COST ANALYSIS OF PRODUCT RECOVERY PROCESS IN SINGLE-USE CAMERA LIFE CYCLE

by

Beatrice C. Munz

B.S., Mechanical Engineering
Massachusetts Institute of Technology (1993)

Submitted to the Department of Mechanical Engineering and the MIT Sloan School of Management in partial fulfillment of the requirements for the degrees of

Master of Science in Mechanical Engineering

and

Master of Science in Management

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
June 1995

Signature of Author ______________________
Department of Mechanical Engineering
Sloan School of Management
May 12, 1995

Certified by ______________________
Kevin N. Otto, Assistant Professor of Mechanical Engineering
Thesis Supervisor

Certified by ______________________
Lawrence M. Wein, Professor of Management Science
Thesis Supervisor

Accepted by ______________________
Ain A. Sonin, Chairman
Graduate Committee, Department of Mechanical Engineering

Accepted by ______________________
Jeffrey A. Barks, Associate Dean
Master's and Bachelor's Programs, Sloan School of Management

COST ANALYSIS OF PRODUCT RECOVERY PROCESS IN SINGLE-USE CAMERA LIFE CYCLE

by

Beatrice C. Munz
B.S., Mechanical Engineering
Massachusetts Institute of Technology (1993)

Submitted to the Department of Mechanical Engineering and the MIT Sloan School of Management on May 12, 1995, in partial fulfillment of the requirements for the degrees of Master of Science in Mechanical Engineering and Master of Science in Management

Abstract

Over the last two decades environmental concerns have become increasingly important in a manufacturer's product strategy. Market dynamics and legislative changes are forcing manufacturers to take responsibility for their products throughout their life cycle. Such developments can bring economic opportunity for companies that recognize and integrate the need for product recovery management into their product strategies. In order to optimize the benefits these manufacturers realize from their recovery program, they must have a thorough understanding of the costs involved in manufacturing, recovering, re-manufacturing, and recycling their products.

This thesis addresses the profitability of the single-use camera recovery management program at the Eastman Kodak Company. A cost/benefit model was developed to better understand what drives the profitability of the recovery system. This model can be applied to (1) help determine appropriate investment opportunities, (2) aid in making policy decisions, and (3) evaluate how design changes affect the total life cycle cost of the cameras.

Thesis Supervisors: Kevin N. Otto
Assistant Professor of Mechanical Engineering

Lawrence M. Wein
Professor of Management Science

Acknowledgments

I wish to acknowledge the Leaders for Manufacturing Program and my advisors, Prof. Kevin Otto and Prof. Larry Wein for their support of this work. I would also like to recognize the employees of Department 686 at the Eastman Kodak Company, and especially Bruce Alexander, for their invaluable help and patience throughout my internship. I would like to thank Tania Munz and Jimmy Hallac for their encouragement and support. Most of all, I would like to thank my parents, for they have helped in more ways than I could possibly describe.

Contents

List of Figures

Chapter 1

Introduction

Recycling of consumer products is a relatively new field. Traditionally, manufacturers focused on minimizing production costs, distribution costs, and, more recently, inventory costs. On the other hand, consumers cared about minimizing the purchase price. Neither the manufacturer, nor the consumer worried about where the product went after it had been used.

Over the last two decades, we have seen an increased interest in the environment's well being and questions are being raised about where products go after they have been used. In fact, manufacturers in some European countries are now required by law to take their used packaging back.[1] Such legislation, along with customer demand for environmentally responsible products, are forcing companies to take responsibility for their products throughout their life cycle. This increased responsibility can increase costs, because manufacturers must now be concerned with minimizing the costs of producing products, as well as, reusing or disposing of these products. However, for companies that recognize the strategic importance of an effective product recovery system, there is also increased opportunity.

---

[1]Bylinsky, Gene: *Manufacturing for Reuse*, Fortune Magazine, (February 6, 1995), p. 104

Friedrich Johannaber, in his book "Injection Molding Machines," describes these changes in the costs of a product as show in Figure 1-1.[2] He predicts that in the future, the recycling and waste disposal processes must already be considered in the design stage.

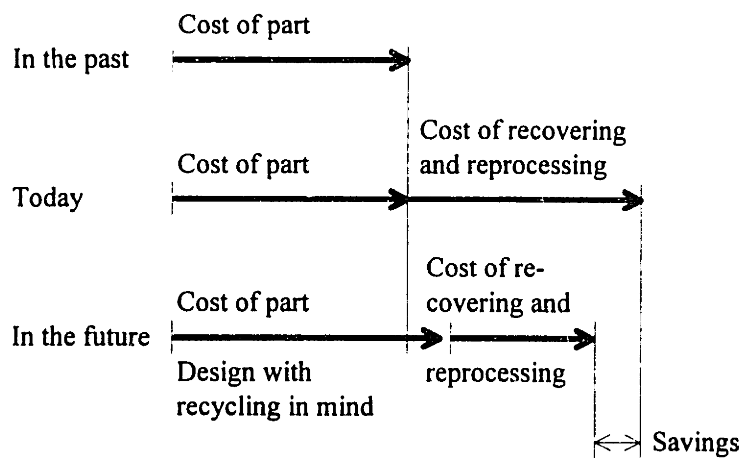


Figure 1-1: Cost Changes Today and in the Future

Many companies view this development as an additional threat in an already complex business environment. Figure 1-1 shows that the recent need for a company to recover and reprocess products can increase their costs. However, these developments can also bring economic opportunity for companies that pursue a product development strategy which minimizes the total costs incurred by the manufacturer. As shown in Figure 1-1, the total cost can be reduced if a company understands and incorporates the recovery process they will eventually use during the initial design phase.

---

[2]Johannaber, Friedrich: *Injection Molding Machines, A User's Guide*, Third Edition, Carl Hanser Verlag, Munich, Vienna, New York (1994)

Friedrich Johannaber's prediction of a product's future cost structure becomes even more significant when a company reuses the product. Figure 1-2 illustrates the dramatic savings that can be realized if a product is re-manufactured two times.

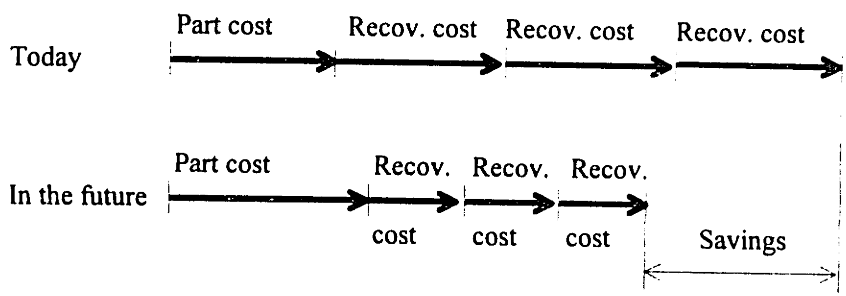


Figure 1-2: Cost Savings Realized by Extending a Product's Life

Companies which plan to compete globally must recognize that increased environmental responsibilities will become, or already are, an integral part of doing business. These developments will force companies to acquire a number of new skills, including the ability to design for disassembly, the ability to create a reverse distribution network to recover used products, and a thorough understanding of the costs involved in manufacturing, recovering and re-manufacturing products. One manufacturer that has acquired many of these new skills is the single-use camera department at the Eastman Kodak Company. Kodak has been successfully re-manufacturing their single-use cameras since 1990 and their product recovery program is unquestionably already "in the future."

This work is the result of a six month internship at the Eastman Kodak Company in Rochester, NY. The objective of this internship assignment was to gain a detailed understanding of what drives the profitability of Kodak's recovery management program and to apply that understanding to making investment, policy, and design decisions. This led to the development of a cost/benefit model that is used to analyze the costs associated with recovering, re-manufacturing and recycling single-use cameras, as well as the benefits realized by selling re-manufactured cameras.

This report will describe the development of a cost/benefit model that allows Kodak to better understand the financial impact of their single-use camera recovery program. Chapter 2 discusses the history of Kodak's single-use cameras and describes the recycling process. In addition, the next chapter describes the motivation behind the recycling program and outlines the objectives of this thesis project. Chapter 3 describes the structure of the model. Chapter 4 illustrates how the model can be used to gain an understanding of the cost and benefit structure of the recovery program. Chapters 5, 6 and 7 describe examples of how the model may be used to make investment, policy and design decisions, respectively. Finally, Chapter 8 provides some thoughts on how the cost/benefit model can be helpful to other companies.

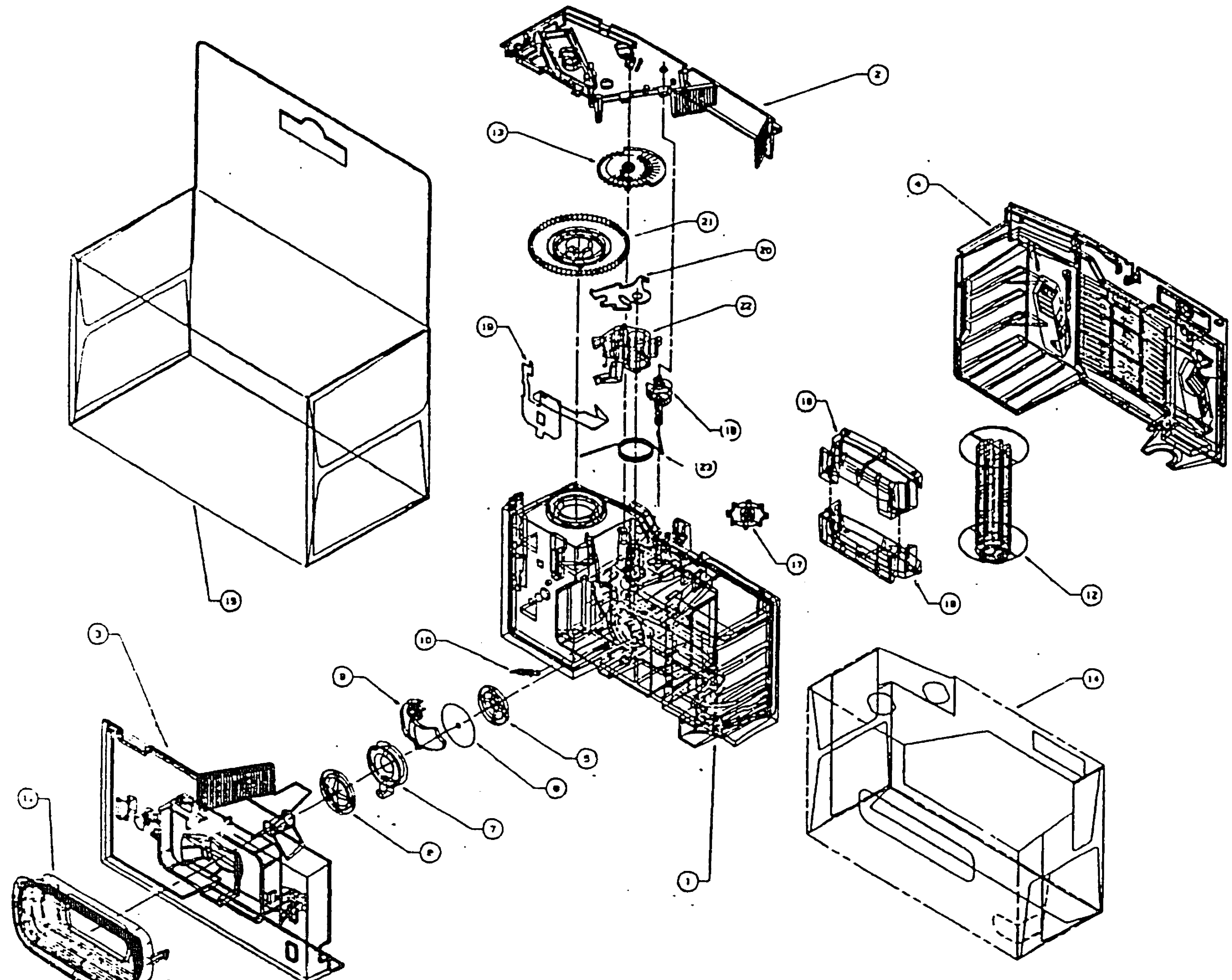
Chapter 2

Background

This chapter will discuss the history of Kodak's single-use camera and the motivation behind starting a recycling program. In addition, it will provide a short overview of the recovery process, starting from the time a camera is manufactured until it is returned to Kodak and rebuilt. Finally, this chapter will discuss Kodak's motivation behind the recovery program and outline the objectives of the project.

2.1 History of the Single-Use Camera Recovery Program

Kodak sold its first 35mm "disposable" camera, called the Kodak *Fling35mm*, in 1988. This type of camera, also known as a single-use camera, is a fixed-focus point-and-shoot camera, consisting of a roll of 35mm film, a polystyrene box, a lens, shutter and a film advancing mechanism. Today, Kodak's employees cringe when these cameras are referred to as disposable, since they have invested heavily into recovering spent camera bodies. However, in 1988 the cameras truly were disposable. The original camera covers were sonically welded together, which meant the photofinisher had to break the camera apart in order to remove the film magazine. Figure 2-1 shows an exploded view drawing of a single-use camera.



Source: Goldstein, Lisa: *The Strategic Management of Environmental Issues: A Case Study of Kodak's Single-Use Cameras*, Massachusetts Institute of Technology, Cambridge, MA (May 1994) p. 23

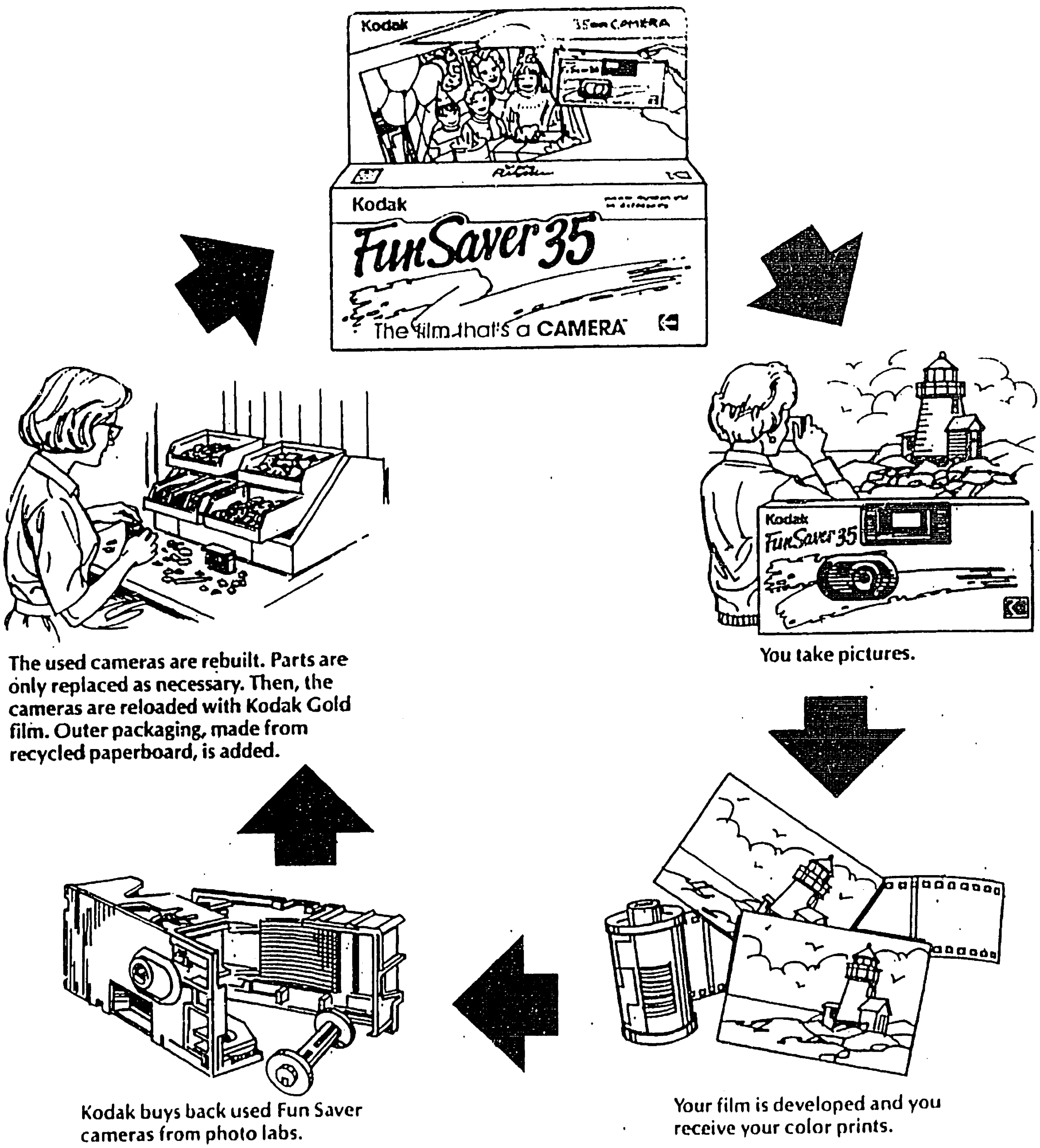
Figure 2-1: Exploded View Drawing of Single-Use Camera

As these disposable cameras gained popularity, so did the environmental objections raised against them. A backlash ensued against the major manufacturers of these cameras, and in 1989 Kodak received a "Waste Maker of the Year" award from a U.S. Senator.[3] As a result, Kodak instituted a recycling program in May 1990, and redesigned the camera for disassembly and re-manufacturability. The design team replaced all sonic welds with snap fits, allowing the camera to be opened and closed a number of times. At this time, the name was changed from *Fling* to *FunSaver* and the disposable camera was replaced with a re-manufacturable single-use camera. A photofinisher can now snap apart the camera body and remove the film magazine without damaging the camera. These spent camera bodies can then be sent back to Kodak. Kodak is providing an incentive for photofinishers to return cameras by reimbursing their shipping costs and compensating them with a seven cents rebate per returned camera.

2.2 Recovery Process

A simplified diagram of the recovery process initiated in 1990 is shown in Figure 2-2. The first part of any recovery program must be the design for disassembly and re-manufacture. The second step of the process occurs while assembling the camera: the entire film is wound out of the magazine onto a spool, ready for the consumer to start taking pictures. The third step is performed by the consumer, who winds the film back into the magazine after each exposure. This step eliminates the need for a rewind mechanism in the camera and ensures that the captured images are protected, should the camera be damaged. The fourth step in the recovery process is performed by the photofinisher, who removes the film magazine from the camera, develops the pictures and sends the spent camera body to the Kodak recycling center. The recycling center sorts the cameras and re-manufactures them into subassemblies that are indistinguishable

[3]Conversation with Bruce Alexander, Senior Manufacturing Engineer at the Eastman Kodak Company



Source: Kodak EnviroNotes Brochure

Figure 2-2: Diagram of Recovery Process

from subassemblies built from new parts. The re-manufacturing process is described in detail in Chapter 3.

2.3 Motivation for Recycling Single-Use Cameras

The recovery program discussed above has a major impact on how Kodak makes design, manufacturing, and management decisions. This raises the question of why Kodak chose such an aggressive recycling program in the first place. There are two major reasons. The most obvious is the environmental need to divert these cameras from landfills. This is essential in avoiding future environmental backlashes, such as the one in 1989. In addition, Kodak feels it is the socially correct thing to do. The second factor motivating Kodak to recycle these cameras is the significant financial benefits that can be realized. The re-manufactured subassemblies cost a fraction of the price of a newly built camera. Naturally there are a number of costs associated with receiving and processing these cameras, but overall the benefits outweigh the costs.

2.4 Project Objective

The primary objective of this internship project was to understand the profitability of Kodak's recovery management program. In addition, Kodak hoped to gain a detailed understanding of what their major costs are and where their savings are realized. Kodak further anticipated, that this knowledge would allow them to make better informed decisions regarding their investments, their policies and their camera designs.

Chapter 3

Description of Cost/Benefit Model

As discussed in Section 2.4, Kodak's objective was to understand the profitability of the recovery management program and to apply this knowledge to aid in decision making. To achieve this goal, a cost/benefit model was developed in order to track the costs associated with recovering single-use cameras and compare these costs to the benefits realized from the re-manufactured cameras. The structure of this model, written in Microsoft Excel, is described in this section.

The first step in understanding the recovery management program is to analyze the way spent cameras flow through Kodak's recycling center. This information can then be used to produce a detailed financial analysis of the recovery program.

3.1 Material Flow Analysis

The most critical step in the recovery process described in Section 2.2 takes place at The Out-Source, Kodak's single-use camera recycling center in Rochester, NY. Photofinishers in the United States return spent camera bodies directly to The Out-Source, while cameras discarded abroad are first collected at Kodak's foreign collection sites and then sent on to Rochester. The Out-Source is a sheltered work shop that is part of the Rochester Rehabilitation Center and provides meaningful job opportunities for physically or mentally challenged people in the Rochester area. The Out-Source receives both domestic and international shipments and weighs them at their receiving dock. These shipments contain claim forms provided by the photofinishers, which indicate the shipping costs incurred. The claim forms are forwarded to Kodak, who reimburses the photofinishers for their shipping costs and pays them a rebate for each returned camera. The actual camera count is either provided by the photofinisher or is based on the weight of the shipment. A diagram of the material flow through the recycling center is shown in Figure 3-1.

The cameras are unloaded at The Out-Source and fed down a long conveyor belt where operators separate out loose parts, such as batteries or circuit boards, and manually sort the intact cameras by model and generation. Since the first single-use camera was launched, a number of camera models have been redesigned, resulting in several generations of the same camera model being returned to Rochester. Each camera type is color coded, allowing operators to easily pick their particular model(s) off the conveyor. In addition, Non-Kodak cameras are separated from the Kodak models. The manual sort operation allows for increased flexibility as new camera models are developed and additional sort stations must be added to the line.

This sorting operation separates the returned cameras into 15 different types of returns, as is shown in Figure 3-1. The Non-Kodak cameras are sent to the incinerator for energy recovery. In the future, these cameras might be exchanged with their respective manufacturers. Similarly, Kodak's sonically welded (first generation) cameras cannot be reused. Since Kodak is familiar with the design and the materials used in these cameras, they are completely broken down and recycled into new parts. Camera models which are still being commercially sold are then inspected and re-manufactured. Each camera is re-manufactured by the same company that supplies Kodak with the virgin subassemblies for the particular model. Depending on the model, the cameras are either inspected as

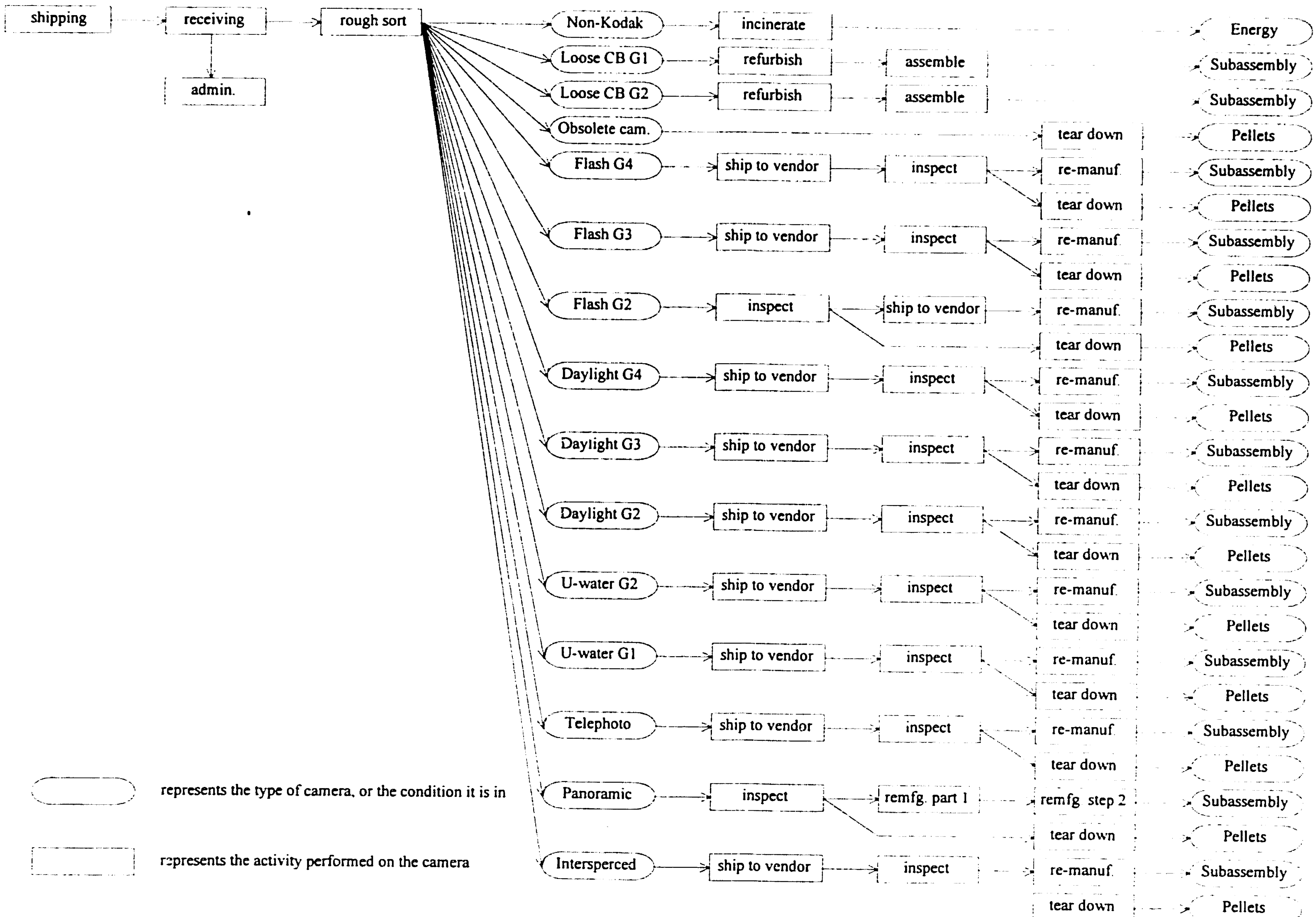


Figure 3-1: Detailed Material Flow Diagram

part of the re-manufacturing process at the individual supplier or initially inspected at The Out-Source and shipped to the appropriate vendor. Each camera is inspected for nicks and scratches that might have occurred during use or shipping. A camera that is in poor shape is torn down, so that the individual parts can be reground for plastic recovery.

Suppliers re-manufacture the cameras by removing the front and back covers of each camera, and replacing the view finder and the lens. The covers are removed because any damage to the cover might result in light leakage that could damage new film. The view finder is replaced because dirt or fingerprints from previous users could bother new customers. The lens is replaced since dirt or fingerprints on the lens can adversely affect the quality of future pictures. The covers and view finder are recycled into new parts. In addition a new battery is provided for each flash camera. The re-manufactured subassembly is now indistinguishable from a subassembly built from virgin parts and is ready to be shipped to Kodak for final assembly.

For the purpose of understanding the financial aspects of the recovery program, the material flow diagrammed in Figure 3-1 and described above can be simplified. The simplified flow diagram is shown in Figure 3-2. The first few steps at The Out-Source, called the 'shipping', 'receiving' and 'administrative' nodes in Figure 3-1 have been combined into a single 'Receiving' node in Figure 3-2. In addition, the tear down operations for each camera model have been combined into one node. The tear down of flash cameras results in loose printed circuit boards (in addition to the recyclable plastic parts), which are refurbished and assembled into new cameras. The same is true for loose circuit boards pulled off the conveyor belt where the cameras are sorted. These two sources of loose circuit boards are combined into one branch, as shown in Figure 3-2.

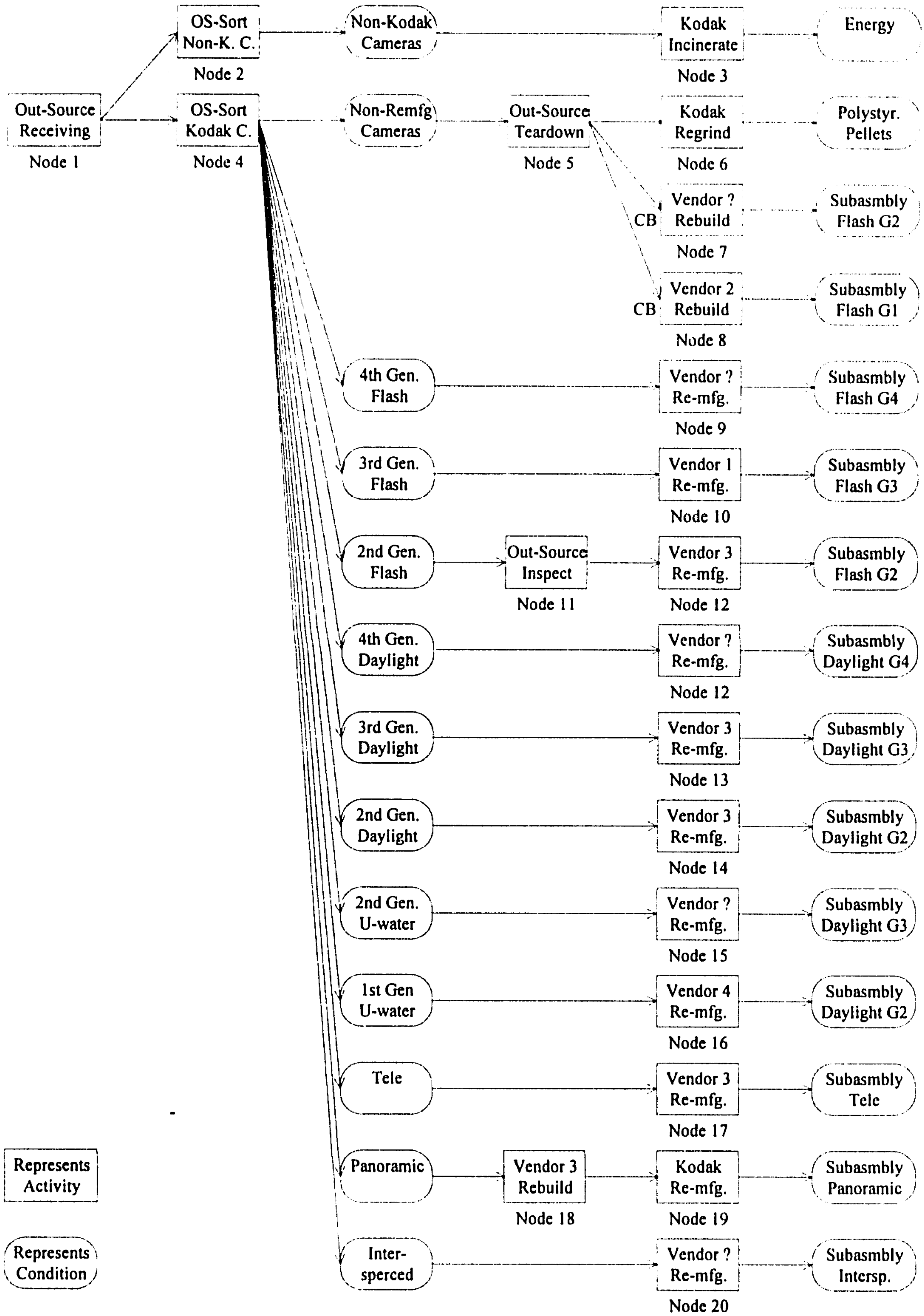


Figure 3-2: Simplified Material Flow Diagram

A circuit board can be reused ten times and a camera body can be reused six times. In order to keep track of how many times a camera is used, they are marked each time they are re-manufactured.

3.2 Financial Analysis

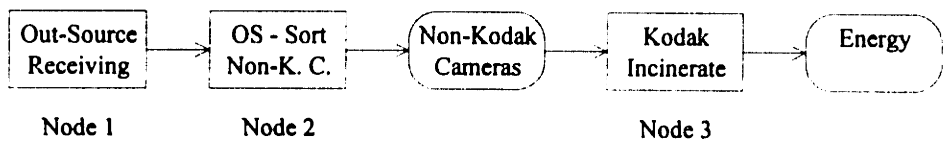
In order to understand the profitability of the recovery program, the costs associated with recovering cameras, as well as the benefits, or value realized by the re-manufactured cameras, must be analyzed. Section 3.2.1 describes how the costs are computed for each branch of the recovery process, while Section 3.2.2 outlines how the benefits of re-manufacturing these cameras are determined. Section 3.2.3 illustrates how benefits relate to costs and how the profitability of the recovery program can be determined.

3.2.1 Cost Analysis

The simplified material flow diagram described in Section 3.1 was used to model the costs associated with recovering single-use cameras. As shown in Figure 3-2, a camera is either incinerated for energy recovery, torn down and recycled for material recovery or re-manufactured to where it becomes indistinguishable from a newly built assembly. Each step in this process has a cost associated with it. However, due to confidentiality reasons, these costs, as well as all subsequent costs shown in this report, are completely fictitious and do not represent the actual costs to Kodak. In reality each of these costs is calculated by summing the labor costs paid to the vendor, the material costs associated with replacing the necessary parts (such as lens and view finder) and the overhead costs. The total cost per re-manufactured camera can then be determined by summing all the costs along each material flow line.

Once the costs associated with each branch of the recovery process are understood, it becomes necessary to determine how many cameras are processed along each flow line. Due to confidentiality reasons, these numbers are also fictitious. A detailed description of each branch and the number of cameras flowing through that branch is provided below in Figures 3-3 through 3-17. The description includes the costs associated with each node in the branch, which is summarized in Figure 3-18.

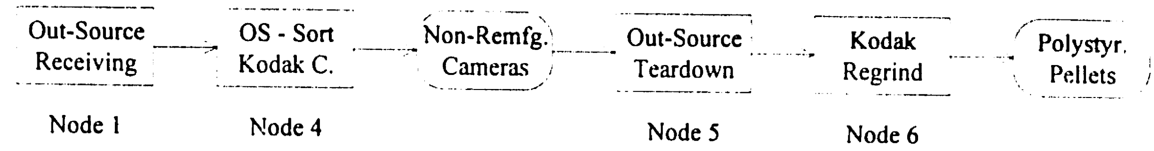
Branch 1 represents the path Non-Kodak cameras take through the Out-Source (O-S) to Kodak's incinerator.



Node 1:	Represents the activity of shipping cameras back to the O-S, paying the photofinishers a rebate and administering the receipt of cameras.	
	Cost:	Includes the \$0.023/camera for shipping and \$0.04/camera for administrative activities. (Kodak does not pay a rebate for Non-Kodak cameras)
Node 2:	Represents the activity of sorting out the Non-Kodak cameras from the stream of returned cameras.	
	Cost:	Quoted at \$0.010/camera
Node 3:	Represents the activity of incinerating the Non-Kodak cameras at the Kodak incinerator.	
	Cost:	Estimated at \$0.082/camera.
Total Cost:	Cost for Node 1 + Cost for Node 2 + Cost for Node 3 = \$0.155 per camera	
Number of cameras flowing through Branch 1:	Estimated from the weight of Non-Kodak cameras the O-S sorts out of the recycling stream, assuming 7 cameras/pound.	

Figure 3-3: Description of Branch 1

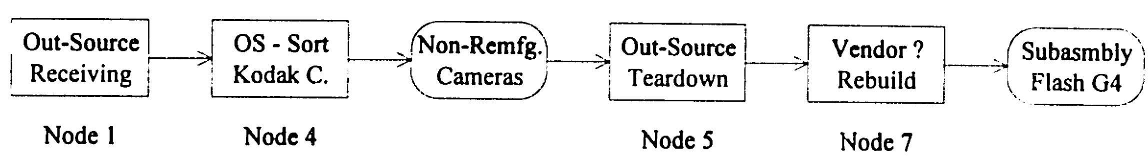
Branch 2 represents the path obsolete camera models (1st generation flash and daylight cameras) and badly damaged cameras take through the O-S to the Kodak regrind facility.



Node 1:	Same as in Branch 1, with the exception that the $0.070/camera rebate cost is incurred for all Kodak cameras
Node 4:	Represents the activity of sorting out the cameras which cannot be re-manufactured from the stream of returned cameras. Cost: Quoted at $0.026/camera
Node 5:	Represents the activity of tearing down the cameras which cannot be manufactured. Cost: Quoted at $0.012/camera
Node 6:	Represents the activity of recycling the torn down plastic parts into new parts. Cost: Not included, as explained in Section 3.3
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 5 + Cost for Node 6 = $0.171 per camera
Number of cameras flowing through Branch 2:	Includes the number of obsolete cameras sorted from the recycling stream, as well as the number of damaged cameras that each subassembly vendor tears down and sends to the regrind facility.

Figure 3-4: Description of Branch 2

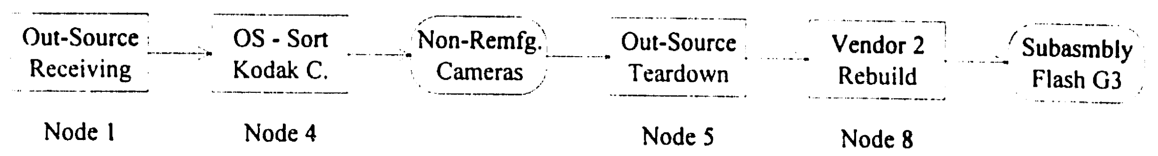
Branch 3 represents the path loose circuit boards for the 2nd and 3rd generation flash camera (use identical circuit board) follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the cameras which cannot be re-manufactured from the stream of returned cameras Cost: The cost associated with sorting the cameras is already included in the tear down cost described for Branch 2
Node 5:	Represents the activity of separating out the loose circuit boards while tearing down damaged 2nd or 3rd generation flash cameras. Cost: The cost associated with separating the circuit board is already included in the tear down cost described for Branch 2
Node 7:	Represents the activity of refurbishing the loose circuit boards and assembling them into subassemblies built from new parts. Cost: Quoted at $0.811/camera
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 5 + Cost for Node 7 = $0.811/camera
Number of cameras flowing through Branch 3:	Determined from the number of circuit boards the vendor refurbishes.

Figure 3-5: Description of Branch 3

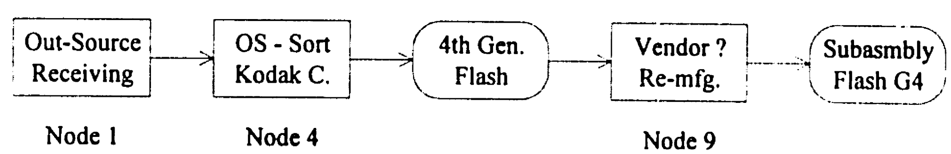
Branch 4 represents the path loose circuit boards for the 4th generation flash camera follow.



Node 1:	Same as in Branch 2	
Node 4:	Represents the activity of sorting out the cameras which cannot be re-manufactured form the stream of returned cameras	
	Cost:	The cost associated with sorting the cameras is already included in the tear down cost described for Branch 2
Node 5:	Represents the activity of separating out the loose circuit boards while tearing down damaged 4th generation flash cameras.	
	Cost:	The cost associated with separating the circuit board is already included in the tear down cost described for Branch 2
Node 8:	Represents the activity of refurbishing the loose circuit boards and assembling them into subassemblies built from new parts.	
	Cost:	Includes quoted price of $.301 for refurbishing the circuit board and $.480 for new parts
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 5 + Cost for Node 8 = $0.781/camera	
Number of cameras flowing through Branch 4:	Determined from the number of circuit boards the vendor refurbishes.	

Figure 3-6: Description of Branch 4

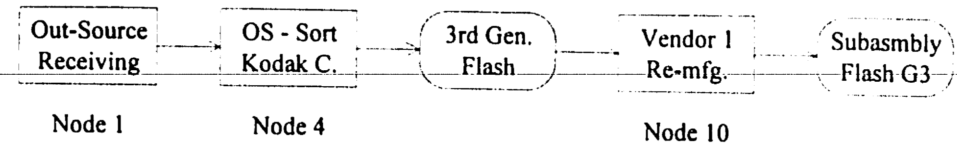
Branch 5 represents the path the 4th generation flash cameras follow.



Node 1:	Same as in Branch 2	
Node 4:	Represents the activity of sorting out the 4th generation flash cameras from the stream of returned cameras.	
	Cost:	Quoted at $0.026/camera
Node 9:	Represents the activity of re-manufacturing 4th generation flash cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.	
	Cost:	Includes estimate of $0.108 for labor and $0.050 for replacement part (top cover)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 9 = $0.317/camera	
Number of cameras flowing through Branch 5:	Number of 4th generation flash cameras that are being re-manufactured at the supplier.	

Figure 3-7: Description of Branch 5

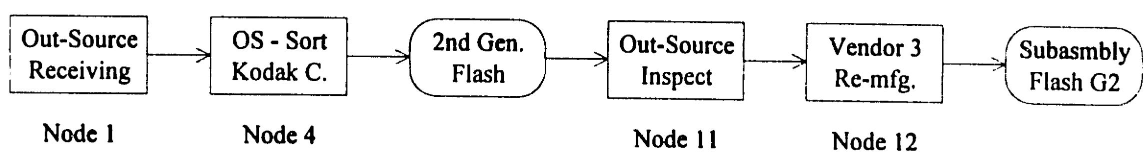
Branch 6 represents the path the 3rd generation flash cameras follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 3rd generation flash cameras from the stream of returned cameras.
	Cost: Same as Branch 5
Node 10:	Represents the activity of re-manufacturing 3rd generation flash cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.
	Cost: Includes estimate of $0.105 for labor and $0.046 for replacement part (top cover)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 10 = $0.310/camera
Number of cameras flowing through Branch 6:	Number of 3rd generation flash cameras that are being re-manufactured at the supplier.

Figure 3-8: Description of Branch 6

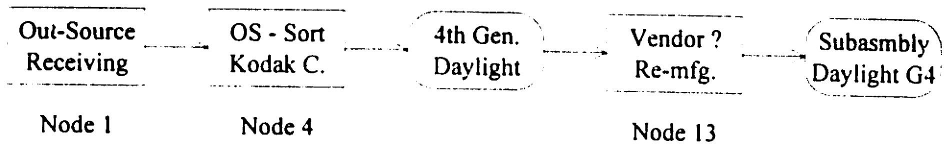
Branch 7 represents the path the 2nd generation flash cameras follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 2nd generation flash cameras from the stream of returned cameras.
	Cost: Same as Branch 5
Node 11:	Represents the activity of roughly inspecting the 2nd generation flash cameras before shipping them to the re-manufacturing vendor.
	Cost: Quoted at $0.066
Node 12:	Represents the activity of re-manufacturing 2nd generation flash cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.
	Cost: Includes quoted price of $0.090 for re-manufacturing and $0.056 for replacement parts (top cover, battery and counter wheel)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 11 + Cost for Node 12 = $0.371/camera
Number of cameras flowing through Branch 7:	Number of 2nd generation flash cameras that are being re-manufactured at the supplier.

Figure 3-9: Description of Branch 7

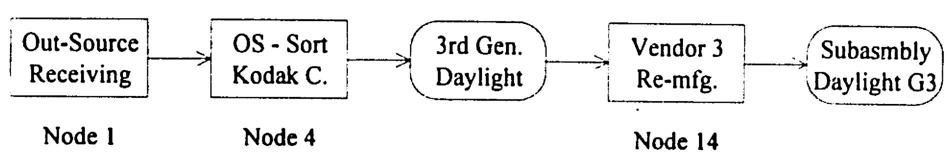
Branch 8 represents the path the 4th generation daylight cameras follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 4th generation daylight cameras from the stream of returned cameras.
	Cost: Same as in Branch 5
Node 13:	Represents the activity of re-manufacturing 4th generation daylight cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.
	Cost: Includes quoted price of \$0.106 for re-manufacturing and \$0.060 for replacement parts (top cover, battery and cam)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 13 = \$0.325 per camera
Number of cameras flowing through Branch 8:	Number of 4th generation daylight cameras that are being re-manufactured at the supplier.

Figure 3-10: Description of Branch 8

Branch 9 represents the path the 3rd generation daylight cameras follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 3rd generation daylight cameras from the stream of returned cameras.
	Cost: Same as Branch 5
Node 14:	Represents the activity of re-manufacturing the 3rd generation daylight cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.
	Cost: Includes quoted price of \$0.103 for re-manufacturing and \$0.030 for replacement part (top cover)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 14 = \$0.292/camera
Number of cameras flowing through Branch 9:	Number of 3rd generation daylight cameras that are being re-manufactured at the supplier.

Figure 3-11: Description of Branch 9

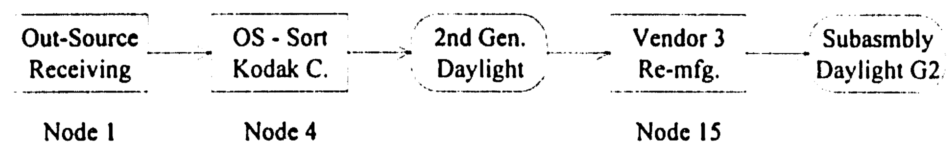
Branch 10 represents the path the 2nd generation daylight cameras follow.	
	
Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 2nd generation daylight cameras from the stream of returned cameras. Cost: Same as Branch 5
Node 15:	Represents the activity of re-manufacturing 2nd generation daylight cameras into camera subassemblies at the supplier that assembles the new camera subassemblies. Cost: Includes quoted price of $0.109 for re-manufacturing and $0.040 for replacement part (top cover)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 15 = $0.308/camera
Number of cameras flowing through Branch 10: Number of 2nd generation daylight cameras that are being re-manufactured at the supplier.	

Figure 3-12: Description of Branch 10

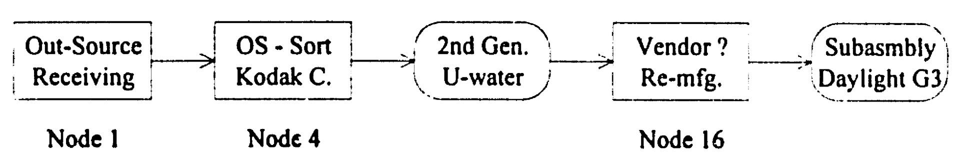
Branch 11 represents the path the 2nd generation underwater cameras follow.	
	
Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 2nd generation underwater cameras from the stream of returned cameras. Cost: Same as Branch 5
Node 16:	Represents the activity of re-manufacturing 2nd generation underwater cameras into camera subassemblies at the supplier that assembles the new 3rd generation daylight camera subassemblies. Cost: Includes quoted price of $0.050 for re-manufacturing and $0.051 for replacement parts (top cover and thumb wheel)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 16 = $0.260/camera
Number of cameras flowing through Branch 11: Number of 2nd generation underwater cameras that are being re-manufactured at the supplier.	

Figure 3-13: Description of Branch 11

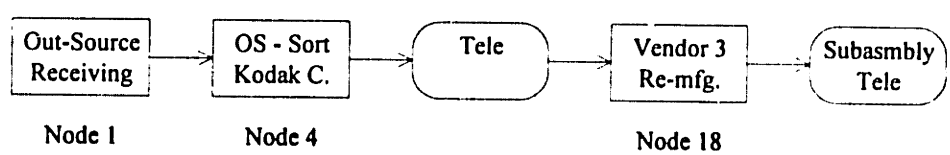
Branch 12 represents the path the 1st generation underwater cameras follow.

Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the 1st generation underwater cameras from the stream of returned cameras.
	Cost: Same as Branch 5
Node 17:	Represents the activity of re-manufacturing the 1st generation underwater cameras into camera subassemblies at the supplier that assembles the new 2nd generation daylight camera subassemblies.
	Cost: Includes quoted price of $0.069 for re-manufacturing and $0.050 for replacement parts (top cover, thumb wheel and counter wheel)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 17 = $0.278/camera

Number of cameras flowing through Branch 12:
Number of 1st generation underwater cameras that are being re-manufactured at the supplier.

Figure 3-14: Description of Branch 12

Branch 13 represents the path the telephoto cameras follow.

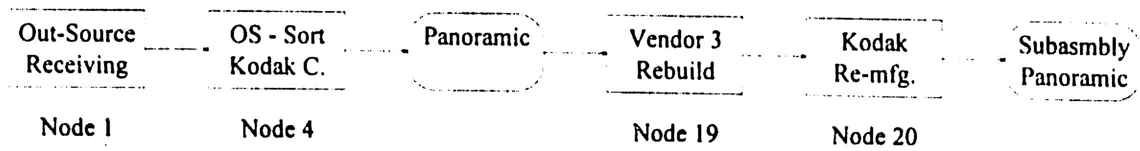


Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the telephoto cameras from the stream of returned cameras.
	Cost: Same as Branch 5
Node 18:	Represents the activity of re-manufacturing telephoto cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.
	Cost: Includes quoted price of $0.059 for re-manufacturing and $0.050 for replacement parts (top cover, thumb wheel and counter wheel)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 18 = $0.268/camera

Number of cameras flowing through Branch 13:
Number of telephoto cameras that are being re-manufactured at the supplier.

Figure 3-15: Description of Branch 13

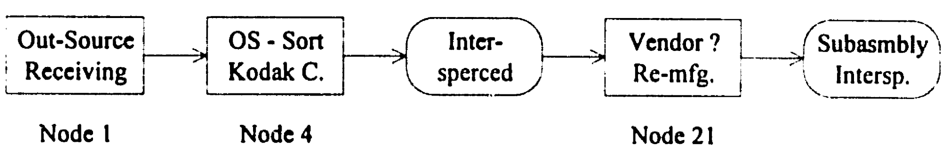
Branch 14 represents the path the panoramic cameras follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the panoramic cameras from the stream of returned cameras.
	Cost: Same as in Branch 5
Node 19:	Represents the activity of re-manufacturing panoramic cameras to an intermediate stage at the supplier that assembles the new camera subassemblies.
	Cost: Includes quoted price of $0.010 for re-manufacturing and $0.010 for replacement parts (top cover, High energy assembly and counter wheel)
Node 20:	Represents the activity of re-manufacturing panoramic cameras into complete subassemblies at Kodak.
	Cost: Includes $0.067 for labor and $0.030 for replacement part (top cover)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 19 + Cost for Node 20 = $0.276 per camera
Number of cameras flowing through Branch 14:	Number of panoramic cameras that are being re-manufactured at the supplier.

Figure 3-16: Description of Branch 14

Branch 15 represents the path the interspersed (can switch between regular and panoramic format) cameras follow.



Node 1:	Same as in Branch 2
Node 4:	Represents the activity of sorting out the interspersed cameras from the stream of returned cameras.
	Cost: Same as Branch 5
Node 21:	Represents the activity of re-manufacturing interspersed cameras into camera subassemblies at the supplier that assembles the new camera subassemblies.
	Cost: Estimated at $0.193 (None re-mfg. yet)
Total Cost:	Cost for Node 1 + Cost for Node 4 + Cost for Node 21 = $0.352/camera
Number of cameras flowing through Branch 15:	Number of interspersed cameras that are being re-manufactured at the supplier.

Figure 3-17: Description of Branch 15

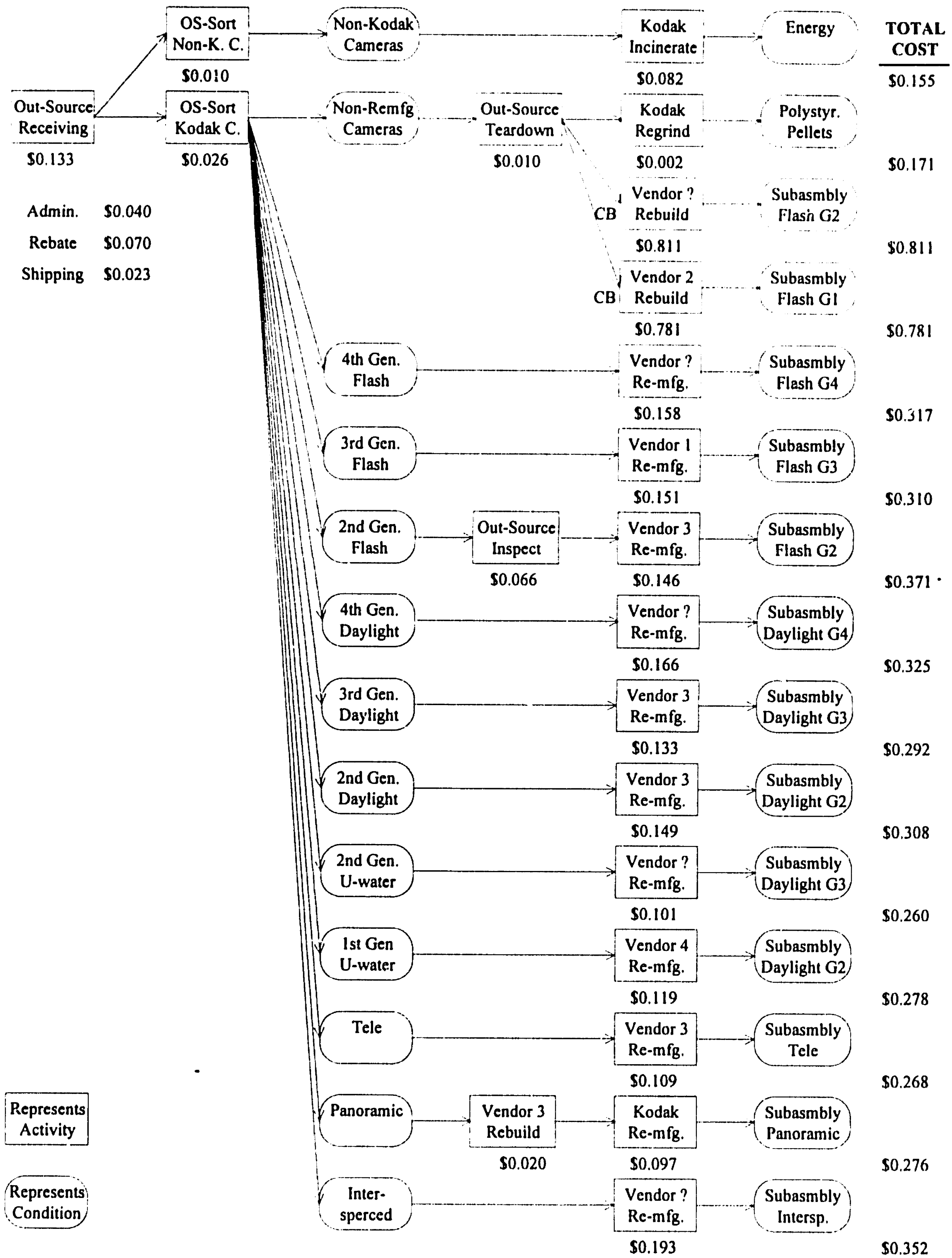


Figure 3-18: Cost Incurred in Material Flow

The diagrams above describe how the model tracks the number of re-manufactured cameras and the number of torn down cameras for each model, as well as the number of flash cameras built with reconditioned circuit boards and the number of Non-Kodak cameras that were sorted. By multiplying the number of cameras in each of these categories by the costs associated with re-manufacturing, tearing down or incinerating cameras, we can determine the total cost incurred by recovering single-use cameras. This can be seen in the cost summary in Figure 3-19.

3.2.2 Benefit Analysis

The value of each re-manufactured subassembly corresponds to what it would have cost to build an appropriate subassembly from new materials. These costs are well known to Kodak and are therefore easily available. It is important to note that while Kodak incurs costs for every received camera, only the reused cameras bring any financial benefit. The number of re-manufactured subassemblies is determined by the number of re-manufactured cameras as well as the number of subassemblies built form refurbished circuit boards, as seen in the benefit summary in Figure 3-20.

3.2.3 Profitability Analysis

The net savings to Kodak can now be determined by comparing the total costs incurred, as shown in Figure 3-19, to the total value realized from recovering spent cameras, as shown in Figure 3-20. The resulting profitability summary is shown in Figure 3-21.

Cost Summary	4th Gen. Flash	3rd Gen. Flash	2nd Gen. Flash	4th Gen. Daylight	3rd Gen. Daylight	2nd Gen. Daylight	2nd Gen. U-water	1st Gen. U-water	Tele	Panoram.	Intersprd.	Non-Kodak	Total
No. of Non-Kodak cam. sorted	--	--	--	--	--	--	--	--	--	--	--	2,550	2,550
Cost/Non-Kodak camera	--	--	--	--	--	--	--	--	--	--	--	$0.155	$0.155
Number of re-mfg. cameras	0	4,754	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,585
Cost/re-mfg. camera	$0.317	$0.310	$0.371	$0.325	$0.292	$0.308	$0.260	$0.278	$0.268	$0.276	$0.352	--	--
Number of torn down cameras	0	2,568	914	0	1,302	1,003	0	1,246	775	1,343	0	--	9,151
Cost/torn down camera	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	--	--
Number of cameras with rebuilt CB	0	107	--	--	--	--	--	--	--	--	--	--	107
Cost/camera with rebuilt CB	$0.811	$0.781	--	--	--	--	--	--	--	--	--	--	--
TOTAL COST OF RECYCLING	$0	$1,996	$721	$0	$1,114	$860	$0	$865	$463	$904	$0	$395	$7,319

Figure 3-19: Cost Summary

Benefit Summary	4th Gen. Flash	3rd Gen. Flash	2nd Gen. Flash	4th Gen. Daylight	3rd Gen. Daylight	2nd Gen. Daylight	2nd Gen. U-water	1st Gen. U-water	Tele	Panoram.	Intersprd.	Non-Kodak	Total
Number of re-mfg. subassemblies	0	4,861	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,692
Value/re-mfg. subassembly	$2.555	$2.456	$2.145	$1.001	$0.456	$0.564	$0.654	$0.678	$0.622	$0.768	$0.898	--	--
TOTAL SAVINGS OF RECYCLING	$0	$11,939	$3,267	$0	$1,392	$1,260	$0	$1,590	$768	$1,876	$0	$0	$22,091

Figure 3-20: Benefit Summary

	4th Gen. Flash	3rd Gen. Flash	2nd Gen. Flash	4th Gen. Daylight	3rd Gen. Daylight	2nd Gen. Daylight	2nd Gen. U-water	1st Gen. U-water	Tele	Panoram.	Intersprd.	Non-Kodak	Total
Cost Summary													
No. of Non-Kodak cam. sorted	--	--	--	--	--	--	--	--	--	--	--	2,550	2,550
Cost/Non-Kodak camera	--	--	--	--	--	--	--	--	--	--	--	$0.155	$0.155
Number of re-mfg. cameras	0	4,754	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,585
Cost/re-mfg. camera	$0.317	$0.310	$0.371	$0.325	$0.292	$0.308	$0.260	$0.278	$0.268	$0.276	$0.352	--	--
Number of torn down cameras	0	2,568	914	0	1,302	1,003	0	1,246	775	1,343	0	--	9,151
Cost/torn down camera	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	--	--
Number of cameras with rebuilt CB	0	107	--	--	--	--	--	--	--	--	--	--	107
Cost/camera with rebuilt CB	$0.811	$0.781	--	--	--	--	--	--	--	--	--	--	--
TOTAL COST OF RECYCLING	$0	$1,996	$721	$0	$1,114	$860	$0	$865	$463	$904	$0	$395	$7,319
Benefit Summary													
Number of re-mfg. subassemblies	0	4,861	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,692
Value/re-mfg. subassembly	$2.555	$2.456	$2.145	$1.001	$0.456	$0.564	$0.654	$0.678	$0.622	$0.768	$0.898	--	--
TOTAL SAVINGS OF RECYCLING	$0	$11,939	$3,267	$0	$1,392	$1,260	$0	$1,590	$768	$1,876	$0	$0	$22,091
Profitability Summary													
TOTAL SAVINGS OF RECYCLING	$0	$11,939	$3,267	$0	$1,392	$1,260	$0	$1,590	$768	$1,876	$0	$0	$22,091
TOTAL COST OF RECYCLING	$0	$1,996	$721	$0	$1,114	$860	$0	$865	$463	$904	$0	$395	$7,319
NET SAVINGS OF RECYCLING	$0	$9,942	$2,546	$0	$278	$400	$0	$725	$304	$972	$0	($395)	$14,772

Figure 3-21: Profitability Summary

3.3 Evaluation of Assumptions

This section outlines the two major assumptions built into this model. As can be seen in the description of Branch 2 in Figure 3-4, the cost associated with regrinding the disassembled polystyrene parts is not included in the cost/benefit model. In addition, the model does not incorporate the savings realized by using the reground polystyrene instead of purchasing additional raw material. It would have been possible to approximate the savings by weighing the disassembled body parts and comparing them to the cost of new polystyrene. However, the regrinding cost was difficult to estimate, due to the fact that the grinder is not dedicated to single-use camera parts. Historically, Kodak has assumed that the savings realized from the polystyrene roughly balances out with the cost of regrinding the parts. This model incorporates the same assumption.

The second assumption concerns the benefits realized from recovered cameras. The value of a re-manufactured subassembly is determined by what it would have cost to build a corresponding subassembly from new materials. However, in order for both cameras to be of equal value to Kodak, the yield during final assembly for the re-manufactured cameras must be equal to the yield for virgin cameras. In reality, Kodak estimates that a camera built from a re-manufactured subassembly is between 2% and 5% more likely to show a defect during the final inspection, than a camera built from new parts. As a result, a re-manufactured subassembly is slightly less valuable than a new subassembly, although this difference was considered negligible.

Furthermore, each application of the model requires additional assumptions to be entered by the user, such as sales forecasts or cost approximations. The output of each applications must therefore be evaluated against all assumptions.

Chapter 4

Understanding the Recovery System

The cost/benefit model has provided Kodak with a deeper understanding of how the recovery management program affects their profitability. The traditional cost accounting systems at Kodak are not equipped to explore the detail of the costs and benefits realized by recycling cameras and therefore cannot provide a comprehensive understanding of the financial impact of the recovery system. This section will demonstrate how the model described in Chapter 4 can be used to analyze these financial implications.

4.1 Cost Sources

The cost/benefit model provides a detailed summary of the individual costs associated with receiving and processing each spent single-use camera. As a result, this model can be used to determine what percentage each process contributes to the total cost.

Kodak chose to divide the recycling process into the sub-processes described below. The following section also illustrates how the total cost for each sub-process was determined for 1994. As discussed in Chapter 3, these costs do not represent the actual costs incurred, but the resulting cost breakdown approximates Kodak's actual cost structure.

Shipping Cost: represents the cost of reimbursing photofinishers for their shipping costs

The shipping cost is incurred for every camera received at The Out-Source, which is determined as follows:

Total number of cameras recovered
= Number of Non-Kodak cameras + Number of re-mfg. cameras
+ Number of torn down cameras
= 2,550,000 cameras + 17,585,000 cameras + 9,151,000 cameras
= 29,286,000 cameras

The shipping cost is estimated at 2.3 cents per camera for every recovered camera, which result in a total shipping cost of:

Total shipping cost
= (Total number of cameras recovered) x (shipping cost/camera)
= (29,286,000 cameras) x ($0.023/camera)
= $ 673,578

Rebate Cost: represents the cost of paying a rebate to photofinishers

Kodak pays photofinishers seven cents per camera for each Kodak camera they send to The Out-Source. Therefore the total cost incurred by paying a rebate is calculated by multiplying the rebate cost by the total number of Kodak cameras received, as shown below:

Total Number of Kodak cameras recovered
= Number of re-mfg. cameras + Number of torn down cameras
= 17,585,000 cameras + 9,151,000 cameras
= 26,736,000 cameras

Total Rebate cost

= (Total number of Kodak cameras recovered)

x (rebate cost/camera)

= (26,736,000 cameras) x ($0.07/camera)

= $ 1,871,520

Administrative Cost: represents the cost of receiving the cameras, weighing them and processing the paperwork provided by the photofinishers

The administrative costs are incurred for each camera received at The Out-Source. Kodak estimates the administrative costs to be four cents per camera, which results in the following total administrative costs.

Total Administrative Cost

= (Total Number of cameras recovered)

x (Administrative cost/camera)

= (29,286,000 cameras) x ($0.04/camera)

= $ 1,171,440

Sorting Cost: represents the cost associated with sorting the recovered cameras by model

The sorting costs are incurred for both Kodak and Non-Kodak cameras. However, The Out-Source charges one cent per Non-Kodak camera and 2.6 cents per Kodak camera. As a result the total sorting cost is calculated as shown below.

Total Sorting cost

= (Total Number of Kodak cameras recovered)

x (Sorting cost/Kodak camera)

+ (Total Number of Non-Kodak cameras recovered)

x (Sorting cost/Non-Kodak camera)

= (26,736,000 cameras) x ($ 0.026/camera)

+ (2,550,000 cameras) x ($ 0.010/camera)

= $ 720,636

Non-Kodak Cost: represents the cost associated with disposing Non-Kodak cameras

The cost incurred from disposing Non-Kodak cameras is calculated by multiplying the number of recovered Non-Kodak cameras by the incineration cost of 8.2 cents per Non-Kodak cameras, as shown below:

Total Non-Kodak cost
= (Number of Non-Kodak cameras recovered)
x (Disposal cost/Non-Kodak camera)
= (2,550,000 cameras) x ($0.082/camera)
= $ 209,100

Re-manufacturing Cost: represents rebuilding Kodak cameras into the appropriate subassembly

The re-manufacturing costs are only incurred for the Kodak cameras which are re-manufactured. However, each camera model has a different re-manufacturing cost, which does not allow us to multiply out the total cost. Instead, the costs incurred to re-manufacture each camera model are first determined by multiplying the model specific costs by the number of cameras that are re-manufactured for each model. These individual costs are then summed, as shown in Figure 4-1. These costs represent only the inspecting and re-manufacturing costs. They do not include the shipping, rebate, administrative or sorting costs, which are calculated separately. The resulting cost is:

Total re-manufacturing cost = $ 2,479,000

	4th Gen. Flash	3rd Gen. Flash	2nd Gen. Flash	4th Gen. Daylight	3rd Gen. Daylight	2nd Gen. Daylight	2nd Gen. U-water	1st Gen. U-water	Tele	Panoram.	Intersprd.	Non-Kodak	Total
Number of re-mfg. cameras	0	4,754	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,585
Cost/re-mfg. camera	$0.158	$0.151	$0.212	$0.166	$0.133	$0.149	$0.101	$0.119	$0.109	$0.117	$0.193	--	--
TOTAL RE-MFG. COST	$0	$718	$323	$0	$406	$333	$0	$279	$135	$286	$0	--	$2,479

Figure 4-1: Total Re-manufacturing Cost

	4th Gen. Flash	3rd Gen. Flash	2nd Gen. Flash	4th Gen. Daylight	3rd Gen. Daylight	2nd Gen. Daylight	2nd Gen. U-water	1st Gen. U-water	Tele	Panoram.	Intersprd.	Non-Kodak	Total
Number of torn down cameras	0	2,568	914	0	1,302	1,003	0	1,246	775	1,343	0	--	9,151
Cost/torn down camera	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	$0.012	--	--
TOTAL TEAR DOWN COST	$0	$31	$11	$0	$16	$12	$0	$15	$9	$16	$0	--	$110

Figure 4-2: Total Tear Down Cost

Tear down Cost: represents the cost incurred by tearing down the obsolete and damaged cameras

The total tear down cost is determined in the same manner as the total re-manufacturing cost and is shown in Figure 4-2.

Total tear down cost = $ 110,000

4.1.1 Results of Major Cost Sources

The results of the cost analysis are graphed in Figure 4-3, showing that the re-manufacturing cost is the largest cost incurred, making up 34% of the total cost. The re-manufacturing cost is a function of the parts and labor costs. The parts costs are for Kodak's standard parts and it is safe to assume that considerable effort has already gone into making these parts as inexpensively as possible. As mentioned earlier, the employees at The Out-Source are part of the Rochester Rehabilitation Center. Their wages are partially subsidized and the overhead is kept very low. As a result, the labor costs are very reasonable compared to other labor costs in the area. Therefore, only marginal improvements can be expected in the re-manufacturing cost.

The second largest cost is the rebate cost, at 25%. Although this cost is substantial, it is considered an essential incentive for photofinishers. Instead of reducing the rebate, Kodak has considered raising it, in order to improve the number of cameras they recover. The financial impact of this decision is discussed in Chapter 6.

The third and fourth largest costs are the administrative and shipping costs, which account for 16% and 9% of the total cost incurred, respectively. Unlike the re-manufacturing and the rebate cost, the concrete value of receiving and processing the

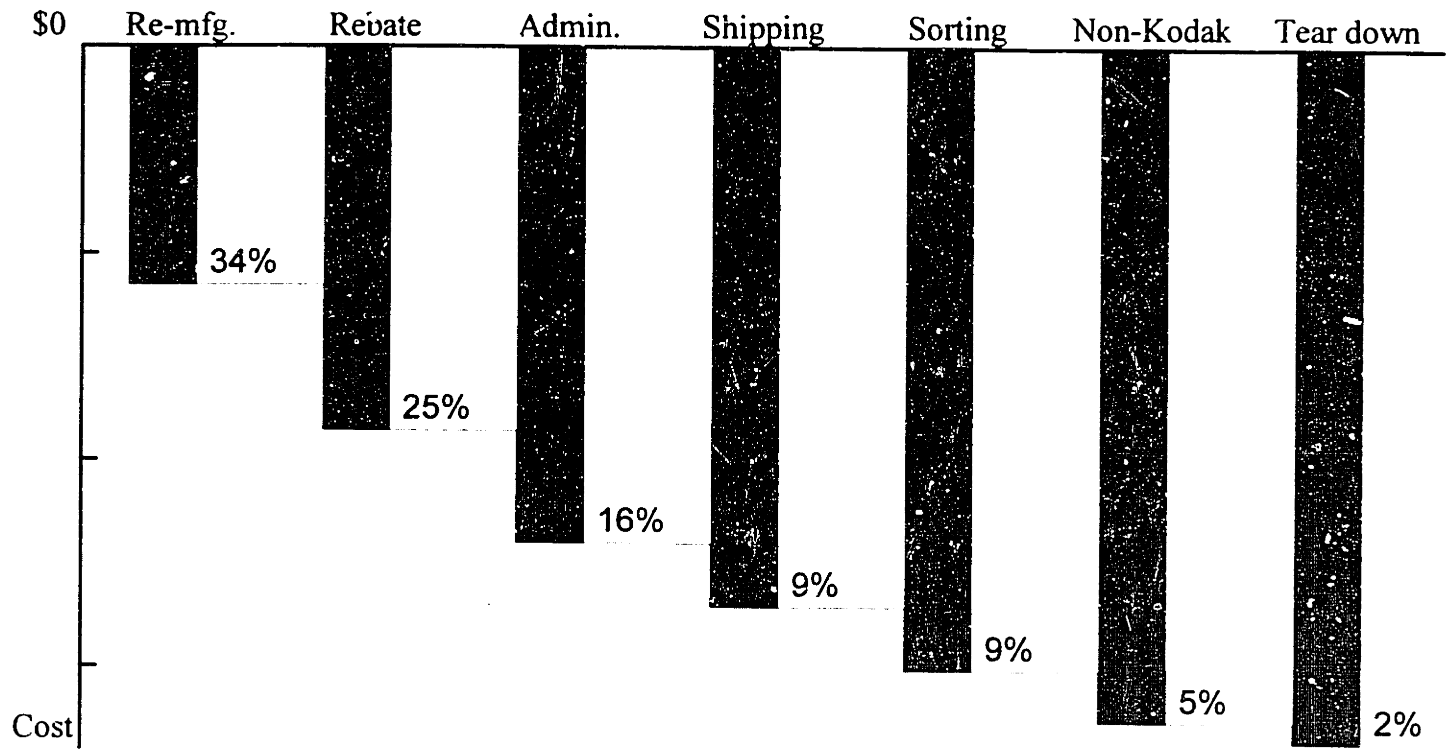


Figure 4-3: Cost Analysis by Sub-process

paperwork is difficult to evaluate. However, Kodak feels that they are spending a disproportionate amount of money on these activities and as a result has decided to simplify the return process. Currently each photofinisher fills out a claim form which states their name, address, identification number, shipping costs incurred and the number of cameras they are returning to Kodak. This claim form is then verified by Kodak and entered into an accounting system, so that a check can be written and sent to the photofinisher. Kodak is currently working with UPS to devise a system that would eliminate the need for this claim form. Instead, each photofinisher would paste their personal identification sticker on the boxes they are sending to The Out-Source, at which point UPS would keep track of the weight of each box and the identification number on it. UPS would then send Kodak a summary sheet which records all shipments sent to The Out-Source from each photofinisher. This would allow Kodak to estimate the number of cameras from the weight of each shipment. Kodak could then automatically reimburse the photofinishers. This process is expected to reduce the administrative, as well as the shipping costs.

4.2 Benefit Sources

The benefit sources can be analyzed by analyzing the total savings realized from each camera model, as shown in Figure 3-20. These savings are graphed in Figure 4-4, illustrating that 69% of the total benefit comes from the 2nd and 3rd generation flash cameras. (The 4th generation camera was not on the market in 1994)

Since the benefit per re-manufactured camera is determined by what it costs to build a new camera subassembly, these savings cannot be improved. However, now that Kodak understands that flash cameras are the profit drivers, they might be able to redesign their recycling process in a way that would allow them to process the high value added flash cameras ahead of the other models.

The cost and benefit source analyses in this chapter provide Kodak with a clear understanding of where their savings and costs are coming from. This understanding can be used to target specific areas for process improvements and subsequently monitor the progress.

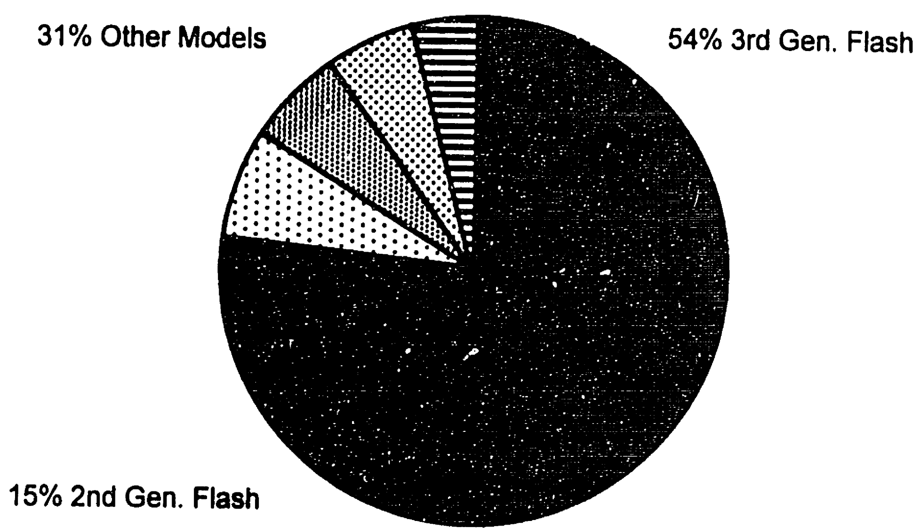


Figure 4-4: Benefit Analysis by Camera Model

Chapter 5

Aid in Investment Decisions

The following three chapters illustrate how the cost/benefit model described in Chapter 3 can be used as a tool in decision making. This chapter discusses how the model can be used in making investment decisions, the following chapter illustrates how the model can be used in making policy decisions, and Chapter 7 describes how the model can be used to decide between different design options.

Kodak is constantly looking for ways to improve the profitability of the recovery program. One way to do this is to reduce the costs of re-manufacturing. However, the cost breakdown described in Section 4.1.1 illustrates that there are no obvious improvement opportunities. The second way to improve the profitability of the system is to increase the benefits realized from the re-manufactured cameras. Since the benefit per camera is predetermined by what it would cost to build a new subassembly, the only opportunity lies in increasing the number of cameras that Kodak re-manufactures. The number of re-manufacturable cameras is dependent on the total number of cameras Kodak receives and the percentage of those cameras that are re-manufacturable.

The cost/benefit model can be used to determine how much Kodak should invest in process improvements which would result in an increase in the number of re-manufacturable cameras. Section 5.1 describes how the return-rate affects the profitability of the system and Section 5.2 illustrates how the profitability is affected by the re-manufacturing yield.

5.1 Benefit of Increased Return Rate

Kodak defines the return rate as the percentage of cameras they receive at The Out-Source divided by the number of Kodak cameras that are sold over the same period of time. This definition is technically incorrect, since the cameras they recover in any particular year are not necessarily the same cameras sold in that year. This return rate also includes Non-Kodak cameras received at The Out-Source. However, over a one year time span this percentage is assumed to approach the actual return rate and is applied as if it were the real return rate throughout this document.

Figure 5-1 shows how this return rate was determined for 1994. In addition, Figure 5-1 illustrates how the number of Non-Kodak cameras, the number of re-manufactured cameras, the number of torn down cameras and the number of cameras built with a refurbished circuit board relate to the total number of cameras recovered in 1994. These percentages are expected to remain constant, as the return rate varies.

Since the return rate affects the total number of cameras, rather than one specific camera model, the cost/benefit model can be applied to the entire system. In order to determine the costs and benefits associated with each camera, the total processing costs have to be averaged over all camera models, as described below.

5.1.1 Averaging the Costs and Benefits in the Model

The costs associated with processing each camera model were first determined by multiplying the number of cameras processed by the cost incurred per camera. These

Yield Determination using 1994 Figures

Total Number of Non-Kodak Cam. sorted	2,550	
Total Number of Re-mfg. Cameras	17,585	
Total Number of Torn Down Cameras	9,151	
Total Number of Cameras with Rebuilt CB	107	
TOTAL NUMBER OF CAMERAS RECOVERED	29,286	
Number of Kodak Cameras Sold	55,345	
Total Number of Cameras Recovered	29,286	
Return Rate		53%
Total Number of Cameras Recovered	29,286	
Total No. of Non-Kodak Cameras sorted	2,550	
Non-Kodak Camera Yield of Total Camera Recovery		9%
Total Number of Cameras Recovered	29,286	
Total Number of Re-mfg. Cameras	17,585	
Re-mfg. Yield of Total Camera Recovery		60%
Total Number of Cameras Recovered	29,286	
Total Number of Torn Down Cameras	9,151	
Tear Down Yield of Total Camera Recovery		31%
Total Number of Cameras Recovered	29,286	
Total Number of cameras with Rebuilt CB	107	
Rebuilt CB Yield of Total Camera Recovery		0.37%

Figure 5-1: Yield Determination

costs were then summed, as shown in Figure 5-2. As an example, the "Total re-mfg. cost" was determined by multiplying the "Number of re-mfg. cameras" by the "Cost/re-mfg. camera" for each model and then summing these individual costs. The average processing costs were then determined by dividing the total cost by the total number of cameras processed. As an example, the "Average cost/re-mfg. camera" was determined by dividing the "Total re-mfg. cost" by the total "Number of re-mfg. cameras".

The benefits are averaged in a similar fashion. The "Total savings of recycling" is divided by the total "Number of re-mfg. subassemblies", which results in the "Average benefit/re-mfg. subassembly", as shown in Figure 5-2.

5.1.2 Analysis of the Return Rate's Effect on Profitability

The averaged numbers can now be used to determine how the profitability of the recovery program would be affected if the return rate was varied. Figure 5-3 illustrates how the net savings realized in 1994 would have been affected by a change in the return rate. The model assumes that the cost incurred to re-manufacture, tear down or rebuild a camera remains constant, regardless of how many cameras The Out-Source would receive. Once again, it is important to point out that the numbers used in this report do not represent Kodak's actual figures.

Below is a description of how the appropriate number of processed cameras shown in Figure 5-3 are determined.

	4th Gen. Flash	3rd Gen. Flash	2nd Gen. Flash	4th Gen. Daylight	3rd Gen. Daylight	2nd Gen. Daylight	2nd Gen. U-water	1st Gen. U-water	Tele	Panoram.	Intersprd.	Non-Kodak	Total
Cost Summary													
No. of Non-Kodak cam. sorted	--	--	--	--	--	--	--	--	--	--	--	2,550	2,550
Cost/Non-Kodak camera	--	--	--	--	--	--	--	--	--	--	--	$0.155	$0.155
TOTAL NON-KODAK COST	--	--	--	--	--	--	--	--	--	--	--	$395	$395
AVERAGE COST/NON-KODAK CAMERA													$0.155
Number of re-mfg. cameras	0	4,754	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,585
Cost/re-mfg. camera	$0.317	$0.310	$0.371	$0.325	$0.292	$0.308	$0.260	$0.278	$0.268	$0.276	$0 352	--	--
TOTAL RE-MFG. COST	$0	$1,474	$565	$0	$891	$688	$0	$652	$331	$674	$0	--	$5,275
AVERAGE COST/RE-MFG. CAMERA													$0.300
Number of torn down cameras	0	2,568	914	0	1,302	1,003	0	1,246	775	1,343	0	--	9,151
Cost/torn down camera	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	--	--
TOTAL TEAR DOWN COST	$0	$439	$156	$0	$223	$172	$0	$213	$133	$230	$0	--	$1,565
AVERAGE COST/TORN DOWN CAMERA													$0.171
Number of cameras with rebuilt CB	0	107	--	--	--	--	--	--	--	--	--	--	107
Cost/camera with rebuilt CB	$0.811	$0.781	--	--	--	--	--	--	--	--	--	--	--
TOTAL REBUILT CB COST	$0	$84	--	--	--	--	--	--	--	--	--	--	$84
AVERAGE COST/CAM. W/ REBUILT CB													$0.781
Benefit Summary													
Number of re-mfg. subassemblies	0	4,861	1,523	0	3,052	2,234	0	2,345	1,234	2,443	0	--	17,692
Value/re-mfg. subassembly	$2.555	$2.456	$2.145	$1.001	$0.456	$0.564	$0.654	$0.678	$0.622	$0.768	$0.898	--	--
TOTAL SAVINGS OF RECYCLING	$0	$11,939	$3,267	$0	$1,392	$1,260	$0	$1,590	$768	$1,876	$0	$0	$22,091
AVERAGE SAVINGS/RE-MFG. SUBASM.													$1.249

Figure 5-2: Average Values for Costs and Benefits

	1994 Return Rate 53%	Return Rate 50%	Return Rate 60%	Return Rate 70%	Return Rate 80%	Return Rate 90%	Return Rate 100%
Number of Kodak Cameras Sold	55,345	55,345	55,345	55,345	55,345	55,345	55,345
Return Rate	53%	50%	60%	70%	80%	90%	100%
Total Number of Cameras Recovered	29,286	27,673	33,207	38,742	44,276	49,811	55,345
Cost Summary							
Non-Kodak Cam. Yield of Total Cam. Recovery	9%	9%	9%	9%	9%	9%	9%
Total No. of Non-Kodak cam. sorted	2,550	2,410	2,891	3,373	3,855	4,337	4,819
Average Cost/Non-Kodak Camera	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155
Re-mfg. Yield of Total Camera Recovery	60%	60%	60%	60%	60%	60%	60%
Total Number of Re-mfg. Cameras	17,585	16,616	19,939	23,263	26,586	29,909	33,232
Average Cost/Re-mfg. Camera	$0.300	$0.300	$0.300	$0.300	$0.300	$0.300	$0.300
Tear Down Yield of Total Camera Recovery	31%	31%	31%	31%	31%	31%	31%
Total Number of Torn Down Cameras	9,151	8,647	10,376	12,106	13,835	15,564	17,294
Average Cost/Torn Down Camera	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171
Rebuilt CB Yield of Total Camera Recovery	0.37%	0.37%	0.37%	0.37%	0.37%	0.37%	0.37%
Total Number of Cameras with Rebuilt CB	107	101	121	142	162	182	202
Average Cost/Camera with Rebuilt CB	$0.781	$0.781	$0.781	$0.781	$0.781	$0.781	$0.781
TOTAL COST OF RECYCLING	$7,319	$6,916	$8,299	$9,682	$11,065	$12,449	$13,832
Benefit Summary							
Total Number of Re-mfg. Subassemblies	17,692	16,717	20,061	23,404	26,748	30,091	33,435
Average Savings/Re-mfg. Subassembly	$1.249	$1.249	$1.249	$1.249	$1.249	$1.249	$1.249
TOTAL SAVINGS OF RECYCLING	$22,097	$20,880	$25,056	$29,232	$33,408	$37,584	$41,760
Profitability Summary							
TOTAL SAVINGS OF RECYCLING	$22,097	$20,880	$25,056	$29,232	$33,408	$37,584	$41,760
TOTAL COST OF RECYCLING	$7,319	$6,916	$8,299	$9,682	$11,065	$12,449	$13,832
NET SAVINGS OF RECYCLING	$14,778	$13,964	$16,757	$19,550	$22,342	$25,135	$27,928
DIFFERENCE IN NET SAVINGS =	**0**	**($814)**	**$1,979**	**$4,771**	**$7,564**	**$10,357**	**$13,150**

Figure 5-3: Summary for Return Rate's Effect on Net Savings

Total Number of Non-Kodak Cameras

The number of Non-Kodak cameras is determined by applying the "Non-Kodak Camera Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-3. This yield, shown in Figure 5-1 to be 9%, is expected to remain constant as the return rate varies.

Total Number of Re-mfg. Cameras

The number of re-manufactured cameras is determined by applying the "Re-mfg. Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-3. This yield, shown in Figure 5-1 to be 60%, is expected to remain constant as the return rate varies.

Total Number of Torn Down Cameras

The number of torn down cameras is determined by applying the "Tear Down Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-3. This yield, shown in Figure 5-1 to be 31%, is expected to remain constant as the return rate varies.

Total Number of Cameras with Rebuilt CB

The number of cameras assembled with rebuilt circuit boards is determined by applying the "Rebuilt CB Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-3. This yield, shown in Figure 5-1 to be 0.37%, is expected to remain constant as the return rate varies.

Total Number of Re-mfg. Subassemblies

The total number of cameras built from a re-manufactured subassembly is determined by adding the number of re-manufactured cameras and the number of cameras built from a refurbished circuit board.

Figure 5-3 numerically summarizes how the net saving realized from recovering single-use cameras is affected by the return rate. These results, which are graphed in Figure 5-4, indicate that a 100% return rate would increase Kodak's net savings by over $13 million.

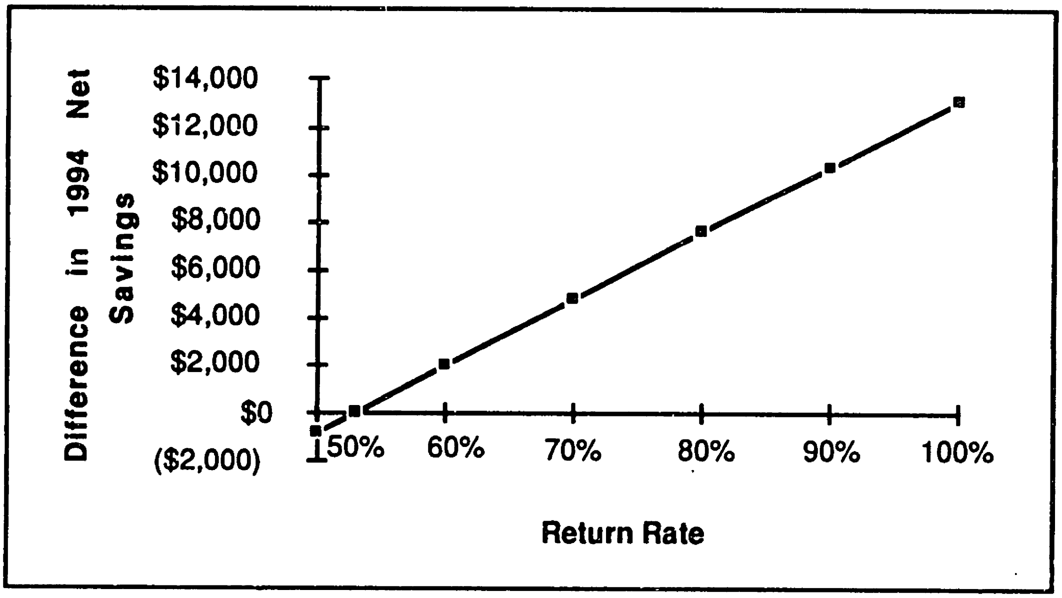


Figure 5-4: Net Savings versus the Return Rate

Clearly, the results found in Figure 5-4 ignore the additional cost required to increase the return rate. In order to realize a higher return rate, Kodak would have to either increase the rebate to photofinishers, simplify the recovery process, or educate consumers and photofinishers about the recovery process. Including these costs would make the savings realized from a higher return rate begin to decrease once these marginal costs exceed the marginal benefit from recovery. The actual savings from a higher return rate would therefore look similar to the curve shown in Figure 5-5. Since it would be very expensive and difficult to obtain an accurate graph of this curve, the line in Figure 5-4 offers Kodak a useful alternative. Figure 5-4 can be used to determine the maximum price Kodak should pay to increase the return rate by an additional percent. For example, Figure 5-4 shows that Kodak should invest a maximum of $1.9 million to improve the return rate from the current 53% to 60%.

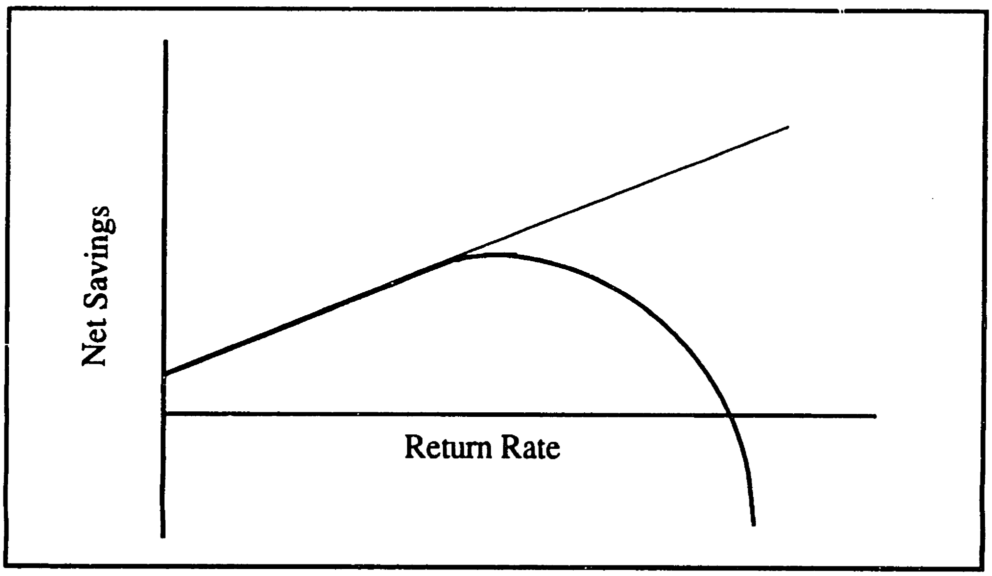


Figure 5-5: Approximation of Actual Net Savings vs. Return Rate

5.2 Benefit of Increased Re-manufacturing Yield

The previous section described how an increase in the return rate increases the number of re-manufacturable cameras Kodak recovers, which in turn increases the net savings associated with recycling single-use cameras. The second way to increase the number of cameras Kodak re-manufactures is to improve the re-manufacturing yield of the cameras Kodak currently receives, as defined in Figure 5-1.

The cost/benefit model can be used to determine how an increase in the re-manufacturing yield would affect Kodak's net savings. Although the re-manufacturing yield differs for each camera model, Kodak chose to analyze how a general improvement in the yield would affect their savings. As a result, the averaged model is used again, as discussed in the following section.

5.2.1 Analysis of the Re-manufacturing Yield's Effect on Profitability

Figure 5-6 illustrates how the net savings realized in 1994 would have been affected by a change in the re-manufacturing yield. The average costs incurred per processed camera and the average savings realized per re-manufactured subassembly were determined in Section 5.1.1. As shown in Figure 5-6, the costs associated with re-manufacturing, tearing down and rebuilding cameras remain constant, regardless of how many cameras are processed.

Below is a description of how the appropriate number of processed cameras, shown in Figure 5-6 are determined.

Total Number of Non-Kodak Cameras

The number of Non-Kodak cameras is determined by applying the "Non-Kodak Camera Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-6. This yield, shown in Figure 5-1 to be 9%, is expected to remain constant as the return rate varies.

	1994 Re-mfg Yield 60%	Re-mfg. Yield 65%	Re-mfg. Yield 70%	Re-mfg. Yield 75%	Re-mfg. Yield 80%	Re-mfg. Yield 85%	Re-mfg. Yield 90%	Re-mfg. Yield 91%
Number of Kodak Cameras Sold	55,345	55,345	55,345	55,345	55,345	55,345	55,345	55,345
Return Rate	53%	53%	53%	53%	53%	53%	53%	53%
Total Number of Cameras Recovered	29,286	29,286	29,286	29,286	29,286	29,286	29,286	29,286
Cost Summary								
Non-Kodak Cam. Yield of Total Cam. Recovery	9%	9%	9%	9%	9%	9%	9%	9%
Total No. of Non-Kodak cam. sorted	2,550	2,550	2,550	2,550	2,550	2,550	2,550	2,550
Average Cost/Non-Kodak Camera	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155
Re-mfg. Yield of Total Camera Recovery	60%	65%	70%	75%	80%	85%	90%	91%
Total Number of Re-mfg. Cameras	17,585	19,036	20,500	21,965	23,429	24,893	26,357	26,736
Average Cost/Re-mfg. Camera	$0.300	$0.300	$0.300	$0.300	$0.300	$0.300	$0.300	$0.300
Tear Down Yield of Total Camera Recovery	31%	31%	31%	31%	31%	31%	31%	31%
Total Number of Torn Down Cameras	9,151	9,151	9,151	9,151	9,151	9,151	9,151	9,151
Average Cost/Torn Down Camera	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171	$0.171
Rebuilt CB Yield of Total Camera Recovery	0.37%	0.37%	0.37%	0.37%	0.37%	0.37%	0.37%	0.37%
Total Number of Cameras with Rebuilt CB	107	107	107	107	107	107	107	107
Average Cost/Camera with Rebuilt CB	$0.781	$0.781	$0.781	$0.781	$0.781	$0.781	$0.781	$0.781
TOTAL COST OF RECYCLING	$7,319	$7,754	$8,194	$8,633	$9,072	$9,512	$9,951	$10,064
Benefit Summary								
Total Number of Re-mfg. Subassemblies	17,692	19,143	20,607	22,072	23,536	25,000	26,464	26,843
Average Savings/Re-mfg. Subassembly	$1.249	$1.249	$1.249	$1.249	$1.249	$1.249	$1.249	$1.249
TOTAL SAVINGS OF RECYCLING	$22,097	$23,909	$25,738	$27,567	$29,396	$31,225	$33,054	$33,527
Profitability Summary								
TOTAL SAVINGS OF RECYCLING	$22,097	$23,909	$25,738	$27,567	$29,396	$31,225	$33,054	$33,527
TOTAL COST OF RECYCLING	$7,319	$7,754	$8,194	$8,633	$9,072	$9,512	$9,951	$10,064
NET SAVINGS OF RECYCLING	$14,778	$16,155	$17,545	$18,934	$20,324	$21,714	$23,103	$23,462
DIFFERENCE IN NET SAVINGS =	**0**	**$1,377**	**$2,767**	**$4,156**	**$5,546**	**$6,935**	**$8,325**	**$8,684**

Figure 5-6: Summary for Re-mfg. Yield's Effect on Net Savings

Total Number of Re-mfg. Cameras

The number of re-manufactured cameras is determined by applying the "Re-mfg. Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-6. This yield was determined to be 60% in 1994, as shown in Figure 5-1. In order to get an understanding of how the net savings are affected by a change in the number of re-manufactured cameras, the re-manufacturing yield is increased to 91%, as shown in Figure 5-6. This percentage represents the theoretical maximum re-manufacturing yield, at which point every recovered Kodak camera would be re-manufactured, given a constant Non-Kodak camera yield of 9%.

Total Number of Torn Down Cameras

The number of torn down cameras is determined by applying the "Tear Down Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-6. This yield, shown in Figure 5-1 to be 31%, is expected to remain constant as the return rate varies.

Total Number of Cameras with Rebuilt CB

The number of cameras with rebuilt circuit boards is determined by applying the "Rebuilt CB Yield of Total Camera Recovery" to the total number of recovered cameras, as shown in Figure 5-6. This yield, shown in Figure 5-1 to be 0.37%, is expected to remain constant as the return rate varies.

Total Number of Re-mfg. Subassemblies

The total number of cameras built from a re-manufactured subassembly is determined by adding the number of re-manufactured cameras and the number of cameras built from a refurbished circuit board.

Figure 5-6 numerically summarizes how the net savings realized from recovering single-use cameras is affected by the re-manufacturing yield. These results, which are graphed in Figure 5-7 indicate that a re-manufacturing yield of 91% would increase Kodak's net savings by over $ 8.6 million.

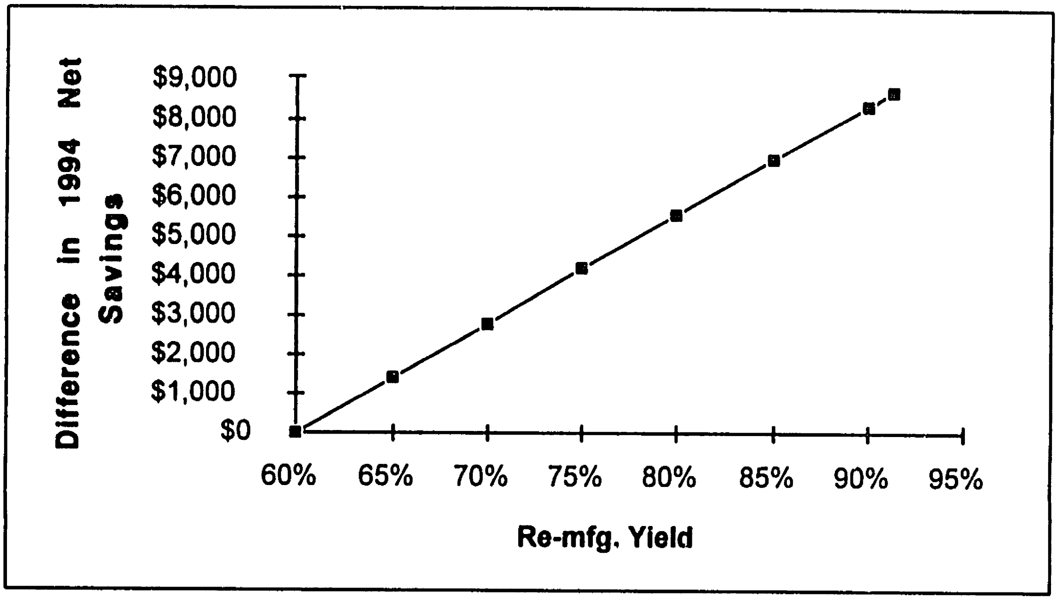


Figure 5-7: Net Savings versus the Re-manufacturing Yield

As was the case when evaluating an increase in the return rate, the results in Figure 5-7 do not take into account the additional costs required to increase the re-manufacturing yield. Taking an extreme case, Kodak would have to investment millions of dollars to manufacture an indestructible camera that would allow for each recovered camera to be re-manufactured. Consequently, the actual shape of the curve representing the increased savings resulting from a higher re-manufacturing yield would be similar to the curve found in Figure 5-8. Nevertheless, Kodak may use the line found in Figure 5-7 to determine the maximum investment it should make in order to increase the re-manufacturing yield by an additional percent. For example, Figure 5-7 shows that Kodak should invest a maximum of $1.3 million to increase the re-manufacturing yield by 5%.

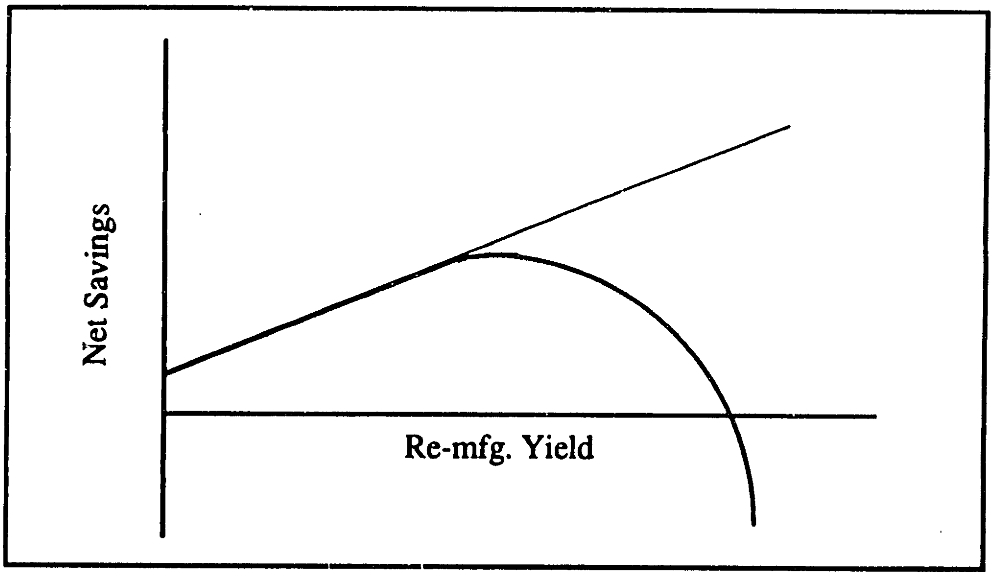


Figure 5-8: Approximation of Actual Net Savings vs. Re-mfg. Yield

Chapter 6

Aid in Policy Decisions

This chapter describes a situation wherein Kodak used the model to make policy decisions relating to the recovery program. Section 4.1.1 illustrated that the rebate paid to photofinishers represents the 2nd largest cost in the recycling process. However, instead of reducing the rebate, Kodak had been considering expanding the rebate program into other regions and/or increasing the amount paid to photofinishers. Kodak anticipated that an increase in the incentive provided to photofinishers would result in an increased number of recovered cameras. As discussed in Section 5.1, this increase in the return rate would improve Kodak's net savings.

Section 6.1 describes how the model was used to decide whether it is financially attractive to expand the rebate program into Canada. Section 6.2 describes how the correct amount of rebate payment can be determined using the cost/benefit model. The values used in this chapter are again fictitious and serve only to illustrate the examples.

6.1 Expand Rebate Program

Kodak has been paying photofinishers in the United States for each used single-use camera returned to The Out-Source since the recycling program was first initiated in 1990. However, each international division decided the structure of their own country's recovery program and therefore could choose how to encourage photofinishers to return cameras. For example, Kodak-Canada had been making contributions to the World Wildlife Fund for each camera they received. More recently, however, Kodak-Canada had been considering adapting the U.S. rebate program in order to increase the number of cameras received. The cost/benefit model was used to evaluate the financial impact of this policy decisions. Kodak was considering paying photofinishers in Canada five cents per camera. Initial forecasts projected a 10% increase in the number of recovered cameras.

The proposed rebate, as well as the return increases stated above, were averaged over all camera models. Therefore, the averaged model described in Section 5.1.1 was again applied here.

6.1.1 Analysis of the Rebate Program's Effect on Profitability

This section discusses how the profitability of the recovery program would be affected, by providing Canadian photofinishers with a rebate. The resulting net savings over the next two years are shown in Figure 6-1.

Below is a description of how the appropriate entries in Figure 6-1 were determined.

Average Costs

Section 5.1.1 discussed how the average costs were determined for each process. These costs include the seven cents rebate per camera paid to the photofinishers in the United States. Since Kodak does not reimburse photofinishers in Canada, these costs are inaccurate. However, there are increased costs associated with collecting the cameras first in Canada, storing them and then shipping them to The Out-Source. Kodak assumed

	Data Sources (Description in Section 6.1.1)	Without Rebate 1995	Without Rebate 1996	¢5/cam. Rebate 1995	¢5/cam. Rebate 1996
Cost Summary	(Numbers in 000s)				
Total No. of Non-Kodak cam. sorted	Incr. by 10% with rebate	306	320	337	352
Average Cost/Non-Kodak camera	Remains constant with rebate	$0.155	$0.155	$0.155	$0.155
Total Number of re-mfg. çameras	Incr. by 10% with rebate	1,836	1,920	2,020	2,112
Average Cost/re-mfg. camera	Incr. by 5¢/camera with rebate	$0.300	$0.300	$0.350	$0.350
Total Number of torn down cameras	Incr. by 10% with rebate	1,224	1,280	1,346	1,408
Average Cost/torn down camera	Incr. by 5¢/camera with rebate	$0.171	$0.171	$0.221	$0.221
Total Number of cameras with rebuilt CB	Incr. by 10% with rebate	44	46	48	51
Average Cost/camera with rebuilt CB	Remains constant - already counted in tear down	$0.781	$0.781	$0.770	$0.770
TOTAL COST OF RECYCLING		$842	$880	$1,094	$1,144
Benefit Summary					
Total Number of re-mfg. subassemblies	Incr. by 10% with rebate	1,880	1,966	2,068	2,163
Average Savings/re-mfg. subassembly	Remains constant - Value of a virgin camera	$1.249	$1.249	$1.249	$1.249
TOTAL SAVINGS OF RECYCLING		$2,348	$2,456	$2,583	$2,701
Profitability Summary					
TOTAL SAVINGS OF RECYCLING		$612	$612	$612	$612
TOTAL COST OF RECYCLING		$534	$534	$534	$534
NET SAVINGS OF RECYCLING		$1,506	$1,575	$1,489	$1,557
NET SAVINGS FOR RECYCLING IN 1995 & 1996		$3,081		$3,046	
DIFFERENCE IN NET SAVINGS =		**$0**		**($35)**	

Figure 6-1: Summary for Canada Rebate Program

that these increased costs were approximately equal to the seven cents saved by not paying a rebate. Therefore the costs used in the averaged model of the previous chapter have been applied to this example. Kodak expected these costs to remain constant in 1995 and 1996 without the rebate. However, the average cost per re-manufactured camera and the average cost per torn down camera would increase by five cents per camera if the rebate program were to be initiated.

Average Savings/re-mfg. subassembly

The average savings per subassembly built from a recovered camera was determined in Section 5.1.1. This saving is independent of the rebate and of the number of cameras recovered and therefore remains constant.

Total No. of Non-Kodak cameras sorted

The number of Non-Kodak cameras depends on the total number of cameras returned to The Out-Source. The number of returned cameras was estimated from the sales forecasts for 1995 and 1996. Historic data showed that Kodak recovered a total of 29,286,000 cameras in 1994, which corresponded to 45% of their sales in 1994. Kodak assumed that this total return rate approximated the return rate realized in Canada. This return rate was not expected to increase in 1995 or 1996, if Kodak did not institute the rebate program.

The return rate could then be applied to the sales forecast for 1995 and 1996, which yielded the total number of cameras Kodak could expect to recover from Canada without the rebate during the next two years.

In order to determine how many of these cameras would be Non-Kodak cameras, the historic yield was analyzed. Data showed that 10% of Kodak's returns from Canada were

Non-Kodak cameras. This Non-Kodak yield was expected to remain constant over the next two years regardless of the rebate program. Kodak could then estimate the number of Non-Kodak cameras they could expect to receive from Canada as described below:

Without Rebate:

1995: Total Number of Non-Kodak cameras
= (return rate) x (sales forecasts for 1995) x (Non-Kodak yield)
= (45%) x (6,800,000 cameras) x (10%)
= 306,000 cameras

1996: Total Number of Non-Kodak cameras
= (return rate) x (sales forecasts for 1996) x (Non-Kodak yield)
= (45%) x (7,111,000 cameras) x (10%)
= 320,000 cameras

With Rebate:

Kodak expected the number of recovered cameras to increase by 10% due to the rebate. They assumed that this 10% increase would be constant for each type of camera received. As a result, the expected number of Non-Kodak cameras with the rebate program was calculated by simply increasing the number of cameras Kodak had expected without a policy change by 10%, as shown below:

1995: Total Number of Non-Kodak cameras
= (100% + 10%)
x (Total Number of Non-Kodak cameras without rebate)
= (110%) x (306,000 cameras)
= 336,600 cameras

1996: Total Number of Non-Kodak cameras
= (100% + 10%)
x (Total Number of Non-Kodak cameras without rebate)
= (110%) x (320,000 cameras)
= 352,000 cameras

Total Number of re-mfg. cameras

The number of re-manufactured cameras was determined in a similar manner to the number of Non-Kodak cameras. The return rate was calculated above as 45%, which was again applied to the Canadian sales forecast to determine the number of recovered cameras. In order to determine how many of these recovered cameras can be re-manufactured, the historic yield was analyzed. In 1994, Kodak re-manufactured 17,585,000 cameras from the 29,286,000 cameras they recovered, which translates into an average re-manufacturing yield of 60%. This re-manufacturing yield was also assumed to approximate the Canadian re-manufacturing yield and was expected to remain constant for 1995 and 1996.

Kodak could then calculate the number of cameras they could expect to re-manufacture from their Canadian receipts as follows.

Without Rebate:

1995: Total Number of re-mfg. cameras
= (return rate) x (sales forecast for 1995) x (re-mfg. yield)
= (45%) x (6,800,000 cameras) x (60%)
= 1,836,000 cameras

1996: Total Number of re-mfg. cameras
= (return rate) x (sales forecast for 1996) x (re-mfg. yield)
= (45%) x (7,111,000 cameras) x (60%)
= 1,919,970 cameras

With Rebate:

The rebate will cause a 10% increase in the number of re-mfg. cameras, as was the case for the Non-Kodak cameras.

1995: Total Number of re-mfg. cameras

= (100% + 10%)

x (Total Number of re-mfg. cameras without rebate)

= (110%) x (1,836,000 cameras)

= 2,019,600 cameras

1996: Total Number of re-mfg. cameras

= (100% + 10%)

x (Total Number of re-mfg. cameras without rebate)

= (110%) x (1,919,970 cameras)

= 2,111,967 cameras

Total Number of torn down cameras

The number of torn down cameras was determined in the same manner as the number of Non-Kodak and re-manufactured cameras. The return rate remained constant and the tear down yield was determined as shown below:

Tear down yield = 1 - re-mfg. yield

As a result, the tear down cost was determined as shown.

Without Rebate:

1995: Total Number of torn down cameras

= (return rate) x (sales forecast for 1995) x (100% - re-mfg. yield)

= (45%) x (6,800,000 cameras) x (100% - 60%)

= 1,224,000 cameras

1996: Total Number of torn down cameras

= (return rate) x (sales forecast for 1996) x (100% - re-mfg. yield)

= (45%) x (7,111,000 cameras) x (100% - 60%)

= 1,279,980 cameras

With Rebate:

The rebate will cause a 10% increase in the number of torn down cameras, as was the case for the Non-Kodak and re-manufactured cameras.

1995: Total Number of torn down cameras
= (100% + 10%)
x (Total Number of torn down cameras without rebate)
= (110%) x (1,224,000 cameras)
= 1,346,400 cameras

1996: Total Number of torn down cameras
= (100% + 10%)
x (Total Number of torn down cameras without rebate)
= (110%) x (1,279,980 cameras)
= 1,407,978 cameras

Total Number of cameras with rebuilt CB

The number of cameras with rebuilt circuit boards is dependent on how many loose circuit boards are collected during the sorting process and how many circuit boards are taken out of flash cameras which are being torn down. However, some of these recovered circuit boards are badly damaged and cannot be refurbished.

The number of refurbished circuit boards was calculated by estimating the number of loose boards that are recovered and the refurbishing yield that can be expected. For this purpose, Kodak assumed that the number of loose circuit boards equals the number of torn down flash cameras. In 1994, Kodak tore down a total of 9,151,000 flash cameras, which represents 31% of the total number of torn down cameras. Historic data showed that in 1994, 11.6% of those circuit boards could be refurbished. This yield is assumed to be equal to the Canadian yield.

Kodak could therefore estimate the number of cameras with rebuilt circuit boards for 1995 and 1996 as follows.

Without Rebate:

1995: Number of cameras with rebuilt CB
= (Number of torn down cameras in 1995) x (percentage of flash cameras)
x (refurbishing yield)
= (1,224,000 cameras) x (31%) x (11.6%)
= 44,000 cameras

1996: Number of cameras with rebuilt CB
+ (Number of torn down cameras in 1996) x (percentage of flash cameras)
x (refurbishing yield)
= (1,279,980 cameras) x (31%) x (11.6%)
= 46,000 cameras

With Rebate:

The rebate will cause a 10% increase in the number of cameras assembled with a refurbished circuit board, as was the case for the Non-Kodak and re-manufactured cameras.

1995: Total Number of cameras with rebuilt CB
= (100% + 10%)
x (Total Number of cameras with rebuilt CB without rebate)
= (110%) x (44,000 cameras)
= 48,400 cameras

1996: Total Number of cameras with rebuilt CB
= (100% + 10%)
x (Total Number of cameras with rebuilt CB without rebate)
= (110%) x (46,000 cameras)
= 50,600 cameras

Total Number of re-mfg. subassemblies

The number of subassemblies that come from recovered cameras could be determined by adding the number of re-manufactured cameras and the number of cameras with refurbished circuit boards, as shown below.

Without Rebate:

1995: Total Number of re-mfg. subassemblies
= (Number of re-mfg. cameras in 1995)
+ (Number of cameras with rebuilt CB in 1995)
= 1,836,000 cameras + 44,000 cameras
= 1,880,000 cameras

1996: Total Number of re-mfg. subassemblies
= (Number of re-mfg. cameras in 1996)
+ (Number of cameras with rebuilt CB in 1996)
= 1,919,970 cameras + 46,000 cameras
= 1,965,970 cameras

With Rebate:

1995: Total Number of re-mfg subassemblies
= (Number of re-mfg. cameras in 1995)
+ (Number of cameras with rebuilt CB in 1995)
= 2,019,600 cameras + 48,400 cameras
= 2,068,000 cameras

1996: Total Number of re-mfg. subassemblies
= (Number of re-mfg. cameras in 1996)
+ (Number of cameras with rebuilt CB in 1996)
= 2,111,967 cameras + 50,600 cameras
= 2,162,567 cameras

The cost/benefit model in Figure 6-1 shows that the net savings would be reduced by $35,000 if Kodak reimbursed photofinishers in Canada with a five cents per camera rebate. However, as in any decision, the financial implications are only one consideration. Kodak now has an understanding of the costs involved in this decision and can balance these costs against the environmental benefit of increasing the number of cameras diverted from the waste stream by 10%. In addition, Kodak must keep in mind that the actual net savings, with or without the rebate program, are dependent on the actual sales figures for 1995 and 1996. This dependency on uncertain sales forecasts is an issue in all the subsequent examples.

6.2 Determine Rebate Level

The cost/benefit model was also used to determine the "correct" amount of rebate to pay the photofinishers for each returned camera. Recently Kodak has been faced with companies competing with them to buy the used single-use camera bodies from photofinishers in the United States. These companies re-manufacture the cameras they purchase and then resell them at a significant discount. As a result, Kodak had been considering increasing the rebate paid to U.S. photofinishers. However, Kodak wanted to understand by how much the recovery stream would have to grow, or by how much the return rate would have to increase in order to offset the additional costs of this higher rebate.

The averaged version of the cost/benefit model was again used. However, in this application the expected increase in returned cameras was unknown. The easiest way to determine the relationship between a five cents increase in rebate and an increase in the return rate, was to enter the increased cost into the model and then vary the percentage that the return rate is increased by until the higher net savings match the increased costs.

Since this represents an extension of the application described Section 6.1, this section will only provide an abbreviated overview of the example. The results of this procedure are shown in Figure 6-2, which illustrates that an increase of 9.947% in the return rate would offset the five cents increase in the rebate.

	Rebate: Current Return Rate: Current	Rebate: 5¢ Increase Return Rate: Current	Rebate: 5¢ Increase Return Rate: Increased by 10.000%	Rebate: 5¢ Increase Return Rate: Increased by 9.000%	Rebate: 5¢ Increase Return Rate: Increased by 9.700%	Rebate: 5¢ Increase Return Rate: Increased by 9.947%
Cost Summary						
Total No. of Non-Kodak cam. sorted	2,550	2,550	2,805	2,780	2,797	2,804
Average Cost/Non-Kodak camera	$0.155	$0.155	$0.155	$0.155	$0.155	$0.155
Total Number of re-mfg. cameras	17,585	17,585	19,344	19,168	19,291	19,334
Average Cost/re-mfg. camera	$0.300	$0.350	$0.350	$0.350	$0.350	$0.350
Total Number of torn down cameras	9,151	9,151	10,066	9,975	10,039	10,061
Average Cost/torn down camera	$0.171	$0.221	$0.221	$0.221	$0.221	$0.221
Total Number of cameras with rebuilt CB	107	107	118	117	117	118
Average Cost/camera with rebuilt CB	$0.781	$0.781	$0.781	$0.781	$0.781	$0.781
TOTAL COST OF RECYCLING	$7,319	$8,656	$9,522	$9,435	$9,496	$9,517
Benefit Summary						
Total Number of re-mfg. subassemblies	17,692	17,692	19,461	19,284	19,408	19,452
Average Savings/re-mfg. subassembly	$1.249	$1.249	$1.249	$1.249	$1.249	$1.249
TOTAL SAVINGS OF RECYCLING	$22,097	$22,097	$24,307	$24,086	$24,241	$24,295
Profitability Summary						
TOTAL SAVINGS OF RECYCLING	$22,097	$22,097	$24,307	$24,086	$24,241	$24,295
TOTAL COST OF RECYCLING	$7,319	$8,656	$9,522	$9,435	$9,496	$9,517
NET SAVINGS OF RECYCLING	$14,778	$13,441	$14,786	$14,651	$14,745	$14,778
DIFFERENCE IN NET SAVINGS	**$0**	**($1,337)**	**$7**	**($127)**	**($33)**	**$0**

Figure 6-2: Summary for Increased Rebate

Chapter 7

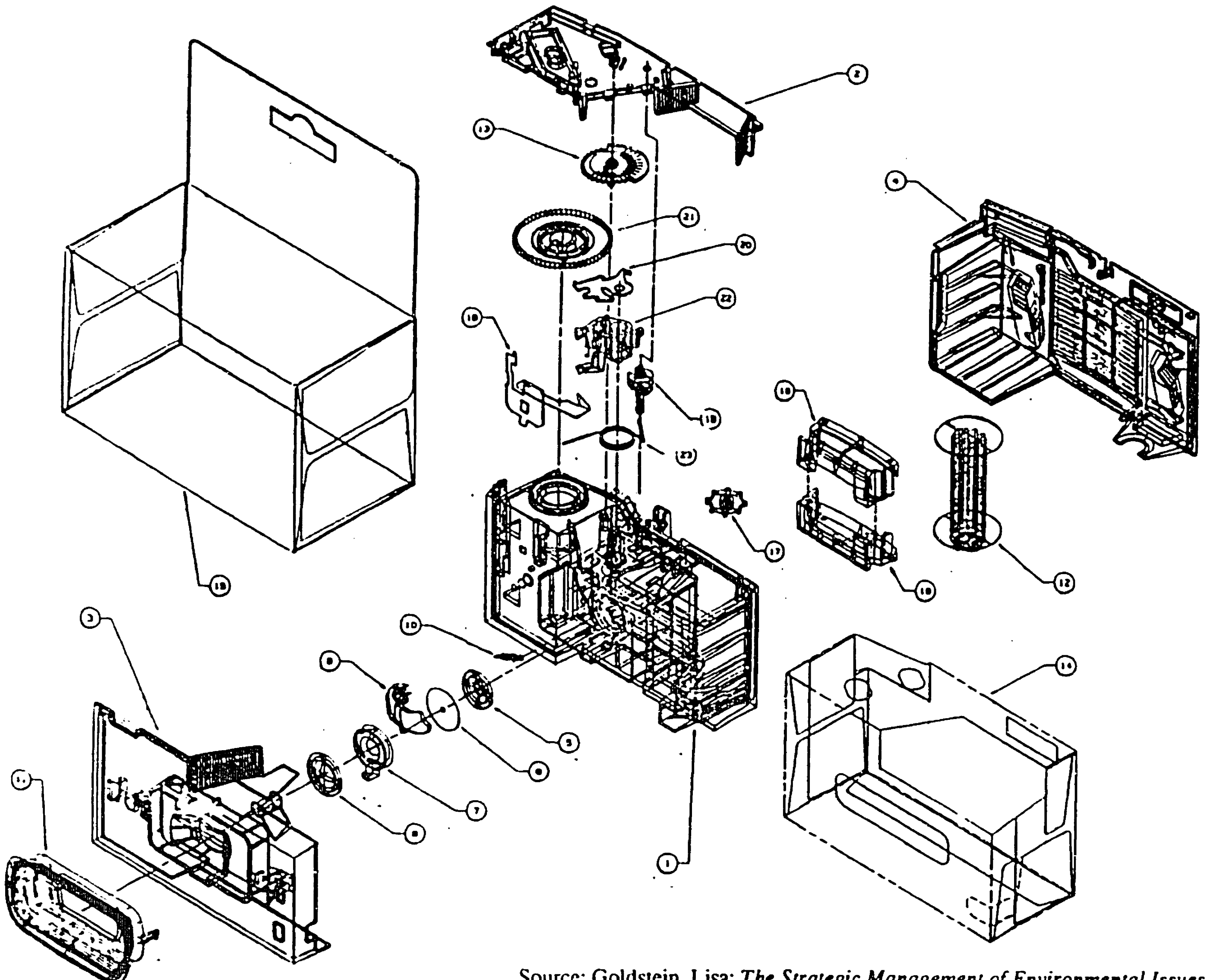
Aid in Design Decisions

This chapter describes two cases where the cost/benefit model was used to decide between different design options, by providing an estimate of how each design option would affect the profitability of recovering and re-manufacturing that particular camera model. Section 7.1 describes how the model was utilized to aid in a design decision concerning an existing camera model. Section 7.2 will address a similar decision between two design options on a next generation camera.

7.1 Existing Camera Redesign

This section describes the results of applying the cost/benefit model to a decision regarding the redesign of the lens mechanism for the existing panoramic camera model. As explained in previous chapters, the numbers cited in this example are fictitious.

The camera design team had come up with three different design variations which would alter the existing camera to varying degrees. The most drastic proposal (Option 1) included a redesigned frame, as well as a new shutter blade, a new lens spacer, a new front baffle and a new front cover. See Figure 7-1 for a schematic of the panoramic camera. Option 2 and 3 contained the same number of new parts as Option 1, however the frame design remained unaltered in these options. Option 2 was identical to Option 3, with the exception of the re-manufacturing and final assembly process. The design team



1 FRAME
2 TOP COVER
3 FRONT COVER
4 REAR COVER
5 REAR LENS
6 STOP
7 LENS SPACER
8 FRONT LENS
9 SHUTTER
10 SHUTTER SPRING
11 FUNNEL
12 SPOOL
13 COUNTER
14 BOX
15 HANGING BOX
16 LIGHT BAFFLE
17 SPROCKET
18 CAM
19 LATCH
20 METERING LEVER
21 THUMBWHEEL
22 HIGH ENERGY LEVER
23 H.E.L. SPRING

Source: Goldstein, Lisa: *The Strategic Management of Environmental Issues: A Case Study of Kodak's Single-Use Cameras*, Massachusetts Institute of Technology, Cambridge, MA (May 1994) p. 23

Figure 7-1: Exploded View Drawing of Panoramic Camera developed a design that would maintain the current re-manufacturing and final assembly process in Option 2, while these operations would have to be performed manually in Option 3 . Naturally, the capital investment needed for each one of these options differed and each design alteration would result in a different quality levels. In addition, each one of these design options was going to affect the recovery program differently. In order to understand the total financial impact of changing the design of an existing camera model, Kodak needed to consider how high the "lost savings" would be, if all the cameras already in the recycling stream would need to be modified or if they were to become obsolete. Naturally, any such estimate would need to consider the uncertainty of the sales forecast assumptions.

Figure 7-2 shows the expected net savings for each design option. The results were obtained using the cost/benefit model described in Chapter 3 for the panoramic camera and include the net savings for 1995 as well as 1996. The option of continuing to produce the existing design is included as Option 0.

Below is a description of how the appropriate entries in Figure 7-2 were determined.

Number of re-mfg. cameras

The number of re-manufactured cameras was determined in the same way as in the "averaged" model of the previous chapter. Historic data showed that Kodak recovered 3,789,000 panoramic cameras in 1994, which corresponds to 48% of their panoramic sales in 1994. Due to improvements in the recovery procedure and some other initiatives, Kodak expected this return rate to increase for the panorama model to 52% in 1995 and to 55% in 1996.

		Design Options for Panoramic Model			
	Data Sources (Description in Sec. 7.1)	Option 0	Option 1	Option 2	Option 3
Cost Summary	(Numbers in 000s)				
No. of Non-Kodak cam. sorted (paid)	Not applicable	--	--	--	--
Cost/Non-Kodak camera	Not applicable	--	--	--	--
Number of re-mfg. cameras	Estimate from historic data	3,647	0	3,647	3,647
Cost/re-mfg. camera	Calculate from labor and parts cost	$0.276	N/A	$0.295	$0.321
Number of torn down cameras	Estimate from historic data	1,964	5,611	1,964	1,964
Cost/torn down camera	Unchanged	$0.171	$0.171	$0.171	$0.171
Number of cameras with rebuilt CB	Not applicable (no flash)	--	--	--	--
Cost/camera with rebuilt CB	Not applicable (no flash)	--	--	--	--
TOTAL COST OF RECYCLING	For 1995 and 1996	$1,342	$959	$1,412	$1,507
Benefit Summary					
Number of re-mfg. subassemblies	Same as above	3,647	0	3,647	3,647
Value/re-mfg. subassembly	Value of a virgin camera	$0.768	$0.774	$0.770	$0.772
TOTAL SAVINGS OF RECYCLING	For 1995 and 1996	$2,801	$0	$2,808	$2,815
Profitability Summary					
TOTAL SAVINGS OF RECYCLING		$612	$612	$612	$612
TOTAL COST OF RECYCLING		$534	$534	$534	$534
NET SAVINGS OF RECYCLING	For 1995 and 1996	$1,458	($959)	$1,396	$1,309
DIFFERENCE IN NET SAVINGS COMPARED TO OPTION 0		**$0**	**($2,418)**	**($62)**	**($150)**

Figure 7-2: Summary for Existing Camera Redesign

This return rate could then be applied to the 1995 and 1996 sales forecast for the panoramic camera, to determine the total number of panoramic cameras returned to The Out-Source.

After Kodak starts selling the newly designed panoramic camera, a certain percentage of their returns would be of this new model. Based on previous launches of new cameras, Kodak estimated that during the first year 20% of the received cameras would be of the new design, while an estimated 50% would be of the new design in the second year after launch. Since Kodak was only concerned about the lost savings incurred by the already existing cameras being returned to the Out-Source, the comparison should be limited to the percentage of existing cameras. (80% in 1995, 50% in 1996)
Historic data shows that the re-manufacturing yield for the panoramic camera is 65%. This yield was expected to remain constant if the design were to remain unchanged, as would be the case in Option 2 or Option 3. However, if Option 1 was chosen, the re-manufacturing yield would be reduced.

Kodak could then estimate the number of cameras they expect to re-manufacture as follows:

1995: Number of re-mfg. cameras
= (return rate) x (sales forecasts for 1995)
x (percentage existing cameras in return stream) x (re-mfg. yield)
1996: Number of re-mfg. cameras
= (return rate) x (sales forecasts for 1996)
x percentage existing cameras in return stream) x (re-mfg. yield)

The number of re-manufactured cameras is calculated for each design option by adding the 1995 and 1996 values, as shown below:

Option 0: Existing camera model

Option 2: Existing frame, new parts, existing process

Option 3: Existing frame, new parts, manual process

All three options will generate the same number of re-manufacturable cameras.

Number of re-mfg. cam. = (52%) x (8,000,000 cameras) x (80%) x (65%)
+ (55%) x (8,300,000 cameras) x (50%) x (65%)
= 3,646,825 cameras

Option 1: New frame, new parts

This option would generate no re-manufacturable cameras, since the frame would have to be replaced, which could only be done if the camera were completely disassembled. At that point it is easier to build a camera from new parts than it is to recycle the disassembled camera.

Number of re-mfg. cam. = (52%) x (8,000,000 cameras) x (80%) x (0%)
+ (55%) x (8,300,000 cameras) x (50%) x (0%)
= 0 cameras

Cost/re-mfg. camera

The cost per re-manufactured camera is determined by analyzing how the three design options affect the labor and part costs.

Option 0: Existing design

The re-manufacturing cost was expected to remain constant over the next two years if the process was not changed.

Ccst/re-mfg. camera = $ 0.276

Option 1: New frame, new parts

Since none of the existing cameras would be re-manufactured, the cost for this design option was irrelevant.

Cost/re-mfg. camera = N/A

Option 2: Existing frame, new parts, existing process

The cost incurred to re-manufacture a camera was dependent on the labor cost and the cost for parts that must be replaced. Since the re-manufacturing and final assembly process were not changed by Option 2, the standard labor cost for the existing model could be applied.

Design Option 2 called for a new shutter blade, a new lens spacer, a new front baffle and a new front cover. However, the front cover would have to be replaced regardless of the design option. In addition, the design changes in the front cover were not expected to affect its cost. As a result the cost of a new front cover was not included in this analysis.

However, in order to calculate the total cost per re-manufactured camera, the shipping, rebate, administrative and sorting costs had to be included. The costs in 1995 and in 1996 are expected to remain constant.

Cost/re-mfg. camera
= (Shipping Cost) + (Rebate Cost) + (Admin. Cost) + (Sorting Cost)
+ (Current labor cost) + (Cost for shutter blade)
+ (Cost for lens spacer) + (Cost for front baffle)
= (\$0.023) + (\$0.070) + (\$0.040) + (\$0.026)
+ (\$0.077) + (\$0.020) + (\$0.009) + (\$0.032)
= \$ 0.295

Option 3: Existing frame, new parts, manual process

In this design option the labor as well as the part costs differ from the existing camera model. The new labor cost was calculated by the department's industrial engineer to include overhead and machine amortization. The resulting costs were as follows:

Cost/re-mfg. camera
= (Shipping Cost) + (Rebate Cost) + (Admin. Cost) + (Sorting Cost)
+ (New labor cost) + (Cost for shutter blade)
+ (Cost for lens spacer) + (Cost for front baffle)
= (\$0.023) + (\$0.070) + (\$0.040) + (\$0.026)
+ (\$0.101) + (\$0.020) + (\$0.009) + (\$0.032)
= \$ 0.321

Number of torn down cameras

The number of torn down cameras was determined the same way as the number of re-manufacturable cameras. However, the re-manufacturing yield was replaced with the tear down yield, which is:

Tear down yield = 1 - (re-mfg. yield)

Kodak could therefore estimate the number of cameras they would re-manufacture as follows:

1995: Number of re-mfg. cameras
= (return rate) x (sales forecasts for 1995) x
(percentage existing cameras in return stream) x
(1 - re-mfg. yield)

1996: Number of re-mfg. cameras
= (return rate) x (sales forecast for 1996) x
(percentage existing cameras in return stream) x
(1 - re-mfg. yield)

The number of torn down cameras was calculated for each design option by adding the 1995 and 1996 values, as shown below:

Option 0: Existing camera model

Option 2: Existing frame, new parts, existing process

Option 3: Existing frame, new parts, manual process

All these option generated the same number of re-manufacturable cameras.

Number of re-mfg. cam.
= (52%) x (8,000,000 cameras) x (80%) x (100% - 65%)
+(55%) x (8,300,000 cameras) x (50%) x (100% - 65%)
= 1,963,675 cameras

Option 1: New frame, new parts

As already discussed above, this design option would require that all existing cameras be torn down and recycled for plastic recover. Therefore the tear down yield is 100%.

Number of re-mfg. cam.
= (52%) x (8,000,000 cameras) x (80%) x (100%)
+ (55%) x (8,300,000 cameras) x (50%) x (100%)
= 5,610,500 cameras

Value/re-mfg. camera

The value per re-manufactured camera is equal to what it would cost Kodak to build a panoramic subassembly from scratch for each of the design options. These costs were obtained by the industrial engineer, by considering the new part costs and the standard assembly time required.

Option 0: Existing camera model

The value for a new subassembly would remain constant in 1995 and 1996.

Value/re-mfg. camera = $ 0.768

Option 1: New frame, new parts

Value/re-mfg. camera = $ 0.774

Option 2: Existing frame, new parts, existing process

Value/re-mfg. camera = $ 0.770

Option 3: Existing frame, new parts, manual process

Value/re-mfg. camera = $ 0.771

The summary in Figure 7-2 indicates that all design alterations would result in a loss, or a reduced savings for Kodak. However, the analysis also indicates that Option 2 minimizes the loss. Naturally, the decision about which design option would best serve Kodak and its customers also dependens on other issues, such as the tooling costs associated with each change or the expected reliability and picture quality each design option would yield. In addition, Kodak must keep in mind that the actual net savings for all of the design options are dependent on the actual sales figures for 1995 and 1996. This dependency on uncertain sales forecasts is an issue whenever using the cost/benefit model for forecasts.

7.2 New Generation Camera Design

A second example of how this model was applied to aid in decisions concerning design options is in the design of a "next generation" camera.

Tests on the first production cameras of the newest generation (4th generation) flash camera suggested that photofinishers might choose to remove the entire back cover of the camera in order to remove the film magazine. The designers intended for the photofinishers to use the film door on one side of the camera to remove the film magazine and the battery door on the opposite side to remove the battery. These doors were specifically designed to provide easy access to the film and battery. However, some tests showed that the back cover could be removed in one easy motion, automatically exposing both the film and the battery. Unfortunately, the front cover is attached to the back cover, which resulted in the front cover coming loose and falling off. Kodak was very concerned about this condition, because the front and back covers were intended to protect the sensitive parts of the camera during shipment back to Rochester. Without the back cover, the track the film rides on could be dented, which would result in a light leak and render the camera body unfit for re-manufacturing. Without the front cover, the circuit board would be exposed and could be damaged, at which point it would have to be replaced. Kodak estimated that as much as 60% of the cameras could be returned to the Out-Source without the front and back cover. As a result, the number of re-manufacturable cameras would be lower than expected.

In order to prevent this problem, Kodak was considering changing the design of the frame, the front cover and the back cover. This design change would make it impossible (or at least much more difficult) to remove the entire back cover, which would also ensure that the front cover remained attached. As a result, Kodak expected the number of cameras recovered without front or back covers to be negligible. Consequently, this would significantly improve the yield of re-manufacturable cameras.

The cost/benefit model was then used to determine the financial impact this design change would have on the expected recycling savings over the next couple of years, as is shown in Figure 7-3. Option 1 represents the existing design, while Option 2 describes the proposed redesign.

The following section describes how the appropriate entries in Figure 7-3 were determined.

Number of re-mfg. cameras

The number of re-mfg. cameras was determined in the same way as in Section 7.1, by estimating how many re-manufacturable cameras are returned to The Out-Source. The total number of cameras received at the recycling center was determined by applying the expected "return rate" to the sales forecasts for 1995 and 1996. However, since this was a new camera, there was no historic data available. Additionally, there is a significant time lag between when the first cameras of a new model are sold and when the first cameras of this model are received at The Out-Source. As a result, Kodak chose to approximate the return rate using the data for the 3rd generation flash camera, which proved to have a return rate of 12% in the first year and 31% in the 2nd year after its launch.

In order to determine how many of the returned cameras could be re-manufactured, Kodak predicted the re-manufacturing yield for the existing and the proposed design. If the camera arrived at The Out-Source intact, the re-manufacturing yield was expected to exceed the current yield for the 3rd generation flash camera by approximately 5%, which

	Data Sources (Description in Section 7.2)	Design Options for 4th Generation Flash Model 1995 Option 1	1996 Option 1	1995 Option 2	1996 Option 2
Cost Summary	(Numbers in 000s)				
No. of Non-Kodak cam. sorted (paid)	Not applicable	--	--	--	--
Cost/Non-Kodak camera	Not applicable	--	--	--	--
Number of re-mfg. cameras	Estimate from market predictions and yield data	133	679	179	914
Cost/re-mfg. camera	Remains constant	$0.317	$0.317	$0.317	$0.317
Number of torn down cameras	Estimate from market predictions and yield data	123	627	77	392
Cost/torn down camera	Remains constant	$0.171	$0.171	$0.171	$0.171
Number of cameras with rebuilt CB	Estimate from market predictions and historic data	9	47	15	78
Cost/camera with rebuilt CB	Remains constant	$0.811	$0.811	$0.811	$0.811
TOTAL COST OF RECYCLING		$70	$361	$82	$420
Benefit Summary					
Number of re-mfg. subassemblies	Number of re-mfg. and refurbished cameras	142	726	194	992
Value/re-mfg. subassembly	Value of a virgin camera	$2.555	$2.555	$2.555	$2.555
TOTAL SAVINGS OF RECYCLING		$363	$1,855	$496	$2,535
Profitability Summary					
TOTAL SAVINGS OF RECYCLING		$363	$1,855	$496	$2,535
TOTAL COST OF RECYCLING		$70	$361	$82	$420
NET SAVINGS OF RECYCLING		$292	$1,494	$414	$2,115
NET SAVINGS FOR RECYCLING IN 1995 & 1996		$1,787		$2,528	
DIFFERENCE IN NET SAVINGS		$0		$741	

Figure 7-3: Summary for Next Generation Camera Design

would result in a re-manufacturing yield of 70%. However, with the existing design, Kodak expected 60% of the returned cameras to be missing the front and/or back cover. Some experiments showed that Kodak could only expect a 40% re-manufacturing yield if the covers were detached.

The number of cameras re-manufactured could then be determined as follows:

1995: Number of re-mfg. cameras
= (return rate) x (sales forecast for 1995)
x (percentage of cameras with detached covers)
x (re-mfg. yield for detached covers)
+ (return rate) x (sales forecast for 1995)
x (percentage of cameras with attached covers)
x (re-mfg. yield for attached covers)

1996: Number of re-mfg. cameras
= (return rate) x (sales forecast for 1996)
x (percentage of cameras with detached covers)
x (re-mfg. yield for detached covers)
+ (return rate) x (sales forecast for 1996)
x (percentage of cameras with attached covers)
x (re-mfg. yield for attached covers)

Option 1: Existing design

1995: Number of re-mfg. cameras
= (12%) x (2,134,000 cameras) x (60%) x (40%)
+ (12%) x (2,134,000 cameras) x (40%) x (70%)
= 133,162 cameras

1996: Number of re-mfg. cameras
= (31%) x (4,213,000 cameras) x (60%) x (40%)
+ (31%) x (4,213,000 cameras) x (40%) x (70%)
= 679,136 cameras

Option 2: Proposed redesign

The proposed redesign was expected to ensure that the covers remain attached. As a result, the "percentage of cameras with detached covers" would be 0%, while the "percentage of cameras with attached covers" would be 100%, as shown below.

1995: Number of re-mfg. cameras
= (12%) x (2,134,000 cameras) x (0%) x (40%)
+ (12%) x (2,134,000 cameras) x (100%) x (70%)
= 179,256 cameras

1996: Number of re-mfg. cameras
= (31%) x (4,213,000 cameras) x (0%) x (40%)
+ (31%) x (4,213,000 cameras) x (100%) x (70%)
= 914,221 cameras

Cost/re-mfg. camera

Although the designs of the front cover, the back cover and the frame are different in the two design options, the process for re-manufacturing a camera would remain the same. As a result, the cost/re-mfg. camera was not affected by this design change.

Option 1: Existing design

Option 2: Proposed redesign

1995 & 1996: Cost/re-mfg. camera = $ 0.317

Number of torn down cameras

The number of torn down cameras was determined the same way as the number of re-manufacturable cameras, with the exception of the re-manufacturing yield, which was replaced with the tear down yield, as discussed in the previous section.

Kodak could therefore estimate the number of cameras they would have to tear down as follows:

1995: Number of torn down cameras

= (return rate) x (sales forecast for 1995)

x (percentage of cameras with detached covers)

x (100% - re-mfg. yield for detached covers)

+ (return rate) x (sales forecast for 1995)

x (percentage of cameras with attached covers)

x (100% - re-mfg. yield for attached covers)

1996: Number of torn down cameras

= (return rate) x (sales forecast for 1996)

x (percentage of cameras with detached covers)

x (100% - re-mfg. yield for detached covers)

+ (return rate) x (sales forecast for 1996)

x (percentage of cameras with attached covers)

x (100% - re-mfg. yield for attached covers)

Option 1: Existing design

1995: Number of torn down cameras

= (12%) x (2,134,000 cameras) x (60%) x (100% - 40%)

+ (12%) x (2,134,000 cameras) x (40% x (100% - 70%)

= 122,918 cameras

1996: Number of torn down cameras

= (31%) x (4,213,000 cameras) x (60%) x (100% - 40%)

+ (31%) x (4,213,000 cameras) x (40%) x (100% - 70%)

= 626,894 cameras

Option 2: Proposed redesign

The proposed redesign was expected to ensure that the covers would remain attached. As a result, the "percentage of cameras with detached covers" would be 0%, while the "percentage of cameras with attached covers" would be 100%, as shown below.

1995: Number of torn down cameras

= (12%) x (2,134,000 cameras) x (0%) x (100% - 40%)

+ (12%) x (2,134,000 cameras) x (100%) x (100% - 70%)

= 76,824 cameras

1996: Number of torn down cameras

= (31%) x (4,213,000 cameras) x (0%) x (100% - 40%)

+ (31%) x (4,213,000 cameras) x (100%) x (100% - 70%)

= 391,809 cameras

Cost/torn down camera

The process of tearing down a camera is hardly affected by the design of the camera. As a result, the cost per torn down camera was not expected to change.

Option 1: Existing design

Option 2: Proposed redesign

1995 & 1996: Cost/torn down camera = $ 0.171

Number of cameras with rebuilt CB

The number of cameras with rebuilt circuit boards was calculated in the same manner as in Section 6.1.1. However, in this example the refurbishing yield would be dependent on whether or not the front cover of the camera was attached during shipment back to Rochester. If the front cover was attached, Kodak estimated that 6% of the circuit boards would be refurbishable; if the front cover fell off, Kodak expected 2% of the circuit boards to be refurbishable.

Kodak could therefore estimate the number of cameras with rebuilt circuit boards for 1995 and 1996 as follows.

1995: Number of cameras with rebuilt CB
= (Number of torn down cameras in 1995 with attached covers)
x (refurbishing yield for attached covers)
+ (Number of torn down cameras in 1995 with detached covers)
x (refurbishing yield for detached covers)

1996: Number of cameras with rebuilt CB
+ (Number of torn down cameras in 1996 with attached covers)
x (refurbishing yield for attached covers)
+ (Number of torn down cameras in 1996 with detached covers)
x (refurbishing yield for detached covers)

Option 1: Existing design

1995: Number of cameras with rebuilt CB
= (102,432 cameras) x (6%) + (153,648 cameras) x (2%)
= 9,219 cameras

1996: Number of cameras with rebuilt CB
= (522,412 cameras) x (6%) + (783,518 cameras) x (2%)
= 47,017 cameras

Option 2: Proposed redesign

1995: Number of cameras with rebuilt CB
= (256,080 cameras) x (6%) + (0 cameras) x (2%)
= 15,364 cameras

1996: Number of cameras with rebuilt CB
= (1,306,030 cameras) x (6%) + (0 cameras) x (2%)
= 78,362 cameras

Cost/camera with rebuilt CB

The process of refurbishing a circuit board does not depend on the camera design. As a result, the cost per camera assembled with a rebuilt circuit board would not change.

Option 1: Existing design

Option 2: Proposed redesign

1995 & 1996: Value/re-mfg. camera = $ 0.811

Number of re-mfg. subassemblies

The number of re-manufactured subassemblies was determined by adding the re-manufactured cameras and the number of cameras assembled with a rebuilt circuit board, as shown below.

1995: Total Number of re-mfg. subassemblies
= (Number of re-mfg. cameras in 1995)
+ (Number of cameras with rebuilt CB in 1995)

1996: Total Number of re-mfg. subassemblies
= (Number of re-mfg. cameras in 1996)
+ (Number of cameras with rebuilt CB in 1996)

Option 1: Existing design

1995: Total Number of re-mfg. subassemblies
= 133,162 cameras + 9,219 cameras
= 142,381 cameras

1996: Total Number of re-mfg. subassemblies
= 679,136 cameras + 47,017 cameras
= 726,153 cameras

Option 2: Proposed redesign

1995: Total Number of re-mfg. subassemblies
= 179,256 cameras + 15,364 cameras
= 194,420 cameras

1996: Total Number of re-mfg. subassemblies
= 914,221 cameras + 78,362 cameras
= 992,483 cameras

Value/re-mfg. subassembly

The value per re-manufactured subassembly is equal to the cost of building a new assembly. The part cost is expected to remain constant for the proposed design change. However, there would be a charge to change the dies for the three affected parts. This cost was considered a one time cost and was not depreciated over the number of parts, in order to create a more accurate comparison. As a result, the value per re-manufactured camera remained constant.

Option 1: Existing design

Option 2: Proposed redesign

1995 & 1996: Value/re-mfg. camera = $ 2.555

The cost/benefit model clearly illustrates that the redesign would increase the net savings realized by recovering these cameras. However, as in the previous example, it is important to stress that the financial data obtained by applying the model should only be one factor of the decision process. Kodak must now compare the increased savings with the other costs incurred, such as the tooling change costs. The goal of this application was to help Kodak better understand the implications of the pending decision, by quantifying the financial impact on the recovery program.

If Kodak decides to proceed with the new design option, it is important to initiate this design change as soon as possible. Since the design affects the frame of the camera, which is part of the re-usable subassembly, it would be important to complete the change before the first cameras are sold. If cameras with the existing frame are sold, some will enter the recovery stream and be returned to Kodak. These cameras would have to be torn down and as a result the net savings predicted by the cost/benefit model would be reduced. The extent to which the net savings would be affected could be determined by treating the situation as an existing camera design change and applying the model in the same way as in Section 7.1.

Chapter 8

Conclusion

Customer demands and environmental legislation have pressured many global companies to take responsibility for their products beyond what is currently viewed as their useful life. In the future, these trends will continue to spread, forcing manufacturers to assume "ownership" of their products throughout their life cycle. For example, BMW estimates that in Europe 20 million cars will be returned to their manufacturers every year by the year 2000.[4] Similarly, Professor D. Navin-Chandra at Carnegie-Mellon University predicts that by the year 2005, every newly purchased personal computer will replace an obsolete PC, which means that computer manufacturers will have to be capable of reprocessing used computers at the same rate they are manufacturing new ones.[5]

The cost/benefit model provides Kodak with a deeper understanding of what drives the profitability of their single-use camera recovery program. This work provides examples of how Kodak used this knowledge to help determine appropriate investment opportunities, to evaluate the financial impact of policy decisions, and to evaluate how design changes affect the cost of recovering cameras.

A thorough understanding of the profit drivers in the recovery process is one element required to effectively manage products through their life cycle. In a recent paper, "The

---

[4]Bylinsky, Gene: *Manufacturing for Reuse*, Fortune Magazine (February 6, 1995), p. 104

[5]ibid., p. 108

Strategic Production and Operations Management Issues in Product Recovery Management," M.C. Thierry and his colleagues wrote that successful product recovery management requires (1) information on the composition of the products, (2) information on the magnitude and uncertainty of the return flow, (3) information on the markets for reprocessed products, components or materials, and finally, (4) information on the product recovery and waste management operations.[6] A cost/benefit model, such as the one described in this work, can be used to collect and, more important, utilize the information on the reprocessing operations. In addition, the cost/benefit model helps answer what Professor D. Navin-Chandra calls the key question about disassembly: "Exactly where and when do you stop it before you start loosing money?"[7]

The ability to collect the necessary information and to gain an understanding of the recovery management processes from an environmental, as well as a financial point of view, is an essential first step for companies that wish to compete in the environmentally conscious markets of the future. Successful companies must go beyond merely understanding their recovery process, to viewing it as an integral part of their strategy. Therefore, in order to optimize the entire operation, a company must view the recovery process as an integral part of their sourcing, their manufacturing, their distribution and their customer's behavior.

---

[6]Thierry, M.C., et al.: *Strategic Production and Operations Management Issues in Product Recovery Management*, Working Paper, Management Report Series No. 145, Erasmus Universiteit/Rotterdam School of Management (October 1993), p. 2

[7]Bylinsky, Gene: *Manufacturing for Reuse*, Fortune Magazine (February 6, 1995), p. 110

Bibliography

Ashley, Steven: *Designing for the Environment*, Mechanical Engineering (March 1993)

Bylinsky, Gene: *Manufacturing for Reuse*, Fortune Magazine (February 6, 1995)

Constance, Joseph: *Can Durable Goods be Designed for Disposability?*, Mechanical Engineering (June 1992)

Eberhard, L.: *Swiss Plastics 11*, 6 (1990)

Goldstein, Lisa: *The Strategic Management of Environmental Issues: A Case Study of Kodak's Single-Use Cameras*, Massachusetts Institute of Technology, Cambridge, MA (May 1994)

Haldenwanger, H.G., S. Schlaper: *Öko-/Energiebilanzierung im PKW-Bau mit verschiedenen Werkstoffen. In Kunststoffe im Automobilbau,* VDI, Düsseldorf, Germany (1994)

Hall, Randolph W.: *Queueing Methods for Services and Manufacturing*, Prentice Hall Inc., Englewood Cliffs, NJ (1991)

Hogg, Robert V., Johannes Ledolter: *Applied Statistics for Engineers and Physical Scientists*, Second Edition, Macmillan Publishing Company, New York, NY (1992)

Kunststoffrecycling - Verwerterbetriebe von Kunststoffabfällen. Hanser, Munich, New York (1994)

Johannaber, Friedrich: *Injection Molding Machines, A User's Guide*, Third Edition, Carl Hanser Verlag, Munich, Vienna, New York (1994)

Law, Averill M., W. David Kelton: *Simulation Modeling and Analysis*, Second Edition, McGraw-Hill, Inc., New York, NY (1991)

Martin, Mark: *Increasing the Effectiveness of Product Development Teams: A study of Quality Function Deployment and Time-to-Market Drivers,* Massachusetts Institute of Technology, Cambridge, MA (May 1994)

Nahmias, Steven: *Production and Operation Analysis*, Second edition, Richard D Irwin, Inc., Homewood, IL (1993)

Thierry, M.C., M. Salomon, J.A.E.E. van Nunen, L.N. van Wassenhove: *Strategic Production and Operations Management Issues in Product Recovery Management*, Working Paper, Management Report Series No. 145, Erasmus Universiteit/Rotterdam School of Management (October 1993)

U.S. Congress, Office of Technology Assessment: *Green Products by Design: Choices for a Cleaner Environment*, OTA-E-541, Washington, DC: U.S. Government Printing Office (October 1992)

Verwertung - Recycling - von GFK am Beispiel von SMC/BMC. Arbeitsgemeinschaft verstärkter Kunststoffe, Frankfurt/Germany

Winston, Wayne L.: *Introduction to Mathematical Programming, Applications and Algorithms*, PWS-KENT Publishing Company, Boston, MA (1991)

Winston, Wayne L.: *Operations Research: Applications and Algorithms*, PWS-KENT Publishing Company, Boston, MA (1987)