Development of a Methodology for the Rapid Implementation of a Sustainable Lean Manufacturing System

by

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Submitted to the Sloan School of Management and
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ABSTRACT

Increasing awareness of the competitive edge that the Toyota Production System (TPS) has afforded to the Toyota Motor Company has led many U.S. companies to implement a lean production system of their own. However, most companies have been unable to achieve the same level of success with lean as the Toyota plants in Japan. The primary problem has been that no one, even Toyota personnel, can describe exactly how TPS really works, much less how too properly implement it.

The Eastman Kodak Company, through the Imaging Materials Manufacturing Division, is actively working on spreading a Kodak Operating System (KOS) philosophy throughout the company. The Kodak Canada, Inc. (KCI) site in Toronto, Canada is supporting some of the pioneer projects. Most companies are forced to implement a lean production system in response to a crisis; however, Kodak has committed to the implementation of KOS in the absence of a great internal sense of urgency for the change. It is generally accepted that the absence of internal rallying points or crises results in the generation of a tremendous amount of resistance to the new lean system. The basic premise of this thesis is that it is possible to design a lean manufacturing system implementation that sufficiently addresses the technical and social system level aspects of lean and thus minimizes the likelihood of "rejection" of the new system.

This thesis will document the Plan, Do, Check, Act (PDCA) methodology used to design and implement a lean manufacturing system using a microfilm finishing work center at the KCI site for the case study. The "Plan" step of the process involved determining the current state of the operation and planning a vision for its future state. The actual implementation steps are covered in the "Do" stage of the cycle. The lean implementation resulted in labor cost savings and an increase in work center capacity and productivity. The thesis will provide analysis to support the "Check" step of the PDCA cycle. Suggestions for continuous improvement of the lean manufacturing system will be offered so that the KCI leadership team can complete the "Act" step of the PDCA cycle. This will ensure the sustainability of the lean manufacturing system implementation process, as well as the continued success of the roll out of KOS throughout the company.

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CHAPTER ONE – Introduction

1.1 Background

The overwhelming success of Toyota Motor Manufacturing with the Toyota Production System (TPS) has led many companies to embark on the journey to revamp their manufacturing systems to imitate the Toyota example. The secret to the Toyota success lies in the term used to describe TPS – lean manufacturing. Lean manufacturing as a manufacturing system seeks to do more (value-added production) with less (scrap, raw materials, handling, idle time, etc.) A well-implemented lean production system gives a company a significant advantage over its competitors in every aspect of its business.

Many companies are able to implement the technical aspects of a lean manufacturing system, even in a brownfield site, without much trouble. It is not too difficult to get your engineers to design and place kanban cards, inventory flow racks, and single-piece flow stations within your manufacturing work center. The trouble with the implementation usually begins when the people aspect of the lean system is first integrated into the picture. People are much harder to motivate and re-align than a group of metal cutting tools. In the examples of companies that did not receive the full benefit of their lean implementations, it was usually a fault with their implementation process. The implementation either focused heavily on the technical system and did very little to get people's buy-in until it was too late, or focused so much on the development of work groups that the technical portion of the implementation was overlooked (Hilbert 1998).

The hypothesis that is being explored in this thesis is that it is possible to design a well-integrated technical and social implementation process that would lead to a successful lean manufacturing implementation. The implementation process would be designed as a scientific experiment using the PDCA cycle for continuous improvement.

1.2 Thesis Objectives

The primary purpose of this thesis is thus to address ways to correct this imbalance between the technical and social systems that develops in some lean manufacturing implementations. The thesis proposes a new model for the implementation of lean manufacturing systems. The lean manufacturing system implementation for the 34-flow work center at Kodak Canada, Inc. (KCI) is presented as an example using this new lean implementation model. The model shows that a successful lean manufacturing system implementation is carried out in the context of an integrated social and technical system framework.

1.3 Thesis Overview

The thesis is divided into six chapters. Chapters two and three provide the background and rationale that lead to development of the new lean manufacturing implementation model in chapter four. Chapter five presents an example of the new model as used to implement a lean manufacturing system at Kodak Canada. Finally, the thesis ends with chapter six that is devoted to lessons learned both from using the new model and from using KCI as a site for the implementation.

Chapter Two – Lean manufacturing at KCI

This opening chapter provides background on Kodak Canada and the reasons why manufacturing system improvements were needed at the plant. The rest of the chapter examines the lean manufacturing philosophy and the barriers that a company has to overcome to ensure the successful implementation of a new lean manufacturing system.

Chapter Three – Kodak Lean Implementation Model

This chapter builds on the previous one by examining in detail the tools used for implementing the technical and social systems of lean manufacturing. The lean implementation model previously used by Kodak Canada is presented in this section. The chapter concludes with a critique of the KCI lean implementation model.

Chapter Four – New Model for Lean Implementation

Based on the problems associated with the model identified in the preceding chapter, a new lean implementation model is presented in this chapter. The model was developed based on a cycle of continuous improvement activity known as the Plan, Do, Check, Act (PDCA) cycle.

Chapter Five – A Lean Implementation Case Study: KCI 34-flow

Chapter five describes the 34-flow work center at Kodak Canada that was used as a case study for the application of the new lean implementation model. Each section of the chapter covers one aspect of the PCDA cycle and how it applies to the 34-flow implementation. The Plan step describes the current state of the work center and proposes a design that resolves the problems with the current state. The execution of the plan is covered in the Do section of the chapter. The Check section addresses the need to verify that the results of the implementation were achieved. The final, Act section is intended to be an assessment of the existing factors within KCI leading to the long-term success or failure of the new lean manufacturing system.

Chapter Six – Conclusions

This final chapter provides conclusions developed from designing and using the new implementation model within the KCI context.

CHAPTER TWO – Lean Manufacturing at Kodak Canada

The first section of this chapter addresses the reasons behind the need for manufacturing improvement efforts at Kodak Canada, Inc. The site needs to reduce manufacturing costs and inventory, and improve customer responsiveness and profitability. Lean manufacturing is seen as a means of achieving the above results based on material published within the last 5 years. In addition, the chapter also examines the typical barriers to successful implementation of a lean manufacturing system in order to avoid them in the design of the implementation at Kodak.

2.1 Why Lean Manufacturing at Kodak Canada?

Kodak Canada, Inc. (KCI) manufactures microfilm products for the Eastman Kodak Document Imaging Business Unit's worldwide market. This is currently a mature, stable market that is not growing. In fact, the market is slightly shrinking from year to year as customers replace their microfilm use with digital storage substitutes. Within the current stable market, Kodak has the majority of the market share; thus, the business is considered a cash cow. With little or no growth in the market size, no major investments are planned for the manufacturing area. However, manufacturing is expected to continue to deliver significant cost reductions in order to maintain a competitive market price, improve profits, and prevent other manufacturers from undercutting prices and stealing Kodak's market share. Eastman Kodak Company, and in particular KCI, is committed to using lean manufacturing techniques to achieve the needed results. The manufacturing system implemented at Kodak is based on a lean manufacturing system of which the

Toyota Production System is the most famous example. Kodak has developed its own version of a lean manufacturing system called the Kodak Operating System (KOS).

2.2 What is Lean Manufacturing?

The term lean manufacturing was first used by Womack, Jones & Roos in *The Machine That Changed the World* to describe manufacturing systems, such as the Toyota Production System (TPS), used by the current automobile industry leaders to replace their old systems of mass production (Womack et al. 1990, Liker 1998). Lean production is much more than just a set of techniques; it is a way of thinking (Liker 1998). It also provides a framework of concepts and methods, both technical and social, which enable the firm to make continual productivity gains while satisfying the customer expectations for quality and prompt delivery (Parker 1999).

The journey to lean manufacturing starts with a definition of the concept of *value*. The only reason producers exist is to create value by transforming raw materials to final goods. Many producers focus on financial returns, product and process technologies, and location of the design and development of a product as the definition of the value of the product. However in reality, the final customer is the only one who can specify the value of a specific product or service by paying a price for it (Womack et al. 1996).

Once the customer has defined the value for a product, then the producer has to identify the corresponding *value stream* by which the product is made. The value stream is composed of the set of activities required to move a product through the three key management tasks of a business. The problem-solving task involves the transformation from product concept through design and engineering to production launch, the information management task is concerned with order taking though to production scheduling, delivery and receipt of payment. The final management task of a business, the physical transformation task, makes the most impact on the value of a product. It involves converting raw materials to a finished product that can be placed in the hands of a final customer. Inevitably, a focus on the entire value stream uncovers enormous amounts of waste designed into the system (Womack et al. 1996).

Lean production is focused on the elimination of all forms of waste from the manufacturing system. Waste is any use of manufacturing resources, which does not add intrinsic value to the product from the point of view of the customer (Parker 1999). The elimination of waste is often a major source of cost reductions within a manufacturing process. This is one of the key opportunities that KCI was looking to tap into in their quest to reap benefits from lean manufacturing.

The next leap in lean thinking is to take value-creating steps and tie them together to make them *flow*. The idea here is to eliminate the focus on the traditional, functional department and batch processing, and replace them with value-creating production teams that straddle the old departmental boundaries and one-piece flow of product. With revolutionary lean thinking, the firm can look outside its boundaries to the entire value stream for ways to create true value flow to the customer (Womack et al. 1996).

The conversion of a manufacturing area to flow production reduces the time needed from product concept to launch, sale to delivery, and conversion from raw material to final product. It also increases the ability of a manufacturer to accommodate shifting demand because current products can be quickly made in any mix quantity required. The ability to design, schedule, and make exactly what the customer wants when they want it enables the planning group to throw out the sales forecasts. Instead, the customers can *pull* product through the value stream. The value stream is only activated in response to a customer placing an order. No more producing huge amounts of unwanted product that sits in inventory forcing manufacturers to offer special discounts and promotions to stimulate demand (Womack et al. 1996).

The final leg of the quest for lean manufacturing is a journey in its own right – the pursuit of *perfection*. The transformation to a lean manufacturing system is not a one-time event; it is a continuous process. As more processes and departments are streamlined, yet more waste is uncovered and eliminated and better flow processes are developed. The fact that suppliers, manufacturers, distributors, and customers are now sharing the same information leads to the continued discovery of ways to improve the entire value stream (Womack et al. 1996).

Studies of lean manufacturing implementations suggest that with lean manufacturing, production lead times can be reduced by 90 percent, defects virtually eliminated, productivity increased by 10 to 15 percent per year without capital investments, and total product cost reduced by 10 percent per year (Liker 1997 p. 498). A properly implemented lean system can reduce product development times by 50 percent, order processing by 75 percent, and physical production by 90 percent (Womack et al. 1996).

Not every company that tries to implement a lean manufacturing system is able to achieve the kind of success described by the advocates of lean manufacturing. The transition to a lean working environment can be very difficult, or nearly impossible, in some manufacturing environments. In *Becoming Lean,* the results of a systematic comparative study of seven small automotive parts plants that had simultaneously launched continuous improvement programs were presented. The plants used the programs as a first step on the path to lean manufacturing. Of the seven plants, three had limited success while the other four received virtually no benefit from their efforts (Liker 1997 p. 409 – 455). Section 2.3 explores possible reasons for such large-scale failures in implementing a lean manufacturing system.

2.3 What Prevents the Success of a Lean Manufacturing Implementation?

In the course of his work in the area of improving the productivity of manufacturing organizations, Frederick Taylor developed principles of management that were more complimentary and humanistic than those previously widely accepted. His principles acknowledged the importance of human behavior, especially trust building, in the technical success of implementing measurable improvement in manufacturing productivity (Taylor, 1967).

In support of Taylor's view, Black (1991) asserts that the "most important factor in successful (economical) manufacturing is the manner in which the resources or workers, materials, and capital are organized and managed to provide effective coordination, responsibility, and control."

In order to realize the full potential of lean production, MacLean (1996) concludes that significant organizational change has to occur because production teams will be responsible for continuous improvement of product quality, productivity, and their working environment. Merely introducing andon cords, kanban cards, and standardized work will not enable the significant human changes needed.

Driscoll (1996) also emphasizes the importance of being sensitive to the needs of people during the transition to lean manufacturing. In his opinion, technology can be deployed to provide flexibility and affordability, but people need to be motivated to learn, perform, and assume additional responsibilities in a lean system. Therefore, human resource management becomes one of the most important functions in a lean environment.

Hilbert's (1998) research suggests that a major reason many lean implementations are unable to achieve the goals of perfect quality, responsiveness, flexibility and low cost is because the company failed to adequately design the socio-technical systems needed to support the new lean system.

Johnson (1998) also emphasizes the importance of the social aspects of lean to the technical aspects. He proposes that the soft, or human, side of the Toyota Production System derives from the interaction of the TPS leadership principles. These TPS leadership principles underlie the development and implementation of the hard, or technical, side of TPS. He identifies the leadership principles as (1) setting of a consistent direction, (2) creating a culture of removing barriers and (3) developing the improvement capabilities of the workers.

The common thread that ties the preceding authors together is an emphasis on the importance of the human factors of a system in determining the success of a technical implementation. Only a properly designed socio-technical system addresses the significant human aspects of a lean implementation in order to achieve the well-publicized benefits of operating in a lean manner.

Due to this evidence supporting the importance of having a well designed, consistent plan for the corporate-wide lean implementation roll out, Eastman Kodak's central manufacturing division, Imaging Materials Manufacturing (IMM), developed an IMM Lean Implementation Plan. The plan designated three pioneer lean implementations with the intent to follow rapidly with additional implementations at an increasing rate. Both local lean leaders and external consultants supported these pioneer projects in order to get some successes throughout the company and build up enthusiasm and momentum for subsequent implementations. A successful project is defined by IMM as "rapid implementation with immediate cashing of all forms of waste, or muda" (Brown 1998).

CHAPTER THREE – Kodak Lean Implementation Model

This chapter begins with a brief overview of the technical and social systems, including the tools, of lean manufacturing as used by Kodak. This is followed by a review of the lean implementation roadmap employed at the Kodak Canada (KCI) site. The roadmap lays out the steps to follow in the design and implementation of a lean manufacturing system, which constitutes the KCI lean implementation model. The final part of the chapter looks at the problems that exist with the Kodak lean implementation model.

3.1 Technical and Social Systems in Lean Manufacturing

Hilbert (1998) and Johnson (1998) both describe the difficulty of implementing the technical and social systems of lean manufacturing. This section aims to outline the tools that Kodak uses for the design of its technical and social systems. Many of the technical system design tools have been widely written about in the published media. Numerous books (Shingo 1985 and 1986, Hirano 1995 and 1998, Nakijama 1988, Rother and Shook 1998) have been written on how to implement 5S, JIT, TPM and value stream mapping programs. There is not a similar wealth of books written on how to get the willing participation of shop floor and management personnel during and after a lean manufacturing system implementation i.e. social system design.

3.1.1 Technical System Implementation Tools at Kodak

Kodak's Imaging Materials Manufacturing (IMM) Division outlined a five-phase implementation process for the rollout of lean manufacturing at Kodak. The stages of the implementation process were in order of implementation – stability, continuous flow, synchronous production, pull production, and level production. The lean manufacturing consultants working with the KCI site proposed a modified implementation process. This modified implementation process and model are discussed in detail in the later sections of the chapter. This section goes into more detail about each of the lean elements used in the implementation process model. The lean elements are significant groupings of the lean tools that are used to deploy the technical systems for a lean manufacturing system. The five lean elements – stability, continuous flow, synchronous flow, pull system and leveled production – are listed below by order of implementation at Kodak.

I. Stability

The purpose of this first lean element is to create stable operations capable of consistent production. Having consistent operations is a prerequisite for going on to the next steps. Consistent operations are those which have well-defined operational performance targets e.g. cycle time, changeover time, standardized work, etc. and are able to attain these targets in a predictable and repeatable manner (Parker 1999). The lean tools employed within the stability element at Kodak are:

- 5S: The steps that make up the 5S's are sort, set in order, shine, standardize, and sustain. These five steps represent an organized effort to remove all forms of physical waste from work areas in order to prepare the area for production.
- Visual Management: The idea behind visual management is to use simple visual techniques to convey information throughout the manufacturing area. Communication needs in a manufacturing area may include information about safety standards, productivity measures, quality data, standardized work instructions, and 5S goals.

- Total Productive Maintenance (TPM): The purpose of a TPM program is to create shared responsibility and ownership for equipment assessment, diagnosis, improvement, and repair between the production and maintenance personnel. The implementation of TPM results in the elimination of unscheduled downtime, reduction in product defects, and an increase in the mean time between failures (MTBF) and overall equipment effectiveness (OEE).
- Single Minute Exchange of Dies (SMED): This tool is sometimes called setup time reduction or changeover reduction. It involves the use of a set of techniques that help to reduce the time that elapses between making the last good part of one product and the first good part of another product.
- Mistake proofing: The aim of the mistake proofing process is to prevent defects from occurring in the manufacturing process. It is a preventative tool that makes it impossible to do a task in the wrong manner. A fail-safe system may also be implemented to minimize the impact when things do go wrong, for example stopping a machine from operating when a bad part is discovered.
- Standardized work: A standardized work process is designed to minimize waste by using the best combination of people, machines, and materials to carry out a specific task. Standardized work is developed for every job contained within the product value stream.
- Problem Solving and Kaizen: After the development of standardized work procedures, kaizen techniques are used to continuously improve the process and drive out more waste. While shop floor personnel are the primary drivers of kaizen events, the entire process needs management support or the full potential gains will not be realized.

II. Continuous Flow

The second element seeks to improve the flow between successive operations by making significant reductions in the amount of buffer materials separating the two operations. In this phase, the focus is on determining the reasons for safety stocks – to combat demand and supply variability – and the factors, or wastes, contributing to the current manufacturing lot sizes (Parker 1999). The key lean tools used by Kodak within this element are:

- Work in process (WIP) inventory reduction: When WIP inventory is lowered, throughput times are reduced because product doesn't spend as much time sitting in inventory waiting for processing. The use of properly sized line side flow racks promotes the visibility of any line side inventory by taking away floor space where excess inventory can be piled up. However, before inventories can be reduced, process disruptions must be minimized.
- Smaller batch/lot sizes: A smaller batch size allows production to switch between multiple products with relative ease. The batch size is determined by the amount of reduction in changeover times that can be achieved.
- Simple station to station flow: As much as possible, equipment should be co-located to create either straight line or U-shaped work cells for production.
- Multi-skilled operators: Operators should be able to run every set of machines or processes contained within the work cell. This allows each operator to complete a product unit from start to finish using single piece flow techniques that encourage high product quality.

III. Synchronous Flow

Synchronous flow refers to manufacturing processes that are paced by the defined average rate of external customer purchases. This is especially difficult at Kodak where there are significant continuous, batch processes such as sensitizing and base extruding to schedule in contrast to highly discrete processes like assembly at Toyota (Parker 1999). The key tools Kodak employs in this element are:

- Takt time i.e. the total available production time divided by the number of units required by the external downstream customer. This determines how often a unit of product needs to be produced in order to satisfy the demand for the product.
- Standardized work: The use of standardized work procedures enables the use of takt time as a pacing element for manufacturing.
- Continuous flow production with small lot sizes
- A pull system which triggers production just-in-time for the next process in the value stream.

IV. Pull System

A pull system is used to control production between flows or elements of the value stream. Production is scheduled and produced at an upstream process based on actual downstream customer orders. Examples of pull systems employed within Kodak are between the sensitizing and finishing operations, and the finishing operation and the distribution centers (Parker 1999). The tools of the pull element at Kodak are:

- Withdrawal and production-ordering kanbans that signal what to make, how much, where to deliver it to, etc.

- Production planning carried out using kanbans to schedule production on a lot-by-lot basis instead of using forecasts
- Inventory buffers between processes called supermarkets from which actual product is pulled based on kanban signals
- Small quantities of line side supplies to support immediate production
- Definition of the roles and responsibilities for personnel handling kanban signals

V. Leveled Production

The final element of lean implementation involves the leveling of production by product type, product volume, and product mix over a defined time period. This phase of production requires clear visibility to final customer order information, which is used to pace production, and produce every product every day in the smallest lot size possible (Parker 1999). The key tools used by Kodak to accomplish level production are:

- Takt time: The takt time is used to set the production pace for all value stream processes.
- Production-leveling or heijunka box: This is used to smooth production both by product volume and mix over the operational time period i.e. one shift or one day.
- Reorder point and lot size: The reorder point determines the timing of the kanban signal back to production while the lot size refers to the defined production quantity tied to that signal.
- Supermarket: A small buffer of inventory from which needed product is removed when authorized by a withdrawal kanban signal.

– Pitch: The time interval on a heijunka box that is directly linked to a defined quantity of production work. For example, one carton of finished goods every 10 minutes, one pallet of finished goods every 4 hours, etc.

3.1.2 Social System Implementation Tools at Kodak

The technical aspects of lean manufacturing have been outlined in numerous textbooks (Shingo 1985 and 1986, Hirano 1995 and 1998, Nakijama 1988, Rother and Shook 1998) and coached by various lean consultants across the U.S. There has not been a similar wealth of expert coaching on the social, or human, side of lean, despite its being one of the key factors that prevents companies from reaping the full benefit of a lean implementation. Without the buy-in of the people who will be living and working with the new system, a lean implementation is doomed to eventually fail.

In order for a lean production system to run effectively, lean management principles must be practiced. The management needs to be focused on the integration of the organization's vision, culture and strategy to ensure that its customers' needs for high quality and low cost product and short product delivery times are being met. A lean culture is one where people are not seen as problems, but problem-solvers. In a lean environment, everyone understands that it is okay to make legitimate mistakes, and problems are welcomed as treasures because they represent opportunities to make process improvement with an emphasis on "what happened" and not "who did it" (RWD 1998).

IMM took into account the need for proper alignment and direction for the lean manufacturing implementation throughout Kodak by developing an IMM Lean Implementation Plan. The plan allows IMM to set a common framework for all the manufacturing plants throughout Kodak to follow as they start to implement lean manufacturing systems. The KCI site in turn developed a KCI Lean Implementation Roadmap to provide focus for the lean manufacturing efforts of all the departments at the KCI site.

3.2 KCI Lean Implementation Roadmap

The KCI Lean Implementation Roadmap is based on the IMM Lean Implementation Plan and is used to ensure that the entire KCI site has a common vision and strategy with respect to the application of lean manufacturing principles. This is especially critical in view of ongoing improvement plans for cycle time, quality, and standards of performance. The roadmap ensures that all departments – Document Imaging, Inkjet, Variable Width Slit Spool and Professional & Motion Picture Imaging Finishing, and Sensitizing and Polyethylene Terephthalate (PET) polymer manufacturing – are using the same language, with the same meaning, in their lean implementation programs (Parker 1999).

The roadmap also identifies the key factors that need to be addressed in concert with a phased implementation process. These factors may adversely impact a lean implementation, if not adequately managed. They include:

- Careful management and coordination of the significant human resource aspects of the lean system
- Coaching by internal and external experts in the concept of total flow, which may initially be counter-intuitive at the functional level.
- Making the best use of internal and external resources, and leveraging learnings through a consistent approach with linked coaching efforts, and shared training opportunities.
- Carefully and consistently managing the interfaces between lean manufacturing implementations and other major initiatives within the company e.g. Enterprise Resource Planning software implementation.

Neither U.S. manufacturers, nor Toyota itself, have been able to duplicate the great successes of TPS outside of the Toyota Japanese sites. The people side of lean manufacturing has consistently been one of the great barriers for imitators of the system. A study of the major obstacles to making lean manufacturing work conducted by the faculty at the University of Tennessee's Lean Forum identified three extremely significant ($p \leq 0.0001$) obstacles. They are (1) the integration of manufacturing with the sales and marketing functions, (2) the lack of hourly associates' buy-in for the change, and (3) the conflict between lean and the current human resource policies (Miller and Greene 1999).

Taylor asserts that the success of TPS is dependent on two major factors. TPS requires highly experienced managers to work with the motivated, well-trained plant workers, as well as a network of dedicated, capable suppliers that are willing to run their operations in rhythm with the Toyota plants (Taylor 1997). Another theory of Toyota's success goes one step further to suggest that the real strength of Toyota lies in its tremendous ability to learn embedded in its problem-conscious and customer-oriented employees (Taylor 1997).

Given that people feature prominently as a success factor for TPS, this suggests that a company must pay very careful attention to the development of their human capital, in addition to the technical design of their lean manufacturing system implementation process. The Eastman Kodak IMM leadership determined that the probability of success for the lean implementations would be significantly improved if they were done in conjunction with a "total flow" lean vision based on a good foundation of basic lean improvement tools (Brown 1998). Based on this belief, a lean implementation model was developed for the rollout of the Kodak lean manufacturing system implementation. The lean implementation model in section 3.3 is a diagrammatic representation of the modified implementation model suggested by the external consultants.

3.3 KCI Lean Implementation Model

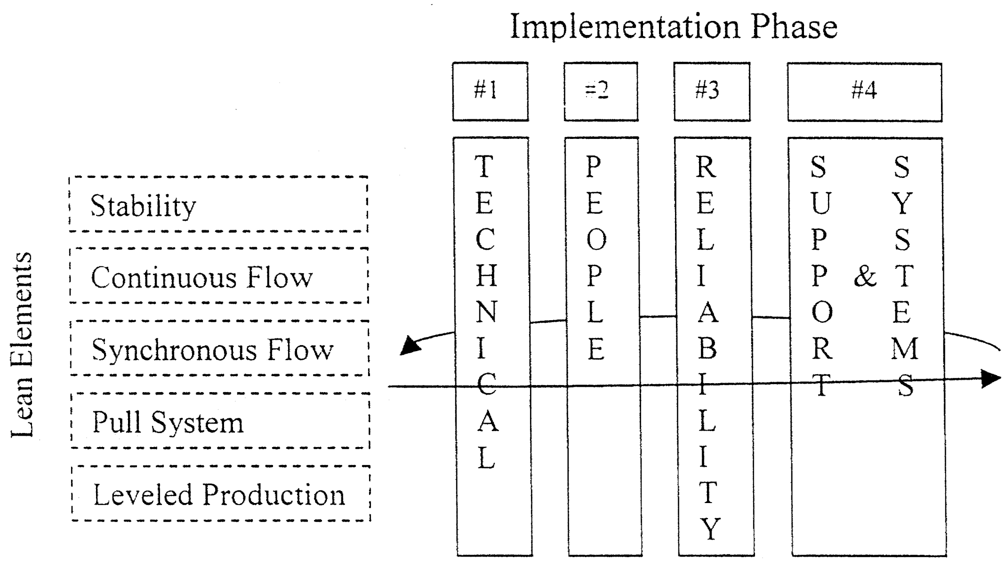

Figure 1. Model for Executing a Lean Implementation

The original Kodak lean implementation model was composed of only the steps contained in the dashed boxes. The modified model encompasses both the dashed boxes and the solid boxes. This new model suggests that a lean implementation be carried out as a four-phase process (solid boxes) using the five lean elements (dashed boxes) as implementation tools. The arrows are there to show that a lean implementation is an iterative process. The first pass through the four phases is not necessarily the only time that each phase will be designed and executed. Within each of the implementation phases, there are also the five lean elements that can be deployed. These are the same lean elements discussed in detail in section 3.1.1 – stability, continuous flow, synchronous flow, pull production and leveled production. In addition, within the implementation of a particular phase, repeated cycling thorough the lean elements may be required in order to improve a particular implementation phase. Thus, there is a lot of iteration going on both within each implementation phase and between the different phases.

The implementation itself is made up of four phases – (1) technical, (2) people, (3) reliability and (4) support & systems. The technical phase involves the design and execution of the physical systems that are necessary to run a lean manufacturing system. Examples of issues that may be executed during the technical phase are kanban signal design and placement, inventory buffer sizing and placement, single minute exchange of dies, and reduction in production batch sizing.

The people phase of the implementation involves creating an environment where everyone in the organization is aligned to the management and improvement of the lean manufacturing system. Issues covered in this phase may include the development of standardized work practices, problem solving and kaizen teams.

The reliability phase looks at ways to improve the reliability of the manufacturing process and systems that have been implemented in the prior stages. A program such as Total Productive Maintenance (TPM) might be the focus of a reliability phase implementation.

The final implementation phase is the support and systems implementation. This refers to ensuring that proper management metrics are in place to reinforce the proper running of the lean system.

3.4 Problems with Current Kodak Lean Implementation Model

The current Kodak model of lean manufacturing system implementation suggests that a lean implementation can be carried out in distinct phases. The model separates the technical, people, reliability, and systems and support issues from one another. The primary problem with this approach is that it promotes the idea that these issues can be addressed in isolation from one another.

The viewpoint that the phases are distinct steps also prevents the implementation process from addressing the joint design of the social and technical aspects of lean. This is a serious problem in light of the fact that proper socio-technical design has been identified as one of the key factors leading to the success of a lean manufacturing implementation (Hilbert 1998).

The final flaw in the implementation model is that it does not provide a disciplined method for continuous improvement. The continuous improvement could refer to improving the process that has just been implemented or to improving the method of executing a lean manufacturing system implementation. In a company the size of Eastman Kodak, it is important to be able to learn quickly from the early implementations and to apply those learnings to the later ones. The current lean implementation model does not force people to document successes and failures with the implementation process so that such information is available for later adopters.

CHAPTER FOUR – New Model for Lean Implementation

This chapter outlines the method used for the development of the new model for lean implementation. The PLAN, DO, CHECK, ACT (PDCA) methodology is used to structure the new implementation so that it incorporates the degree of scientific rigor and feedback necessary for continuous process improvement. The second half of the chapter presents the new model for lean implementation deployment and the rationale behind why the new model is better than the old model.

4.1 The PDCA Methodology

Continuous improvement incorporates the idea of improvement as a problem solving process (Shiba et al.1993). The problem solving process is composed of a systematic, or scientifically based, improvement component and an iterative improvement component. The systematic improvement process involves considering a variety of possible solutions until the best one is identified. By contrast, iterative process improvement involves continued improvement of a process that has been improved at some time in the past. The Plan, Do, Check, Act (PDCA) cycle seeks to apply the principle of iterative process improvement to the problem solving (Shiba et al.1993). The PDCA cycle is particularly suited for use in a lean manufacturing system where existing processes require continual and incremental improvement over time.

4.1.1 The PDCA Cycle

The PDCA cycle is the form in which the scientific method is applied in an industrial, quality assurance situation where there is a known, relatively constant target.

Improvements are made in a step by step fashion in a relatively short time and the cycle is repeated as many times as needed. The steps in the PDCA cycle are defined as:

I. PLAN: Determine analytically and quantitatively what the key problems are with an existing process or existing activities and how they might be corrected.

II. DO: Implement the plan.

III. CHECK: Confirm quantitatively and analytically that the plan works and results in improved performance.

IV. ACT: Modify the previous process appropriately, document the revised process, and use it.

The quick cycles of improvement afford the opportunity to get rapid feedback about the direction and progress towards the intended target (Shiba et al. 1993).

4.1.2 Relevance of PDCA Methodology

There is evidence in the published literature to suggest that one of the strengths of the Toyota Production System is its continued use of the scientific method of hypothesis setting and testing (Spear and Bowen 1999). PDCA represents a scientific approach to planning and executing an implementation. It allows an implementation to be carried out in a relatively short period of time and provides rapid feedback on the design and execution of the project. This provides valuable information that can be used both to improve the current implementation and the design of the next implementation project.

4.2 New Lean Implementation Model

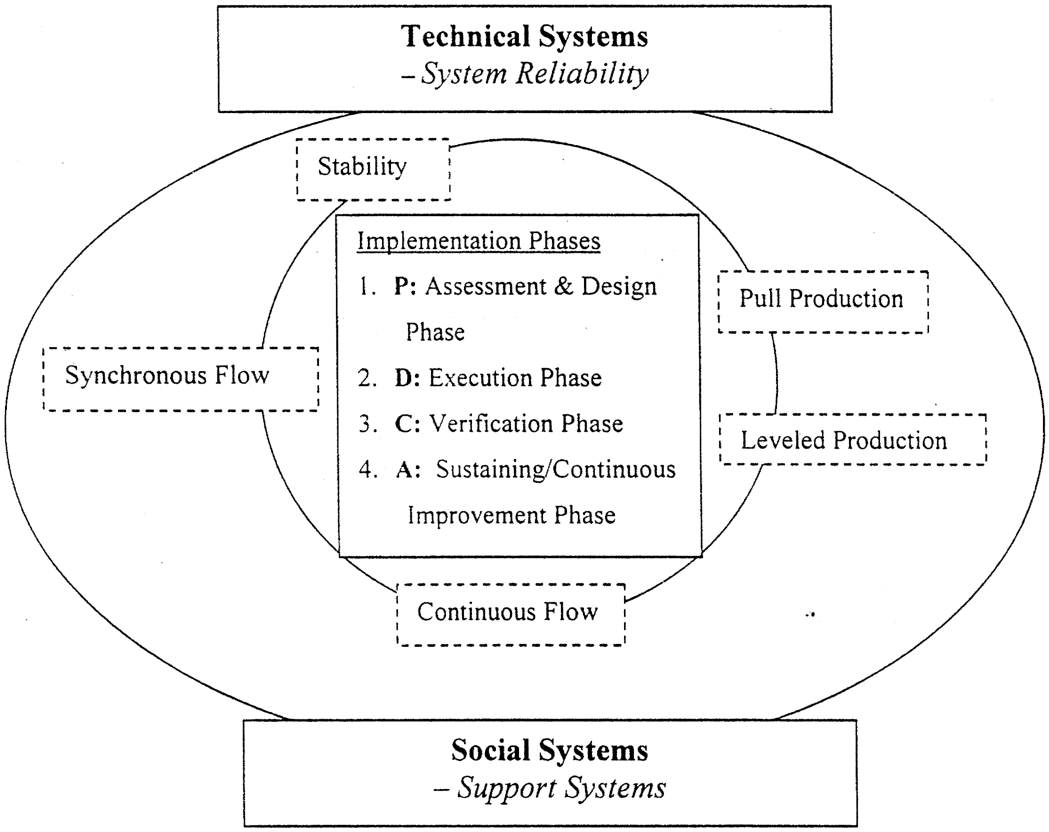

Figure 2. New Model for Executing a Lean Implementation

The model shows that the implementation phases are carried out in the context of an over-arching framework of system level issues that must be addressed in order for the implementation to be successful. The solid boxes on the outer circle represent the system level issues, technical and social. The issues drive the design and execution of all the phases of the implementation process. For example, standardized work procedures and TPM programs can be designed and executed, using the lean elements – stability, continuous flow, etc – represented by the dashed boxes, without getting the buy-in of the shop floor workers. However, such programs do not last because lean manufacturing systems really require the active participation of the work force in order to be successful. The model outlines a four-phase lean manufacturing implementation process. The four phases strongly mirror the four steps in the PDCA cycle. The first phase in the implementation is the PLAN step involving the assessment of the existing manufacturing system and the design of the new lean manufacturing system. This phase involves uncovering the problems or areas for possible improvement with the current system. Problems may be in the form of either a manufacturing process that is not meeting its current performance targets or one that can be redesigned to achieve a theoretically better state. This phase also includes coming up with a design to correct any problems identified during the assessment step.

The second phase of the implementation process is the DO step or execution phase. This is where the design developed in the first phase is deployed to the shop floor level and tested. During a shop floor execution, problems will often arise that may not have been anticipated in the design phase leading to the need to tweak the design once it is finally in use. The execution phase can easily last for a few weeks or months depending on the complexity of the system implemented.

The verification phase, or CHECK, of the implementation process is very important and is not always carried out, as it should be. It is essential to actually document at some point that the process, as implemented, resulted in improved manufacturing system performance; otherwise, the entire implementation process has been a futile exercise.

The final phase involves sustaining the new lean manufacturing system by performing continuous improvement on the process. This is the essence of the ACT step of the PDCA cycle. It is not enough to improve the manufacturing system once; it has to be improved on a daily basis through the interaction of the people who work within the system.

4.2.1 Why the New Implementation Process Model?

The evidence presented in section 2.3 suggests that proper design of the technical and social aspects of a lean manufacturing implementation is the single most important factor in determining the final success of an implementation. The technical aspect of lean manufacturing involves the design of the manufacturing processes and pathways in a manner that minimizes all forms of waste in the system. On the other hand, the social aspect of lean manufacturing looks at how people interact with the designed system and how they are engaged in the daily operation and improvement of the system.

The tools for designing the technical parts of a lean implementation are widely discussed in the literature and available through various lean consulting experts to companies just embarking on the lean journey. The tools used at Kodak are no different from those used at other companies such as Toyota, Ford, Alcoa, etc. to develop their lean production systems. However, on the social side there are not many, if any at all, experts in the design of an effective social system for an implementation. There is even less information about how to design a well-integrated socio-technical system for the lean implementation. This new model attempts to provide an integrated socio-technical framework within which to carry out the phases of a lean manufacturing system implementation.

The old model directed the focus of the implementation phases to the systems, such as people. technical, reliability and support. In contrast, the new model focuses on the functions that need to be performed for the long-term success of the lean manufacturing system implementation. In this model, the social and technical system level issues are considered throughout every phase of the implementation process instead of only during one phase.

Most importantly, from the point of view of Eastman Kodak, the new model incorporates a distinctly scientific approach to the process of lean implementation. Using the PDCA cycle enables each implementation project to be set up as an individual experiment with a built in continuous improvement step. This is very important not only for capturing the learnings from each implementation that is executed, but also for driving much needed continuous improvement efforts within the already implemented process. Implementing a lean manufacturing system is only the first step in the journey to manufacturing excellence. Kodak will be able to use the new model of lean manufacturing implementation to spread the idea throughout the company that continuous improvement is a way of life with lean manufacturing.

CHAPTER FIVE – A Lean Implementation Case Study: KCI 34-Flow

This chapter covers the implementation of the 34-flow lean manufacturing system using the model developed in chapter four. The 34-flow lean manufacturing implementation process took four months from the planning phase to the execution phase. The next two months involved running the system and checking that the anticipated results were being achieved. The final part of the chapter examines the factors that contribute to the success or failure of a lean manufacturing implementation at KCI. The KCI management can try to strengthen the success factors and seek to eliminate those factors leading to failure as they move forward with future lean manufacturing system implementations across the site.

5.1 The KCI 34-Flow Work Center

The 34-flow work center is part of the Document Imaging Film Finishing department located at the Kodak Canada, Inc. Toronto manufacturing site. This department makes 16-mm, 35-mm and 105-mm microfilm products. The 34-flow work center is responsible for approximately 30% of the production volume of 16-mm microfilm products made by the department. The work center is comprised of a coupled slitting and packing operation. The slitting operation takes in a wideroll of sensitized film and cuts it down to the 16-mm width required for finished goods going to final customers. The packing operation is responsible for packing the finished good rolls into light-tight bags and cases for sale to the final customer. The 34-flow work center produces long-length microfilm product i.e. with final lengths between 500 and 2500 feet. The final product is sold directly to domestic customers in Canada and exported to the Central Distribution Center in Rochester for sale to the US and worldwide market.

The business environment faced by the Document Imaging Division serves as a valuable precursor for the rest of the Kodak business divisions. The document imaging business is in a mature and fairly stable market, with Kodak holding the lion's share of the market. Therefore, the organization must aggressively manage manufacturing costs in order to maintain the profitability of business.

5.2 PLAN: Assessment and Design Phase

The plan step involves the assessment of an existing process to determine the opportunities for improvement within the system. This first phase of the implementation process also includes the design of methods to close the gap between the opportunities identified and the new improved process. The assessment and design phase took 2 ½ months to complete.

The first step in the plan step involves the development of a current state map, which outlines the work center operational performance data, customer demand, material and information flows. The current state map is a schematic representation of the manufacturing system under investigation at a point in time. The current state map for 34-flow is presented in section 5.2.1.

During the design phase of the project, a future state map. section 5.2.3, was developed with the appropriate operational performance, material and information flow targets necessary to respond to a daily-leveled schedule of customer demand-pulls. The new process is designed specifically to close the gaps identified in the assessment phase and bring the work center more in-line with customer demand.

5.2.1 Current State of 34-Flow Work Center

The aim of the current state assessment is to evaluate the work center with respect to the lean manufacturing system goals of:

- high work center flexibility
- high responsiveness to customer demand
- high product quality
- low manufacturing cost

The first step in the assessment process is to map out the work center with respect to the flow of materials and information throughout the value stream. A simplified map of the materials flow within the 34-flow work center is shown in Figure 3.

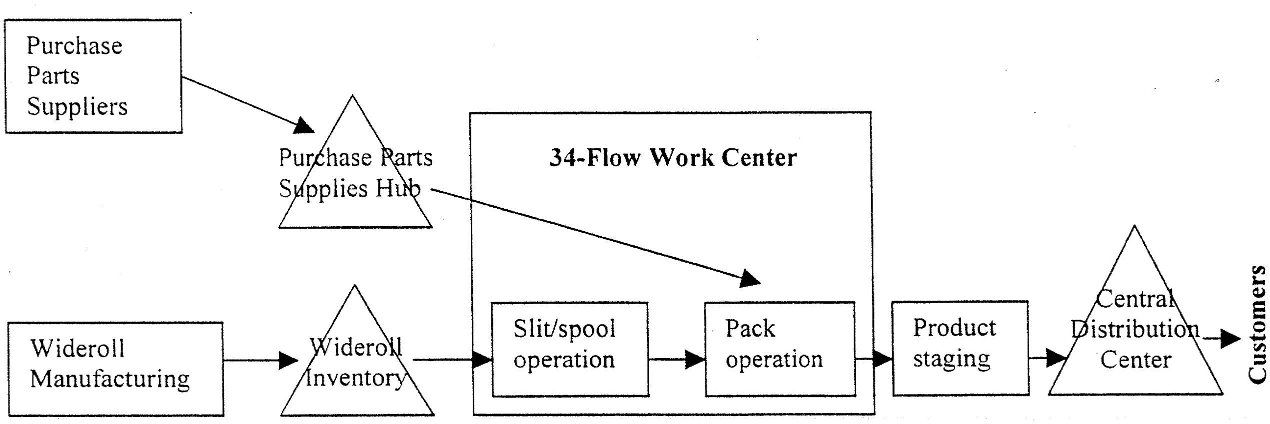

Figure 3. Current State Map for Material Flow in 34-Flow Work Center

On the map, the boxes represent manufacturing operations and the triangles represent inventory. The arrows indicate the path of flow for the materials, or products, as they are transformed to finished goods. The map shows how the inputs into the 34-flow operations enter the work center from wideroll and purchase parts inventories.

Wideroll, which is a large roll of sensitized film, is received from the sensitizing operation into the slit/spool operation of the 34-flow work center. The slit/spool operation cuts the film down to the standard width of 16-mm and the customer desired length. In the same slit/spool operation, the film is wrapped into a roll for sale. The pack operation is responsible for taking the spooled rolls of film, placing them into light-tight bags and then sealing them in case loads for transportation. The purchase parts suppliers provide the bags, cases, and labels used in the pack operation through the purchase parts hub. Product staging is where the finished goods are aggregated into pallet loads, reconciled, and released by the information systems for shipment to the Central Distribution Center (CDC) and on to the final consumer.

- Current State Key Performance Data
  - More than thirty products are produced by this work center with six of the products making up 75% of the sales volume.
  - Three categories of final product: Kodak label, Original equipment manufacturer (OEM) label, and Shared/Private label.
  - Final product is shipped twice a day to the Central Distribution Center (CDC) in Rochester, NY

- Cycle time is greater than takt time, which means that the work center is incapable of meeting daily customer demand without utilizing overtime.

- Production Planning
  - Production scheduling is done in the weekly Sales and Operation Planning meeting using actual orders plus sales forecasts as the demand signal for shop floor execution. Production is used to replenish inventory, based on actual orders plus some sales forecast. This causes higher inventory levels within the system than are needed simply to satisfy actual orders with some level of safety stock.

  - Production is scheduled each week for either 2 or 3 shifts per day depending on how much demand the work center is being loaded with for the week. This leads to long customer lead times because production schedules are set the week before product is made. The ability of customers to change their orders is thus limited to two weeks before actual production starts.

- Customer Profile
  - Types of customers: Direct end users e.g. banks, distributors, and resellers
  - Customer order patterns: Daily (off the shelf items), weekly, and monthly orders

5.2.2 Development of Future State Vision

Based on the current state assessment some improvements were identified that needed to be in place for the successful launch and future operation of a lean manufacturing system. They included:

- Education in lean manufacturing concepts for the shop floor personnel to increase the feeling of being a part of the lean transformation process.
- The definition of new operational performance targets for the lean operation.
- The conversion of production scheduling from a weekly supply-push process to a daily demand-pull schedule based on responding to actual sales and not forecasts.
- The creation of a level production schedule by smoothing out the product mix and volume demand on the work center every day.

In order to achieve the improvements outlined above, there are some gaps between the current performance of the work center and the level of future performance required of the work center in a lean system.

For the successful development of the future state map for 34-flow, a few major performance gaps must be filled.

- The first issue that has to be addressed involves setting a new level for the work center cycle time in order to obtain a consistent 2-shift operation. With the current cycle time, the average daily sales volume can be produced in just over 2 shifts of production per day. However, production is often scheduled for either 2 or 3 shifts per day depending on the schedule created by sales forecasts. This creates an opportunity to close the gap between the demand and supply of production time by reducing the cycle time of both the slit/spool and pack operations.

- The production planning process needs to be improved and streamlined so that shop floor scheduling can be done daily with actual sales data and not sales forecasts. This will help to lower the level of inventory in the system i.e. on average the system will have half a day versus having half a month worth of inventory on hand to buffer demand variability.

- In a lean manufacturing environment, production schedules have to be leveled with respect to product variety and volume in order to avoid making large batches of any one product. This allows the entire supply chain, from raw materials to finished goods and internal to external suppliers, to experience stable, predictable demand on their resources and allows them to improve their planning for the future. A reduction in the changeover time is a key enabler for achieving the smaller batch sizes required to create a truly level production schedule.

5.2.3 Future State of 34-Flow Work Center

The gaps identified in the current state have to be closed in the future state design of the work center. The future state map portrayed in Figure 4 represents one solution to the set of problems that were uncovered in the current state mapping exercise.

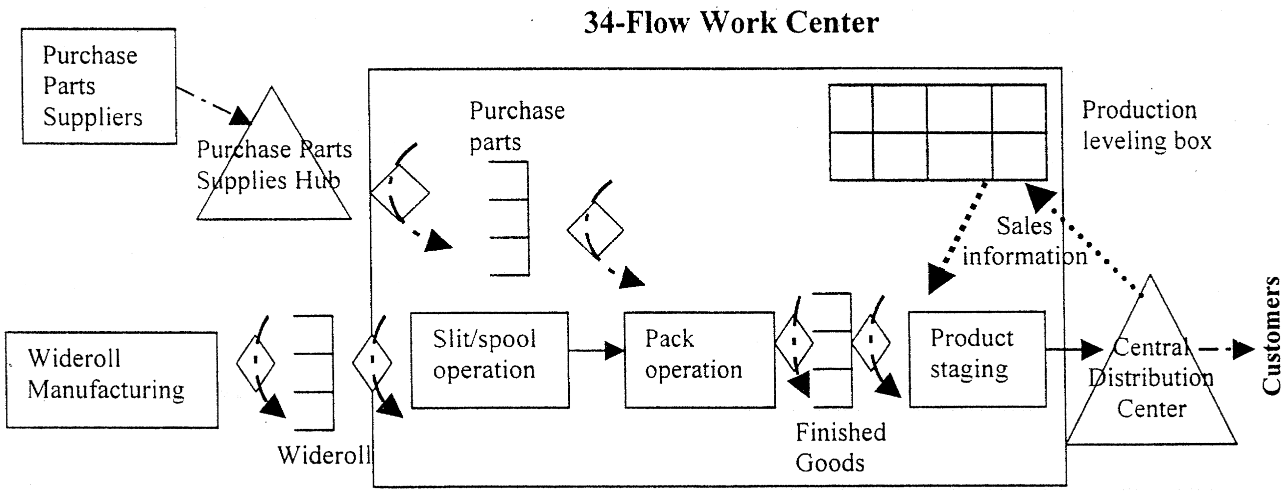

Figure 4. Future State Map for Material and Information Flow in 34-Flow Work Center

In this work center map, the boxes still represent the operations and the triangles are still inventory. However, a new type of buffer inventory is now included in three supermarket locations, indicated by the shelf-like symbols. In the future state map, unlike the current state map, some material flows only take place when the corresponding signal has been sent to release material i.e. the diamond shapes coupled with the arrows. The final new features are the daily sales information transmitted from the CDC to the work center and the production leveling box that is loaded every day using the sales information. Additional features of the future state of the 34-flow work center are:

- A production leveling box that takes the data of actual sales from the Central Distribution Center on a daily basis and levels it by product type and volume.

- The level schedule is translated back into the work center when product staging pulls product from the finished goods supermarket and triggers the preset reorder points for each of the products in the supermarket.

- The production ordering kanban cards flow back to the slit/spool operation and trigger the production of more of a particular product. The product flows through to the pack operation, which eventually replenishes the finished goods supermarket.

- Wideroll, purchase parts, and even finished goods are all kept in small, buffer inventory (supermarket) quantities at the work center. The buffer inventory affords the work center limited protection against demand and supply variability.

- A simple information flow system using kanban cards that flow from right to left, counter to the material flow path, in place of the more complicated information systems.

- Future state operational performance data: The key performance metric for the future state is whether cycle time is equal to or less than takt time. If this condition is not met, then the future state implementation cannot proceed.

To achieve all the above improvements, the cycle time and changeover time had to be improved first. The improvements in these parameters are addressed in the kaizen design and execution in section 5.3.3. This improvement work was done in a kaizen in order to involve the shop floor personnel in making some of the decisions about how their work will be done.

5.3 DO: Execution Phase

The Do step of the implementation process covers the period between the end of the design phase to the start of the new lean system. For the 34-flow work center this step was completed in a six-week period. This was the first stage in which the shop floor personnel were involved in the lean implementation process in order to communicate the new vision developed in the design phase. During this execution phase, a 3-day kaizen event was organized to drive the changeover & setup reduction times to the levels identified in the assessment and design phase as needed to launch the lean manufacturing system. The work center personnel also had the opportunity to run a manufacturing supply chain simulation of the work center. The aim of all these initiatives was to tie the technical and people systems together to ensure a quick and smooth launch.

5.3.1 Education

Weekly education sessions were held throughout the execution phase with the shop floor personnel to explain the lean manufacturing principles and the business case for the change. The education sessions were used as a way to involve the shop floor personnel in the lean transformation that was going to be happening in their work center. The topics covered in these sessions with the shop floor operators included:

- The business need for the lean transformation, including topics such as
  - The sales projections for the work center including takt time
  - The current gap between production demand and supply
  - The current inventory levels

- Lean manufacturing principles such as
  - Continuous flow production
  - Waste elimination
  - Inventory reduction

5.3.2 Manufacturing Simulation Design & Execution

The 34-flow manufacturing simulation was used as an aid to demonstrate product flow through the supply chain for the 34-flow work center using lean manufacturing principles. The tabletop model used actual customer sales data and operation cycle times to simulate the operation of the work center supply chain. The simulation was run with personnel from the overall supply chain community – shop floor, planning and scheduling, material handling and ERP. See Appendix A for a detailed description of the working of the simulation.

5.3.3 Kaizen Design & Execution

The assessment and design phase of the implementation process identified a gap between the current level of operation staffing and the level of staffing needed to meet the average daily demand. A kaizen blitz exercise was identified as a means of closing the gap that would involve the shop floor personnel in doing the technical design work. This approach was consistent with the implementation model in section 4.2 and involved the simultaneous use of both technical and social system frameworks. The kaizen also enabled the personnel from the work center to work on solving a problem with personnel from their customer and supplier groups across the KCI site.

The expectation was that the kaizen activity would result in a standardized work procedure that reduced the time needed for changeover on both the slitting and packing operations. The reduced changeover times were needed to enable the work center to bring the cycle time in line with the takt time for the work center. A more detailed discussion of the kaizen blitz design and execution is provided in Appendix B.

5.3.4 Launch

The launch date was scheduled for exactly six weeks after the start of the shop floor roll out. Prior to the launch, there was a slight pre-build of products, including the six A-item products and two B-items, to fill the finished goods supermarket at the work center. On launch day, the production leveling box was filled for the first time and the first product pulls started at 9:00 am.

5.4 CHECK: Verification Phase

Once the execution phase has been completed, the function of the verification step in the implementation process is to ask and answer the question – Did the implementation actually achieve the targets that it was supposed to achieve? The expectation going into the lean implementation process was that the work center responsiveness, and flexibility would increase, product cost would be reduced and product quality would remain unaffected.

5.4.1 Launch Results

1. Work center responsiveness and flexibility

   The work center was able to increase its responsiveness and flexibility to customer orders by using a level production schedule, which enables every one of the six major products to be made every day and all others to be made weekly.

2. Elimination of waste

   By eliminating some of the work that is non-value added to the customer, the work center was able to virtually double its productivity per worker.

3. Work center cost reduction

   The lean implementation resulted in a labor cost savings on each finished goods roll. This extra margin can be taken as additional profit, shared with customers through price rebates, or used when needed to carry out defensive pricing strategies to prevent the entry of competitors into the market.

4. Work center production capacity

   The work center achieved a thirty three percent increase in production capacity by converting a three-shift operation to a two-shift operation. This capacity increase was accomplished with no job losses because the people freed up were used to run a new operation coming into the KCI plant instead of hiring new people.

5. Work center continuous improvement activity

   In addition to the other more tangible benefits, the work center gained the ability to highlight production problems every 45 minutes i.e. every time product is withdrawn from the supermarket. Note that production problems still happen, such as wideroll and purchase part shortages, but they are quickly highlighted and resolved.

This is not by any means an exhaustive list of the benefits that are obtained from running a lean manufacturing system. These are just the subset of the benefits that could be estimated by the end of the two-month period between the launch day and the end of the internship period. Other potential benefits are inventory reductions of an average of 50% in the CDC and lower labor costs due to replacing previously needed premium paid weekend overtime for the maintenance crews with an open shift every day in normal work hours.

5.5 ACT: Sustaining/Continuous Improvement Phase

The purpose of this section is to point out the areas that can be improved both for this and future implementations at KCI. The sustaining/continuous improvement step is easily the most important phase of the implementation process. If this step is overlooked, the entire implementation could be in jeopardy of failure at some time in the future. In addition, Eastman Kodak has a "lean leaders" group that shares learnings from implementations across the whole company. That group would greatly benefit from a disciplined approach to capturing the results of each implementation.

This section is divided into two parts. The first part examines the factors that help promote the success of the implementation while the second half of the section describes the factors that impede the implementation a lean manufacturing system

5.5.1 Enablers for Lean Manufacturing at KCI

- Manufacturing Supply Chain Simulation: The simulation helped the implementation process immensely by providing a high level overview of a lean manufacturing system for the shop floor personnel. It allowed them to understand the new process through taking part in a fun exercise. It also provided a frame of reference during the implementation process. There were times when in order to explain a particular part of the system, we would remind them of the part of the simulation that was relevant to the problem. Last, but not least, the simulation became a great plant-wide tool to expose people throughout KCI to lean manufacturing in action in a more familiar context than an auto assembly plant.

- Kaizen: The kaizen served multiple purposes within the 34-flow lean manufacturing implementation. The first reason was to develop a means to reduce the cycle time for the operations within the work center by reducing the amount of time to do a product changeover. The shorter and easier changeover process enabled smaller batch sizes, and greater product variety without impacting the product quality. The major reason for using this method is that a kaizen involves the shop floor personnel in the process of making the change and this helps make the improvement process more legitimate to them.

- Learning from previous implementation: It was extremely helpful for the 34-flow implementation process that some people from KCI who had been involved in the previous lean manufacturing were also involved with this project. They were able to provide some analysis of what worked and what didn't in the previous implementation. This helped to avoid some the big pitfalls such as not involving the people in the process early and often enough to enable them to feel ownership. The need to involve people was one of the driving forces behind the development of the new implementation model in section 4.2. The use of the weekly education sessions, the manufacturing simulation and the kaizen were all done to reinforce the objective of getting information to people and involving them in the process.

5.5.2 Barriers to Lean Manufacturing at KCI

- Information Systems: The information systems used across Eastman Kodak Company, and KCI is no exception, do not promote the introduction of lean manufacturing techniques. The systems are quite inflexible and the level of complexity involved in system transactions often makes the system a bottleneck to the smooth and rapid flow of product through the work center and out to the CDC. The system was set up for the old, large batch production system, and so in the case of export goods, an extra set of paperwork had to be set up to capture information needed solely for the purpose of reconciling the systems. This created a whole new set of wastes in the value stream.

- Sensitizing Department: Sensitizing is a major, shared resource at Eastman Kodak. Given a large number of customers that have to be satisfied, sensitizing has come up with various ways to optimize its own production planning and scheduling processes. Some of the areas of optimization involve wideroll widths, lengths, and production lot sizes. Widerolls are typically optimized for certain widths and lengths based on the needs of the department with the highest volume usage. All other departments just accommodate what they get. The fact that all upstream supply lines eventually lead to sensitizing makes it extremely difficult to implement any supply chain improvements that involve wideroll lengths or widths. Since much of the cashing in lean manufacturing is achieved through lower inventory levels, smaller batch sizes and speedy material replenishment, sensitizing will always be the function that limits the achievements of lean manufacturing at Eastman Kodak.

- Work Team Development: The KCI facility has a unionized, hourly work force made up of the members of a Kodak Canada employee-only association. Therefore, every new position offered across the plant has to be posted and jobs are awarded based primarily on seniority. On the job experience, or training, is considered only after seniority has been taken into account. This creates a situation where certain departments are seen as more or less favorable based on the likelihood of reaching the higher job brackets quickly or having to do less strenuous work for the same bracket. Unfortunately, this gaming attitude creates flux into and out of departments and undermines the concept of dedicated work teams promoted by lean manufacturing.

- Value Stream Alignment: The 6-week implementation was highly successful from a technical point of view. The shop floor personnel were actively engaged in the process, so it appeared to also be a success from the social point of view. However, once you go beyond the limits of the work center, it is not clear that there has been an equally successful buy-in to the concepts of lean manufacturing across the site. There appears to still be a strong functional alignment of people across the site as opposed to the value stream alignment that is needed for the long term success of lean manufacturing at the site. The personnel in the support functions such as materials handling and delivery, maintenance, and production scheduling must have direct reporting lines into the work center that they support and not to a functional line manager.

- Performance Metrics: It is often very difficult to convince people who have been with a company for many years, and seen program after program sweep through the factory, that lean manufacturing is more than just a program of the month. This sometimes has to do with the fact that many companies forget to realign the goals and metrics that people are measured by when they implement a lean system. As the old adage goes, "What gets measured, gets done." If KCI is serious about lean manufacturing being the way forward, then certain process and people performance metrics must be developed to promote and encourage lean behaviors.

  Two new people performance metrics needed are the level of cross training and the involvement of the work force in lean manufacturing activities such as 5S and kaizen.

Developing a process to track these new metrics will encourage people to be involved in the new lean system, to learn new skills, and to train others on their current jobs. Currently, there is no incentive for workers to make themselves less indispensable, and more vulnerable to being laid-off, by training others on their job. Department managers should be evaluated on the performance of their people with respect to each of the metrics in order to demonstrate management commitment to the lean manufacturing implementation process.

With respect to process performance, the new metrics should revolve around ensuring that production is keeping up with the pace set by the takt time. A simple metric such as units produced per hour versus units demanded per hour can be displayed in a prominent place where everyone in the work center can see. This helps to keep everyone in production focused on keeping up with demand.

CHAPTER SIX – Conclusions

This final chapter highlights the conclusions developed by carrying out the lean manufacturing implementation at the KCI site. The first section deals with the lessons learned from using the new implementation model for the 34-flow project at KCI. The second section addresses the things that I view as factors that could contribute to either the long term success or failure of the lean manufacturing implementation. The KCI management team will want to carefully reinforce the behaviors that promote success, while taking active steps to curb the negative behaviors across the site, as more areas begin the transformation to lean manufacturing.

6.1 Lean Implementation Model

The lean implementation model that KCI used in the past treated the lean elements and implementation phases as independent silos. It implied that work couldn't be done on the next element or phase until all facets of the previous one were completed. The new model shifts the focus from the tools to the process using a PDCA model. If the goal is a successful implementation, the most important thing is to make sure to complete all the PDCA phases.

I think the model is flexible enough for use in any area that is starting its transformation to lean manufacturing. The focus of this model is on the process and not the specific tools to use. Some manufacturers may not start out with daily customer demand that allows them to level production by mix and volume. However, that does not preclude them from beginning the journey towards that state by building in the work center capability to respond to such demand. This gives the manufacturer a competitive advantage for wooing new customers that they hadn't been able to serve in the past.

The one drawback of the implementation model is that it may not be prescriptive enough for use by a company with no experience in lean manufacturing. At Kodak there were external consultants, as well as people within the company with lean manufacturing experience, supporting the implementation. Therefore, there was not much debate about which tools to use for the implementation, just on the process for applying them.

6.2 The Future of Lean Manufacturing at KCI

The Role of the Production Supervisor

The role of the production supervisor changes when a lean manufacturing system is implemented. In the pre-lean days, the supervisor was responsible for monitoring people's compliance with the established procedures and rewarding or punishing people according to their behavior. With a lean manufacturing system, the people on the shop floor are more responsible for the daily running of the work center. The production supervisor thus becomes more of a coach and helper for the work team instead of a policeman/enforcer of the rules. I think that more explicit education and training of the production supervisors is needed to ease their transition into this new role.

KCI Management Involvement

The management at KCI has already begun to break down some of the barriers to lean manufacturing identified at the plant site. I was able to take part in some of the initial design work to streamline the job bracket system and create an hourly workforce that is more team oriented. I also witnessed plans to dismantle some of the functional silos and realign people around the value stream. For example, the maintenance and planning personnel would now report to either the department manager or production supervisor to ensure their alignment to the product flow. While these initial efforts are commendable, the management team cannot afford to relent in its efforts to keep driving the much-needed improvements across the site.

Information Systems

Eastman Kodak is in the middle of an implementation of an Enterprise Resource Planning (ERP) software package. The ERP system is supposed to replace the thousands of local, incompatible software systems that exist throughout the company with one global system. The problem that I see here is that the ERP implementation is being done without addressing the specific information needs of the lean manufacturing work centers. The ERP systems are being built with transactions that track the way the business is being run today, but with no provision to adapt as lean processes come onboard. I think that this could create a serious disadvantage for Kodak in the future as the information systems impose future behaviors that may well be sub-optimal for the entire organization.

Sensitizing Department

The sensitizing department is the heart of Kodak in terms of technology and political power. The road to lean manufacturing will have to go through the sensitizing function if

Kodak is to realize the true benefits of lean. As long as sensitizing continues to operate in the same old way, it will not matter what can be accomplished with lean manufacturing in the finishing departments because it cannot be translated back up the value stream. I think Kodak is going to have to allocate adequate resources to address this area of weakness before true cashing of the benefits of lean manufacturing will ever occur throughout the company.

APPENDIX A – Building a 34-Flow Lean Manufacturing Simulation

BACKGROUND

The 34-flow lean manufacturing simulation is a physical representation of the supply chain of the future state of the 34-flow work center. The simulation provides a model of the lean work center that can be physically manipulated in order to understand the impact of different operational patterns on the smooth functioning of the work center.

OBJECTIVES

The major goal is to use the simulation as a training tool to educate the shop floor personnel in lean principles, as they apply to this work center, including but not limited to:

- Continuous flow production
- Takt time
- Level loading
- Balanced operations
- One piece flow
- Inventory reduction

The simulation can also be used to educate other departments at KCI in lean principles as these departments begin to incorporate lean practices to run their work centers.

Finally, the simulation can be used to run "what-if" scenarios in the future to analyze the impact of proposed changes on the work center supply chain. This is possible because the simulation is based on actual demand data and operational process times as demonstrated by the 34-flow work center. The fact that the simulation model is based on real data provides a good approximation of the real supply chain. The one limitation of this model is that none of the typical production problems that occur in the actual 34-flow work center are incorporated into the running of the simulation. Typical problems that may occur during the course of a production run include missing supplies, missing wideroll, incomplete or inaccurate paperwork, label printer failures, etc. The omission of the production problems was done mainly because there was not accurate data about the frequency of these different failures and also to simplify the running of the simulation.

DESIGN OF 34-FLOW MANUFACTURING SIMULATION

The manufacturing simulation was designed to mimic, as closely as possible, the actual production operation and supply chain linkages that exist in the real 34-flow work environment. This led to the construction of a model with four major sub-sections – production staging area, production leveling box, slit/spool operation and packing operation.

Product Staging Area

The product staging area is responsible for getting product to the Central Distribution Center (CDC). The demand signals from the CDC are directed to the production leveling box discussed in the next section for fulfillment. However, it is the personnel in the staging area that are ultimately responsible for translating kanban cards into finished goods headed to the CDC. This translation is accomplished through the use of a production leveling box. The function of the production leveling box is to smooth out the production volume over a predetermined period i.e. a day consisting of two 8-hour shifts. The box is loaded with kanban cards evenly spaced over the course of the day. Each card represents permission to transfer a certain amount of product from the finished goods supermarket to the CDC. The finished goods supermarket is an inventory pool strategically placed to buffer the work center from some of the demand variability experienced at the CDC. The size of the finished goods supermarket is determined by the average daily sales data for each of the products stored in the supermarket and the production lot size used to reordering product. The higher the sales. production lot size, and variability of product demand, the greater the amount of product that must be held in the finished goods supermarket buffer to satisfy demand.

Slit/spool operation

In the 34-flow work center, the slit/spool operation is the pacesetter operation and thus is the recipient of the kanban signals that initiate the production process. Production reorder cards flow into a production queue to signal to the slitters the next product to load onto the slitting machine.

The slitting operation is supplied with raw material from the wideroll supermarket. The wideroll supermarket contains long, wide rolls of coated film sheets wrapped in protective light-tight material. Similar to the finished goods supermarket, the wideroll supermarket is sized to buffer variability. However, in this case, the variability is due to the uncertainty of having the right wideroll in the right quantity available at sensitizing and having it delivered in on time to replenish the supermarket levels.

Packing operation

The packing operation in this work center is coupled to the slit/spool operation in a continuous flow mode. There is no buffer between the slit/spool and packing operations, therefore all product taken off the machine is immediately bagged and packed into boxes becoming finished goods. Packing is really controlled by slitting; if the product makes it to the packing operation, except for quality problems, the product is converted to finished goods and transported to a warehouse for sale. Packing receives its raw materials from slitting, in the form of slit rolls, and from a purchase parts supermarket.

The purchase parts supermarket is a shared resource that holds all the different types of corrugated cases, bags, bag labels, case labels, and filler pads purchased from outside vendors. The supermarket is replenished by the material flow services personnel every 8 hours based on the return of the reorder kanban cards.

USE OF SIMULATION

The simulation was run with the workers in the 34-flow work center during the execution phase of the lean manufacturing system implementation. The simulation was set up as a two-round game and run in two sessions so that all three shifts of productions had an opportunity to play with the simulation.

In the first round, the production lots were large and production runs and process times were long to mimic the current state of the work center. At the end of the round, the level of finished goods inventory was compared to the starting safety stock level in the finished goods supermarket. The operators were then given time to comment on their impressions of how close the simulation was to the existing situation. In both sessions, the people agreed that it was fairly close to the real conditions that they experienced in the work center every day.

The second round started with the assumption that changeover time reduction had been made to the process such that the process cycle times were now shorter. The finished goods safety stock inventory was reduced by a factor of five. The reduction in process cycle time was translated into smaller production lot sizes and shorter production runs with more frequent product changeovers. Again at the end of the round, the operators were asked for their impressions about the round. What was the pace of production like? Were the various operations balanced throughout or did one station have to wait for another? There was also a discussion about how round two compared to round one.

SIMULATION RESULTS

Every time we ran the simulation, round two always resulted in lower finished goods inventory and more evenly paced production. In round one, the slitters often had to stop and wait for the packers to catch up during production runs. However, in round two they were both evenly paced and it was easy for the packers to keep up with the demand placed on them. The simulation really helped prove to the operators that the second scenario, a lean operating system, provided them with a better working environment.

APPENDIX B – Development of a Kaizen Blitz Exercise at Kodak

BACKGROUND

I took part in a 3-day kaizen blitz at the Steelcase Canada site in Markham near Toronto, with the production supervisor for the 34-flow work center at Kodak Canada. After returning from the exercise, we decided to use the 34-flow work center as the site for the first ever kaizen activity at the Kodak Canada, Inc plant site.

The 34-flow work center is part of the 16-mm microfilm-finishing department of Document Imaging Media Manufacturing and is in the process of being converted to a lean manufacturing system. An analysis of the sales data showed that average sales were at a little over 2 shifts worth of production per day given the current operating times. The operation is currently staffed for, and often does run, up to 3 shifts per day. Instead of keeping permanent staffing for 3 shifts, we decided to move to a permanent 2-shift production schedule. The work center thus had to undergo major process capability improvements in order to satisfy the same level of demand while on a permanent 2-shift operation.

There were two major hurdles to beginning production on an every-part-every-day schedule instead of the current every-part-every-week schedule.

1. The wideroll slitting operation would now have to carry out more wideroll changeovers per day and this would reduce the available production time for slitting, if changeover times could not be reduced.

2. The packing operation would have to label, bag, and pack many different types of finished goods rolls per day without having a negative impact on customer quality. With the current process times, the packers are barely able to keep up with the slitters, who often have to stop and wait for the packers before an order can be completed.

KAIZEN PROCESS

In order to fix those two key operational problems, the work center underwent a 3-day kaizen blitz exercise. The kaizen blitz is a quick, continuous improvement exercise carried out by improvement teams. The design of the kaizen involved alternating education modules with application exercises that made use of the lean tools that had just been learned. The idea is to provide lean manufacturing tools on a just-in-time basis for the application exercises instead of doing all the education one time only at the beginning of the three-day period.

The kaizen teams were made up personnel from within the operation, suppliers to the process, customers of the process and "outside eyes". The outside eyes in the kaizen event are people who work outside the area to be improved and participate in the kaizen exercise to provide a fresh perspective of the work area. The outside eyes aspect of the kaizen is absolutely essential to achieving the real out-of-the-box thinking needed to develop truly creative final solutions. The composition of the teams used in the 34-flow kaizen exercise is shown in Table 1.

Table 1. Composition of 34-Flow Kaizen Teams

Team 1 – Slitting Kaizen	Team 2 – Packing Kaizen
Slitter (+ Safety Coordinator)	Packer (experienced)
Slitter	Packer (newer)
Sensitizing personnel	Material flow services personnel
Maintenance personnel	Outside eyes (+ Black Belt Training)
Outside eyes personnel	Outside eyes personnel
	Outside eyes (+ Safety Coordinator)

PROBLEM DEFINITION

Another key factor that affects the ability to obtain rapid results out of the kaizen exercise is to have a very focused problem scope and deliverable target. The two problem statements developed for the 34-flow kaizen exercise were as follows:

1. Define a procedure for slitting to complete a changeover from one wideroll to a different wideroll in 10 minutes or less without increasing the overall slitting cycle time.
2. Define a procedure for packing to complete a changeover from one sequence of one product to another sequence of another product in 15 minutes or less.

The problem statements were developed based on the minimum known targets needed to reduce the cycle time to a level equal or less than the takt time. This was a key hurdle to the start of the lean transformation for the 34-flow work center. Without a balance between cycle time and takt time, the work center would be unable to satisfy demand without using overtime. While it was not clear when we defining the problem statements that these were obtainable goals, we had nothing to lose by giving the people on the floor the necessary tools and involving them in the process to come up with a solution to the problems.

DESIGN AND EXECUTION OF KAIZEN

Design of Education Modules

A series of education modules were developed to teach lean manufacturing principles and tools to the participants of the kaizen blitz exercise. The manual was made up of sub-sections covering the following topics:

i. Lean Manufacturing Overview
ii. Kaizen
iii. Waste
iv. Continuous Flow Production
v. Quick Changeover
vi. Poka Yoke (Error proofing)
vii. Just-In-Time & Inventory Reduction
viii. Kanban

Schedule of Events

The kaizen exercise activities are focused around two major themes. One theme revolves around teaching needed lean principles and tools to the team members, while the other focuses on applying the tools in specific, directed improvement exercises. The education modules are taught in small sections with no more than three topics covered per section. At the end of each education session, there is an exercise designed for each team that makes use of the concepts that were just presented. The design of the kaizen itself is set up with a just-in-time model – providing the education just in time for the application exercises. Breaks were scattered throughout the day, not only to give the team members a brief rest period, but also as times that the facilitator could use to re-focus a team that was going off track or not keeping to the schedule.

The presentation on the final day allows the team to educate the other members of the work center and management about the new procedures. It also provides a means for the team to solicit management commitment and support for the changes because work center management is represented at these meetings. Finally, the feedback time at the end of the kaizen gives the facilitator a chance to solicit information that will help improve the process for future kaizen events.

Detailed Schedule for Execution of 3-day Kodak Canada, Inc. (KCI) Kaizen Blitz

Table 2. Day One Plan

TIME	ACTIVITY
8:30 – 9:30 am	EDUCATION: Introduction, Lean Manufacturing Overview, Kaizen, Waste
9:30 – 10:00 am	**Break, with snacks**
10:00 – 10:30 am	EDUCATION: 5S Explanation of deliverables from application exercise #1
10:30 – 12:00pm	EXERCISE #1: Develop complete and accurate list of steps involved in current process
12:00 – 12:30pm	**Lunch**
12:30 – 1:00pm	Complete current state mapping (exercise #1)
1:00 – 1:30pm	EDUCATION: Continuous Flow Production Explanation of deliverables from application exercise #2
1:30 – 2:30pm	EXERCISE #2: 1. List of waste in the current system 2. List of any 5S opportunities identified 3. List of approximate times on each step of current process 4. Assess/identify the gap between the current times & kaizen goal
2:30 – 2:45pm	**Break, with snacks**
2:45 – 3:30pm	Complete application exercise #2
3:30 – 4:00pm	EDUCATION: Explanation of kaizen problem statement and goal

Table 3. Day Two Plan

TIME	ACTIVITY
8:30 – 9:30 am	EDUCATION: Quick Changeover, Poka Yoke
9:30 – 9:45 am	**Break, with snacks**
9:45 – 11:00 am	EXERCISE #3: 1. Complete spaghetti diagram/flow chart of the people movement in current state 2. Complete spaghetti diagram/flow chart of material movement in current state
11:00 – 12:00pm	EDUCATION: JIT & Inventory Reduction, Kanban Explanation of deliverables from application exercise #4
12:00 – 12:30pm	**Lunch**
12:30 – 2:30pm	EXERCISE #4: 1. Create a vision for a new process that closes the gaps identified between the current state and kaizen goal 2. Create a flow chart/spaghetti diagram for the future state process 3. Create a list of approximate times for each process step in the future state 4. Create a list of action items and required resources in order to implement future state process 5. Begin implementation
2:30 – 2:45pm	**Break, with snacks**
2:45 – 4:30pm	Continue with application exercise #4
4:30 – as needed	Continue with exercise #4, as needed to complete implementation

Table 4. Day Three Plan

TIME	ACTIVITY
8:30 – 10:00 am	EXERCISE #5: 1. Complete any outstanding implementation items 2. Validate new process times 3. Generate a 20-day action item list for the work center leadership – Items to monitor over the next 20-days – Items still left to do after the kaizen is over
10:00 – 10:15 am	**Break, with snacks**
10:15 – 11:30 am	Continue with application exercise #5
11:30 – 12:00pm	**Lunch**
12:00 – 12:30pm	EDUCATION: Explanation of deliverables for presentation
12:30 – 2:00pm	Continue with application exercise #5
2:00 – 3:00pm	PRESENTATION: Prepare presentation for work center
3:00 – 3:30pm **(with snacks)**	PRESENTATION: Presentation to the work center consisting of – Old process spaghetti diagram/flow chart with approximate process times – New process spaghetti diagram/flow chart with approximate process times – 20-day action item list
3:30 – 4:00pm	FEEDBACK: Feedback to facilitator about kaizen process and opportunities for improvement Make sure to turn in all paperwork to facilitator

RESULTS OF KAIZEN

The results of the kaizen were extremely positive and were achieved without any major capital expenditure.

1. The slitting team was able to reduce the changeover time wideroll to wideroll to 9.75 minutes. They achieved this result by designing a standardized work procedure for the operators involved in the changeover process. They converted as many of the internal steps in the changeover process i.e. steps performed while the machine is stopped, to external steps i.e. ones performed while the machine is still running. Doing more of the changeover during a machine run allows more of the available working time to be used for running production lots. The team's design also included an increase in the number of parallel steps performed by the operators. The combination of the conversion of internal to external steps and creating parallel process steps enabled the team to achieve the reduction in wideroll to wideroll changeover time.

2. The packing team was able to reduce their changeover time to 15 minutes. This was achieved primarily by creating parallel processes for the operators to perform during the changeover period. Each operator had a distinct set of tasks to complete during the allocated time period. All the tasks that could not be completed by either operator during the changeover period were assigned to the team leader for completion until such time that they can be completely eliminated from the process.

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