

# Integrating the Value Chain: A Step-by-Step Approach for Creating a World-Class Supply Chain for Kodak Professional Digital Cameras

by

Tomasz P. Wala

B.S., Mechanical Engineering  
University of Kentucky, 1995

Submitted to the Sloan School of Management and the  
Department of Mechanical Engineering  
in Partial Fulfillment of the Requirements for the Degrees of

Master in Business Administration

and

Master of Science in Mechanical Engineering

at the

Massachusetts Institute of Technology  
June 1999

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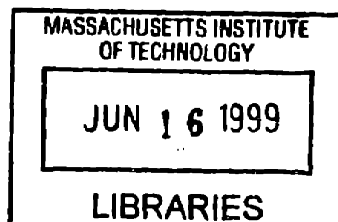
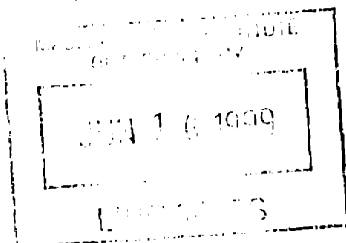
Signature of Author .....  
Department of Mechanical Engineering  
May 21, 1999

Certified by .....  
Don Rosenfield  
Sr. Lecturer, Sloan School of Management  
Thesis Supervisor

Certified by .....  
Anna Thornton  
Associate Professor, Department of Mechanical Engineering  
Thesis Supervisor

Accepted by .....  
Lawrence S. Abeln  
Director of Master's Program  
Sloan School of Management

Accepted by .....  
Ain Sonin  
Chairman, Committee on Graduate Students  
Department of Mechanical Engineering



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## **ABSTRACT**

Manufacturers of electronic equipment today face a new competitive battle. This battle does not just focus on the most efficient methods of production, but also the effectiveness of the entire supply chain. The next competitive advantage in manufacturing will shift from competition between leaner production systems to fully integrated and optimized supply chains. To assimilate the effectiveness of their supply chains, manufacturers must answer the following questions:

What is the appropriate supply chain model for the type of product and volume?  
How should inventory levels be calculated and optimized for the entire supply chain?  
Is the distribution network designed toward the needs of the final customer?  
How can communication in the supply chain be managed most effectively?

This thesis focuses on each question as they relate to the development of a more integrated supply chain. It is important to note that there is no one optimal solution because much depends on product characteristics. The thesis is based on research done at Eastman Kodak Company on the supply chain for the professional digital cameras. The goal is to provide a framework and model that can be used in improving any supply chain based on optimizing inventory levels and modifying the structure of the supply chain. The tools utilized include the MIT Strategic Inventory Placement (SIP) Model and improved communication via the Internet. By applying the framework described in this thesis, the digital camera manufacturing and supply chain team identified opportunities to double inventory turns and reduce its worldwide finished goods inventory by approximately \$1.8 million. Furthermore, a newly designed communication management system will improve supply chain delivery performance and customer service.

Thesis Advisors: Don Rosenfield, Sr. Lecturer, Sloan School of Management  
Anna Thornton, Associate Professor, Department of Mechanical Engineering

## **Acknowledgements**

The author would like to recognize all those who have made the project and research an outstanding learning experience:

The author would like to thank the Kodak Professional team that was extremely supportive of his project and contributed greatly to its success. Most of all, the author is indebted to Vince Andrews, Bill Carleton, Michael Kraitsik, and Steve Kralles for sharing all of their insights and rallying support for the project throughout the Kodak organization. In addition, the following people shared considerable amounts of time and effort and contributed greatly to this research: Brian Benamati, Gary Carter, Darren Johnson, Gerry Edd, Jeff Hissink, Jim Mitchell, Bob Nealon, Gary Smith, Ginny Spielman, and Scott Wagner. To everyone else working at Camera Assembly, MTD, OMT, CBA and Distribution— thank you very much for all of your help.

The author is grateful to fellow LFM student, Mark Graban, whose internship was located at the Kodak Microelectronics Technology Division, for working closely with him on this research. This project offered a unique opportunity by allowing the students to work at different stages of the digital camera supply chain and share cross-departmental knowledge to improve the entire process.

The author would also like to thank Sean Willems for sharing his expertise on the theory and implementation of the MIT Strategic Inventory Placement (SIP) Model.

The author is indebted to his faculty advisors, Anna Thornton and Don Rosenfield, who have been extremely helpful in guiding him through the entire research and thesis process.

The author gratefully acknowledges the support and resources made available to him through the MIT Leaders For Manufacturing program, a partnership between MIT and major U.S. manufacturing companies.

## **Dedication**

I would like to dedicate this thesis to my loving parents, Elzbieta and Andrzej, and my beautiful sister, Magda. They have given me the opportunity to study at the most prestigious academic institution, Massachusetts Institute of Technology, and without their constant support none of this would be possible. I will be forever grateful for the sacrifices that they have made for me.

This work is also dedicated to all of my dear relatives in Poland- grandparents, aunts, uncles, cousins and the new baby- that have supported me along every step of this journey.

This work is a token of my love.

# Table of Contents

<b>1. Introduction .....</b>	<b>8</b>
1.1. Background .....	8
1.2. Thesis Overview .....	13
1.3. Thesis Outline .....	15
<b>2. Project Description.....</b>	<b>16</b>
2.1. Motivation .....	16
2.2. Setting.....	17
2.3. Market Overview.....	18
2.4. Technology Overview .....	19
2.5. Product Overview .....	20
2.6. Process Flow.....	22
2.7. Summary .....	27
<b>3. Problem Statement.....</b>	<b>28</b>
3.1. Current Situation .....	28
3.2. Ideal Situation & Barriers.....	37
3.3. Summary .....	40
<b>4. New Supply Chain Model.....</b>	<b>41</b>
4.1. Problem Definition.....	41
4.2. Removal of Barriers .....	46
4.3. Approach .....	48
4.4. Summary .....	51
<b>5. Results .....</b>	<b>53</b>
5.1. “As-is” Supply Chain Model.....	53
5.2. “To-be” Integrated Supply Chain Model .....	54
5.3. Support of Hypothesis.....	64
5.4. Summary .....	68

<b>6. Conclusion/Recommendations .....</b>	<b>69</b>
6.1. Successes .....	69
6.2. Shortcomings.....	70
6.3. Project Lessons.....	71
6.4. Recommendations .....	71
6.5. Future Opportunities .....	72
<b>7. Bibliography .....</b>	<b>73</b>
<b>8. Appendix I.....</b>	<b>76</b>

# **1. Introduction**

The objective of this thesis is to establish a framework with which high-technology supply chains can be improved. The proposed model was applied to the supply chain for the Kodak Professional digital cameras. The thesis includes the modeling of the supply chain, determining its overall performance, re-designing parts of the supply chain, establishing appropriate inventory levels and improving managerial communication. The background section highlights critical issues that must be explored prior to designing a new supply chain. The framework of the thesis describes the process of developing an integrated supply chain.

The most effective supply chain is designed based on the requirements of the product and the needs of the customer. The supply chain design should be based on the properties of the product – high or low technology and volume. The model must be structured so the suppliers have an effective means of delivering components and, if required, must be sensitive to lead-time and quality issues. The model should also allow manufacturing the ease of communicating with both its customers and suppliers. This will give the business and its supply chain greater flexibility to react to changes in the market.

## **1.1. Background**

“There is no competency more critical than that of superior design of one’s capability chain- from final consumer all the way upstream to the sources of raw materials and new technological concepts” (Fine, 1998, p. 71).

However, there is no one optimal design for a supply chain. The solution is dependent on features of the product, reliability of suppliers, type of manufacturing process, design of distribution and the needs of the customer. The recommendations made for optimizing the Kodak Professional supply chain must be viewed as the interaction of these aspects for the digital cameras but the framework can be applied to many other supply chains.



The thesis covers several methods of improving the supply chain for a high-tech product. The following literature is used to provide a background on supply chains as well as to develop the framework for optimizing a supply chain. The literature covers the methods of determining the appropriate supply chain design and understanding the drivers of supply chain performance. The framework, used to optimize the Kodak supply chain, is developed upon an inventory management strategy, the need for Internet-based supply chain communication and lessons learned from the Dell Computer Direct Model.

Today, an integrated supply chain is necessary to compete in the global arena (Engardio, 1998). The product must flow smoothly from suppliers to manufacturing, through distribution, and be delivered with a high service level to the final customer. To obtain quicker time to market and reduce inventory costs, firms must focus on designing an extended organization, including its supply network, its distribution network, and its alliance network (Fine, 1998, p. 75). For high-tech manufacturers, this is especially important. Electronics manufacturing has entered a new era where efficient production and high quality is not enough to obtain market success, even when there is strong demand for the product.

To be designed most effectively, supply chains must be first analyzed with a holistic approach. Frequently, various stages in the chain are managed with established goals and performance metrics that appear to be the best for the stage. However, these strategies often do not match the global optimum that benefits the entire system. The goal is to design a supply chain that focuses on the needs of the customer and delivers its products in the most cost-effective way (Verespej, 1998).

The production method by which the product is manufactured is important in the design of the supply chain. The differences in manufacturing processes drive the amount of inventory and flexibility in the supply chain. The two types of a manufacturing processes are job shop (or batch) and continuous flow (or pull). The batch processes are typically used for lower volume products where several different tasks and various sequences are used to produce the products. For example, fifty widgets are manufactured together at

one process, then painted at another process and finally returned for a finishing operation. Batch processing tends to build-up work-in-process inventory as the product waits to be moved from one process to the next. In contrast, a pull system processes product in a line flow one-by-one. Each process is broken down into simple operations and a completed product is then moved to the next process. The advantages of the continuous line flow are that defects can be spotted quickly at the next process and work-in process inventory is reduced. This reduction in inventory allows greater flexibility for the supply chain in adjusting to customer needs. This occurs because there is less pipeline inventory that must first be consumed, prior to shipping the improved product (Garvin, 1981).

The type of product that is being produced has a large effect on the design of its supply chain. Fisher (1997) describes the differences in supply chain design for a primarily functional versus a primarily innovative product. Primarily functional products are those that satisfy basic needs, change little over time, have stable, predictable demand and long life cycles. In contrast, primarily innovative products do not have predictable demand and “the uncertain market reaction to innovation increases risk of shortages or excess supplies.” These products tend to have shorter life cycles and higher profit margins. Therefore, costs of managing these life cycles, with enough inventory for the important early sales to establish market share but not having excess because of the risk of obsolescence, dominate the primarily innovative products.

The causes and effects of demand uncertainty and variability of high-tech (innovative) products also have enormous effects on supply chains. Forrester (1961) discusses these effects, often called the “bullwhip effect ” or the “beer game,” as applied to inventory management. This is the theory that demand and inventory volatility are increased starting from the final customer and moving “upstream” through the entire supply chain to suppliers. Therefore, as described in 4.1.2, the effects of volatility and its inherent amplification must be minimized to establish a world-class supply for high-tech products. The complexity of forecasting customer demand is a crucial driver of the supply chain. This ultimately leads to demand variability that causes the “bullwhip effect” in the supply chain. Fisher (1994) discusses the effects of demand uncertainty on the supply chain for

ever-changing innovative products. Galbraith and Merrill (1996) discuss the reasons why demand forecasting is difficult and often inaccurate. These include the reactive mode of forecasting, organizational pressures and lack of understanding of demand dynamics. Barnett (1988) provides a solution to improved forecasting by dividing demand into component parts, forecasting demand drivers, and conducting sensitivity analysis.

Inventory is another driver of a supply chain and requires an effective distribution strategy. Narus and Anderson (1996) point out the need for flexibility in the distribution network to cope with unexpected or unusual customer demands. Rosenfield and Pendrock (1980) describe how the design of the distribution network contributes to the levels of aggregate inventory. Factors such as the proportion of demand served by central warehouse, ratio of transit time to procurement time, and transshipment costs should determine the warehouse configuration. Lee and Billington (1992) outline an overall list of pitfalls in inventory management. These included the lack of an adequate supply chain information system, no metrics to monitor the performance of the supply chain and not understanding the impact of uncertainties.

To minimize the “bullwhip effect,” an effective inventory strategy is required to compensate for supply and demand variability throughout the supply chain. The basic paradigm for establishing these inventory levels is to create a buffer when the production cycle time of an upstream process is longer than the quoted delivery time to the downstream process. Stated differently, this buffer is used to compensate when the promised product lead-time to the next processes is smaller than the time it takes the process to produce another unit of product. For example in distribution, if a customer requires delivery of a product within three days but delivery from the factory takes five days, the dealer must hold two days of inventory to be able to satisfy her customers.

Staying close to the customer and maintaining open communication is also crucial to the effectiveness of the supply chain. Fites (1996) discusses the advantages of open communication with dealers to facilitate improvements in product design and customer service. Gouillart and Sturdivant (1994) emphasize the importance of understanding the

needs of the final customer and the positive effects this creates when the company can react quickly to changes in the market. A faster feedback loop between the customer and manufacturing can become a major competitive advantage for a firm.

Therefore, the importance of moving supply chain management to the Internet is being advocated. Gormley (1997) discusses the need for real-time supply chain monitoring, a feature not offered by today's ERP (enterprise resource planning) vendors. This improves supply performance by reducing reaction time to any schedule modifications. Zimmerman (1997) expresses the importance of moving toward forecast sharing, scheduling and reliable communication via the Internet. This is the most cost-effective and simplest method to link and share data with members of the supply chain. Likewise, Moad (1995) describes how companies are moving from EDI (Electronic Data Interchange) toward Intranet-based supply chain management systems.

The correct design of the supply chain can offer a company a competitive advantage over other firms in the high-tech industry. This notion applies directly to Eastman Kodak because the company is in a transition, moving from the traditional supply chain that supported its film and paper business to create a more flexible supply chain that will also support its high-tech products. As discussed in Section 3.2, although it can not be directly applied, Kodak can use the Dell Computer Direct Model as its benchmark. Optimal inventory management strategies should be used to improve inventory turns and product cycle time in manufacturing. In addition, Kodak should work toward eliminating layers of its distribution network to reduce costs and reduce lead-time to its customers. Other industrial companies that are working toward improving their supply chain can use the lessons learned at Eastman Kodak.

This research project is a follow-up on the work done by Brain Black, of the MIT Sloan School of Management and the Leaders for Manufacturing Program. The author used Black's (1997) thesis entitled *Utilizing the Principles and Implications of the Base Stock Model to Improve Supply Chain Performance* in developing the larger scope of this project. Black's project focused on improving the supply chain for a single camera

component as well as setting inventory levels in Kodak distribution. The author has extended the previous work into integrating the entire supply chain.

## **1.2. Thesis Overview**

This thesis focuses on the framework required to develop a more integrated supply chain at Eastman Kodak Company. The research uses the redesign of the Kodak Professional digital camera supply chain as a basis. However, the goal is to provide a framework and model that can be used in improving any supply chain. The framework consists of three major components that were crucial in the implementation at Kodak. These included an inventory management strategy for the entire supply chain, redesign of the distribution network and improvement of communication in the supply chain. The tools utilized include the MIT Strategic Inventory Placement (SIP) Model, the Dell Direct Model and the Internet.

The Strategic Inventory Placement (SIP) Model is a software tool that can be used to optimize inventory levels (Graves and Willems, 1998). The supply chain is modeled as a spanning tree (a multi-stage system) subject to uncertain demand from the final customer. The model utilizes an optimization algorithm for finding the optimal locations and levels of strategic stock in the supply chain. As discussed in Section 4.1.2, the model is powerful since it allows for the optimization of the entire supply chain, including internal and external suppliers, manufacturing and all stages of distribution.

The Strategic Inventory Placement Model is based on several key assumptions. The optimization assumes that each stage in the supply chain operates with a periodic review, base-stock policy, quotes a guaranteed service time to its customers and that the demand is bounded. The model then can be used to minimize the inventory costs in the entire supply chain, while maintaining user-specified customer service levels. The model establishes these stock levels based on product-specific cycle times, yields, direct costs, and final customer demand. The cycle time used in the SIP Model is the time that it takes

95% of the product to complete a stage. The product yield is the average quality of the components at each process stage (Graves and Willems, 1998).

The re-design of Kodak Professional supply chain features many lessons learned from Dell Computer Corporation of Austin, TX, one of the world's leading manufacturers of corporate and personal computer products. The following articles were excellent in describing the extremely efficient supply chain model called the Dell Direct Model. In an interview with Magretta (1998), Michael Dell describes the strategies and philosophy behind the company's supply chain model and emphasizes the importance of open communication with supplier and customers. In Verespej (1998) and McWilliams (1997), Dell also describes the company's successes from employing the Internet as a major part of the business.

The advantages of the Dell Direct supply chain model and how they relate to Kodak will be discussed in Section 3.2. The supply chain at Dell is based on reducing the company's exposure to inventory risk as well as eliminating all layers in the distribution network by shipping the product directly to the final customers. The inventory risk is minimized with the use of "Revolver" inventory, which are component inventories held by Dell's suppliers outside of its computer manufacturing plants. The inventory is held at the supplier warehouse until Dell receives an order for a computer and sends a component order to each of their suppliers. The suppliers have made a commitment to deliver the components, within hours of the order, directly to the Dell computer production floor, where they will be assembled.

Following assembly, the product is shipped directly to the final customers. Unlike most of its competitors, Dell does not use a distribution network of wholesalers and retailers to sell its products. This allows Dell to communicate directly with its customers and in the process retain the profit margin usually given up in the distribution channel (Verespej, 1998). Although it can not be applied directly, the Dell Model is used as a basis for the new Kodak Professional supply chain.

### **1.3. Thesis Outline**

This thesis is divided into six sections: introduction, project description, problem statement, new supply chain model, results and conclusions/recommendations. The Introduction section gives background to the issue of supply chain management, its dynamics and necessary improvements. The Project Description section covers the overview of the project, internship setting, as well as the camera products and business. The Problem Statement section will compare and contrast the current supply chain for Kodak digital cameras with an ideal supply chain model. Next, the New Supply Chain Model section will describe the project hypothesis and approach for improving the Kodak Professional supply chain. The Results section will detail the steps of re-designing, integrating and improving this supply chain. Finally, the Conclusion/Recommendation section will highlight the improvements and benefits of an integrated supply chain.

## **2. Project Description**

This research project was based at the Kodak Professional division within Eastman Kodak. The focus of the project was the analysis and improvement of the digital camera supply chain. The Kodak Professional digital cameras are viewed as one of the strategic corporate initiatives at Eastman Kodak. In 1999, a key project in the improvement of digital camera operations was the development of an integrated supply chain. This section contains the background material including motivation, project setting, camera market overview, technology overview, product mix and manufacturing processes to describe the current Kodak Professional supply chain.

### **2.1. Motivation**

Digital technology is one of the major corporate strategies of Eastman Kodak Company going into the year 2000. George Fisher, the Chief Executive Officer of Kodak, has communicated the core business strategies going forward to be digital photography, digitalization of conventional photography, and expanding global reach with the traditional film and paper products. Because of its technological expertise, the products developed at Kodak Professional will define the future of digital technology at Eastman Kodak.

#### **2.1.1. Digital Products Business part of Kodak Strategy**

As part of the Kodak strategy, Kodak Professional is the world's leader in developing and marketing high performance digital cameras to professional photographers. As the camera world moves further into the digital arena, Kodak Professional needs to maintain its market power by fulfilling the growing global demand for its products. This market is driven by technological innovation and Kodak must maintain its superior design capabilities. In addition, to establish a manufacturing advantage, Kodak Professional



requires a world-class supply chain that is flexible and can adjust to a changing global market.

### **2.1.2. Market Becoming More Competitive**

As the market for digital cameras grows increasingly competitive, competitors will not only compete with their product technology but also with the efficiencies of its supply chains. The supply chain requires the ability to improve product time-to-market, adjust to changing consumer needs and deliver a satisfactory customer service level. Therefore, the competitive battle for high-tech products, such as digital cameras, will include the entire supply chain needed to supply components, manufacture the product and deliver it to the customer. The goal of the supply chain is to provide demand flexibility, build-to-order production and on-time delivery to the customer.

## **2.2. Setting**

The author's six-and-half month internship was located at Eastman Kodak Company in Rochester, New York. He was assigned to Global Equipment Manufacturing to work with the High Performance Imaging Systems (HPIS) group within the Kodak Professional Division, the second largest business unit within the company. Kodak Professional focuses on the needs of professional photographers with products such as high-performance digital cameras, scanners, printers and output. The project was designed to improve the supply chain for one of the High Performance Imaging Systems main products: the High-Resolution Digital Cameras.

Global Equipment Manufacturing (GEM), which is aligned to primary Kodak business units, designs and manufactures a variety of reloadable cameras, single use cameras, digital cameras, photofinishing equipment, printers, scanners, systems and output media. Global Equipment Manufacturing is divided into product flow clusters that include High Performance Imaging Systems. The HPIS group manufactures products that include high-

resolution digital cameras, scanners, ink jet printers, thermal printers, proofers, and LED/Laser/CRT Printers.

The author was assigned to work for the Operations Manager for High Performance Imaging Systems – Digital Capture. He also worked very closely with the Supply Chain Manager for Digital Capture. The main focus of the Digital Capture group is the manufacture of high performance digital cameras and scanners.

### **2.3. Market Overview**

The market for professional digital cameras is very competitive and focuses on performance and technology rather than price. There are about 15 competitors in this market, who in 1998, were competing for estimated revenue of \$250 million. Competitors include large companies such as Canon, Nikon, Fuji, Minolta and Sony that Kodak also competes with in film photography. Smaller companies, such as Leaf, PhaseOne, and Dicomed, are also included in this market.

The Kodak-manufactured professional digital cameras are the market leaders in this industry. Canon professional cameras, which are manufactured by Kodak, have the largest share of the high-resolution camera market, followed by Fuji, Leaf, PhaseOne, Dicomed, Associated Press (manufactured by Kodak), Minolta, Sony and Nikon (manufactured by Kodak). Three of the top nine companies in the high-resolution digital camera market have their products manufactured by Kodak.

The main differentiation between the professional digital cameras is the resolution and quality obtained by the image sensor, which captures and processes the image into a digital output. The rest of the camera is a traditional SLR, except that many of the inside components (motors, etc.) of the camera are removed to make room for the image sensors, circuit boards and color LCD display. One main reason for Kodak's leadership in this market is the inability of competitors to match the digital resolution obtained by the Kodak digital cameras. Other than Kodak's internal expertise in image sensor

manufacturing, there are a very limited number of sensor suppliers. This provides these companies with pricing power in the market. However, the technological expertise and high start-up costs required prevent new entrants from entering the market.

According to Kodak Professional Product Marketing, the keys to success in this market are proper market segmentation (for performance and price), timely entry into the market, and ability to supply the early demand for the product. This ability provides the significant competitive leverage gained when “firms get to market faster and more efficiently with products that are well matched to the needs and expectations of target customers” (Wheelwright and Clark, 1992).

The different market segments served by Kodak Professional are commercial studio, portrait studio, photojournalism, applied (medical, scientific and industrial) and high-end amateurs. Out of these segments, the product mix has been focused (in descending order) on photojournalism, commercial studio, as well as applied and portrait studio.

## **2.4. Technology Overview**

As their competitor’s technology improves, Kodak Professional can only insure itself that it will remain the market leader in this high-tech industry by meeting the performance needs of their professional customers. As stated above, the main driver of the professional digital camera industry is the technology and performance of image sensor used in the camera. Kodak must continue to innovate and keep improving image quality to stay ahead of its competitors. The two competing image sensor technologies are the charged-coupled devices (CCD) and complementary metal-oxide silicon (CMOS) devices.

The CCD was invented in the late 1960s by researchers at Bell Labs. Although originally conceived as a new type of computer memory circuit, CCD sensors were quickly used in many applications including signal processing and imaging – the latter because of the light sensitivity of silicon. The CCD sensor in a digital camera is the primary tool to

capture an image. The sensor collects light and converts it to a charge and subsequently emitting a signal that results in a digital image. Kodak's CCD sensors are comprised of thousands of pixels grouped in either a linear or matrix array to register the overall light intensity of each point in a scene. A color image can be obtained with the addition of filters, in a proprietary red-green-blue pattern, during the CCD sensor manufacturing process.

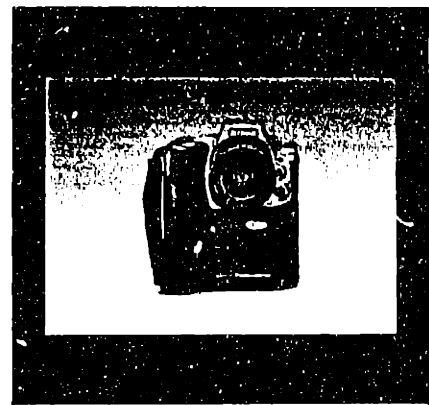
Kodak uses its proprietary CCD technologies to make the highest resolution cameras on the market. In 1998, the resolutions on the two main products developed and manufactured for Kodak Professional were 1.5 million-pixels (or mega-pixel) in the DCS 315 and 2.0 million-pixels in the DCS 520 camera model. In 1999, the newly introduced DCS 560 features an image sensor with a 6 million-pixel resolution. In comparison, the image resolution of photographic film is about 16 million pixels, but digital technology is forecasted to meet such resolution in the next five years.

In contrast, the CMOS devices are currently not able to achieve such high resolution as the CCD. However, many engineers at Kodak believe that in the next five years CMOS may be able to match or even beat the resolutions offered by CCD sensors. One advantage of the CMOS technology is that it utilizes the same processes used to make microprocessors. Therefore, CMOS sensor manufacturing could inherently achieve higher process yields that would significantly reduce the price of these sensors. In response to the CMOS threat, Kodak signed a joint venture with Intel to work together on the next generation of image sensors. This partnership will allow Kodak to share its world-leading digital image sensor design expertise, while enabling Intel to utilize its world-class process technologies.

## **2.5. Product Overview**

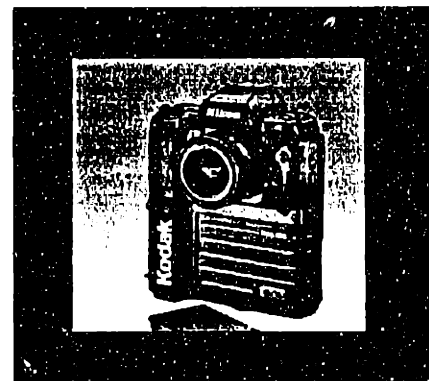
The digital camera product lines of Kodak Professional include the following main model families: DCS 315, the DCS 400 series, and DCS 500 series.

**DCS 315.** The DCS 315 camera is the most affordable camera product. It combines a high-resolution digital camera with the versatility and functionality of a Nikon SLR. The camera features a 1.5 mega-pixel CCD sensor with variable ISO speeds (100-400). The camera can use interchangeable lenses from Nikon. This allows the re-use of lenses (previously used with the reloadable cameras) which lowers the photographers' cost of switching to digital. The camera also includes a color LCD that allows instant review of the images as well as storage of exposure information, date/time stamping, thumbnail images and voice recording. Finally, the camera has dual PCMCIA slots for removable PC cards that store the images.



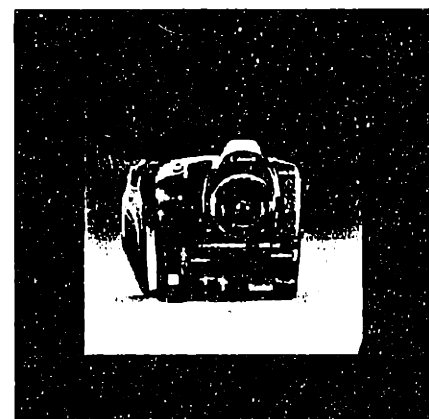
**Figure 1. Kodak DCS 315 Digital Camera**

**DCS 400 Series.** The 400 series cameras are known as Kodak's "traditional" digital cameras because they are some of the first-manufactured digital camera systems. The DCS 420 camera includes a 1.5 mega-pixel CCD sensor, ISO 100-400, 36-bit color and a rechargeable battery. The DCS 460 camera includes a 6 mega-pixel CCD sensor, ISO 80, 36-bit color, and permits telephone-quality voice recording.



**Figure 2. Kodak DCS 420 Digital Camera**

**DCS 500 Series.** The DCS 500 series are the flagship digital cameras for Kodak Professional. The DCS 520 includes a 2 mega-pixel CCD sensor, full ISO 200-1600, and rapid burst rates of up to 3.5 images per second. In addition, it is built around the Canon EOS camera subsystem, which allows for interchangeable lenses. As the newest product in the product line, the DCS 560



**Figure 3. Kodak DCS 520 Digital Camera**

features a 6 mega-pixel CCD sensor, ISO 80-200, and is also built on the Canon EOS camera subsystem.

## **2.6. Process Flow**

The Kodak Professional digital cameras are manufactured by Global Equipment Manufacturing (GEM), at the Kodak Elmgrove Plant in Rochester, NY. The High Performance Imaging Systems factory is currently in the process of moving away from a batch (or push) manufacturing system to a DFT (Demand Flow Technology) pull system. In this new system, the deliveries of components and subassemblies are triggered only when final camera assembly is ready to process (Hayes, 1988, p.186). This means that when one CCD image sensor is installed into a camera, a replacement sensor is ordered (or pulled) from the supplier. The new system is based on kanban stock levels, set on each of the components, to manage the amount of work-in-process (WIP) on the assembly floor. The kanban establishes the levels of on-hand inventory and the re-order point when inventory needs to be replenished.

The factory utilizes a computerized quality management system that tracks each camera and component by barcode, to ensure that all assembly and testing procedures are completed prior to shipping. The process procedures are maintained electronically on the assembly floor and the factory is currently working toward its ISO9000 certification. In the last few months of the author's project, the factory has successfully been moved to a clean-room environment, within the Elmgrove facility, to accommodate higher volumes and improve product quality.

The supply chain for the Kodak Professional digital cameras includes both internal and external component suppliers. The main components of the cameras are the CCD image sensor, circuit board assembly and the camera body. The CCD image sensors are manufactured at Kodak Microelectronics Technology Division at Kodak Park in Rochester, NY. The circuit board assemblies are manufactured internally at the Elmgrove Plant. In contrast, the camera bodies are purchased from Canon and Nikon in Japan.

Figure 4 shows the manufacturing supply chain for the Kodak Professional digital cameras.

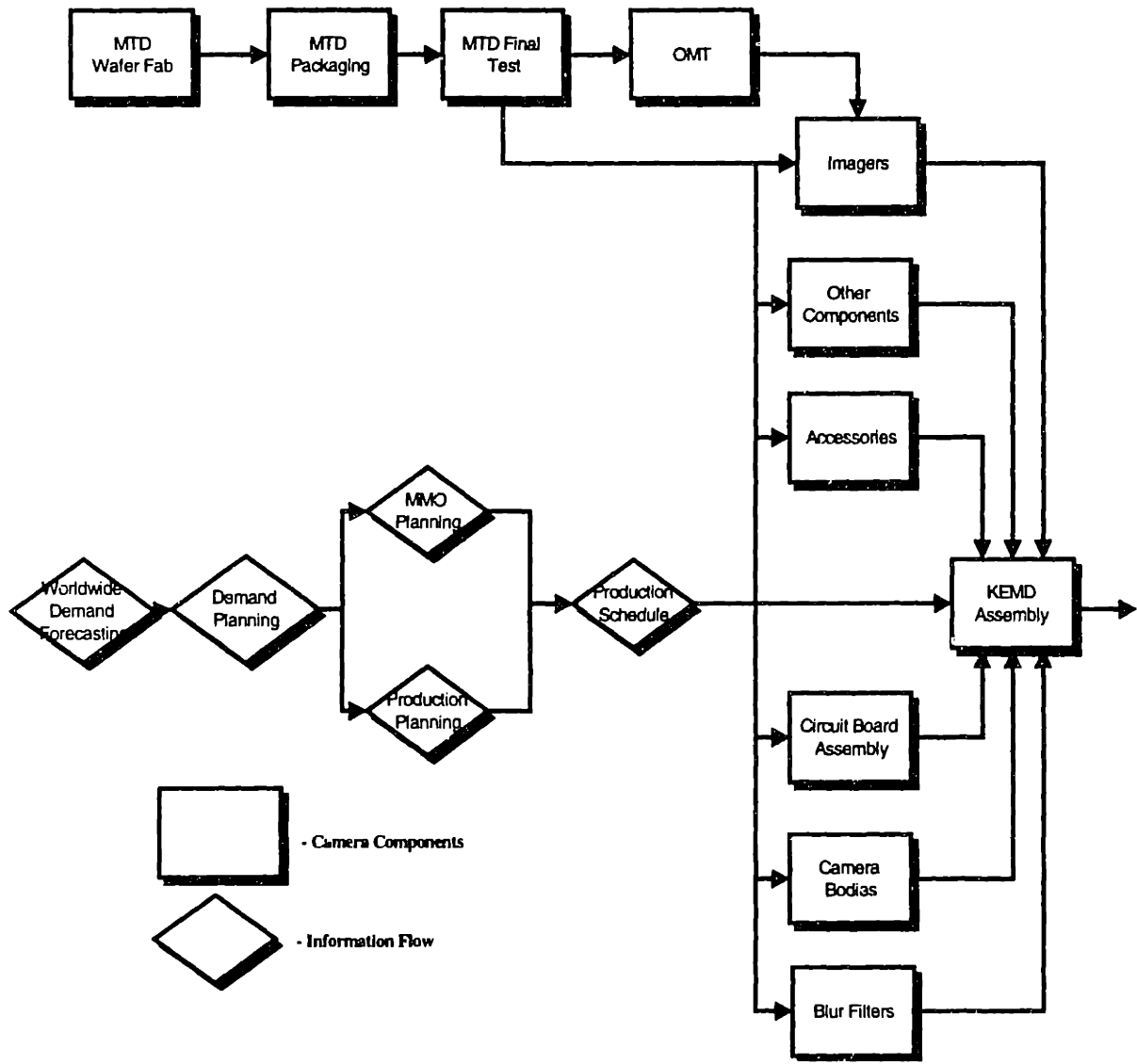
The current supplier purchasing is managed by the Kodak Manufacturing Resource Planning (MRP) system. This system is based on forecasted demand at the camera level being relayed throughout the supply chain for each individual component. The internal suppliers are linked together through the Kodak GEMS system and the system generates weekly orders to the external suppliers. The major suppliers, as seen in Figure 4, are Kodak's internal Microelectronics Technology Division and Optical Mechanical Technology Division (MTD/OMT) for image sensors, Canon and Nikon for camera bodies and Kodak's internal Electronics Products Division (CBA) for circuit boards.

**CCD Imager Assembly (MTD/OMT).** The Microelectronics Technology Division is the sole-source supplier for all of the image sensors used by Kodak Professional. The charge-coupled devices (CCDs) are manufactured in a semiconductor wafer fabrication plant at Kodak Research Laboratories. The manufacturing process for the devices includes wafer fabrication, packaging, final testing and shipment to the Elmgrove plant. However, before the devices can be installed in the cameras, an alignment process is performed at the Optical Mechanical Technology (OMT) Department at Elmgrove. This process aligns the CCD image sensor to a base plate before it can be installed into the camera body.

The MTD/OMT production process has the largest supplier lead-time and yield variability for the digital cameras. The yield of each wafer lot can not be determined until wafer probing is performed. However, probing can only be performed after completion of all of the wafer fabrication process steps, which takes 6 to 10 weeks of cycle time.

Therefore, the number of devices that will be delivered downstream in the supply chain is difficult to estimate until the completion of the manufacturing process.

Following the wafer probing and packaging processes, the image sensors undergo a final test that maps the capability of each pixel on the sensor. During the OMT process, the maps are reviewed and any software manipulation is performed to improve the



**Figure 4. Manufacturing Supply Chain for Digital Cameras (flow continued - Fig. 5)**

performance of the sensor. The final imager focus and quality verifications, at various ISO speeds and lighting, are performed at camera assembly.

**Circuit Board Assembly (CBA).** The circuit board assemblies for the digital cameras are manufactured at the Circuit Board Assembly (CBA) department within the Electronic Products Division at the Elmgrove Plant. The factory utilizes surface mount technology (SMT) processes and equipment to produce the circuit boards. The circuit boards are assembled on a pull system. Over the past several years, the department has focused on

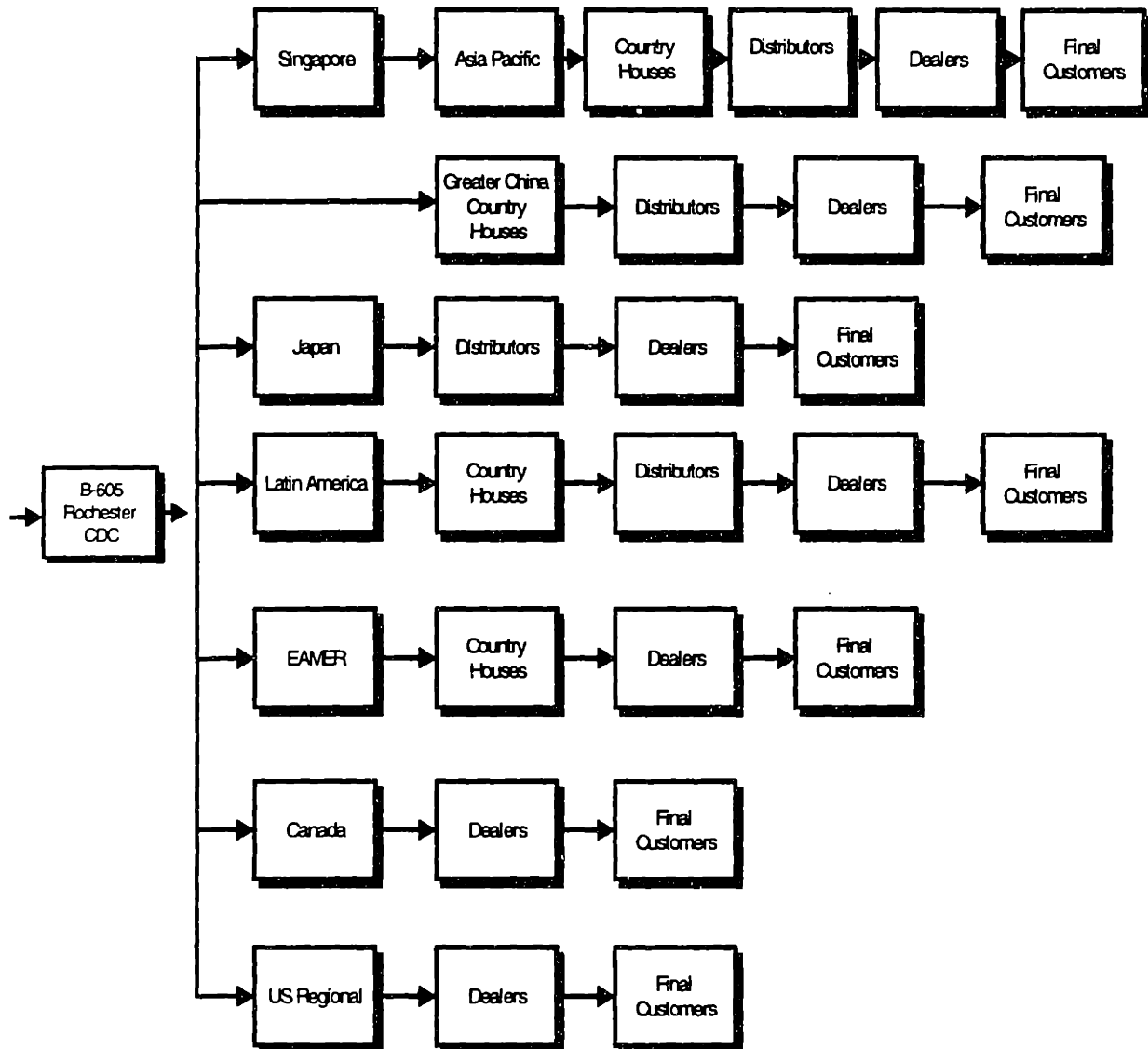


reducing customer lead times by reducing cycle times and improving process yields. In addition, CBA has been involved in establishing consignment inventories for many of the high-price and high lead-time components. This consignment inventory is managed by an external company, which holds and delivers necessary components to CBA with a one-day lead-time. This reduces the holding costs incurred by CBA and Kodak as well as reducing the risk of holding inventory of high cost parts. This is important because circuit board component prices tend to decrease over time. Therefore, CBA can buy these parts at lower costs when they are needed, instead of holding inventories themselves. For example, for the four major circuit board assemblies produced for the Kodak Professional digital cameras, over 40% of the component costs are held in consignment inventory.

**Camera Bodies.** The camera bodies are manufactured by Canon and Nikon in Japan. Through a partnership with both companies, Kodak manufactures certain camera models under its own brand name and sells a percentage to its Japanese partners. This ensures that the professional photographer will be able to utilize the interchangeable Canon or Nikon lenses when making the transition to digital photography. The camera bodies experience long order lead-times that causes difficulties for Kodak to respond to changes in customer demand.

**Worldwide Distribution.** The cameras are shipped throughout the world using the Kodak Worldwide Distribution network. Figure 5 shows the distribution network in the supply chain for digital cameras. Following completion of camera assembly, each camera is sent to the Rochester Central Distribution Center to be unloaded and put into inventory stock. After some transportation planning, the camera is picked from inventory and moved depending on its final destination. A camera designated for the US or Canadian market is moved into designated distribution centers. This camera will then be delivered to a dealer and sold to the professional photographer.

A camera designated for export is consolidated with other products going overseas, loaded on a truck and delivered for shipment by air or boat. The camera will then be received at a Regional Distribution Center where it may be put into inventory or



**Figure 5. Worldwide Distribution Network (flow continued from Fig. 4)**

expedited directly to a Kodak Country Distribution House. At each Country House, the camera is customized for the local market, delivered to a dealer and sold to the final customer.

## **2.7. Summary**

The digital camera products are one of the main corporate technology strategies at Eastman Kodak going into the year 2000. The market for Kodak Professional digital cameras is very competitive with about 15 companies going after revenue exceeding \$250 million. The professional camera market is driven by innovation in imager technology and Kodak is the leader in developing the world's highest-resolution imager sensors (Charge Coupled Devices).

The manufacturing process flow, for the digital cameras, includes imager assembly, circuit board assembly, camera bodies, camera assembly and the worldwide distribution network. The supply chain for the digital cameras includes both internal and external Kodak suppliers. The MTD/OMT imager assembly has the largest supplier lead-time and yield variability. Circuit board assembly utilizes consignment to minimize its component holding costs. The distribution network includes three sequential inventory locations prior to cameras being delivered to the dealers. Therefore, the current supply chain for the digital cameras has many opportunities for improvement.

### **3. Problem Statement**

The current supply chain for Kodak Professional digital cameras is based on the model used for high volume film manufacturing and distribution. The supply chain is driven by a forecasted demand schedule, which loads the factory and establishes fixed supplier requirements. However, the high-tech features of the digital cameras cause long lead-times and quality variability of the components. The highly competitive digital camera market forces a product that requires quick market entry and an optimal inventory management strategy, with its suppliers and in distribution, through the product life. The new supply chain must utilize a manufacturing pull system and deliver product with high customer satisfaction. Therefore, a new design of a more integrated supply chain is required for the Kodak Professional digital cameras.

#### **3.1. Current Situation**

Kodak Professional sells the world's most technologically superior digital cameras, based on the performance of its technology and the current market share of its products. As described in Section 2.5, these digital camera product families offer the highest resolution and image quality of any competitor in the market. The performance generates high market demand for the products by professional photographers. Simultaneously, technology limits are being pushed with each new innovation and product. The increasing demand causes problems for suppliers in meeting product volumes because little time is provided to improve manufacturing capabilities for each new technology.

The current supply chain for the Kodak Professional cameras experiences low inventory turns, production line-down situations, and inaccurate demand forecasts. Since the lead-times for the major components are high, suppliers try to protect themselves by not allowing any flexibility in procurement orders, within a certain time frame. This limits Kodak's ability to react to the changing market conditions by ramping up or decreasing production because fixed amounts of components are being delivered. In addition, the

design of the distribution network is not conducive to obtaining a high customer service level. The current network, designed after the film distribution network, experiences long delivery times and high inventory costs.

The performance of a supply chain can be characterized by determining how efficiently inventory is used and the effectiveness of on-time delivery of the product. However, one of the main difficulties, in designing an effective supply chain, is to understand its underlying dynamics. As described in Section 1.1, the critical concept that must be understood is the “bull-whip” or “beer game” effect which causes huge swings in inventory levels between supply chain stages. For example, in times of product shortage, upstream stages attempt to protect themselves, from running out of product, by increasing their orders on their downstream supplier (without additional demand coming from the customer). When production is resumed, the effect is excess inventory at various stages of the supply chain. Strategic inventory levels can be utilized to absorb some of these effects but must be done in a cost-effective manner.

A new inventory management strategy is necessary to eliminate inventory between processes where it is not needed and increased in other locations. The effect of the long lead-times, quality and demand variability of the camera components causes the Kodak Professional supply chain to carry additional inventory. This inventory is currently staged between every manufacturing process shown in Figure 4. The amounts of required inventory depend on the delivery lead-time that the downstream process requires compared with the time required by the upstream process to replenish the inventory. For example, if camera assembly requires daily deliveries of CCD image sensors but it takes OMT five days to complete its imager alignment process then four days of inventory must be kept between OMT and camera assembly. Furthermore, if there are imager quality problems after the sensors are delivered to assembly, more imager inventory must be kept to replace the defective sensors.

Currently, digital camera component inventories are not calculated by taking into account the variability of lead-time, quality or demand. The inventory levels are based on average

lead-times, yields and camera demand. The effects are that inventory levels fluctuate which causes both too much inventory at certain processes and not enough inventory at others. This problem is made even worse when a quality problem is identified on a high-inventory component and all of these components must either be re-worked or scrapped. Furthermore, high inventory levels also cause components to become obsolete when a design change is implemented in an upstream process.

It is crucial to take also take into account the variability of lead-time, quality or downstream demand. The variability causes production line-down situations or excess inventory problems in camera assembly. For example, if average yield for the CCD sensors is 85% but the standard deviation is 5%, additional inventory must be carried to make up the difference when the yield experienced at camera assembly falls below 85%. The same argument is true for lead-time or demand because additional inventory can be used to minimize the effect of the variability on camera assembly and the entire supply chain.

After the cameras are assembled, the distribution network is used to deliver product to the customer. For low volume/high cost products, such as the digital cameras, this network must be designed to minimize delivery time to the customer while not holding large amounts of very expensive inventory. The current distribution network has four possible inventory-holding locations, all owned by Kodak, prior to the camera reaching a distributor or dealer, as shown in Figure 5. The new paradigm is to begin eliminating these locations individually to ultimately move toward shipping product from camera assembly to the distributors or dealers. As described in Section 4.1.3, this re-design will require a phased approach together with newly optimized inventory levels. As the distribution centers are eliminated, camera inventories will have to be re-calculated and moved to minimize the effects of the variability of customer demand. Currently, there is no strategy on the amount of inventory that should be held at each distribution center which causes stock-outs at some and excess inventory (sometime obsolete products) at other locations worldwide.

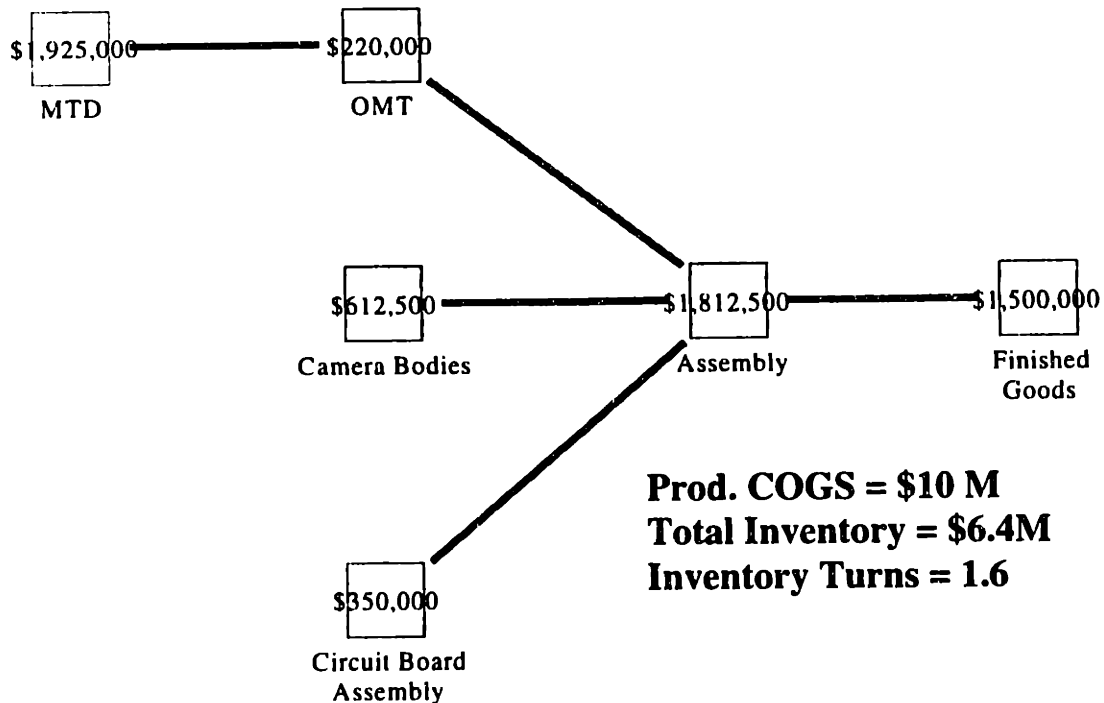
In addition to optimizing these inventory levels, another critical issue in the supply chain is the management of information throughout the extended organization. Today, the standard ERP (enterprise resource planning) software packages do not provide the real-time data necessary to make optimal decisions in the supply chain. These packages tend to focus on financial transactions, without understanding the effects of demand and manufacturing capacity. A new supply chain management solution is needed based on real-world supplier availability, production constraints and delivery options.

### **3.1.1. Low Inventory Turns**

The supply chain for the digital cameras has a low inventory turns rate when analyzed in its entirety, from the internal suppliers through to the distribution network. The inventory turns data is shown in Figure 6. Since camera production is vertically integrated for two of the three major components, Kodak has to pay the holding costs of the manufacturing and testing cycle time required to produce these components. In addition, the external suppliers have negotiated up to a 4-month procurement fixed zone, within which Kodak can not expedite any more components. This causes Kodak to hold excess inventory as a safeguard against any increased demand within that fixed timeframe. Finally, the design of the distribution network, which includes inventory stocking locations at Central Distribution, Regional Distribution and Country Houses, causes an increase in the amount of product held in the distribution channel.

### **3.1.2. Line-Down Situations**

The unavailability of good-quality components in the supply chain often causes line-down situations on the production floor. As stated in Section 2.4, the technology limits are being pushed on some of the components in the supply chain. With higher volumes being required, some internal and external suppliers have a difficult time delivering to schedule. Likewise, quality problems with some of the delivered components also cause production-scheduling discontinuity on the assembly floor.



**Figure 6. Inventory Turns of Entire Supply Chain (Actual \$'s have been modified)**

An example of this can be seen in the supply chain for the CCD image sensors. The high production cycle time and yield variability cause production scheduling delays in camera assembly. With the move toward the DFT pull system, sensor delivery problems can shut down assembly in one or two weeks. This is especially important when there are not enough sensors in the supply chain pipeline to offset some of the delivery delays.

### 3.1.3. Inaccurate Forecasts

The demand forecasting for Kodak Professional digital cameras is performed by the worldwide Kodak sales and marketing organization. The demand forecasts are obtained from each country and these forecasts estimate the demand of the dealers in the country. The country level forecasts are then aggregated at each one of the Kodak distribution regions. The regions include US & Canada, Europe, Latin America, Asia-Pacific, Greater China and Japan.



It is very difficult to accurately estimate the demand for high-tech products, such as digital cameras. The professional digital camera market changes quickly as new products are introduced. When a camera receives great reviews at a technology show, a large amount of orders may be obtained prior to a new product being ready for full production. The timing and quantities of camera orders are also difficult to predict because of the large number of independent dealers worldwide. Therefore, the product mix of cameras, balanced with an adequate supply of accessories, is also almost impossible to forecast without getting real-time updated forecasts from the dealers.

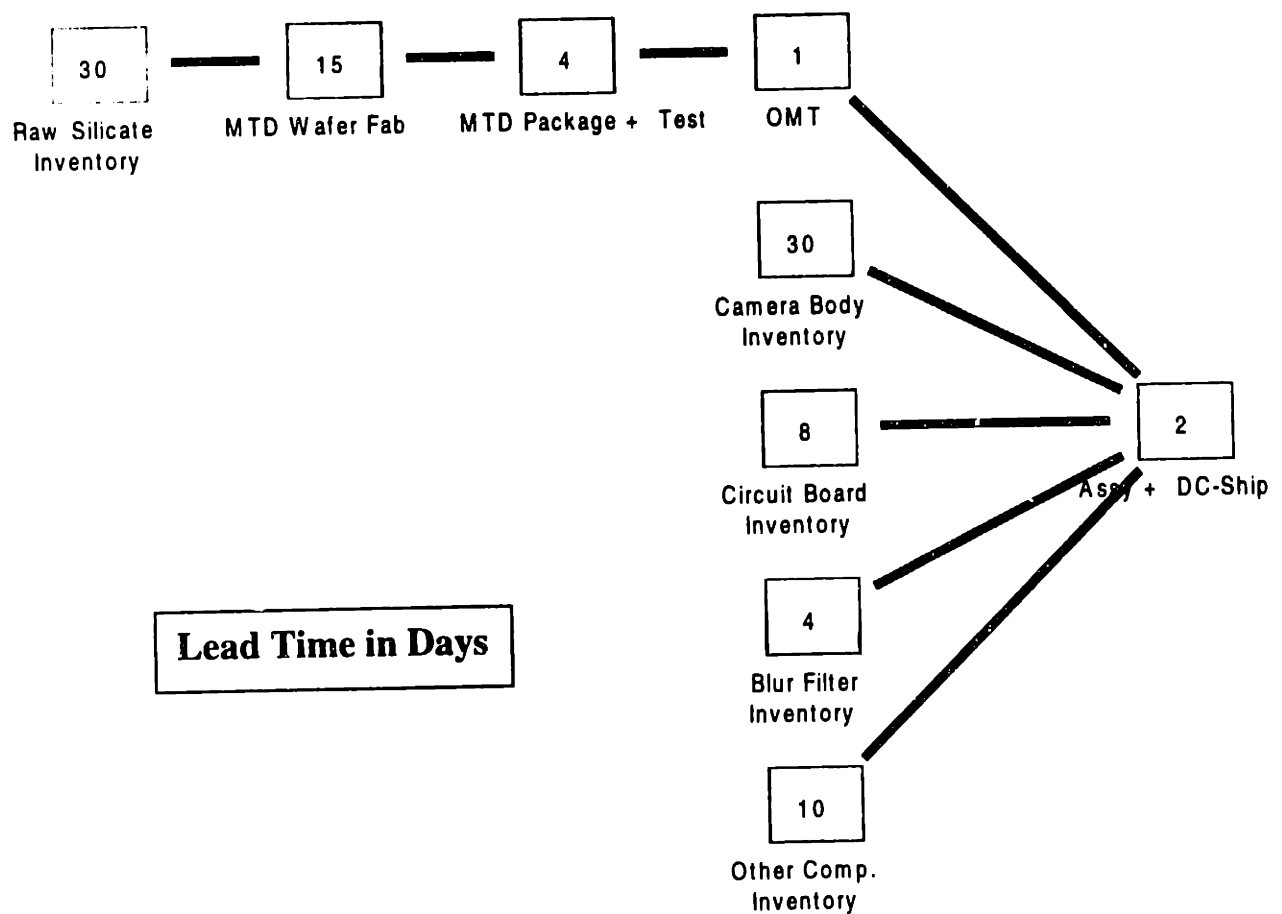
The inaccuracy of the forecasted demand is another cause for problems in the digital camera supply chain. Because of quick product introductions and life cycles of only one to two years, it is difficult to accurately forecast the final customer demand. However, inaccurate demand forecasts can lead to unfulfilled customer demand or excess inventory in the supply chain. Therefore, improved accuracy of the demand forecasts is crucial because the entire supply chain is affected by these estimates.

#### **3.1.4. Long Manufacturing Cycle Time**

Long manufacturing and procurement cycle times affect the digital camera supply chain on some of the major components. These long cycle times, together with demand uncertainty, cause the “beer-game” effect as discussed in Section 1.1. This occurs when various stages in the supply chain try to sub-optimize their own inventory levels as to eliminate shutting down the downstream stage. However, this effort increases total inventory in the pipeline and is not optimal for the entire supply chain. The manufacturing and procurement times should be managed more effectively in order to smooth the flow of components and assembled products through the entire supply chain. The magnitudes of component and assembly lead times are shown in Figure 7.

The effect of the long manufacturing cycle times can be seen in the procurement of the image sensors from MTD. The time to manufacture an image sensor takes many weeks

and once wafers are started in process, the maximum amount of sensors that will be produced is fixed. The production yield of the lot will determine the final output of finished wafers but this will not be known until the final stages of production. Therefore, the processes following wafer fabrication attempt to buffer their inventories to be able to deliver product if the sensor lead-time increases or a low-yielding run occurs. It is inefficient for each stage to optimize its own inventory however; the entire system should be analyzed to determine the most cost effective locations for the inventory.



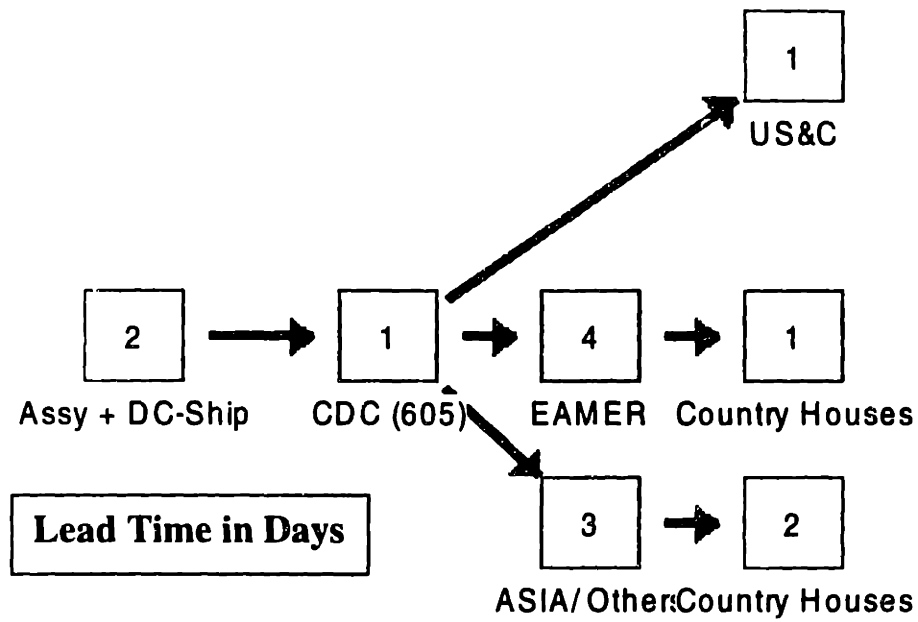
**Figure 7. Component & Assembly Lead time (only relative magnitudes not modified)**

### **3.1.5. Long Distribution Cycle Time**

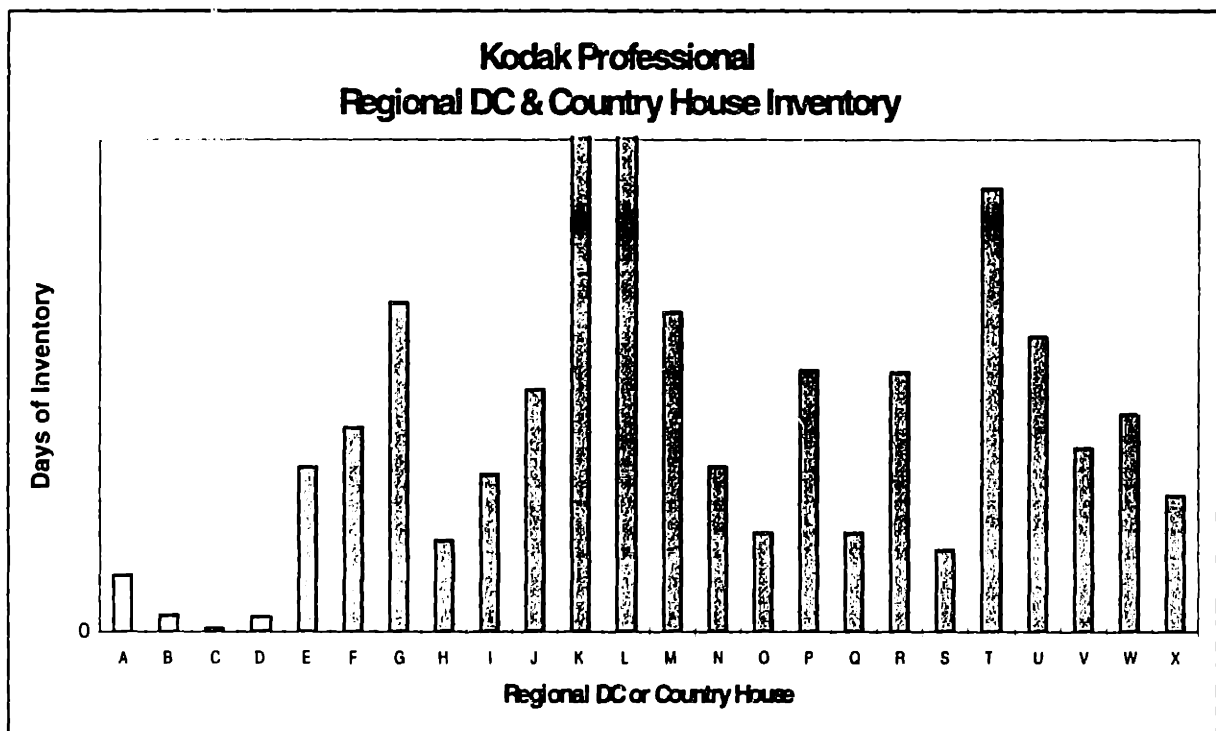
The current worldwide distribution network is not conducive to a high-value technical product for which customers require timely delivery. The digital camera must move through Rochester Central Distribution, Regional Distribution, Country Houses and dealers before reaching the final customer. The value-added of the current network are consolidated shipments, country product customization and customer billing. However, the majority of the time in the distribution network is not value-added. Most of the time is spent as the product waits to be received, put into inventory stock, and shipped further through the network. Furthermore, there are too many stages in the distribution network. Since each one is an inventory storage location, the entire distribution network includes excess inventory because each stage is trying to buffer inventory to be able to deliver product more reliably to the next stage. The assembly and distribution lead times are shown in Figure 8. For a non-expedited shipment, a camera on average spends four to five days to Central Distribution before being shipped out of Rochester. The total delivery time to customers can be as long as four or five weeks.

### **3.1.6. No Inventory Strategy in Distribution**

The current distribution network and its camera inventory were also analyzed. A model of the network was constructed and included the locations of regional distribution centers and country houses. Average monthly unit demand and current days of inventory were then calculated for each Region and country house. This was performed to determine current inventory levels and to develop a strategy of where strategic stock should be utilized most effectively. Figure 9 shows the days of inventory calculations for each entity. When compared with the individual monthly demands, it was clear to see that currently there was no sustained strategy used for calculating inventory levels.



**Figure 8. Assembly & Distribution Lead time (only relative magnitudes not modified)**



**Figure 9. Regional Distribution & Country House Inventory Levels**

### **3.2. Ideal Situation & Barriers**

The goal of the project is to establish a responsive supply chain for Kodak Professional digital cameras. The Dell Direct Model was selected as the basis for the new supply chain. The Dell Direct model incorporates a build-to-order manufacturing system with distribution that ships product directly to final customers. Although the Dell Direct model can not be applied directly, there are several key lessons from Dell that can be utilized while redesigning the Kodak supply chain. These include an inventory strategy that reduces holding costs and optimizes the amount of in-process inventory, improved product distribution to reduce delivery time and improved communication with suppliers.

The Dell Direct model utilizes an inventory strategy that protects the company from dropping component prices and obsolete inventory. The suppliers own Dell's inventory until Dell receives a customer order and begins to assemble a computer. These component inventories are stores in so-called "Revolver" inventories consisting of trucks docked at one end of the computer assembly plant. At the beginning of assembly, these components are moved to the manufacturing floor and kited with other components necessary for the product. At that time, Dell takes ownership of the materials. In addition, Dell focuses on working with their suppliers on reducing "Revolver" inventory levels. This reduces the holding cost for the suppliers and in turn Dell is charged a lower price (Magretta, 1998).

To establish competitive advantage, Kodak Professional should focus on reducing its inventory risk. Although Kodak manufactures many of the high-value components internally and therefore is forced to pay the holding costs of that inventory, a new strategy is required whereby components are pulled on an as-needed basis by manufacturing. . For these components, Kodak Professional should work toward optimizing its inventory levels between its suppliers and camera assembly. This can be accomplished by implementing a mathematical method of calculating strategic inventory.

The Dell inventory strategy, of supplier owned inventory, can be utilized for Kodak external components such as camera bodies, blur filters or circuit board components. The important issue is for the Kodak materials group to negotiate and persuade their suppliers to hold this inventory. This can be accomplished in two ways, either paying a slightly higher price per component to the supplier or using a third-party consignment warehouse to hold this inventory. The higher component cost compensates the supplier but more importantly, reduces Kodak's inventory risk of obsolete inventory.

The Dell Direct model also features a distribution strategy that ships product directly to customers. The advantage is that each order arrives at the customer in two or three days, instead of going through a network of warehouses and distributors. In addition to not paying for a distribution network, direct shipments gets Dell closely in-touch with their customers and better positioned to react to changes in their needs. By staying close to their customers, Dell can also offer value-added and customization services that help to add to its profit margin (Magretta, 1998). While this particular strategy would be difficult to follow at Kodak, a variation of this model can be implemented.

In contrast, Kodak Professional utilizes the corporate distribution network that currently has four inventory tiers before product reaches the customer. A new network is required to reduce worldwide finished goods inventory as well as improving delivery time and responsiveness to the customer. To create more of a direct shipment network, several of the distribution centers must be eliminated and cameras should be shipped from manufacturing, instead of Rochester Central Distribution. The strategy for eliminating the distribution tiers will be discussed in Section 5.2.2.

Lastly, the Dell Direct Model is based on open real-time communication with customers, suppliers and manufacturing. Michael Dell highlights the importance of sharing customer order information with its suppliers. The premise is that only through real-time communication can the supplier obtain the best possible forecast and be able to deliver product on time, without holding large amounts of inventory. Therefore, Dell is able to

obtain the same responsiveness from its suppliers that it can deliver to its customers (Magretta, 1998).

The communication throughout the Kodak Professional supply chain must also be improved. As discussed in Section 4.1.4, ineffective communication between camera assembly and some of its suppliers cause production line stoppage and contribute to an increase of component inventories. To obtain similar advantages of seamless communication at Dell, Kodak should develop and install a supply chain monitoring and decision-support system to improve its communication link from final customer back through the entire supply chain.

The advantages of the Dell Direct model can be compared with its rival Compaq Computer. The days of inventory held at Dell factories are about seven while Compaq carries about 25 days of inventory. The cost advantage of the smaller amounts of components held at Dell translates to a 6% profit advantage. The time from-order-to-cash at Dell is about 1 day compared with 35 days at Compaq, because of its dependence on distributors. Likewise, the Return on Invested Capital at Dell Computer remains at about 50% while only 20% at Compaq (McWilliams, 1997). As discussed in the Results section, implementing the above framework can guide Kodak Professional to improve its inventory turns and offer quicker customer service that will lead to a competitive advantage in the digital camera market.

However, there are several barriers that must be overcome to establish a responsive supply chain for Kodak Professional digital cameras. As described in Sections 1.1 and 3.1, the current Kodak supply chain is not an effective model for a high value and high-tech product. The supply chain is based on the model used for conventional film and paper distribution and it is a cost-efficient model for primarily functional products. However, high-tech products, for which demand is difficult to forecast, require a supply chain designed for flexibility and reliable delivery of small orders to final customers. The supply chain model must be an integrated system, optimal for the camera components and assembly processes, together with a re-designed worldwide distribution network.

Kodak should move toward a direct-ship approach as the method of delivering cameras, regardless of the products being high or low volume. This is particularly important since the shipping costs are such a small percentage of the value of the professional digital cameras.

### **3.3. Summary**

The current supply chain for digital cameras applies a model based on fixed forecasted demand, which is used for Kodak's high volume film manufacturing and distribution. However, the demand for the digital cameras is very difficult to predict and highly variable, which requires a more flexible supply chain model that can react quickly to any customer or market changes. Because of its current supply chain design, Kodak Professional experiences several problems that include low inventory turns, line-down situations, inaccurate forecasts, long manufacturing cycle time and long distribution cycle time.

The supply chain model for the digital cameras can be based upon the Dell Direct supply chain model. This model would help to minimize Kodak's inventory risk as well as improve product delivery to customers. The inventory holding costs of components made externally would be assumed by outside suppliers and internal components would be moved to a pull system. Furthermore, the assembled cameras would be shipped through a leaner distribution network. The transformation to the Dell Direct model will be difficult but is required for Kodak Professional to stay competitive in digital cameras.



## **4. New Supply Chain Model**

A new supply chain model is required for Kodak Professional digital cameras. The model must focus on delivering products to meet final customer demand and not on building product to forecasts. The Demand Flow Technology pull system that will drive camera assembly must support a highly effective supply chain. First, strategic stocking locations and levels must be developed between stages in the supply chain for components to flow more smoothly to camera assembly. Next, the distribution network should be re-designed to deliver cameras to final customers in the most direct and cost-effective process. Finally, the communication in the supply chain between camera manufacturing, its suppliers and customers must be improved.

The approach taken to develop the new supply chain model is described in the following phases. First, the “As-is” supply chain model was developed and the current performance was quantified. Second, a benchmarking trip was taken to compare the results with a world-class supply chain at Dell Computer. Third, the results were communicated to the Kodak organization, together with a proposed “To-be” design, and everyone agreed to proceed with the implementation of the project at Kodak Professional.

### **4.1. Problem Definition**

The most effective supply chain for Kodak Professional must be responsive to customers, with its suppliers, manufacturing and distribution. The responsiveness can be improved on several levels. The use of strategic inventory levels can greatly reduce the effects of production variability with the suppliers. In addition, inventory can be utilized to improve customer service levels in distribution. Finally, a new communication system is required to further integrate the Kodak supply chain.

#### **4.1.1. Supply Chain needs to be responsive**

As discussed in Section 1.1, the required supply chain should be analyzed based on the demand patterns of the customer. The digital camera is classified as a primarily innovative product and thus requires a supply chain that supports an environment where market demand is not predictable. The critical decisions are not based on minimizing costs but where in the supply chain to place inventory in order to hedge against uncertain demand. The responsiveness of the entire supply chain and product availability is more important than the physical efficiency metrics, such as equipment utilization and inventory turns. Therefore, the decision becomes whether the product is innovative enough to generate additional profit to cover the cost of a responsive supply chain (Fisher, 1997). The Kodak Professional digital cameras, with their leadership in a quickly growing market, demand a more responsive, integrated supply chain.

#### **4.1.2. Strategic Inventory Levels need to be established**

Many of the issues described in Section 3.1, including long lead-times, yield variability, difficulty in predicting demand and others, cause many inventory fluctuations within the supply chain. Many of these fluctuations can cause difficulties in scheduling camera assembly and ultimately lead to production slowdowns or line-down situations. The Strategic Inventory Placement (SIP) Model, developed at the Massachusetts Institute of Technology and described in Sections 1.1 and 1.2, can be used to predict supply chain performance and analyze the effects of these fluctuations. The implementation of the SIP Model strategic inventory levels will help to dampen the “bullwhip effect” on camera assembly.

There are several important strategic benefits for using the SIP Model to optimize the supply chain. First, the business needs to specify the customer service level that the supply chain will support. The higher the established service level, the more inventory must will be held to support the supply chain. In actuality, the business has the opportunity to establish in advance the amount of pipeline inventory that it will hold to

maintain a selected service level. This is the opposite of loading a supply chain with material and then trying to calculate the customer service level that is being accomplished. Management knows immediately the amount of inventory that should be in the supply chain and this simplifies inventory management.

Furthermore, the business can also better assess and manage the upside potential of sales. The SIP Model can quickly and easily calculate the increase in pipeline inventory costs when more demand is placed on the supply chain. Conversely, the business as a whole can make a decision on how to size the supply chain and require the sales organization to work toward this established plan. This would reduce the demand-forecast variability that is currently experienced at camera assembly.

The use of the SIP Model to establish inventory levels also has many operational benefits. The model reduces the overall inventory levels by optimizing for the entire supply chain, eliminating the local sub-optimizations done between each stage. The model improves product lead-time management and delivery performance by establishing strategic stock levels based on the variability of demand. Furthermore, the SIP Model allows more flexibility to respond to fluctuations upstream in the supply chain as well as to increased customer demand. Ultimately, the SIP Model and the established strategic stock levels help to reduce production line stoppages and lower cycle times throughout the entire supply chain.

#### **4.1.3. New Distribution Strategy needs to be designed**

The ideal distribution network for the digital cameras would be direct shipments from the factory directly to the final customers. The professional digital cameras have a very high value to weight ratio that makes them a good candidate for air shipments. A business case was put together at Kodak Professional which justified shipping these cameras by air. However, there are some value-added steps that take place along the current distribution network. In addition, the current Kodak systems require physical movement of product through the network because each move is viewed as a financial transaction.

First, the Central Distribution Center performs export customs and plans consolidated overseas shipments. The CDC also maintains inventory levels of digital cameras on a kanban system, when the inventory reaches a replenishment point then more cameras are ordered from manufacturing. However, the process to ship the cameras out of Rochester can take up to five days. Second, the Regional Distribution Centers are currently used to hold safety stock and to aggregate the demand forecasts of each country. The Regions carry enough inventories to be able to ship to each country within a defined service time.

Next, the Country Houses are used for product and packing customization and processing customer payments. The Country Houses also carry inventory to be able to supply its dealers within a certain service time. Finally, the dealers maintain the day-to-day interactions with the final customers. The dealers also hold a small amount of inventory to fulfill immediate customer demand. In order to develop a more cost-efficient distribution network, the value-added processes and camera inventories must be consolidated such that certain stages of distribution can be removed. The inventory carried at these locations should be optimized to equal the difference between the quoted customer service time and the delivery response time from an upstream inventory location.

#### **4.1.4. Supply Chain Communication needs to be improved**

During a benchmarking tour of Dell Computer Corporation, it became apparent to the author that besides having an appropriate design of the supply chain for the product type, the next most important step is improved communication throughout the supply chain. Dell management emphasized the following critical elements to a supply chain: obtain the best possible forecast, have enough capacity with each supplier, have the required logistics to get the product, and, most importantly, have open communication with suppliers and sales. It is crucial for the entire supply chain to be working from the same production plan, instead of every stage trying to sub-optimize by its processes.

Dell Computer prides itself on sharing information in a real-time fashion with its suppliers. According to Michael Dell, “we tell our suppliers exactly what our daily production requirements are” (Magretta, 1998). This eliminates uncertainty and sub-optimization in the supply chain. The suppliers can use Dell’s production data to forecast future demand and establish their safety stock levels. In a discussion with the author, Michael Dell stated that suppliers are very willing to work with Dell toward optimizing the supply chain because this leads to improving their own time-to-cash conversion cycles.

Although demand for primarily innovative products is difficult to predict, improved communication throughout the supply chain can help reduce its overall effect on the system. Open communication between sales and manufacturing, together with aligned performance metrics, can improve the accuracy of demand forecasts that are currently used to schedule production (Galbraith, 1996). Since currently Kodak worldwide sales and marketing does not have visibility to production numbers, they buffer their demand forecasts to ensure that they receive the amount of cameras for which they have firm orders. Likewise, manufacturing does not see the final customer demand because of the multi-tiered demand aggregation at regional and country levels. Therefore, manufacturing modifies its production plans according to their belief in what marketing can sell. Along with a re-design of the supply chain, open communication can improve the planning process by minimizing the impact of inaccurate forecasts (Fisher, 1994).

Similar to communication between sales and manufacturing, improved communication between manufacturing and its suppliers is also required. Currently, the suppliers and manufacturing do not have visibility into each other operations. This is more reasonable with outside suppliers because of proprietary issues however; the situation is similar with Kodak internal suppliers. Realizing that the production requirements which are input several months into the future are based on often inaccurate demand forecasts and will probably change several times, some of the internal suppliers attempt to second guess what camera assembly will need. This may optimize the suppliers own inventory levels; however, it reduces the flexibility of the camera factory to respond to customer demand.

## **4.2. Removal of Barriers**

To fully implement the project and accomplish a more, integrated supply chain there were many barriers at Kodak that first had to be overcome. These included changing the mindset of employees that the supply chain was not as effective as it could and should be. In addition, the organizational structure was not designed so that one group had the authority over each of the steps required in the project. There were numerous manufacturing, supplier and distribution processes that have to change although they had been in place at Kodak for many years.

### **4.2.1. Mindset**

To be able to implement necessary changes to the Kodak Professional supply chain, the author first had to show the differences between the performance of the digital camera supply chain versus a world-class high-tech supply chains. The organization needed to see the current state of the entire camera supply chain. This process required an in-depth analysis of the lead-times and inventory costs in the entire supply chain. Likewise, a world-class supply chain was needed as a benchmark, to which the current supply chain could be compared.

The shift to the new mindset took many months to accomplish however, unilateral agreement and support of the project was necessary for the success of the project. Many one-on-one meetings and tours were required to analyze the supply chain and ascertain what individuals thought could be improved. The author believed that the best supply chain design would be obtained after everyone's expertise and opinions were reviewed and many suggestions implemented as part of the project.

#### **4.2.2. Organizational Structure**

The organizational structure of the digital camera supply chain, at the beginning of the project, was not conducive to a successful implementation. The support groups, for Kodak Professional and the rest of equipment manufacturing, were structured in a heavily matrix organization. The material management, supply chain, and logistics organizations did not have a product-focus. Material management teams worked with the suppliers while supply chain and logistics concentrated on sales forecasts and distribution. Each organization worked within its functional structure and none had ultimate responsibility of getting product to the customer.

All of these support groups were driven by their own performance metrics and were not focused on the need of the final customer. Although manufacturing required supply flexibility because of market changes, material management was driven by their suppliers to maintain order fixed zones. When demand was high, this caused manufacturing to put digital cameras on allocation to the Regions because total market demand could not be met. Likewise, the incentives for the distribution network were based on high-volume film and paper distribution. This prevented fast execution of orders and deliveries of camera products to customers, without going through a time-consuming manual operation. Because of customer pressure to receive cameras, the expedite delivery procedure became a regular occurrence at Kodak Professional.

#### **4.2.3. Supplier Relations**

Another barrier to successful implementation of the project was the relationship of manufacturing with its suppliers, both internal and external. There was considerable tension in the organization in dealings between manufacturing and its suppliers. Manufacturing, trying to react to the market, was pushing for flexibility from their suppliers. Manufacturing, which was in the process of installing a pull system in assembly, was also asking its suppliers to establish a pull system with them.

With some suppliers, there seemed to be a breakdown in communication. In some cases, the suppliers were not sure what components were required and when those deliveries should take place. Production flexibility is very difficult in an environment where there are order fixed zones of several months. The suppliers seemed to deliver whenever product was pushed through their processes and not based on when their customer needed the product. In contrast, because of part shortages of certain CCD image sensors, the camera assembly operation needed to establish daily or at least weekly deliveries to continue to run the production line.

### **4.3. Approach**

The first two months of the project were focused on analyzing and modeling the current supply chain for Kodak Professional digital cameras. The supply chain model at Dell Computer Corporation was selected as a benchmark and a plant tour was conducted. After the completion of the “As-is” model, several presentations were made to review the current supply chain results and recommend a new supply chain model. The presentations were very well received at Kodak and the implementation of an integrated supply chain began.

#### **4.3.1. Definition of “As-Is” Supply Chain Model**

The author began the project by modeling the “As-is” supply chain. The model included process flow charts of each stage in the supply chain, cycle times, quality levels, and inventory costs. During the analysis, the “As-is” model included inventory value calculations that were higher than many at Kodak had anticipated. This was caused by a paradigm shift that the inventory costs in the entire supply chain should be included. Until then, only component inventory costs tied directly manufacturing and finished goods inventories were used in calculation inventory turns. For example, the new inventory turns calculation included the MTD wafer fabrication inventory for all of the professional digital products. Previously, these MTD inventories were accounted for through a business unit and camera manufacturing was not held responsible for reducing



these levels. Since these costs are part of the digital camera supply chain, manufacturing now has incentives to reduce these inventories.

#### **4.3.2. Benchmarking a World-class Supply Chain**

In July of 1998, the author took a benchmarking trip to Dell Computer Corporation in Austin, TX as described in Section 4.1.4. The interviews and meetings at Dell proved very enlightening in regards to how a world-class supply chain should be managed. The findings included how communication with suppliers should be handled, how product lead-times are managed and how the company focuses on reducing cycle times, everywhere in the supply chain including the time-to-cash cycle.

#### **4.3.3. Get Organizational Buy-in for “To-Be” Integrated Supply Chain Model**

Following the completion of the “As-is” model and the tour of Dell, the author began a series of presentations discussing the findings. The people involved included internal suppliers, manufacturing, marketing, material management and supply chain organizations. The framework of how the new supply chain should look and be optimized was slowly beginning to take shape. However, the organizational structure was not conducive to making such changes happen.

After several months of discussion at Kodak, the matrix organization was modified and the entire product-support responsibility was given to the supply chain organization. The author believes that the organizational change was part of the new Kodak manufacturing strategy to align toward the needs of the customer. This was the same motivation as for the Kodak Professional integrated supply chain project. Following the change, material management employees now had product-specific responsibilities and reported to the supply chain organization. In addition, the supply chain organization assumed the responsibility of working with suppliers to improve delivery performance. Supply chain

was also given the authority to design a distribution network that would focus on the final customer.

#### **4.3.4. Create Environment for Open Communication**

As discussed in Section 4.2.3, there was a strained relationship between manufacturing and certain internal suppliers. The trust between the departments was low and caused delivery problems in camera assembly. For example, between MTD and camera assembly, both sides were hedging each other's production plans and delivery reports in an attempt to balance supply and demand of components and cameras. This caused large swings in inventory levels, between high excess inventory and inventory shortage situations.

The author began to facilitate a weekly meeting to discuss MTD delivery performance, with the goal of improving production planning with camera manufacturing. At first, the meeting focused on sharing weekly camera assembly schedules and matching them with MTD production runs. Next, it was decided that, instead of the MTD waiting for a large quantity to be completed prior to delivery, daily deliveries of equal amounts of product would be made. MTD now had a performance metric that needed to be met everyday. This metric helped to increase managerial focus, on both sides, on delivery performance. These daily deliveries quickly began to smooth out the start and stop mode experienced at camera assembly.

With improved delivery performance, the meetings began to focus on quality issues for the delivered components. The weekly review of deliveries and quality began to shorten the feedback of quality problems being reported to the supplier. In addition, the supplier began to report on engineering changes and other action items that were being undertaken to improve quality. When there were delivery or quality problems, they were discussed and anticipated proactively instead of shutting the production line down without warning. This early notification allowed assembly to effectively switch to another product and continue to run production.

#### **4.3.5. Model Implementation**

The integrated supply chain model implementation was a coordinated effort of many individuals and several organizations. The Operations Manager, to whom the author was assigned, was the leading driver of the project. The manager would communicate progress of the project to upper levels of management and work toward breaking down any barriers. Most importantly, there was a lot of support for the success of the project within Kodak Professional.

The author worked most closely with the newly assigned Supply Chain Manager for digital cameras. This manager greatly facilitated work of obtaining data from suppliers and in modeling the old and new distribution networks. The author also worked with a SIP Model expert from Kodak, who provided his technical expertise, as well as with one of the developers of the MIT SIP Model.

#### **4.4. Summary**

The implementation of the new supply chain model was done in a phased approach. The “As-is” model analysis showed that the digital camera supply chain was not optimized to support flexible market response. There was a lack of inventory strategy for both camera components and finished cameras. The analysis highlighted the need for the creation of strategic inventory levels to minimize holding costs and improve factory throughput. A new distribution network was required to improve customer deliveries. Furthermore, improvements in supply chain communication were necessary to further integrate the supply chain.

There were several barriers that had to be overcome prior to successful implementation of the new supply chain. These included managerial mindset, organizational structure, and supplier relations.

The project approach included building an “As-is” supply chain model and analyzing its performance. Furthermore, a benchmarking tour of Dell Computer was taken to determine how a world-class supply chain is managed. This tour along with other benchmarking research created the basis of the “To-be” model design. Following many presentations discussing the results of the project, the Kodak Professional organization agreed to begin implementation of a new integrated supply chain model.

## **5. Results**

The integrated supply chain project included many insights and learnings for both the Kodak organization and the author. This was the first time that a model of the entire supply chain was constructed for the professional digital camera flow. The cycle time, yield and inventory cost analysis and its overall impact on supply chain performance was very enlightening. The “As-is” supply chain model made the organization realize how much improvement was possible.

Moving the organization toward a new, more integrated supply chain was an enormous challenge, based on the three component framework of inventory management, distribution and communication. The MIT SIP Model was utilized to establish safety stock locations and levels. The distribution network was beginning to be redesigned toward a direct air shipment model. The communication between manufacturing and its suppliers was being improved with an Intranet solution.

### **5.1. “As-is” Supply Chain Model**

The modeling of the “As-is” supply chain unveiled the complexities of the entire system. Unlike companies, such as Dell, that just assemble components to make high-tech devices, the Kodak Professional supply chain is vertically integrated and supplies many of its high value components. The effect of vertical integration is that Kodak must hold its own component inventory, on many of the high dollar components. This can be seen with the calculation of inventory turns. As discussed in Section 3.1.1, at the beginning of the project, the camera business was turning inventory at a rate of 1.6 times per year.

The inventory turns calculation was a key learning to the organization that thought the number to be at least twice higher. The previous inventory turns calculation did not take into account the inventory held at MTD. Because the sensors first had to pass through the alignment step at OMT, the MTD inventory was not directly attributed to manufacturing

but was passed down through the business unit. Without this visibility, manufacturing did not know the amounts of inventory held at MTD and had no incentive to work closely with their supplier to better manage this inventory.

As stated in Section 3.1.2, production line slowdowns and stoppages, due to inconsistent component deliveries and/or quality problems, hamper camera assembly. These problems were caused by long lead-times and quality feedback loops on the camera components. Although the internal suppliers have been working hard to reduce both, the effects that each causes on camera assembly requires a supply chain strategy that further minimizes these effects.

The author began to implement a new strategy of improving the performance of the supply chain by establishing mathematically calculated strategic stock levels. In addition to the strategic stock, performance metrics are required that focus of the performance of the entire digital camera supply chain. In contrast to what is currently being done at Kodak, overall success of the supply chain is necessary instead of rewarding each department for optimizing only its own process.

## **5.2. “To-be” Integrated Supply Chain Model**

The plan and process toward a more integrated supply chain consisted of three projects: establishing strategic stock levels throughout the supply chain, implementing direct air shipments and improving supply chain communication. The MIT Strategic Inventory Placement model was utilized for the first two parts that required inventory optimization. For improving the communication, an Intranet web site was developed to better manage information.

### **5.2.1. Establishing Strategic Stock using the MIT SIP Model**

As described in section 4.1.2, the need for an overall inventory strategy was established for the digital camera business. The inventory stocking levels must be optimized with suppliers and at camera assembly to improve the manufacturing cycle time. In addition, the inventory, held in the distribution network, needs to be optimized to better serve final customers and reduce holding costs of the inventory.

There were problems acquiring data needed to apply the MIT SIP Model to the Kodak Professional supply chain. The demand, used in the SIP model, should be the average and standard deviation of the final customer demand. However, since the Kodak MRP (manufacturing resource planning) systems does not have visibility into final customer demand, the aggregated country house average demand and the variability of demand were used. The two issues, which effect demand variability, are aggregation over many locations and time batching of orders. As demand is aggregated over many order locations, the variability of these orders is reduced. At Kodak, the country level demand is aggregated from many dealers, which decreases the variability of demand, and thus, by using this data the supply chain would be designed to carry too little inventory. On the other hand, the batching of orders over a longer time horizon increases the variability of demand. For example, this occurs when orders from the Country Houses are communicated to manufacturing on a monthly basis but the dealer demand (on the Country Houses) is obtained and calculated on a daily basis. Therefore, the demand variability at camera assembly would be reduced with visibility of daily demand patterns. However, the Kodak MRP system is not being able to provide daily demands but aggregates the demand and creates orders on a monthly basis. Therefore, it was decided that the more conservative estimate of the variability would first be used in the implementation and these levels could be lowered in the future after material planners gained more experience with the model.

Figure 10 shows the SIP Model that was developed for one of the Kodak cameras. Using the established strategic stock levels, the inventory turns would more than double to 3.8

turns. It is important to note that this inventory turns number includes a heavily vertically integrated supply chain and includes all Kodak-owned inventory. This should not be compared with inventory turns for companies that only assemble products. The assembly-only manufacturers, such as Dell Computer, are able to obtain inventory turns in the range of about 40 turns per year (McWilliams, 1997). In order to make a comparison, an inventory turns calculation can be made for Kodak Professional by only using inventory at camera assembly. This assumes that all of the Kodak suppliers are external and pay carrying costs on the component inventory that they are holding. Also, it is assumed that Kodak does not own the cameras while they are in the distribution network. Under these assumptions, the Kodak inventory turns would be about 5.5 turns per year.

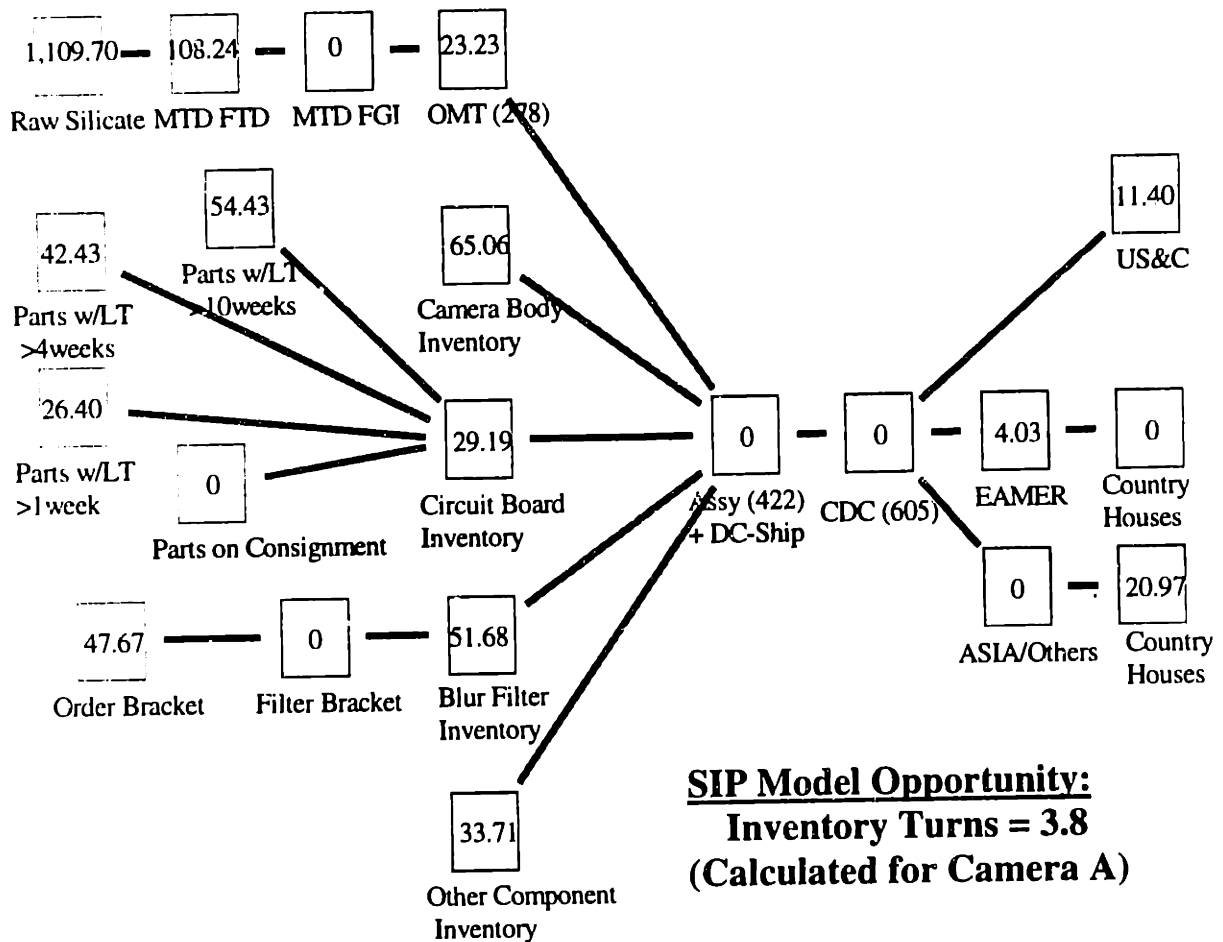


Figure 10. Strategic Stock Levels for Camera A



The results of the SIP Model recommend where safety stock should be allocated most cost-effectively in the supply chain. The key learning from this optimization was that no safety stock should be held at assembly and all component inventories should be held by the suppliers and “pulled” into camera assembly. This is because it is less expensive to hold components in-process at the suppliers instead of incurring the higher costs when the components are delivered to manufacturing. This can occur if the suppliers are able to meet the delivery response time required by camera assembly. If this response time is not met, camera assembly must hold inventory to buffer the difference between its required delivery response time and the lead-time provided by the supplier.

For the MTD sensors, all of the inventory should be held at “fully-tested” die (FTD) and packaged-to-order for camera assembly. The sensors should be held at FTD because at this point MTD has completed the manufacturing of the image sensor (except for colorization of the sensor, if needed) and can test the electronic performance of the device. This is the least expensive phase where MTD is assured of the performance of the sensor. In addition, the sensor can be designated as color or monochrome as required by camera assembly. Holding inventory at FTD also prevents MTD from holding excess inventory of one type of sensor since the devices can now be packaged-to-order as required by camera assembly (Grabau, 1999).

In addition, the finished goods inventory should be held closer to the final customer and that Rochester Central Distribution should be eliminated. The elimination of Rochester Central Distribution would eliminate four to five days of delivery lead-time. In Europe, it was determined that the regional distribution center could handle these deliveries (within quoted customer lead-times) and Country Houses could be eliminated.

### **5.2.2. Moving Toward Direct Ship**

The re-design of the distribution network requires a phased approach where only the value-added processes get integrated into the new network. To eliminate most of the four

to five days of lead-time in Rochester Central Distribution, as described in Section 4.1.3, camera shipments will be made directly from the Elmgrove plant. The Central Distribution Center will be utilized to plan the consolidated shipments, to which cameras would be included; however, cameras will never be physically stored at Rochester Central Distribution.

With the elimination of Central Distribution, air shipments will be made directly from manufacturing to the Regional Distribution Centers. A business case was developed to justify air shipments for the digital cameras. Because the digital cameras have such a high price-to-weight ratio, the additional cost required for air shipment is justified under Kodak internal policies. For example, the price-to-weight ratio of air shipping Camera A to Germany was twice the minimum ratio required to breakeven. In addition, air shipments significantly decrease delivery time to the customer and improve responsiveness to changing customer needs. There are two system changes required before going to air shipments from manufacturing to the Regions. First, the current Kodak distribution systems require physical movement of product through distribution; therefore modifications will be necessary for virtual product transfers. Second, a computer system that provides shipping capability is required in camera manufacturing.

In the second phase of the re-design, the Country Houses will be eliminated and their customization processes performed at the Regions. This will eliminate the inventory that each one of the countries carries in an attempt to better serve the dealers or as a result of inaccurate demand forecasts. The country houses are also currently used for financial reporting and customizing products for each country, with different adapters and product literature. These processes can be moved to the Regions and ultimately the product customization can be done at camera assembly in Rochester. With the customization performed at camera assembly, the cameras can then be shipped directly from the assembly floor to the dealers.

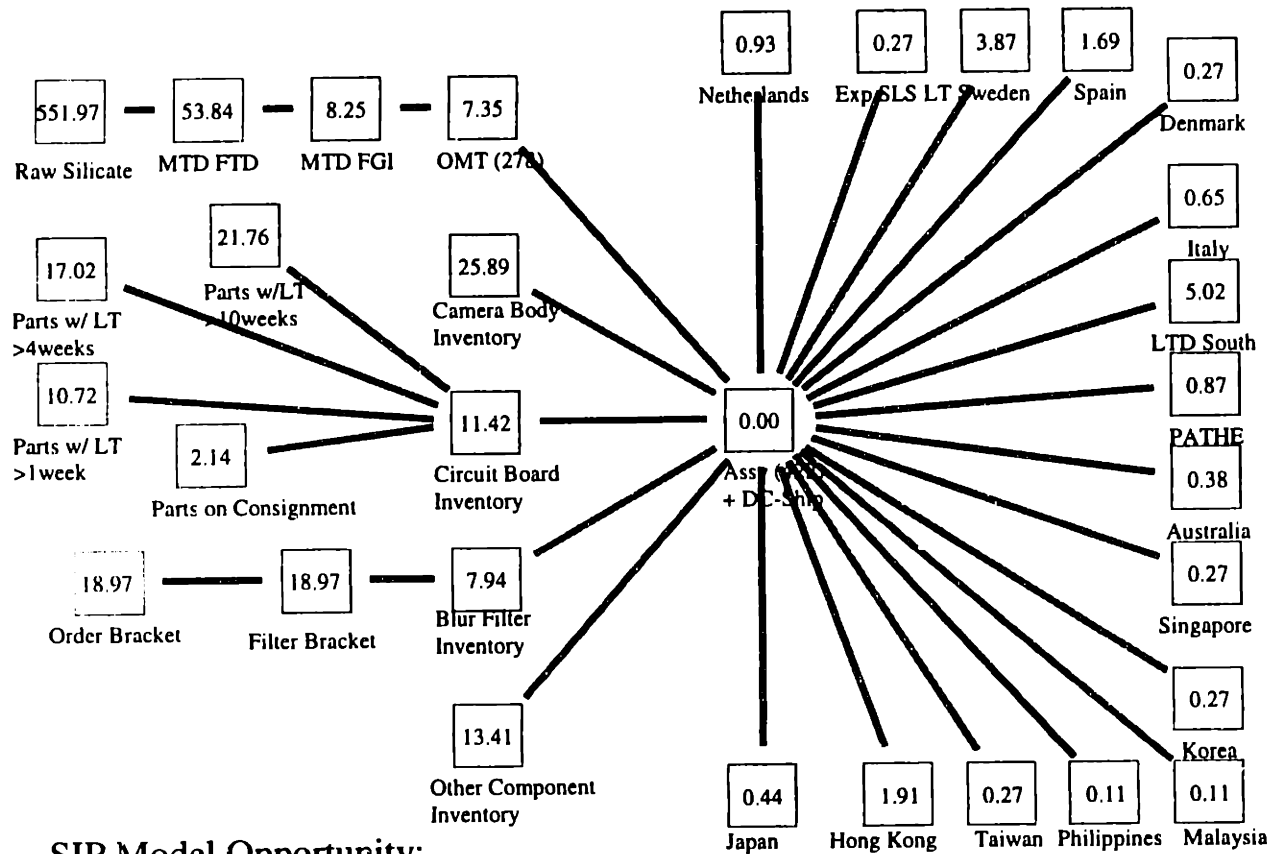
The third phase of the project involves the elimination of Regional Distribution Centers. The cameras will be shipped directly to dealers from Rochester, eliminating the inventory

carried at each one of the regions. In addition, with the elimination of both Regions and Country Houses, Rochester will finally see the demand patterns of its final customers, the dealers. These are the demand patterns that currently are not available in the Kodak MRP system in Rochester as discussed in Section 5.2.1. However, this demand, instead of regional and country forecasts, will be used to schedule camera assembly and used in the SIP Model to establish strategic stock levels.

Although the implementation of direct air shipments to dealers will use a phased approach, the SIP model was utilized to estimate the cost savings of the project. The distribution network in the SIP model eliminated the Central Distribution Center in Rochester and the Regional Distribution Centers. In addition, the average demand and the variability of demand were calculated for each country individually. Similar to the first optimization, it was assumed that the country level demand was the aggregated dealer demand.

Figure 11 shows the optimized SIP Model showing the stocking levels required at each one of the country houses in Europe and Asia, that had sufficient demand to carry camera inventory. The potential cost savings were calculated, for two camera models, to be about \$1.8 million dollars. This includes the one time elimination of inventory at the Rochester Central Distribution and Regional Distribution Centers. The savings also include the holding cost reduction of inventory currently held at the country houses.

It is important to note this SIP Model analysis used the camera demand of each Country House. If the average demand and its variability of the dealers were known, a similar calculation could be performed to estimate the savings from eliminating all Kodak-internal distribution locations and shipping directly to dealers. The SIP Model provides a simple method of analyzing and establishing savings from each phase of the distribution re-design process.



**SIP Model Opportunity:**  
**Direct Ship Savings = \$1.8M**  
**(Calculated for Camera A & B)**

**Figure 11. Strategic Stock Levels for Direct Ship to Country Houses**

### 5.2.3. Developing the Intranet Supply Chain Management System

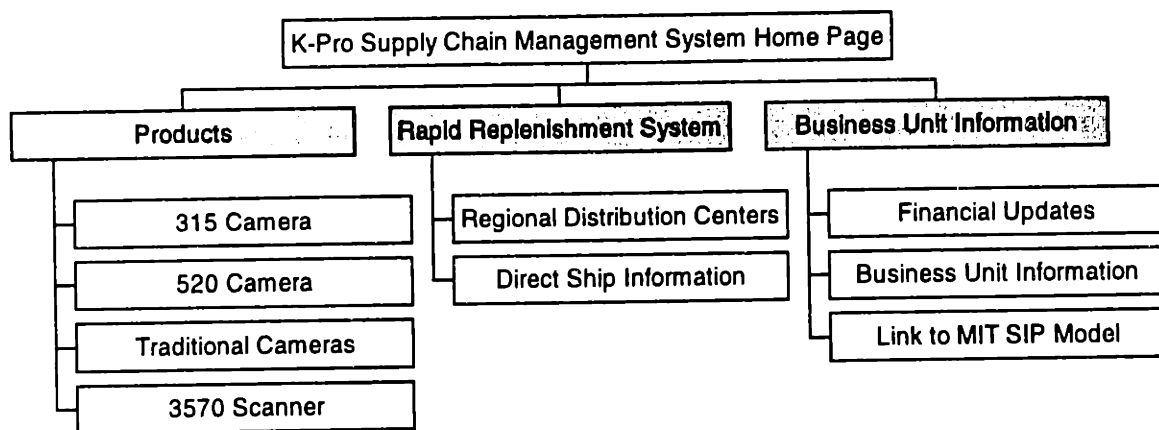
The need for improved supply chain communication began with the benchmarking trip to Dell Computer as described in Section 4.1.4. Dell management emphasizes that open communication is one of the crucial aspects of the supply chain. Communication should flow smoothly through the entire system from the final customer to the supplier. This includes demand forecasts, production plans, quality reports, and inventory levels. The collaboration between members of the supply chain will improve component deliveries and reduce inventory by reducing the level of uncertainty of how the supply chain should be managed.

The entire information system should be designed so the needs of the customer are met and everyone shares the same information. As described in Section 5.3.1, this system promotes a partnership between each member of the supply chain, such as MTD and camera assembly, instead of creating competition among these stages. After several months of analyzing and studying the current Kodak supply chain, the author recommends that an information management system be developed to improve communication. The new system would involve day-to-day data on manufacturing, suppliers and distribution. The system would also include sales and marketing forecasts and business unit information. This data is important since it drives the daily decision making process in the supply chain.

The new communication system will require the supply chain members and camera assembly to open up access to their production data, which previously was not disseminated throughout the supply chain, for the benefit of the entire business. This would require a new managerial mindset that all members are willing to share information that will improve that performance of the supply chain. For example, manufacturing would report daily production numbers via the Intranet and marketing could use this information to better quote product lead-times. As seen during the project, marketing often makes product forecasts without knowing exactly how these will influence manufacturing.

A communication channel was needed to which access was granted to every member of the digital camera supply chain worldwide. The Kodak Intranet was chosen as the most cost-effective location for the pilot of the system. However, because the Intranet is a Kodak internal-only computer system, this means that external suppliers would have to be excluded. The implications are that initially performance improvements will be targeted toward internal suppliers, which produce the majority of the high value components. In the future, the external suppliers could be integrated into this system through the Internet with limited access to the Kodak-internal information.

The design of the Kodak Professional Supply Chain Management System was developed to include product information, supplier, manufacturing, and distribution data as well as business unit information. The overview of the types of functionality and information provided in the new system is shown in Figure 12. The detailed description of the proposed web site can be found in Appendix 1. To simplify access to the site, the supply chain web site would have a password-protected link from the Kodak Professional main page.

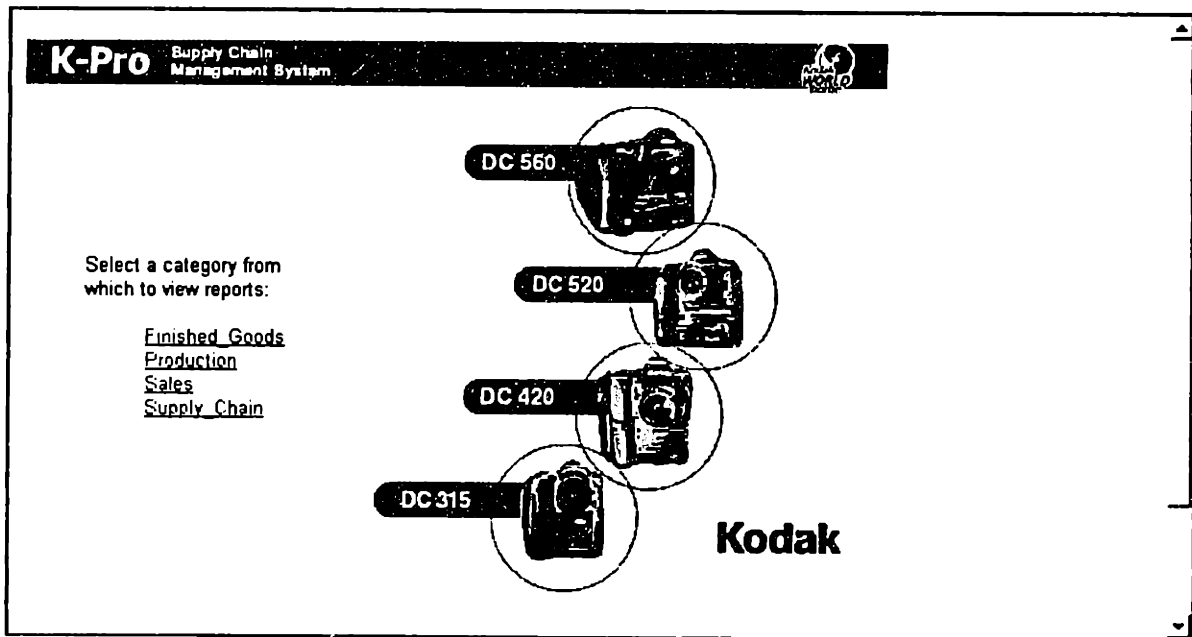


**Figure 12. Intranet Supply Chain Management System Main Page**

Although the preliminary design for the system was completed and a development cost estimate was obtained from the Kodak Intranet Services Group, the design of the central database and the web site was estimated to take about 3 to 4 months. To get the project started, an interim web site was being developed to which information in the form of spreadsheets could be uploaded. Initially, this would offer people the chance to begin to share information and interact via the Intranet site.

The main page for this Kodak Professional web site is shown in Figure 13. The page includes the different camera models and general information categories. The information is grouped into sales, supply chain, production and finished goods. Currently, updated

weekly and monthly information is being posted to the site and is managed by the supply chain organization.



**Figure 13. Interim Kodak Professional Supply Chain Main Page**

Some of the data being posted includes monthly sales and forecast data, weekly production numbers, supplier component information, and finished goods inventory data. An example of the Sales web page is shown in Figure 14. This page provides access to summary sales data as well as forecast accuracy results.

The information selected for the web site includes data that members of the supply chain described as important to their decision making process. The author interviewed suppliers, supply chain analysts, sales and marketing, distribution and production. The data includes summary numbers that allow for a global view of what is occurring in the supply chain and strategic business decisions. In addition, the daily and weekly numbers provide the opportunity for camera manufacturing to have constant visibility upstream and downstream of the supply chain. For example to improve inventory management, the system will be utilized to set the strategic stock levels that were calculated by the MIT SIP Model. To improve delivery performance, suppliers will have instant access to

demand forecasts and assembly production plans that will provide them more time to react to changes.

**K-Pro** Supply Chain Management System

The following files are available for download in the 'Sales' category. Simply click on the file to download it.

File Title	Name of File	Description of File
S&OP Forecast Accuracy	<a href="#">sales_forecast_accuracy.xls</a>	Sales Forecast Accuracy Report
S&OP Data by Region	<a href="#">Camera_12.xls</a>	Sales Forecasts and Actuals by Region
S&OP Data Summary	<a href="#">Dec_12.xls</a>	Sales Forecasts and Actual Summary Report

[home](#) | [downloadable files](#) | [Kodak World](#)

For technical questions or problems contact: [Intranet Services](#)  
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**Figure 14. Example of Sales Web Page**

This web site allows the opportunity for everyone, internal to Kodak Professional, to see the same supply chain data from any location within Kodak via the Intranet. For example, anyone attending a worldwide business meeting such as a monthly sales and manufacturing meeting, now has on-line access to all of the necessary information and data.

### 5.3. Support of Hypothesis

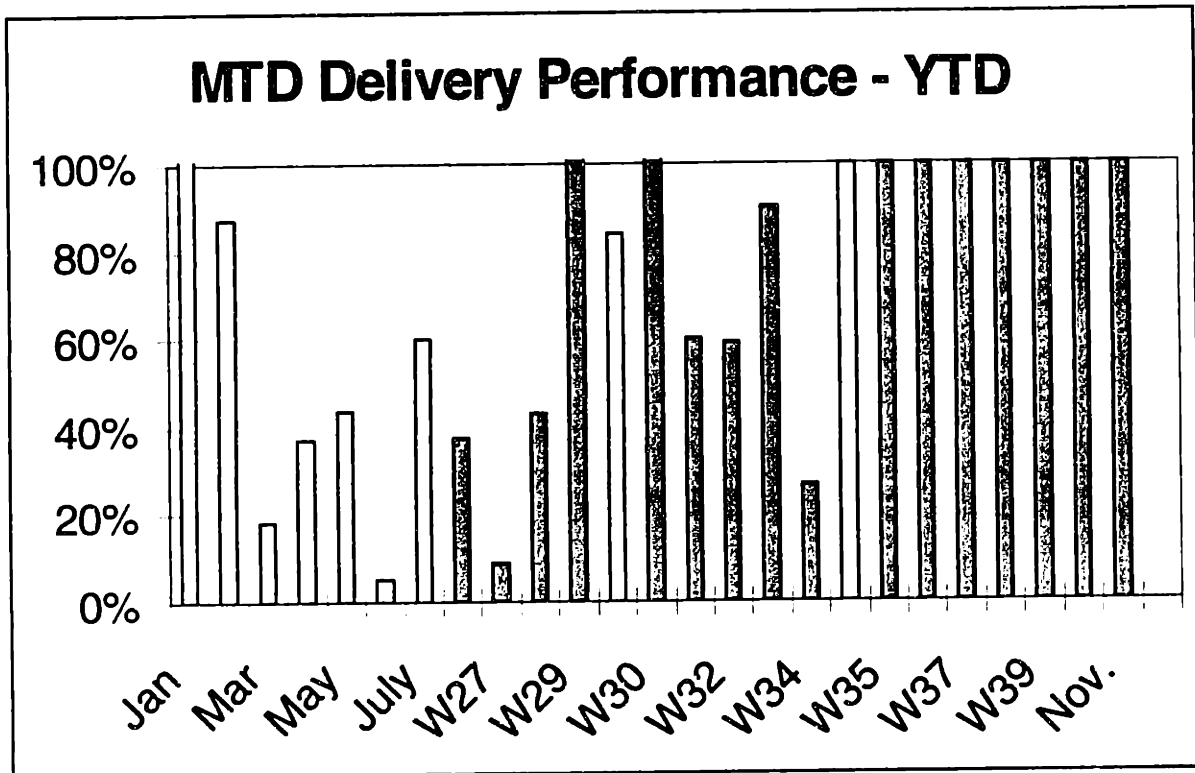
The goal of the project was to create a framework for the improvement of the Kodak Professional supply chain. The hypothesis included enhancements in three major categories: an inventory management strategy for the entire supply chain, redesign of the distribution network and improvement of communication in the supply chain. As stated before, the author was able to gain plenty of support for the integrated supply chain project within Kodak Professional as well as the supporting organizations. There were



several successes in the project that will keep the project implementation moving forward following the author's internship. These included the improvement of supplier delivery performance of the MTD image sensors as well as the beginning of a strategic inventory pilot at MTD. In addition, there was an agreement with one of the Regional Distribution Centers to begin to eliminate county house inventories in Europe. Finally, the development has begun on the central database for the Intranet Supply Chain Management System.

### **5.3.1. Improved Supplier Delivery Performance**

One of the major short-term issues, during the internship, was delivery difficulty of MTD image sensors to manufacturing. These problems stemmed not only from process cycle time and yield variability but also from inconsistent communication. As stated in Section 4.3.4, the author facilitated a weekly meeting to review image sensor deliveries during which MTD and manufacturing could set and compare production schedules and discuss quality and delivery issues. Figure 15 shows the improvement in MTD delivery performance during the second half of 1998. The delivery performance improved by both departments sharing more information about camera production and discussing these impacts on sensor manufacturing. Agreements to shift camera production away from a certain camera model (because of an up-coming delivery problem) were now being made earlier, giving manufacturing more time to react. Furthermore, because of regular weekly meetings, quality problems were highlighted earlier and MTD was able to solve these more rapidly. The author believes that this kind of improvements can be obtained throughout the supply chain with improved communication that will occur with the Intranet Supply Chain Management System.



**Figure 15. Example of Improved Supply Chain Performance**

### 5.3.2. SIP Model Implementation Pilot at MTD

Another success of the project was to persuade the Microelectronics Technology Division (MTD) to agree to begin work on implementing strategic inventory as calculated by the MIT SIP Model. In contrast, the MTD management mandate for 1999 was to establish very strict order fixed zones with each customer and to allocate all of its inventory costs to these customers. By doing so, MTD was trying to protect itself from any schedule changes within its production lead-times that could leave MTD holding excessive inventory. However, this mandate does not give incentive for inventory cost reductions that would benefit the Kodak internal customers, as described in Section 3.1. Following many presentations discussing the benefits of the Strategic Inventory Placement model for both MTD and camera assembly, MTD agreed to attempt an implementation pilot that will begin in Q1 of 1999 on one of the image sensors made for the Kodak Professional digital cameras. The pilot involves setting a strategic stock level for the sensor and

determining the impact on delivery performance. This will increase inventory held at MTD, however, it will also allow MTD to better react to the demand variability of camera assembly and most importantly to Kodak, increase the numbers of digital cameras produced.

### **5.3.3. Agreement with Regions on Direct Shipments**

The redesign of the Kodak Professional distribution network began with an agreement on direct shipments in Europe, directly from the regional center to the dealer. The Regional Distribution Center in Stuttgart, Germany agreed to begin eliminating inventory stock locations at the European county houses. As described in Section 5.2.2, this will reduce overall inventory and improve responsiveness to the dealers. The Region Distribution Center will also begin to perform the product customization, currently done at the country houses.

### **5.3.4. Development of Central Supply Chain Database**

In addition to the interim Intranet web site discussed in Section 5.2.3, development has begun on the central database that will support the entire Intranet Supply Chain Management System. This development is being completed by an external contractor and is being managed by the supply chain organization. The central database will maintain all of the sales, supply chain, manufacturing, and distribution data used in the web site. This database will be used instead of attempting to obtain the data through the Kodak MRP and other legacy systems. Linking the web site with the legacy systems would be a large programming task and could take more than one year to accomplish. The new system will provide simpler daily or weekly monitoring of the entire supply chain. Furthermore, it will provide the appropriate performance metrics that will help drive behavior to optimize the integrated supply chain for Kodak Professional digital cameras.

## **5.4. Summary**

The first step of analyzing the Kodak Professional supply chain was the development of the “As-is” model. The model showed the current performance of the existing digital camera supply chain. The inventory turns were calculated for the entire supply chain from suppliers through distribution. Based on the analysis, the Kodak Professional organization decided to pursue a new model which would at least double inventory turns. The new, integrated supply chain model included calculating strategic inventory levels using the MIT SIP Model, re-designing the distribution network for cameras and developing the Intranet Supply Chain Management System to improve communication.

Furthermore, during the project of improving the supply chain, there were additional benefits gained by Kodak Professional. These included improved supplier delivery performance at MTD, implementation of the MIT SIP Model at MTD, agreement with the Distribution regions on more direct camera shipments, and development of a central database of supply chain data.

## **6. Conclusion/Recommendations**

The framework of this thesis included three major components: establishing strategic inventory levels, re-designing the distribution network and improving communication in the supply chain for Kodak Professional digital cameras. The approach focused on developing and analyzing the “As-is” model and making a comparison with a world-class supply chain at Dell Computer. Following the comparison, the “To-be” model framework was developed and tools were selected for its implementation. The MIT Strategic Inventory Placement model was utilized to calculate inventory levels as well as help in determining the cost savings of a newly proposed distribution network. The supply chain communication was improved through the development of the Intranet Supply Chain Management System.

### **6.1. Successes**

The benefits and implementation successes of the new integrated supply chain project are the following:

- The entire supply chain for Kodak Professional digital cameras was modeled and analyzed for the first time.
- Inventory turns were calculated for the entire supply chain, including inventory levels at MTD. After the data was communicated within the organization, camera assembly obtained responsibility of helping to manage the MTD imager inventory.
- A benchmarking study was performed at Dell Computer in Austin, TX. The major learning were the use of “Revolver” (or supplier-owned) inventories, real-time communication with suppliers and accuracy of the demand forecasts.
- The new supply chain model needed to be more flexible to allow manufacturing to react quicker to changing customer demand. The digital camera supply chain should be based upon the Dell Direct model.

- After a re-organization of Global Equipment Manufacturing, the supply chain organization obtained responsibility for entire product flow, from suppliers through distribution.
- The MIT SIP model was used to establish pipeline and strategic stock levels throughout the supply chain. Using these levels, the inventory turns for the digital camera supply chain will double.
- Improvement of delivery performance by MTD on all of its image sensors.
- Agreement was made between MTD and camera assembly to begin a SIP Model pilot on one of the image sensors.
- The cost savings of re-designing the distribution network, to ship from manufacturing directly to countries, was estimated to be \$1.8 million for two camera models.
- Agreement was made with the Distribution Regions to move toward a more direct shipment of cameras.
- The importance of real-time communication between suppliers, manufacturing and sales was emphasized for Kodak Professional.
- Initial design completed for the Kodak Professional Supply Chain Management System.
- The implementation started on the interim Kodak Professional Intranet supply chain web site.
- The development began on the Kodak Professional central supply chain database.

## **6.2. Shortcomings**

The items that were planned to be implemented however, were not by the end of the project include:

- The implementation of the strategic inventory levels was slow to develop with internal suppliers.
- The direct ship terminals, required to ship cameras from manufacturing, were not installed.
- The Kodak Professional supply chain web site was not fully operational.

### **6.3. Project Lessons**

The following key learning were obtained during this project:

- The benefits of modeling and analyzing the entire supply chain from suppliers, through manufacturing and distribution, to the customer. Local inventory optimization between process stages does not lead to an optimal supply chain inventory strategy.
- The advantages and ease of use of the MIT Strategic Inventory Placement (SIP) Model. The model is used to calculate the pipeline and strategic inventory necessary to fulfill a certain customer service level based on average customer demand and variability.
- Inventory is necessary as a buffer between stages in the supply chain where the lead-time required by a downstream process is less than the response time to deliver the product from an upstream process.
- A change in the distribution network strategy is necessary when high-tech products (with high value-to-weight ratios) are distributed in a similar method to traditional film and paper. The result for the digital cameras is a phased transition toward air shipping cameras from manufacturing to dealers.
- Open communication and collaboration between members of the digital camera supply chain is extremely important. Improved communication channels, with the use of the Internet, can lead to improvements in delivery performance, faster quality feedback and more accurate demand forecasts.

### **6.4. Recommendations**

Following the conclusion of the integrated supply chain research project, the following recommendations are made to the Kodak Professional organization:

- Focus effort to reduce order fixed zones with both internal and external suppliers.
- Move to pull systems with each one of the suppliers as soon as possible.

- Work to breakdown communication barriers with each of the main component suppliers.
- Continue to push for the re-design of the worldwide distribution network for digital cameras.

## **6.5. Future Opportunities**

There are several operational areas in the supply chain where future projects should be explored:

- Improving the quality system that camera assembly maintains with its suppliers. Improvements are necessary in the management of data, management of action items and due dates, and faster problem resolution.
- Improving the product development (or commercialization) cycle to ensure all components are designed for manufacturing. Stricter measures should be in place for moving products through design into manufacturing.
- Analyzing the production capabilities of all of the equipment to determine theoretical capacity in each of the manufacturing processes, at camera assembly and each one of the suppliers.
- Developing a real-time supply chain monitoring capability and further collaborating on demand and scheduling with each of the suppliers.
- Improving the accuracy of worldwide demand forecasting. Install performance metrics which track to effect of forecasts on the cost of inventory in the digital camera supply chain.



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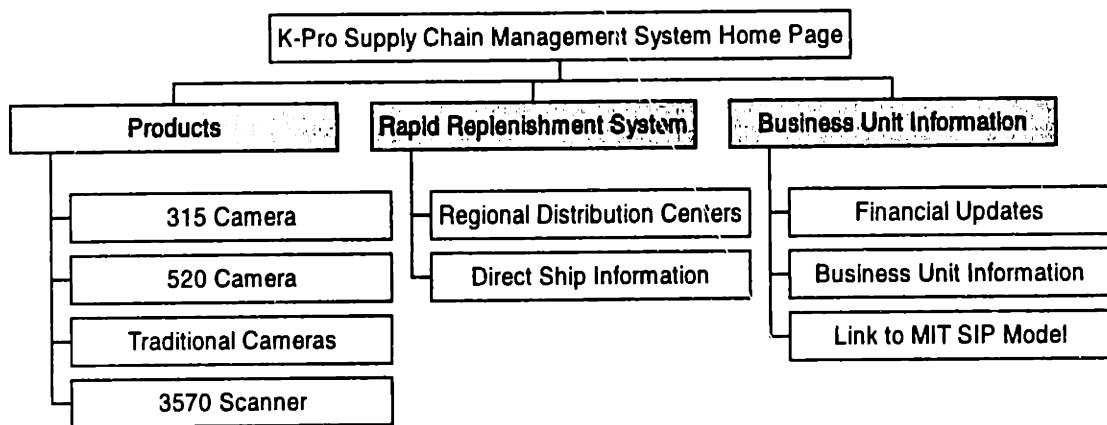
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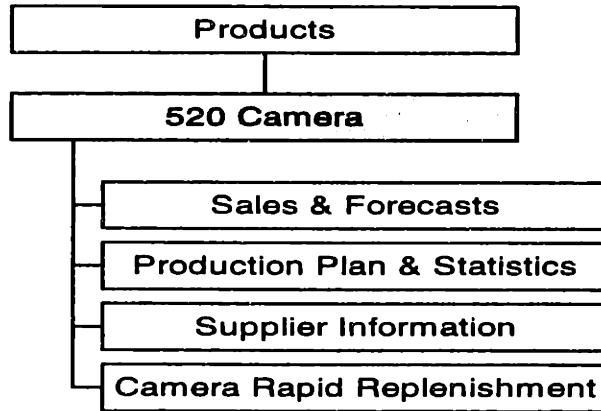
## 8. Appendix I

The Kodak Professional Supply Chain Management System is currently being developed for Kodak Professional. The following is the proposed design and features of the system. Figure 16 shows the first web page in the proposed site. The web site will provide Kodak Professional with product, distribution and business unit information.



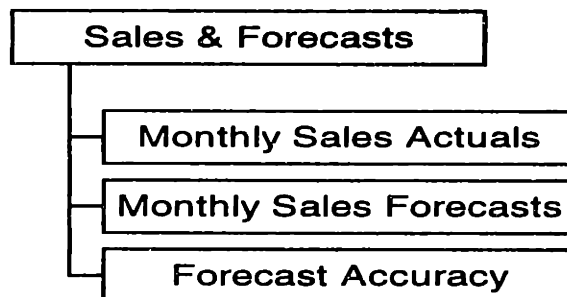
**Figure 16. Intranet Supply Chain Management System Main Page**

Figure 17 displays the type information that would be included for each specific product. The user could easily select between any of the camera products. The information would include sales and forecasts, production plans and data, supplier data and distribution network information. The advantage over the current MRP system is that every member of the digital camera supply chain will have access and the ability to easily query and create many various reports (by product, supplier, region, etc.) from anywhere within the Kodak organization.



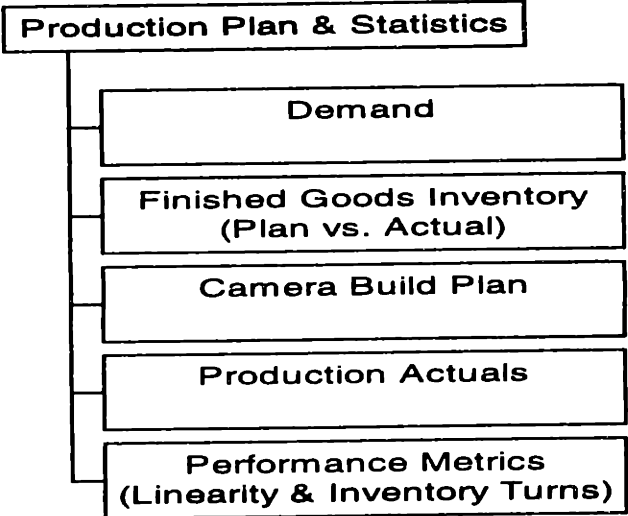
**Figure 17. Product Web page**

One piece of product-specific information would be the sales and forecast data. The sales and forecast information would include monthly sales, monthly sales forecasts and forecast accuracy (by region, country, etc.). The main purpose of this web page would be to have a central location where sales and forecasts could be updated instantaneously. In addition, this would provide management a simple tool to monitor forecast accuracy and drive improvement efforts. Figure 18 shows the layout of the Sales and Forecasts page. This would be the central storage location for all sales data and could be used by manufacturing and its suppliers to plan future production.



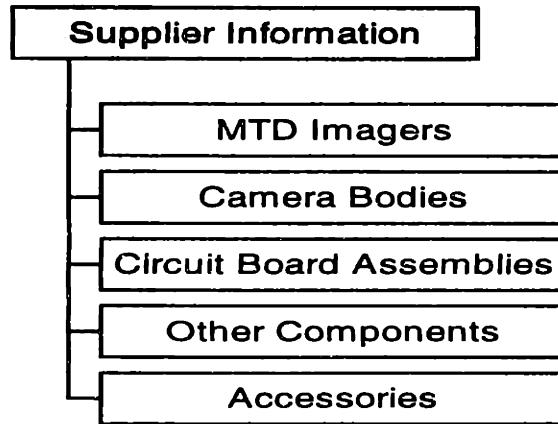
**Figure 18. Actual Sales and Forecasts Web page**

The supply chain management system would also include production data. Figure 19 shows the Production Plan & Statistics web page. The underlying pages would show the demand placed on manufacturing by customers. From this demand and with a comparison with finished goods inventory (planned vs. actual), the camera assembly build plan would be established and communicated to the suppliers. These pages would also track production and calculate performance metrics. This web page could provide daily or weekly production data that would help suppliers plan their own production. This would also help to eliminate a re-occurring problem where production seems to be running based on several different plans. This would be the one official production plan.



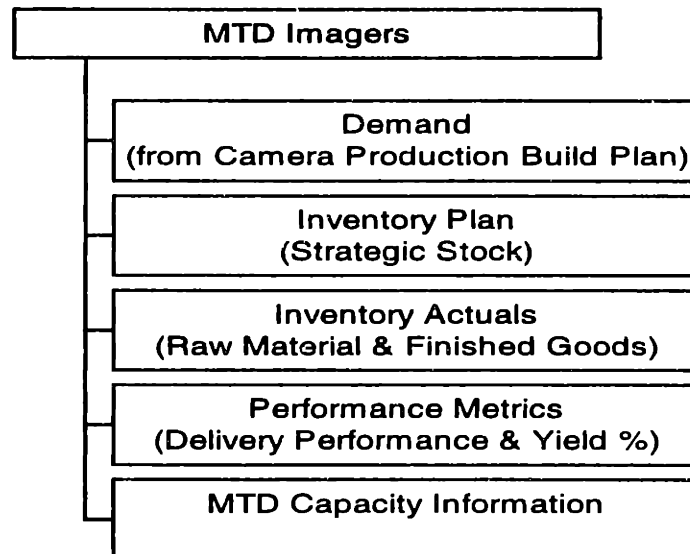
**Figure 19. Production Web page**

Supplier information, displayed in the system, would be divided for each one of the major components as seen in Figure 20. Each supplier would have the ability to enter its own data into the web site. The supplier could show its production schedules and constraints. This would provide an early warning if camera assembly plans did not coincide with their suppliers. In addition, management could easily monitor delivery performance data for each supplier.



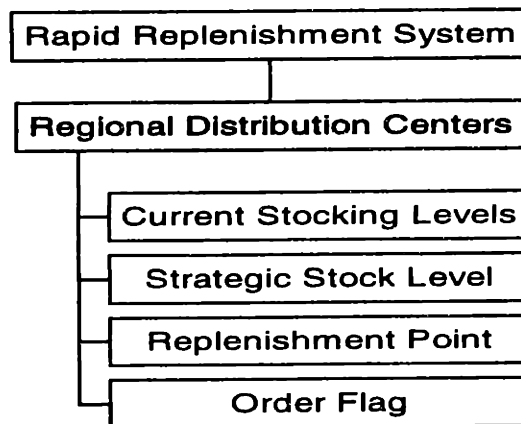
**Figure 20. Supplier Main Web page**

For example for the CCD image sensors, the camera assembly build plan would be displayed, from which the MTD production plan would then be created. In addition, the established strategic stock levels and inventory could also be tracked. Finally, the supplier performance metrics and individual capacities would be included. The MTD image sensor web page is shown above in Figure 21.



**Figure 21. Example of Supplier Web page**

The distribution network information would be included in the Rapid Replenishment System web pages as shown in Figure 22. The information that could be accessed would be current stocking levels, established stock levels, and replenishment points. Ideally, the supply chain management system would generate automatic orders from distribution to manufacturing.



**Figure 22. Distribution Network Web page**

The longer-term goal of the Rapid Replenishment System would be for the sales organization to be able to guarantee customer delivery dates by having visibility of the entire distribution network. Furthermore, this improved visibility would also allow regions and country houses to expedite cameras from each other's inventory (when available) instead of ordering from manufacturing.

Finally, the Kodak Professional Supply Chain Management System will include links to Kodak financial information, business unit information and the MIT Strategic Inventory Placement (SIP) Model.