactured within the X cell. In the middle of the board was the part number of the parent part, or the part which those tubes went to, so that there would be no confusion as to which tubes went where. On the right a space was left so that the requirements could be written in for each day of production. The tube Kanban board is shown in Figure 7.

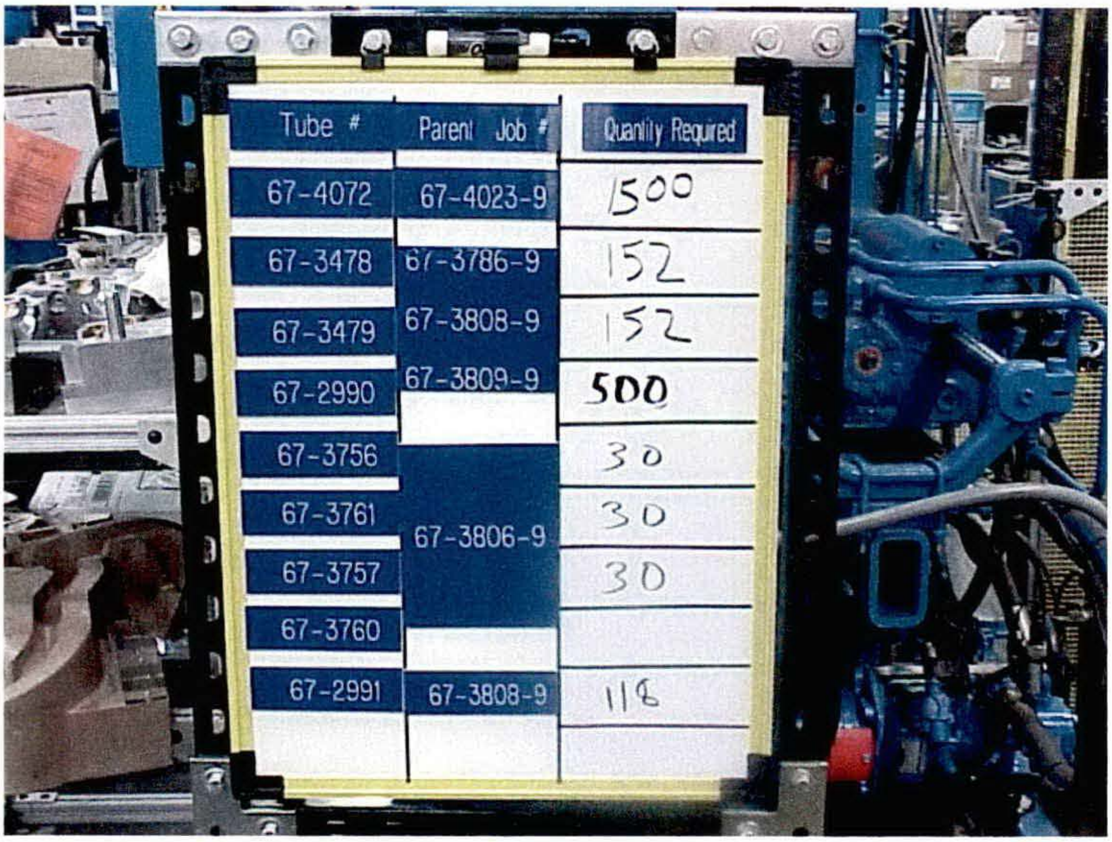

Figure 7. Photo of Implemented Tube Kanban Board

A second dry erase board was also designed and implemented in order to increase efficiency within the tube assembly area of the X cell. This second board came about as a result of observing several of the workers standing around throughout the day. When asked why they weren't working they replied that they didn't have the necessary parts on hand and had to wait until the previous process was done before they could continue. This down time was especially evident on the two brazers that were waiting on bended tubes from the benders. In order to prevent this lag in production from occurring, a second dry erase board was designed and placed next to the CNC bender. This board's design was similar to that of the other tube Kanban board in that it had the numerical designations of the unbent tubes on the left side, the numerical designations of the tube after it was bent, and a space to write in the required number on the left. The difference in this case being that the number required refers to number of bent tubes required to ensure that the other processes within the cell have parts. This buffer number is added to the day's production so that the part will always be available even after the production numbers are met. This number was determined by retrieving the rate data on each of the parts. The rate data is the number of parts that the cell should be capable of producing in one hour's time. This rate data was on file within the X cell and is determined by Cooper. By ensuring that one hour's worth of extra parts were produced each day workers within the cell did not have to lose production time due to a lack of parts. The buffer Kanban board is shown in Figure 8.

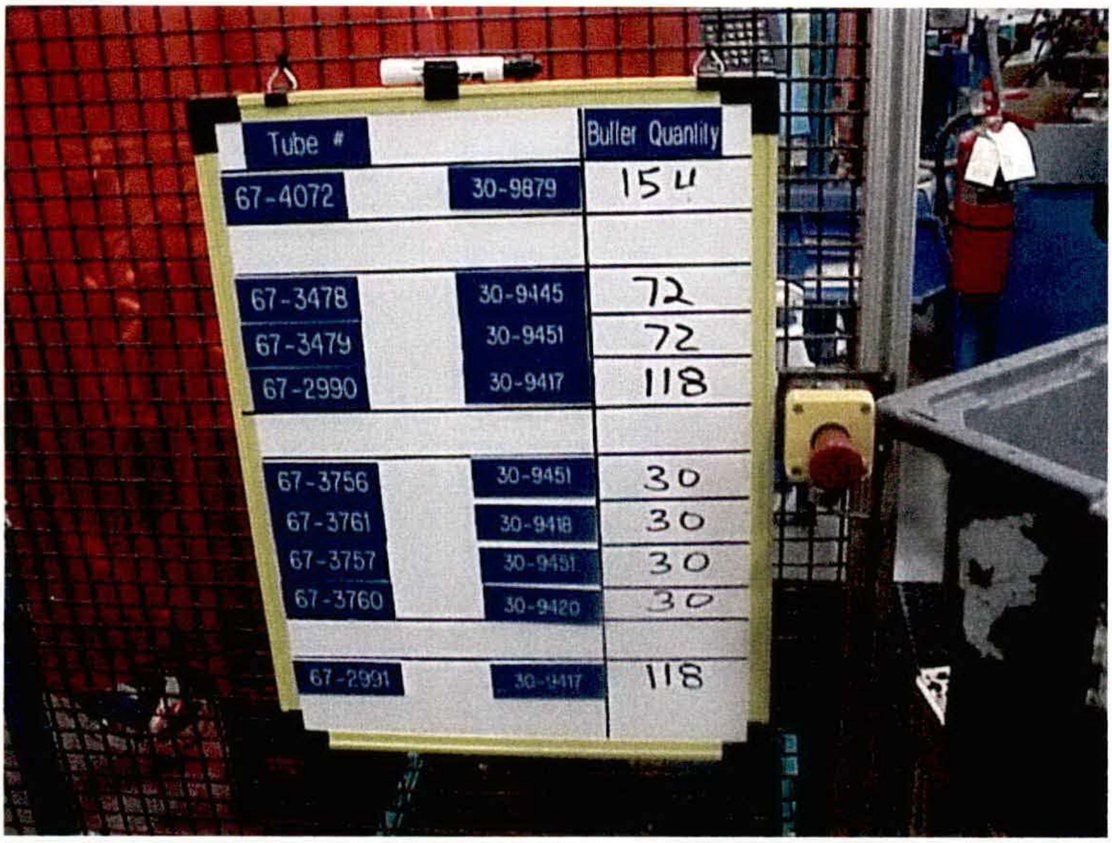

Figure 8. Photo of Tube Buffer Kanban Board

Chapter 4

Findings

The purpose of this research is to update and re-design the current Kanban system within the X-cell at Cooper. Specifically, the research sought to analyze the current state of production within the X-cell and implement a Kanban system that would improve efficiency and level production.

In order to complete this research several different research techniques were used. Statistical analysis of shipping and production data was completed, as well as the gathering of survey and observational data. All of the research techniques used in this study were part of an effort to answer the two research questions of this study:

1. What problems caused the previous system to fail?
2. Can a re-designed Kanban system improve efficiency and level production within the X cell?

This chapter presents an analysis of these three research questions.

Discussion of Research Question One

The first research question that had to be answered to progress was what problems caused the previous Kanban system within the X cell to not incorrectly control production. In order to seek an answer to this question, the shipping data of each of the five parts was collected and analyzed for the months of October through March. This data was collected and analyzed to determine past trends in customer demand. Summarized in Table 1 are the results of the descriptive statistical analysis of the shipping within the X cell for the 3806 part, including the mode, median, mean, and standard deviation.

Table 1

Descriptive Statistical Analysis of 3806 Shipped Parts for the Duration of the Research

	Mode	**Median**	**Mean**	**Standard Deviation**
3806	200	150	143	67

The analysis of the number of shipped 3806 parts shows that the overall customer demand for the 3806 part was low, with a mean value of only 143 parts per order. The standard deviation of the customer demand was high with a value of 67. This meant that there was a variation in demand of nearly 70 parts throughout the duration of the research. In order to clarify the shipping data further the data for each of the five parts was entered into Excel software and graphed into the form of a line graph in order to see if the customer demand played a role in the previous system failing. Figure 9 is the graph generated for the number of shipped 3806 parts for the months of October through March.

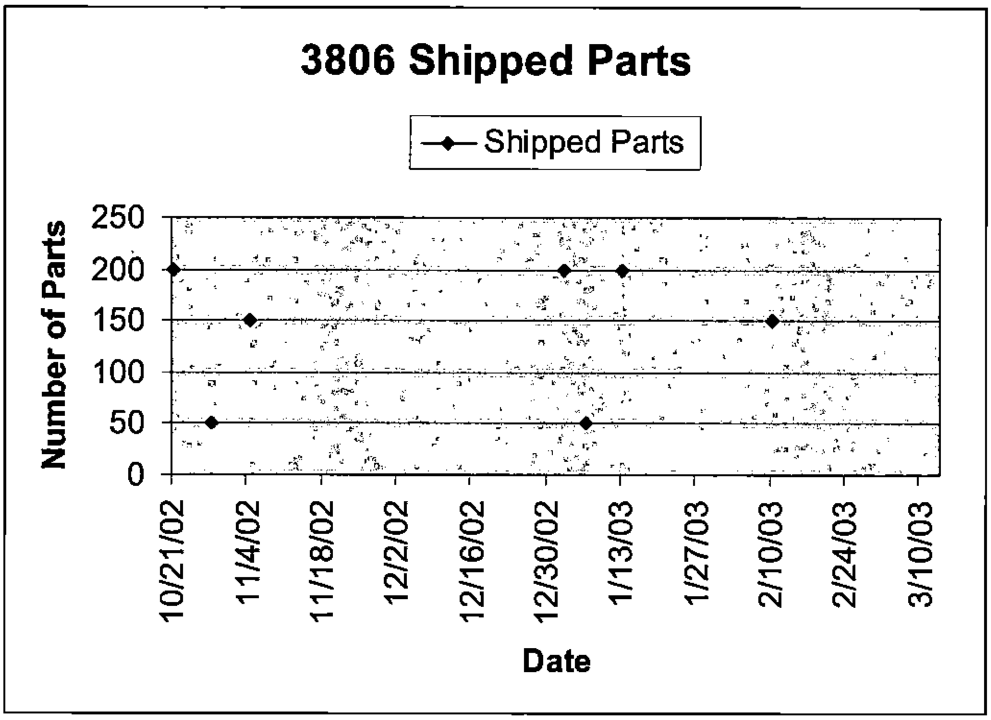

Figure 9. Graph of Shipped 3806 Parts

Figure 9 shows the infrequency with which the customer ordered the 3806. Figure 9 also shows the extreme variation in the level of demand of the customer.

Summarized in Table 2 are the results of the descriptive statistical analysis of the shipping within the X cell for the 3786 part.

Table 2

Descriptive Statistical Analysis of 3786 Shipped Parts for the Duration of the Research

	Mode	Median	Mean	Standard Deviation
3786	560	560	702	546

The data for the 3786 part shows a higher per order demand than the 3806, with an average value of 702 parts shipped. The standard deviation of the demand for the 3806 was also very high with a value of 546 parts, a mere 156 parts from the average value of 3786 parts shipped. In Figure 10 the data for the 3786 was graphed highlighting further the variation in customer demand.

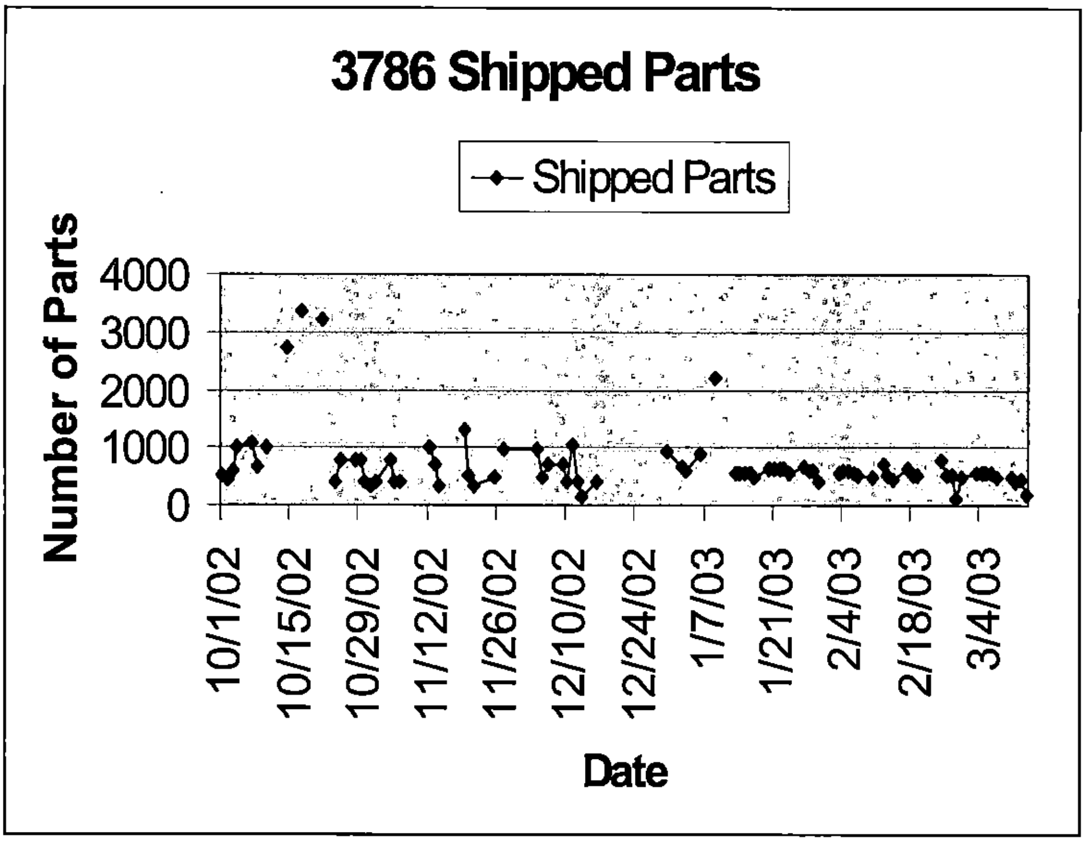

Figure 10. Graph of 3786 Shipping Data

Figure 10 shows that the customer ordered the 3786 part more frequently and the variation in demand was less than in the 3806 part. However the graph does show incidents where the customer demand did fluctuate greatly in the month of October and moderately in the month of November as well as a short spike in demand for the month of January.

Summarized in Table 3 are the results of the descriptive statistical analysis of the shipping within the X cell for the 3808 part.

Table 3

Descriptive Statistical Analysis of 3808 Shipped Parts for the Duration of the Research

	Mode	**Median**	**Mean**	**Standard Deviation**
3808	1200	1200	1600	1064

The customer demand for the 3808 was higher than that of the previous two parts. Also the variation in customer demand, as shown by the high standard deviation, was also very high. In Figure 11 the shipping data of the 3808 is shown highlighting this trend.

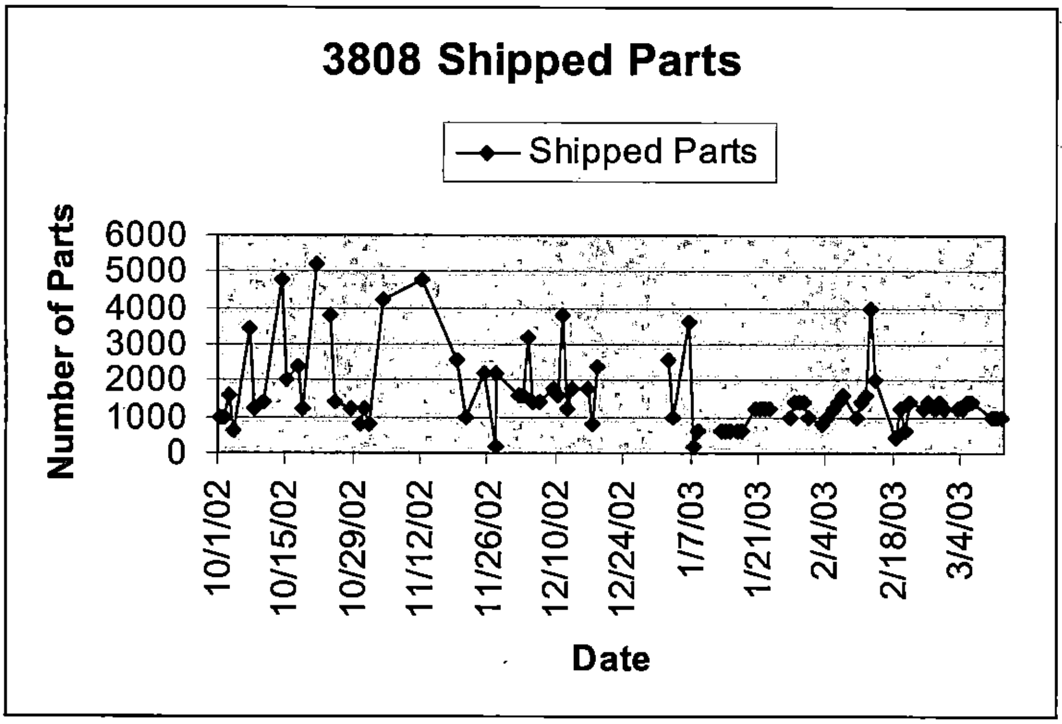

Figure 11. Graph of 3808 Shipping Data

Figure 11 shows that there is an extreme fluctuation in demand for the 3808 part. This fluctuation is especially extreme in October and continues all the way until January. After January customer demand for the 3808 seems to level out, with the exception of a large fluctuation around the middle of February, after which demand levels out again.

Summarized in Table 4 are the results of the descriptive statistical analysis of the shipping within the X cell for the 3809 part.

Table 4

Descriptive Statistical Analysis of 3809 Shipped Parts for the Duration of the Research

	Mode	Median	Mean	Standard Deviation
3809	300	300	458	377

The customer demand for the 3809 part was relatively low compared to the other parts produced in the X cell. The variation in demand was still high as shown by the high standard deviation value, which was only 77 parts from equaling the mean value of shipped 3809 parts. In Figure 12 the shipping data for the 3809 is shown.

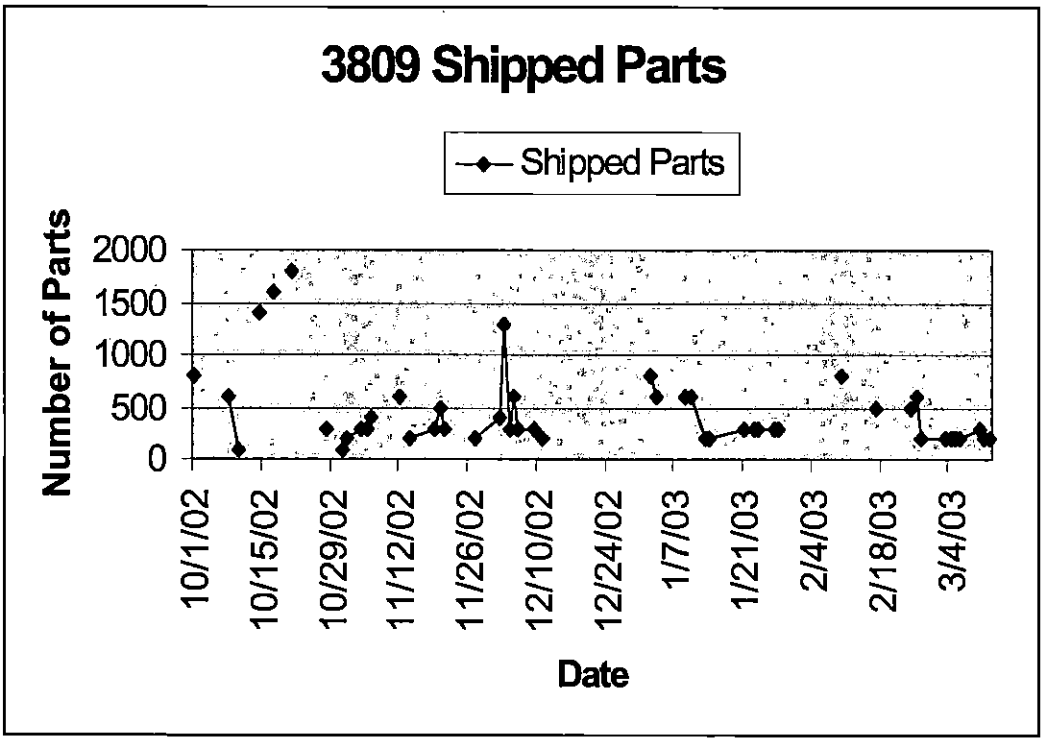

Figure 12. Graph of 3809 Shipping Data

Customer demand for the 3809 part fluctuated dramatically throughout the entire duration of time from which the data was taken. The fluctuation in demand did seem to diminish somewhat toward the end of the study, but was still very high compared to other parts within the X cell.

Summarized in Table 5 are the results of the descriptive statistical analysis of the shipping within the X cell for the 4023 part.

Table 5

Descriptive Statistical Analysis of 4023 Shipped Parts for the Duration of the Research

	Mode	Median	Mean	Standard Deviation
4023	1800	1800	1901	588

The customer demand for the 4023 part was the highest of the five parts. This high customer demand seemed to lower the deviation in customer demand as the standard deviation was 588 parts. This was still a very high deviation in demand and confirmed that there was a trend for customer demand to fluctuate greatly. Shown in Figure 13 is the graph of the 4023 shipping data.

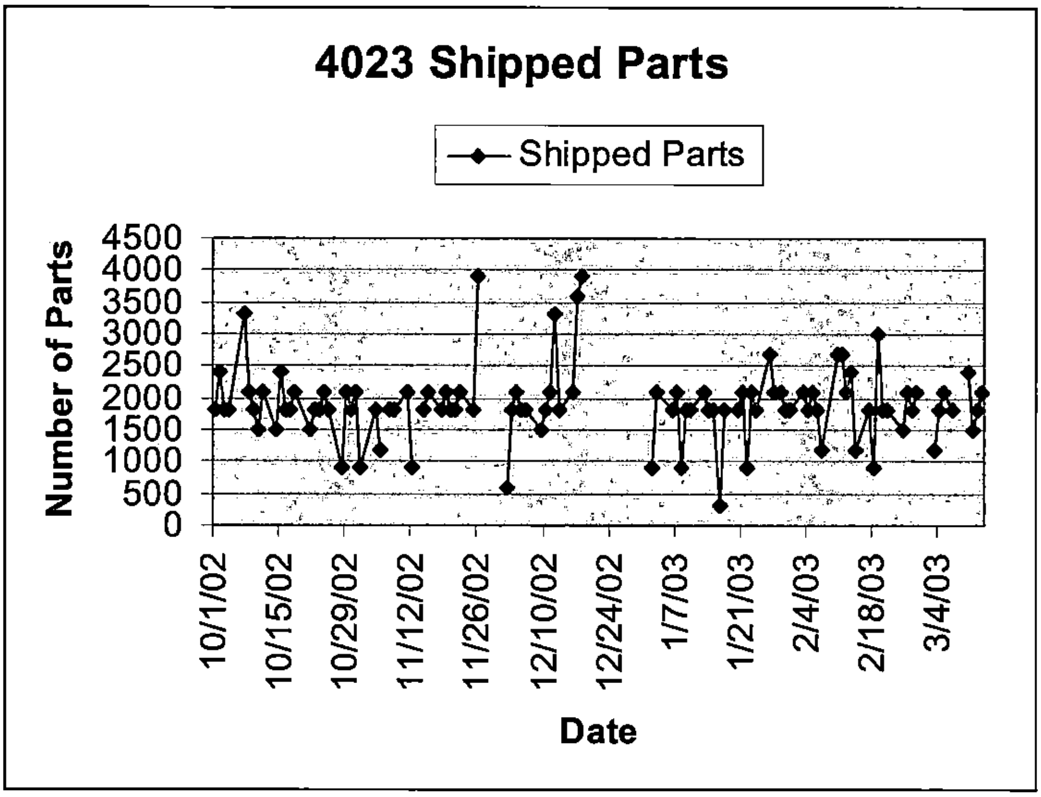

Figure 13. Graph of 4023 Shipping Data

Customer demand of the 4023 part seemed to hold steadier than previous parts, but large variations did still occur. The overall higher demand for 4023 parts seemed to lower the variation within that demand, with the exception of the month of December which had high fluctuations.

Discussion of Research Question Two

As a determination of whether the implemented Kanban increased efficiency and leveled production, two approaches were used. First the production data for each of the five parts was input in Excel and line graphs were generated in order to see if the production within the cell had leveled after the implementation of the new Kanban system. The second method was to generate a survey that could be used to gather data from the employees who worked within the X cell as to whether they thought the new system worked more effectively than the previous one.

Shown in Figure 14 is the graph of the production numbers for the 3786 part.

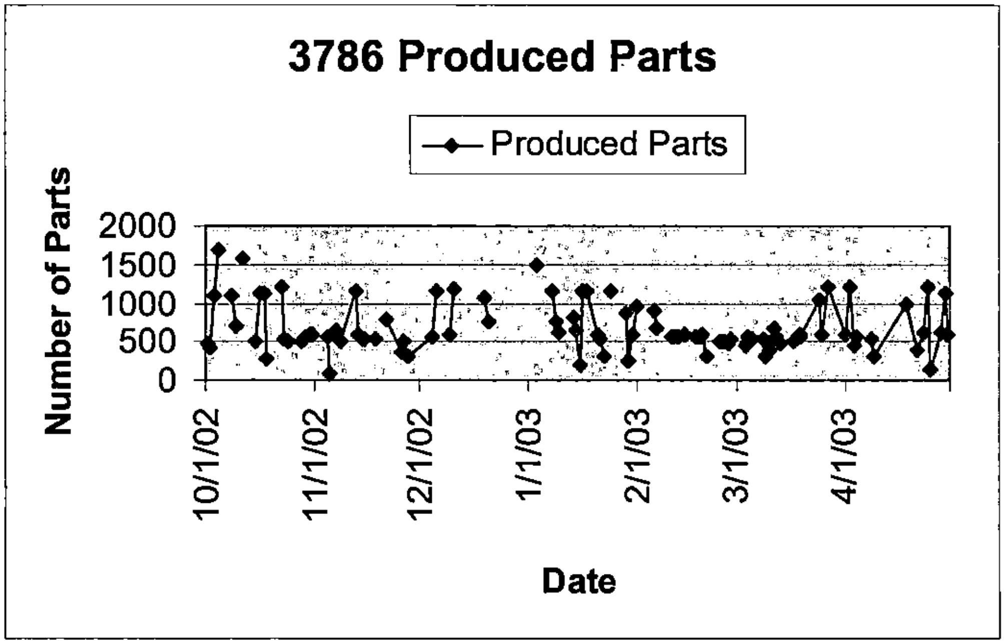

Figure 14. Graph of Produced 3786 parts

The graph of the production data shows how erratic production for the 3786 part was. Production levels vary from high values to low values for the duration of the research until the new Kanban system is implemented in the early part of March. The introduction of the new system causes production levels to reach a level value of around 500 parts, a value that is dictated by the new Kanban system. However, after March the production once again becomes erratic with production levels varying.

In Figure 15 the production data of the 3806 part is shown.

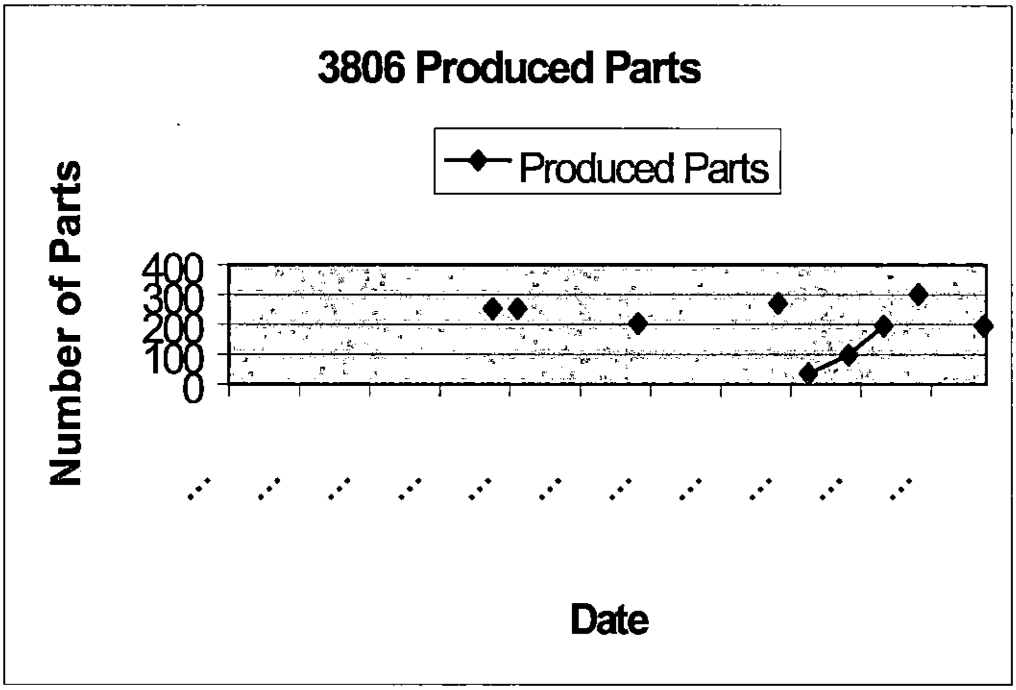

Figure 15. Graph of 3806 Produced Parts

Figure 15 shows the produced 3806 parts of which there are very few. The 3806 are produced in very low volume and are produced infrequently. The graph shows the level of production for the 3806 is very erratic which is understandable given the infrequency of production.

Figure 16 shows the produced parts for the 3808 part.

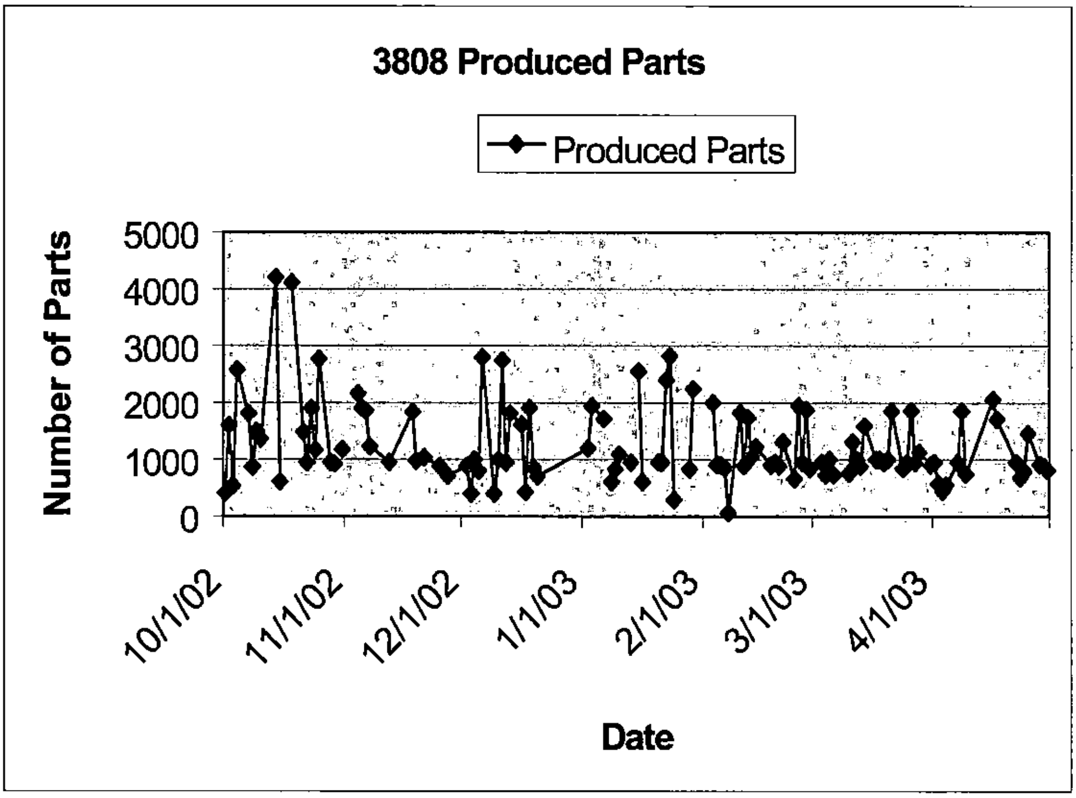

Figure 16. Graph of 3808 Produced Parts

The graph shows the erratic nature of production up until the new Kanban system is implemented in early March. Even after implementation of the new Kanban system production levels fluctuate. The fluctuation is reduced a great deal from previous levels, but variance still exists. Production volumes for the 3808 part also steadily decrease from October to April indicating a decrease in demand for this part for the customer.

In Figure 17 the production data for the 3809 is shown.

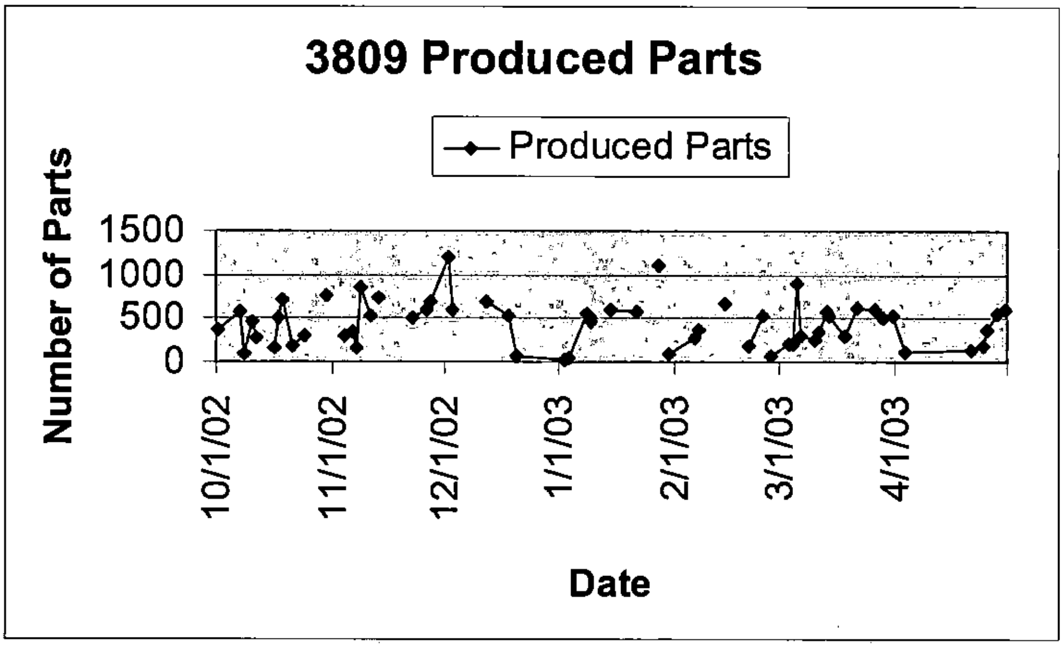

Figure 17. Graph of 3809 Produced Parts

Production of the 3809 part is erratic through the course of the research. Production levels seem to level out somewhat around March when the new Kanban system is implemented. However, in April production of the 3809 drops and there are few parts produced until the end of April. This is a result of customer demand for the part dropping throughout much of April. Therefore production for the 3809 is unleveled.

In Figure 18 the production data for the 4023 is shown.

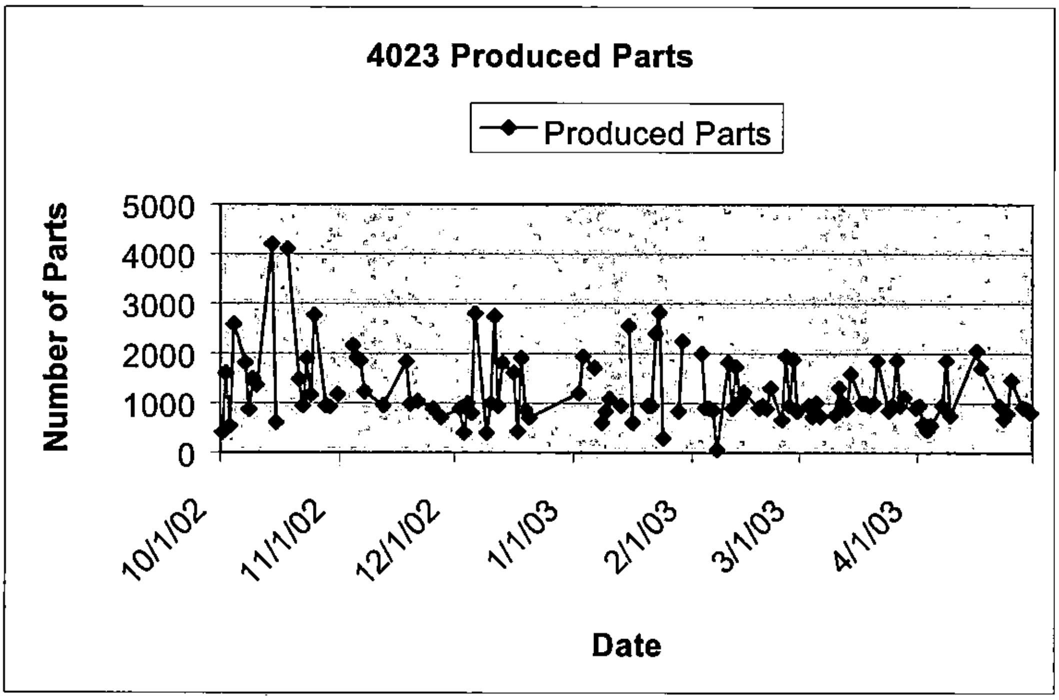

Figure 18. Graph of 4023 Produced Parts

Production of the 4023 part is also erratic, as were the other four parts. However, the production of the 4023 does seem to level substantially around the time that the new system is implemented in early March. In April the production once again starts to fluctuate although not as much as was the case previously.

The second approach used to determine if the newly implemented Kanban system increased efficiency and leveled production was to generate a survey to ask employees within the X cell whether the implemented Kanban system was more effective than the previous system. The survey consisted of four yes or no questions designed to evaluate the new Kanban system's effectiveness. The final question was a rated response question allowing those surveyed to express their opinion of the effectiveness of the system on a scale of one to five, with one being not effective and five being very effective. A total of six people were surveyed from a total of 14 workers who work within the X cell. The survey is located in the Appendix C of this research. Summarized in Figure 19 are the survey results of the first question.

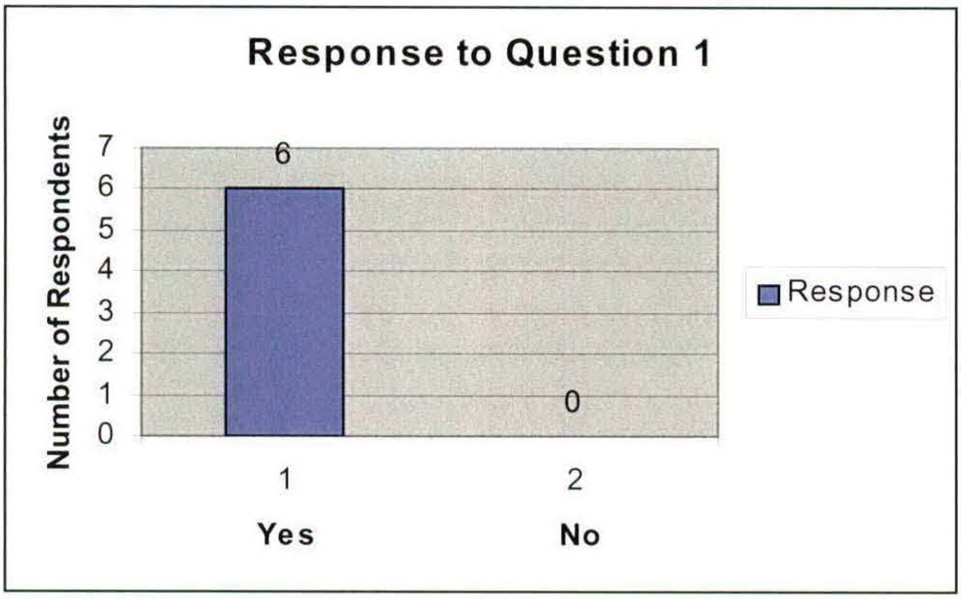

Figure 19. Survey responses to Question 1

The first survey question asked the respondents whether or not the new Kanban system worked better than the previous system. Figure 18 shows that all of the employees were of the opinion that the new system did work better than the previous system, by an overwhelming majority.

Summarized in Figure 20 are the survey results of the second question.

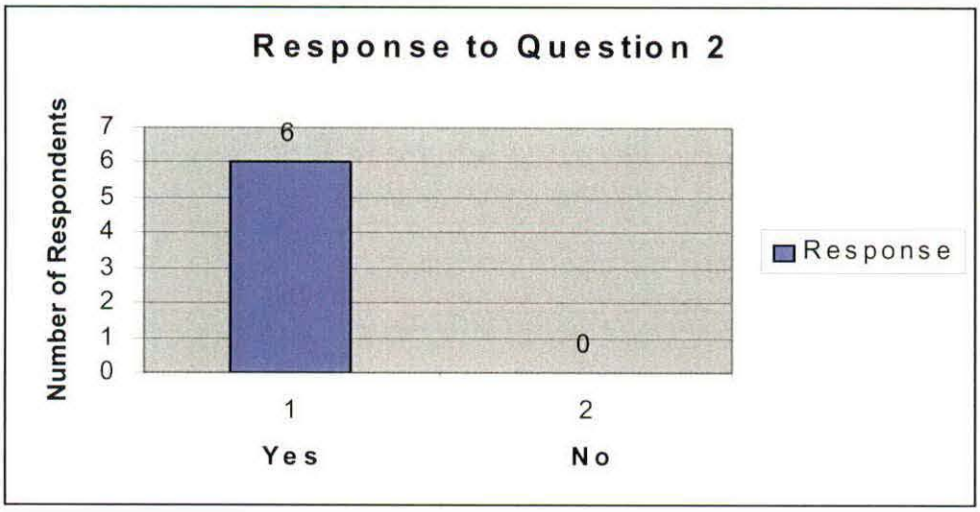

Figure 20. Survey Responses to Question 2

The second survey question asked the respondents whether or not the new Kanban system was easy to understand. All of those surveyed felt that the new system was easy to understand as demonstrated by their responses.

Summarized in Figure 21 are the survey results of the third question.

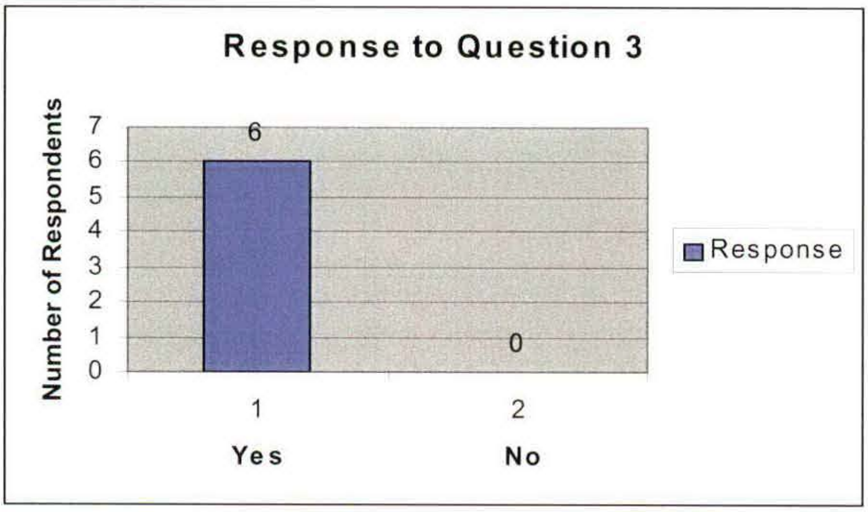

Figure 21. Survey Responses to Question 3

The third survey question asked the respondents if they felt that the multiple board design of the new Kanban improved efficiency. All of the respondents answered yes to this question.

Summarized in Figure 22 are the responses to the fourth survey question.

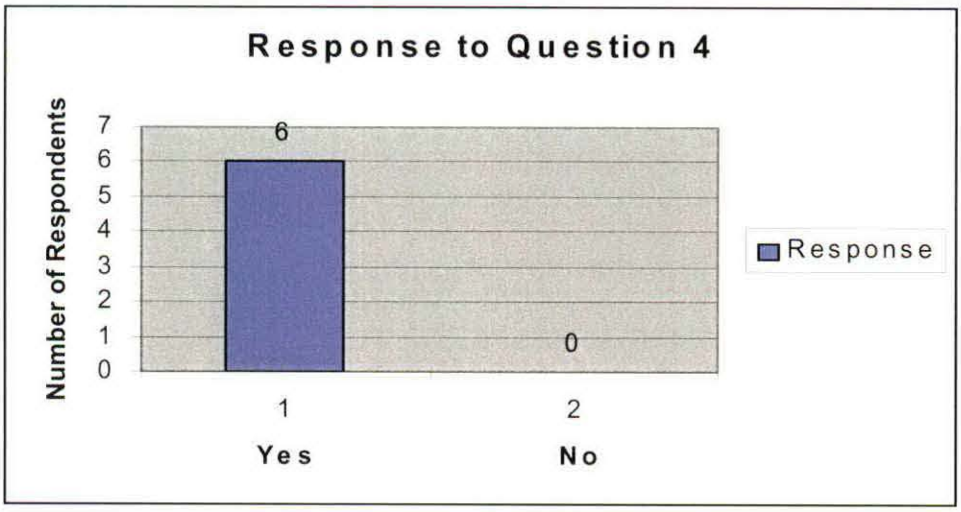

Figure 22. Survey Results of Question Four

The fourth survey question asked the respondents if they felt that the newly implemented Kanban system addressed the needs of production control within the X cell. All of the respondents answered yes to this question.

The final survey question asked the respondents to rate the effectiveness of the new Kanban system on a scale of one to five, with one being not effective and five being very effective. Summarized in Figure 23 are the results of question five.

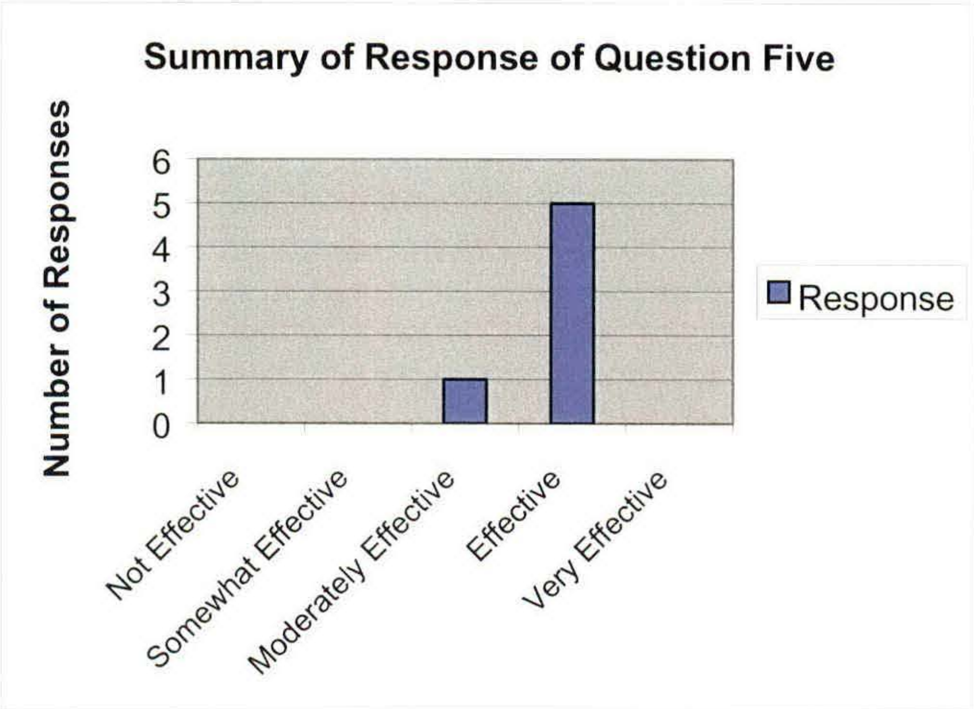

Figure 23. Survey results of Question Five

Most of the respondents felt that the new Kanban system was effective. Only one of the respondents felt the newly implemented system was moderately effective.

Chapter 5

Conclusions

This study sought to examine the X cell within the Cooper facility and determine if a re-designed and updated Kanban system could improve production efficiency within that workcell. The results of the study revealed the following.

The research showed the main problem that prevented the old Kanban system from working effectively to control production was the inability of the customer to schedule their production needs effectively. The customer had an extremely high variance in demand for each of the five parts produced within the X cell. This variance in demand is shown by the high standard deviation of the shipping number for each of the five parts. Such variance in demand made it very difficult to successfully utilize the previous Kanban system to control production since it was impossible to predict what production would be needed each day to fulfill customer demand.

The re-designed system that was implemented as a result of this research improved production control within the X cell for a short time. The implemented Kanban did level production within the X cell once it was implemented, however a month after the implementation the production levels once again began to show large variations. At the time the new Kanban system was implemented customer production scheduling had leveled off considerably from previous months. This improvement in production scheduling of the customer was significant in the new Kanban system working effectively. Since the production levels began to have high variations a month after the new Kanban system was implemented it can be surmised that customer demand once again began to have high variations, which resulted in the new Kanban system becoming less effective at leveling production.

The result of this research shows that a Kanban system can be effective at production control provided that the customer does not have high variance in demand.

Survey data was collected from employees within the X cell to determine whether the employees using the new Kanban system felt that it was an improvement over the previous system. The five question survey consisted of four yes/no questions and one rated response question and can be found in Appendix C of this research. Overall, the responses to the survey questions were very positive and the employees who responded to the survey felt the new Kanban system improve efficiency within the X cell.

Two research questions were developed to guide this research. The research questions were:

1. What problems caused the previous system to fail?
2. Can a re-designed Kanban system improve efficiency and level production within the X cell?

The following conclusion is presented for each question of the study.

Research Question One

The first research question sought to determine what problems may have caused the previous Kanban system within the X cell to fail. To perform an analysis of research, question one the statistical analysis of each of the five parts produced in the X cell was summarized into Table 6.

Table 6

Summary of Statistical Analysis of Shipping Data for each of the Five parts.

	3786	**3806**	**3808**	**3809**	**4023**
Mode	560	200	1200	300	1800
Median	560	150	1200	300	1800
Mean	702	143	1600	458	1901
Standard Deviation	546	67	1064	377	588

This data, once summarized, gave valuable insight as to the needs of the customer. Since this data was based upon shipping records it shows clearly what the customer was ordering for the duration of the research. Two critical points are exhibited by the data. First, that for all five parts, the mean and mode values were very close. This trend in the data shows that the most frequently occurring value, represented by the mode, is very close to the mean value. This data shows a trend in the needs of the customer that allows for the prediction of future production needs. Production was scheduled according to the mode since it was very close to the average and generally was an even number with fewer significant digits, which made it easier to select an even number of Kanban cards. Producing at this level should ensure enough parts are produced to fulfill customer demand. Second, there was a large fluctuation in demand in the majority of the parts as exhibited by the standard deviations of parts being almost equal to the mean. This data indicates that the customer demand was varying a great deal through the duration of the research.

One cause of this high variation may have to do with the lack of a time frame in which the data was collected. The standard deviation was generated without consideration of the time in which production occurred and was instead generated for the entire group of numbers from October to April. The data was taken from reports generated within the Cooper facility and those reports did not include the exact time of production for each part. This resulted in a very high standard deviation for each of the five parts.

This high variation in demand is detrimental to a successful production scheduling technique such as a Kanban system. In order for a Kanban system to work effectively the customer must be able to predict with reasonable certainty how much product they intend to purchase. This prediction then allows the supplier to set up the schedule of production that is required to produce the needed quantities. Although some variation in customer demand is expected, the variation must be very slight in order for the supplier to ensure that the production schedule can cover the fluctuation.

Kanban systems, are a type of production control, and as such also need customer predictions of needs to be relatively accurate in order to work correctly. Given the high variation in demand that is shown by the high standard deviation values of each of the five parts produced in the X cell, it is reasonable to assume that poor customer predictions of demand was a direct cause of the X cell's previous Kanban system's ineffectiveness.

Research Question Two

The second research question sought to determine if a re-designed Kanban system could improve efficiency and level production within the X cell. In order to determine an answer to the second research question two types of data were collected and analyzed. The first type of data gathered was production data for each of the five parts, which showed what quantities were produced for the duration of the study. This production data was input to Excel and line graphs were generated to see if production leveled after the implementation of the updated Kanban system. The second type of data involved surveying the employees who worked within the X cell and utilized the Kanban system to control the amount of parts they produced. The results of the survey were then summarized and analyzed to determine if the employees felt the new Kanban system worked better than the previous system.

The production data for each of the five parts is summarized in line graph form for each of the five parts in chapter four of this research. Figures 13 through 17 show the production levels for the duration of this research. Each production graph, with the exception of Figure 14, shows that the production levels off after the implementation of the new Kanban system in March. In April however, the production levels start to have high variations again. It can be surmised from this research that high variation in customer demand is the cause of the fluctuation in production after the Kanban is implemented. The high variation in customer demand was a direct cause of the previous system and it seems to be the root of the problem with the newly implemented system.

Overall, the production levels show a much lower variance after the new Kanban system is implemented than prior to its implementation. Customer demand also shows a leveling off prior to the implementation of the Kanban as is exhibited in the graphs of shipping levels shown in Figures 9 through 13 in Chapter Four of this research. This is an indication that the new Kanban system does work provided the customer scheduling does not have high variation of demand.

The survey data was also an important determination of whether the implemented Kanban system was more effective than the previous system.

Summarized in Table 7 are the results of the survey given to the employees who work within the X cell. Six employees were surveyed out of a total of 14 employees working within the X cell. The results of the survey show that overall all of the employees surveyed thought the new Kanban system is better than the previous one. The positive response by those employees surveyed shows that while the newly implemented Kanban did not level production completely, it was still successful for those who were using it.

Table 7

Survey Results of X Cell Employees

Survey Question Choices	Number	Percentage
Question One: Does the implemented system Kanban work better?		
Yes	6	100%
No	0	0%
Question Two: Is the new system easy to understand?		
Yes	6	100%
No	0	0%
Question Three: Do the separate boards improve efficiency?		
Yes	6	100%
No	0	0%
Question Four: Does the new system address production control needs?		
Yes	6	100%
No	0	0%
Question Five: How would you rate the effectiveness of the new Kanban system?		
1 Not Effective	0	0%
2 Somewhat Effective	0	0%
3 Moderately Effective	1	17%
4 Effective	5	83%
5 Very Effective	0	0%

Survey question one required the workers within the X cell to indicate whether or not they felt the newly implemented Kanban system worked better than the previous Kanban system. All of the workers surveyed felt that the newly implemented Kanban system did indeed work better. This was evident since all six of the employees surveyed answered yes to question one.

Question two asked the employees if the newly implemented Kanban system was easy to follow and understand. All of the employees answered yes to the question indicating that new Kanban system was easy to understand.

The third question asked the employees if the separate Kanban boards to control tube production improved efficiency within the X cell. All of the employees responded yes to this question. This was important since the separate tube board design was a change from other Kanban systems within the Cooper facility. It was important to determine if this change would cause problems, however given the overwhelming response of yes to question three the change was not a problem.

The fourth question asked the employees if they felt the newly implemented system addressed the needs of production control within the X cell. All of the employees surveyed responded yes indicating that they felt the newly implemented system did address the needs of production control within the X cell. The results of this question show that overall the employees who worked within the X cell felt very positive about the ability of the newly implemented system to control production within the cell.

The fifth and final question of the survey allowed the employees to rate the effectiveness of the new Kanban system on a scale of one to five, with one being not effective and five being very effective. Of the six people surveyed five of them responded with a number four rating of the new system. A number four rating meant that the new Kanban system was effective. This was an eighty-three percent majority of the employees surveyed who felt the system was effective. Only one employee responded with a rating of three, which meant that they felt the new system was moderately effective. None of those surveyed rated the new system below moderately effective.

<u>Implications</u>

Given the findings of this research, it is important to examine the implications of this study. The study had implications for future practice such as:

1. An investigative study of customer scheduling practices to which the X cell supplies would strengthen research on the Kanban for the X cell.
2. A more in depth study of the shipping and production numbers that also includes analysis of the time that would be needed for the production of the parts.
3. A time and motion study on production within the X cell would improve knowledge of the production capabilities and time constraints for the X cell.
4. Studies of other Kanban systems within the Cooper Standard facility would strengthen research on the Kanban for the X cell.

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Appendix A:

Shipping and Production Data

3786 Shipping and Production Data

Date	Number Shipped	Number Produced
1-Oct	520	480
2-Oct	440	409
3-Oct	580	1100
4-Oct	1000	1685
7-Oct	1080	
8-Oct	680	1105
9-Oct		703
10-Oct	1000	
11-Oct		1585
14-Oct	2720	
15-Oct		520
16-Oct		1125
17-Oct	3360	1120
18-Oct		290
21-Oct	3200	
22-Oct		1200
23-Oct		525
24-Oct	400	495
25-Oct	800	
28-Oct	800	505
29-Oct	800	575
30-Oct	400	580
31-Oct	320	580
1-Nov	400	
4-Nov	800	560
5-Nov	400	90
6-Nov	400	
7-Nov		650
8-Nov		520
12-Nov	1000	1160
13-Nov	720	600
14-Nov	320	544
15-Nov		535
18-Nov		530
19-Nov	1320	
20-Nov	520	
21-Nov	320	795
25-Nov	480	374

Date	Number Shipped	Number Produced
26-Nov		520
27-Nov	960	313
4-Dec	960	560
5-Dec	480	1160
6-Dec	720	
9-Dec	720	600
10-Dec	400	1180
11-Dec	1040	
12-Dec	400	
13-Dec	160	
16-Dec	400	
19-Dec		1065
20-Dec		770
30-Dec	920	
2-Jan	680	
3-Jan	600	1495
6-Jan	880	
7-Jan		1160
8-Jan		750
9-Jan	2200	610
13-Jan	560	830
14-Jan	560	650
15-Jan	560	200
16-Jan	560	1165
17-Jan	480	1152
20-Jan	640	580
21-Jan	640	540
22-Jan	640	320
23-Jan	640	
24-Jan	560	1160
27-Jan	680	
28-Jan	600	880
29-Jan	600	265
30-Jan	400	600
31-Jan		955
3-Feb	560	
4-Feb	600	
5-Feb	600	915
6-Feb	560	665

Date	Number Shipped	Number Produced
7-Feb	520	
10-Feb	480	560
11-Feb		560
12-Feb	720	560
13-Feb	520	
14-Feb	440	600
17-Feb	640	560
18-Feb	520	560
19-Feb	520	600
20-Feb		320
24-Feb	800	520
25-Feb	520	520
26-Feb	520	480
27-Feb	120	537
28-Feb	480	
3-Mar	560	440
4-Mar	560	570
5-Mar	560	540
6-Mar	560	
7-Mar	480	
8-Mar		540
9-Mar		304
10-Mar	480	400
11-Mar	400	680
12-Mar	440	560
13-Mar	200	480
17-Mar		520
18-Mar		560
19-Mar		600
21-Mar		560
24-Mar		1040
25-Mar		600
27-Mar		1200
1-Apr		581
2-Apr		1200
3-Apr		440
4-Apr		570
8-Apr		540
9-Apr		304

Date	Number Shipped	Number Produced
18-Apr		990
21-Apr		395
23-Apr		615
24-Apr		1200
25-Apr		154
28-Apr		610
29-Apr		1120
30-Apr		600

3806 Shipping and Production Data

Date	Number Shipped	Number Produced
21-Oct	200	
28-Oct	50	
4-Nov	150	
12-Dec		252
17-Dec		252
2-Jan	200	
6-Jan	50	
10-Jan		203
13-Jan	200	
7-Feb		270
10-Feb	150	
13-Feb		35
21-Feb		98
28-Feb		196
7-Mar		301
14-Mar		196

3808 Shipping and Production Data

Date	Number shipped	Number Produced
1-Oct	1000	410
2-Oct	1000	1602
3-Oct	1600	536
4-Oct	600	2578
7-Oct	3400	1810
8-Oct	1200	872

Date	Number shipped	Number Produced
9-Oct		1500
10-Oct	1400	1364
14-Oct	4800	4200
15-Oct	2000	612
17-Oct	2400	
18-Oct	1200	4113
21-Oct	5200	1476
22-Oct		945
23-Oct		1900
24-Oct	3800	1166
25-Oct	1400	2770
28-Oct	1200	945
29-Oct		927
30-Oct	800	
31-Oct	1200	1176
1-Nov	800	
4-Nov	4200	2158
5-Nov		1907
6-Nov		1854
7-Nov		1229
12-Nov	4800	954
18-Nov		1834
19-Nov	2600	981
21-Nov	1000	1037
25-Nov	2200	890
27-Nov	200	
27-Nov	2200	713
2-Dec	1600	887
3-Dec	1600	400
4-Dec	3200	1000
5-Dec	1400	800
6-Dec	1400	2800
9-Dec	1800	400
10-Dec	1600	1000
11-Dec	3800	2745
12-Dec	1200	945
13-Dec	1800	1807
16-Dec	1800	1618
17-Dec	800	425

Date	Number shipped	Number Produced
18-Dec	2400	1905
19-Dec		862
20-Dec		708
2-Jan	2600	1200
3-Jan	1000	1942
6-Jan	3600	1710
7-Jan	200	
8-Jan	600	600
9-Jan		830
10-Jan		1090
13-Jan	600	950
14-Jan	600	
15-Jan	600	2550
16-Jan	600	600
17-Jan	600	
20-Jan	1200	950
21-Jan	1200	950
22-Jan	1200	2400
23-Jan	1200	2822
24-Jan		295
27-Jan	1000	
28-Jan	1400	830
29-Jan	1400	2240
30-Jan	1400	
31-Jan	1000	
3-Feb	800	2000
4-Feb	1000	900
5-Feb	1200	900
6-Feb	1400	850
7-Feb	1600	61
10-Feb	1000	1820
11-Feb	1400	887
12-Feb	1600	1730
13-Feb	4000	1051
14-Feb	2000	1220
18-Feb	400	900
19-Feb	1200	945
20-Feb	600	890
21-Feb	1400	1305

Date	Number shipped	Number Produced
24-Feb	1200	662
25-Feb	1400	1948
26-Feb	1200	945
27-Feb	1400	1875
28-Feb	1200	839
3-Mar	1200	945
4-Mar	1200	725
5-Mar	1400	1000
6-Mar	1400	731
10-Mar	1000	760
11-Mar	1000	1305
12-Mar	1000	1000
13-Mar		885
14-Mar		1591
17-Mar		1000
18-Mar		1000
19-Mar		950
20-Mar		1000
21-Mar		1850
24-Mar		841
25-Mar		960
26-Mar		1860
27-Mar		945
28-Mar		1120
31-Mar		900
1-Apr		945
2-Apr		580
3-Apr		450
4-Apr		550
7-Apr		945
8-Apr		1855
9-Apr		745
16-Apr		2055
17-Apr		1715
22-Apr		945
23-Apr		680
24-Apr		800
25-Apr		1458
28-Apr		914

Date	Number shipped	Number Produced
29-Apr		885
30-Apr		810

3809 Shipping and Production Data

Date	Number shipped	Number Produced
1-Oct	800	360
7-Oct		581
8-Oct	600	98
10-Oct	100	469
11-Oct		287
14-Oct	1400	
16-Oct		161
17-Oct	1600	500
18-Oct		714
21-Oct	1800	192
24-Oct		301
28-Oct	300	
30-Oct		751
31-Oct	100	
1-Nov	200	
4-Nov	300	301
5-Nov	300	
6-Nov	400	343
7-Nov		160
8-Nov		865
11-Nov		537
12-Nov	600	
13-Nov		750
14-Nov	200	
19-Nov	300	
20-Nov	500	
21-Nov	300	
22-Nov		504
26-Nov		602
27-Nov	200	681
2-Dec	400	1202
3-Dec	1300	602
4-Dec	300	

Date	Number shipped	Number Produced
5-Dec	600	
6-Dec	300	
9-Dec	300	
11-Dec	200	
12-Dec		700
18-Dec		535
20-Dec		63
2-Jan	800	14
3-Jan	600	51
9-Jan	600	504
8-Jan		556
9-Jan		455
10-Jan	600	
13-Jan	200	
14-Jan	200	602
21-Jan	300	587
23-Jan	300	
24-Jan	300	
27-Jan	300	1097
28-Jan	300	
30-Jan		98
6-Feb		273
7-Feb		362
10-Feb	800	
14-Feb		667
17-Feb	500	
20-Feb		182
24-Feb	500	533
25-Feb	600	
26-Feb	200	70
3-Mar	200	203
4-Mar	200	202
5-Mar	200	910
6-Mar	200	294
10-Mar	300	256
11-Mar	200	337
12-Mar	200	
13-Mar		582
14-Mar		525

Date	Number shipped	Number Produced
18-Mar		302
21-Mar		617
26-Mar		602
28-Mar		504
31-Mar		541
3-Apr		106
21-Apr		150
24-Apr		196
25-Apr		375
28-Apr		553
30-Apr		602

4023 Shipping and Production Data

Date	Number Shipped	Number Produced
1-Oct	1800	2226
2-Oct	2400	2606
3-Oct	1800	1300
4-Oct	1800	3685
7-Oct	3300	2868
8-Oct	2100	1127
9-Oct	1800	1603
10-Oct	1500	3422
11-Oct	2100	3016
14-Oct	1500	2884
15-Oct	2400	2018
16-Oct	1800	1014
17-Oct	1800	565
18-Oct	2100	2341
21-Oct	1500	3102
22-Oct	1800	1037
23-Oct	1800	1984
24-Oct	2100	863
25-Oct	1800	3155
28-Oct	900	1875
29-Oct	2100	1156
30-Oct	1800	1811
31-Oct	2100	2074

Date	Number Shipped	Number Produced
1-Nov	900	
4-Nov	1800	2614
5-Nov	1200	2631
6-Nov		4050
7-Nov	1800	1349
8-Nov	1800	935
11-Nov	2100	2842
12-Nov	900	
13-Nov		2083
14-Nov	1800	749
15-Nov	2100	
18-Nov	1800	2312
19-Nov	2100	3590
20-Nov	1800	2288
21-Nov	1800	1578
22-Nov	2100	3224
25-Nov	1800	838
26-Nov	3900	1896
27-Nov		1075
2-Dec	600	
3-Dec	1800	3024
4-Dec	2100	2396
5-Dec	1800	1047
6-Dec	1800	1597
9-Dec	1500	2444
10-Dec	1800	1080
11-Dec	2100	3244
12-Dec	3300	2112
13-Dec	1800	3402
16-Dec	2100	3704
17-Dec	3600	3089
18-Dec	3900	
20-Dec		814
2-Jan	900	2984
3-Jan	2100	3050
6-Jan	1800	3195
7-Jan	2100	1205
8-Jan	900	
9-Jan	1800	1056

Date	Number Shipped	Number Produced
10-Jan	1800	1253
13-Jan	2100	392
14-Jan	1800	2300
15-Jan	1800	697
16-Jan	300	1324
17-Jan	1800	2284
20-Jan	1800	2233
21-Jan	2100	2178
22-Jan	900	2587
23-Jan	2100	1905
24-Jan	1800	
27-Jan	2700	2014
28-Jan	2100	2141
29-Jan	2100	2680
30-Jan	1800	2253
31-Jan	1800	1112
3-Feb	2100	2616
4-Feb	1800	1998
5-Feb	2100	1239
6-Feb	1800	1157
7-Feb	1200	4058
10-Feb	2700	1231
11-Feb	2700	2560
12-Feb	2100	2596
13-Feb	2400	2026
14-Feb	1200	2088
17-Feb	1800	52
18-Feb	900	2248
19-Feb	3000	2362
20-Feb	1800	1121
21-Feb	1800	2819
24-Feb	1500	1036
25-Feb	2100	1158
26-Feb	1800	2234
27-Feb	2100	2250
28-Feb		
3-Mar	1200	1670
4-Mar	1800	380
5-Mar	2100	1156

Date	Number Shipped	Number Produced
6-Mar	1800	1808
7-Mar		2345
10-Mar		1910
11-Mar	2400	1542
12-Mar	1500	1670
13-Mar	1800	1358
14-Mar	2100	2575
17-Mar		1200
18-Mar		1300
19-Mar		1320
21-Mar		2421
24-Mar		945
25-Mar		2375
26-Mar		2442
27-Mar		1117
28-Mar		1168
1-Apr		2344
2-Apr		1204
3-Apr		1968
4-Apr		2136
7-Apr		2328
8-Apr		2226
9-Apr		892
10-Apr		1668
11-Apr		1542
14-Apr		2352
15-Apr		2003
16-Apr		1153
17-Apr		770
18-Apr		1345
21-Apr		2368
22-Apr		2162
24-Apr		1200
25-Apr		991
28-Apr		2546
29-Apr		1174
30-Apr		2332

Appendix B:

Production Rate Data

Table 8

Production Rate Data Table

Part Number	Maximum Number of Parts Produced each Hour
3786	72
3806	30
3808	118
3809	72
4023	154

Appendix C

Employee Survey

Employee Survey

Please answer the following questions by answering a yes or no, unless specified by the question.

1. Does the new Kanban system implemented within the X-cell work better than the previous system?
   (Yes, No)

2. Is the new Kanban system implemented within the X-cell easy to follow and understand?
   (Yes, No)

3. Do the separate Kanban boards to control tube production and create buffer inventory improve efficiency within the X-cell?
   (Yes, No)

4. Does the new Kanban system address the needs of production control within the X-cell?
   (Yes, No)

5. Overall, on a scale of 1 to 5, with 1 being not effective and 5 being very effective, how would you rate the new Kanban system?

1	Not Effective
2	Somewhat
3	Moderately
4	Effective
5	Very Effective